Published: 28th September 2026

INTERNATIONAL JOURNAL OF REAL ESTATE

ISSN: 2476-8073

DEVELOPING AN ENVIRONMENTALLY SUSTAINABLE FRAMEWORK FOR MANAGING URBAN GROWTH IN ABUJA, NIGERIA

Opeyemi Lucky EYINLA

Department of Estate Management and Valuation, Auchi Polytechnic, Auchi, Edo State, Nigeria.

Email: rallyberry@yahoo.com

DOI: https://doi.org/10.5281/zenodo.23024859

Abstract

Urbanisation has emerged as a key source of land use change and environment change in developing cities. The study utilized geospatial analysis and a stakeholder assessment to evaluate the dynamics of urban growth and formulate an environmentally sustainable urban growth framework for the city of Abuja, Nigeria. Geographic Information Systems (GIS) and Google Earth Engine (GEE) were used to assess changes in land use/land cover (LULC) based on multi-temporal satellite imagery from 1987, 2002, 2017 and 2025. Exploratory Factor Analysis (EFA) and descriptive statistics were applied to identify the factors driving urban growth and the related sustainability challenges. The findings showed that there was a huge landscape change during the study period. Built-up land increased from 6.0 km² (1.0%) in 1987 to 267.6 km² (44.2%) in 2025, while vegetation declined from 519.7 km² (85.9%) to 195.2 km² (32.3%). The results show that urban growth has occurred quickly and in conjunction with significant loss of natural vegetation. The population growth, housing demand, infrastructure development, commercialization and real estate investment were major contributing factors to urban growth. The factor analysis revealed five dimensions that are key to sustainable urban development: Urban Growth Pressure, Infrastructure and Economic Development, Environmental Sustainability Challenges, Governance and Planning Control, and Sustainable Urban Growth Strategies. The study developed an Environmentally Sustainable Urban Growth Framework that combines these elements to assist planning and decision making. The framework offers a workable solution to the challenge of implementing sustainable, resilient, and good land-use planning in Abuja during urban development.

Keywords: Urban Growth, Land Use/Land Cover Change, Environmental Sustainability, GIS, Google Earth Engine, Urban Planning, Abuja.

1. Introduction

Urbanisation has emerged as one of the most significant global transformations of the twenty-first century, reshaping landscapes, ecosystems, and socio-economic systems across both developed and developing countries. While urban growth contributes to economic development, employment generation, infrastructure expansion, and improved access to services, uncontrolled urbanisation often results in environmental degradation, biodiversity loss, declining ecosystem services, increased flood risks, and the depletion of natural resources (United Nations, 2022). Consequently, achieving a balance between urban expansion and environmental sustainability has become a critical challenge for urban planners and policymakers worldwide. Sub-Saharan Africa is currently experiencing the fastest rate of urbanisation globally, with urban populations projected to more than double by 2050 (UN-Habitat, 2023). Nigeria, as Africa's most populous nation, has witnessed substantial urban growth driven by population increase, rural–urban migration, economic transformation, and infrastructure development. Although this growth presents opportunities for economic advancement and social development, it has simultaneously intensified pressure on land resources, environmental quality, housing provision, transportation systems, and public infrastructure (United Nations, 2022; UN-Habitat, 2023).

Among Nigeria's rapidly growing urban centres, Abuja occupies a unique position as the Federal Capital Territory (FCT). Since becoming the nation's capital, Abuja has experienced sustained physical expansion beyond the limits envisioned in the original Abuja Master Plan. This expansion has been characterised by the conversion of vegetation, agricultural land, and open spaces into residential, commercial, industrial, and transportation infrastructure. Recent studies have reported substantial increases in built-up areas accompanied by significant declines in vegetation cover, indicating accelerated urbanisation and land transformation within the city-region (Enoguanbhor et al., 2019; Okoduwa & Amaechi, 2024). The environmental implications of this rapid urban expansion are increasingly evident. Urban growth has contributed to vegetation loss, ecosystem fragmentation, encroachment into environmentally sensitive areas, increased impervious surfaces, deterioration of natural drainage systems, and heightened vulnerability to environmental hazards. These challenges threaten the long-term sustainability and resilience of Abuja's urban environment and underscore the need for effective growth management strategies capable of balancing development needs with environmental conservation (UN-Habitat, 2023). Advances in Remote Sensing (RS), Geographic Information Systems (GIS), and cloud-based geospatial platforms such as Google Earth Engine (GEE) have significantly enhanced the ability of researchers and planners to monitor urban growth and assess land use/land cover (LULC) dynamics over time. The integration of satellite imagery, GIS, and machine learning techniques enables accurate mapping of urban expansion, quantification of land transformation processes, and identification of environmentally sensitive areas requiring protection. These technologies have become essential decision-support tools for sustainable urban planning because they provide objective evidence for evaluating spatial growth patterns and environmental change (Gorelick et al., 2017; Wulder et al., 2022; Okoduwa & Amaechi, 2024). Despite increasing studies on urban growth and LULC dynamics in Abuja, much of the existing research has focused primarily on

mapping land cover changes and quantifying urban expansion. Comparatively fewer studies have integrated geospatial evidence, stakeholder perspectives, environmental sustainability indicators, and urban planning principles into a comprehensive framework for environmentally sustainable urban growth management. Furthermore, limited attention has been given to understanding the underlying factors driving urban growth and how these factors can be incorporated into practical policy interventions for sustainable urban development (Enoguanbhor et al., 2019; Okoduwa & Amaechi, 2024).

This study addresses these gaps by analysing the spatio-temporal dynamics of land use and land cover change in Abuja between 1987 and 2025 and examining stakeholder perceptions of the factors influencing urban growth and sustainable urban development. By integrating geospatial analysis, stakeholder assessment, and sustainability principles, the study develops an environmentally sustainable urban growth framework capable of supporting evidence-based planning, strengthening urban resilience, and promoting sustainable urban development within the Federal Capital Territory.

2. Literature Review

Urban growth has become one of the most significant drivers of land transformation in contemporary cities, particularly in rapidly urbanising regions of the developing world. While urban expansion contributes to economic growth, infrastructure development, and improved access to social services, uncontrolled growth often results in environmental degradation, loss of vegetation cover, ecosystem fragmentation, increased pressure on land resources, and heightened vulnerability to environmental hazards (United Nations, 2022; UN-Habitat, 2023). These challenges are particularly evident in rapidly growing African cities where urban development frequently outpaces the capacity of planning institutions to regulate land use and protect environmentally sensitive areas. Abuja, Nigeria's Federal Capital Territory (FCT), has experienced unprecedented urban growth since its designation as the national capital. Population increase, rural–urban migration, infrastructure expansion, commercial development, and rising housing demand have accelerated the conversion of natural landscapes into built-up areas. Although the Abuja Master Plan was designed to guide orderly development and ensure environmental sustainability, increasing development pressure, weak enforcement of planning regulations, informal development, and encroachment into environmentally sensitive areas have contributed to significant deviations from the original planning objectives (Federal Capital Development Authority [FCDA], 1979; Enoguanbhor et al., 2019).

Recent geospatial studies have reported substantial increases in built-up land within the Abuja city-region, accompanied by corresponding declines in vegetation cover and agricultural land (Enoguanbhor et al., 2019; Okoduwa & Amaechi, 2024). The continuous conversion of vegetated landscapes into residential, commercial, and transportation infrastructure has raised concerns regarding biodiversity conservation, ecosystem stability, environmental quality, climate resilience, and the long-term sustainability of urban development. Furthermore, increasing impervious surfaces and declining green infrastructure have heightened the risk of flooding, urban

https://doi.org/10.5281/zenodo.23024859

heat island effects, and other environmental challenges commonly associated with rapid urbanisation (United Nations, 2022). Although previous studies have successfully applied Remote Sensing, Geographic Information Systems (GIS), and Google Earth Engine (GEE) technologies to monitor land use and land cover (LULC) changes in Abuja, most have concentrated primarily on mapping urban expansion and quantifying land-cover transitions (Enoguanbhor et al., 2019; Okoduwa & Amaechi, 2024). Consequently, limited attention has been given to integrating geospatial evidence with stakeholder perspectives, environmental sustainability indicators, and urban planning principles to develop practical strategies for managing future urban growth. As a result, there remains an inadequate understanding of the underlying factors driving urban expansion and how these factors can be incorporated into an environmentally sustainable urban growth management framework.

This gap is particularly important because sustainable urban development requires not only an understanding of spatial patterns of urban growth but also an appreciation of the socio-economic, institutional, environmental, and governance factors that influence urbanisation processes. Without such integrated knowledge, planning interventions may fail to address the root causes of environmental degradation and unsustainable land-use practices. Therefore, there is a need for a comprehensive assessment that combines geospatial analysis of land use/land cover dynamics with stakeholder-based evaluation of urban growth drivers to provide evidence-based guidance for sustainable urban development.

This study addresses this need by analysing the spatio-temporal dynamics of land use and land cover change in Abuja between 1987 and 2025 and examining stakeholder perceptions of the factors influencing urban growth and environmentally sustainable urban development. The study further develops an environmentally sustainable urban growth framework that integrates geospatial evidence, sustainability principles, and stakeholder perspectives to support effective planning, environmental management, and long-term urban resilience in Abuja.

3.0 Materials and Methods

This study adopted a mixed-methods research design that integrated geospatial analysis and stakeholder assessment to evaluate urban growth dynamics and develop an environmentally sustainable framework for managing urban expansion in Abuja, Nigeria. The geospatial component involved the analysis of multi-temporal satellite imagery to assess Land Use/Land Cover (LULC) changes between 1987 and 2025, while the social survey component examined stakeholder perceptions regarding the drivers of urban growth, environmental sustainability challenges, and appropriate planning interventions. Multi-temporal satellite imagery covering the Abuja City-Region was acquired for the years 1987, 2002, 2017, and 2025. Image processing and analysis were conducted using Geographic Information Systems (GIS), Remote Sensing techniques, and Google Earth Engine (GEE). The images were pre-processed through geometric correction, atmospheric correction, cloud masking, image mosaicking, and clipping to the study boundary. A supervised classification approach was employed to classify the imagery into four major land-use/land-cover classes, namely Built-up Area, Vegetation, Bare Land, and Water Body.

Post-classification comparison techniques were used to quantify changes in land-cover categories across the study period. Land-cover statistics were generated to determine the extent, magnitude, and direction of urban growth and associated environmental transformation. Net-change analysis was further conducted to assess gains and losses within individual land-cover classes.

The stakeholder assessment targeted key actors involved in urban planning, environmental management, land administration, real estate development, and community governance within the Federal Capital Territory. Structured questionnaires were administered to selected respondents drawn from planning institutions, environmental agencies, estate surveying and valuation firms, academia, real estate development organisations, and community groups. A total of 250 valid responses were obtained, representing a 100% response rate relative to the proposed sample. The sample comprised 156 male (62.4%) and 94 female (37.6%) respondents drawn from the six professional and community categories listed in Table 1.
Descriptive statistics were used to analyse stakeholder responses, while Exploratory Factor Analysis (EFA) was employed to identify latent dimensions underlying urban growth drivers and environmentally sustainable urban development. Prior to factor extraction, the suitability of the dataset for factor analysis was evaluated using the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity. The overall KMO was 0.957, indicating excellent sampling adequacy, and Bartlett's test was highly significant ($\chi^2 = 6766.7$, df = 465, $p < 0.001$), confirming that the correlation matrix was appropriate for factor analysis. Principal Component Analysis (PCA) with Varimax rotation was applied. Three factors had eigenvalues greater than one and together explained 71.7% of the total variance; a five-factor solution (forced to align with the conceptual framework) explained 75.1% of the variance. The extracted factors were interpreted based on factor loadings and grouped into meaningful dimensions influencing urban growth and sustainability.Findings from the geospatial analysis and stakeholder assessment were subsequently integrated to develop an Environmentally Sustainable Urban Growth Framework for Abuja. The framework synthesises urban growth drivers, environmental sustainability concerns, governance mechanisms, and strategic interventions required for achieving sustainable urban development within rapidly urbanising environments.

Objectives of the Study
The specific objectives of the study are to:

i. Examine the land use and land cover patterns of the Abuja city-region between 1987 and 2025 using geospatial technologies.
ii. Assess the magnitude and trends of land use and land cover changes associated with urban growth in Abuja between 1987 and 2025.
iii. Identify the underlying factors influencing urban growth and environmentally sustainable urban development in Abuja using stakeholder perceptions.
iv. Develop an environmentally sustainable framework for managing urban growth in Abuja based on geospatial evidence, stakeholder perspectives, and sustainability principles.

https://doi.org/10.5281/zenodo.23024859

The Study Area

The study was conducted in the Abuja City-Region within the Federal Capital Territory (FCT), Nigeria's administrative and political capital. The Federal Capital Territory is located in the central part of Nigeria between latitudes 8°25′N and 9°20′N and longitudes 6°45′E and 7°39′E. The FCT occupies approximately 8,000 km² and comprises six Area Councils, namely Abuja Municipal Area Council (AMAC), Bwari, Gwagwalada, Kuje, Kwali, and Abaji. It is bounded by Kaduna State to the north, Niger State to the west, Nasarawa State to the east, and Kogi State to the south (FCDA, 1979). Although the Federal Capital Territory covers approximately 8,000 km², the present study focused on the Abuja City-Region covering approximately 605.1 km², representing the metropolitan core and adjoining rapidly urbanising areas where the most significant land-use transformation has occurred over the past four decades. This delineated urban region was adopted for the Land Use/Land Cover (LULC) analysis because it encompasses the principal development corridors and areas experiencing intense urban expansion. Abuja was established as Nigeria's Federal Capital Territory in 1976 and officially became the seat of government in 1991. Since then, the city has experienced rapid demographic growth and physical expansion driven by population increase, rural–urban migration, government activities, economic opportunities, infrastructure development, and increasing demand for residential, commercial, and institutional land uses. The Abuja Master Plan was originally designed to promote orderly urban development through land-use zoning, infrastructure provision, environmental protection, and controlled urban growth. However, sustained development pressure and population increase have resulted in substantial modifications to land-use and land-cover patterns across the city-region (FCDA, 1979).

The study area experiences a tropical savannah climate characterised by two distinct seasons: a wet season extending from April to October and a dry season occurring between November and March. Annual rainfall ranges from approximately 1,100 mm to 1,600 mm, while average temperatures generally vary between 20°C and 35°C. The natural vegetation is predominantly Guinea Savannah, comprising grasses, shrubs, and scattered trees. Topographically, the area is characterised by undulating terrain with elevations ranging from about 300 m to over 700 m above sea level. The area is drained by several rivers and streams, including tributaries of the Rivers Usuma and Gurara, which contribute significantly to water supply, ecological stability, and watershed functions. Over the last three decades, Abuja has emerged as one of the fastest-growing urban centres in Sub-Saharan Africa. Rapid urbanisation has led to extensive conversion of vegetation, agricultural land, and open spaces into residential, commercial, industrial, and transportation infrastructure. Previous studies have reported significant increases in built-up areas accompanied by substantial declines in vegetation cover, indicating growing environmental pressures associated with urban expansion (Enoguanbhor et al., 2019; Okoduwa & Amaechi, 2024). These transformations have generated increasing concerns regarding environmental sustainability, ecosystem conservation, climate resilience, biodiversity protection, and the long-term effectiveness of urban growth management strategies within the Abuja City-Region.

The selection of Abuja City-Region for this study was informed by its strategic importance as Nigeria's capital city, its rapid rate of urban expansion, the availability of multi-temporal satellite imagery, and the documented evidence of significant land-use and land-cover changes. These characteristics make the area an appropriate case for examining urban growth dynamics and developing an environmentally sustainable framework capable of supporting effective urban planning, environmental management, and sustainable urban development.

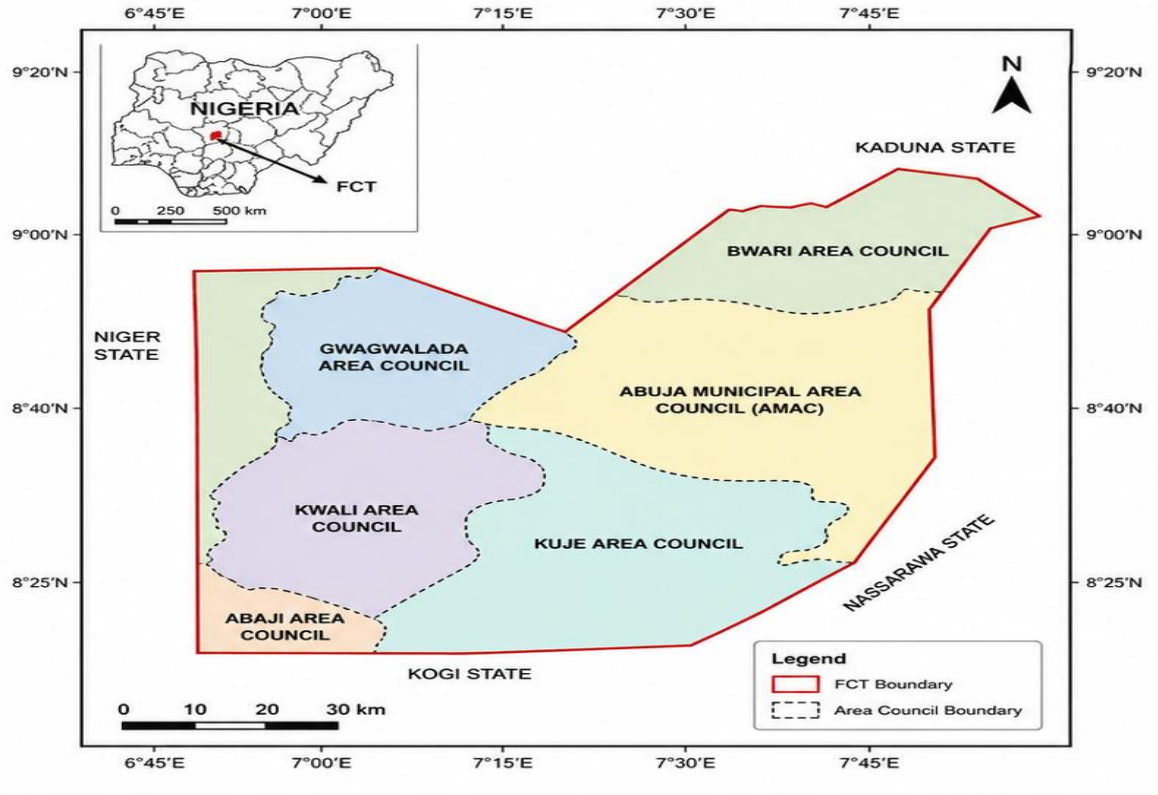


Figure 1: Federal Capital Territory Map
Source: URP Department, Federal Polytechnic, Auchi (2026)

Table 1: Proposed Sample Distribution of Respondents

Respondent Category	Rationale	Sample Size
FCDA/FCTA Officials	Responsible for urban policy formulation and implementation	30
Development Control Officers	Enforce planning regulations and monitor compliance	30
Physical Planners	Prepare and implement urban development plans	35
Environmental Experts	Assess environmental impacts of urban expansion	30
Estate Surveyors and Valuers	Provide expertise on land markets and land-use changes	30

https://doi.org/10.5281/zenodo.23024859

Real Estate Developers	Major factors influencing urban expansion and housing development	25
Academics/Researchers	Provide technical and research-based perspectives	20
Community Leaders/Residents	Offer local knowledge and perceptions of urban growth	50
Total		**250**

Source: Authors' computation (2026)

4.0 PRESENTATION AND DISCUSSION OF RESULTS

Preamble

This chapter presents and discusses the findings of the study on urban growth and land use/land cover (LULC) dynamics in the Abuja City-Region between 1987 and 2025. The results are organised according to the study objectives and include analyses of land use/land cover patterns, urban expansion trends, stakeholder perceptions of urban growth drivers, and the development of an environmentally sustainable urban growth framework. The findings are interpreted using geospatial evidence and stakeholder perspectives to provide insights into the environmental implications of urbanisation and the strategies required for sustainable urban growth management in Abuja.

4.1 Land Use/Land Cover Pattern of the Abuja City-Region between 1987 and 2025

The analysis in Figure 2 revealed substantial changes in the land use and land cover pattern of the Abuja City-Region between 1987 and 2025, reflecting rapid urbanisation and significant landscape transformation. In 1987, vegetation was the dominant land-cover class, occupying 519.7 km² (85.9%) of the study area, while built-up land accounted for only 6.0 km² (1.0%), indicating a predominantly natural environment with limited urban development. By 2002, built-up land had expanded considerably to 63.8 km² (10.5%), corresponding with Abuja's emergence as Nigeria's Federal Capital Territory and the increasing concentration of administrative, commercial, and residential developments. During the same period, vegetation declined to 406.7 km² (67.2%), representing a loss of approximately 113 km². Bare land also increased substantially from 75.6 km² (12.5%) to 130.8 km² (21.6%), reflecting extensive land clearing and construction activities associated with urban development. Urban expansion accelerated further between 2002 and 2017 as built-up land more than doubled to 152.6 km² (25.2%). Simultaneously, vegetation cover declined to 323.8 km² (53.5%), indicating continued conversion of natural landscapes and agricultural land into urban uses. The relatively stable extent of bare land during this period suggests that many previously cleared areas had already been transformed into permanent urban developments.

The most pronounced changes occurred between 2017 and 2025 when built-up land increased to 267.6 km² (44.2%), becoming the second-largest land-cover category within the city-region. Conversely, vegetation declined sharply to 195.2 km² (32.3%), representing an overall reduction of approximately 324.5 km² from its 1987 extent. This decline indicates significant

environmental pressure arising from sustained urban growth and land conversion. The results demonstrate a substantial transformation from a predominantly vegetated landscape to an increasingly urbanised environment. The observed expansion of built-up areas at the expense of vegetation reflects the influence of population growth, infrastructure development, housing demand, and economic activities. These findings underscore the need for sustainable urban planning, effective development control, and environmental conservation measures to ensure that future urban growth occurs within environmentally sustainable limits.

Table 2: Land Use/Land Cover Pattern of the Abuja City-Region (1987–2025)

Land Cover Class	1987 (km²)	1987 (%)	2002 (km²)	2002 (%)	2017 (km²)	2017 (%)	2025 (km²)	2025 (%)
Urban/Built-up	6.0	1.0	63.8	10.5	152.6	25.2	267.6	44.2
Vegetation	519.7	85.9	406.7	67.2	323.8	53.5	195.2	32.3
Bare Land	75.6	12.5	130.8	21.6	124.8	20.6	130.1	21.5
Water Body	3.7	0.6	3.7	0.6	3.9	0.6	12.1	2.0
Total	**605.1**	**100.0**	**605.1**	**100.0**	**605.1**	**100.0**	**605.1**	**100.0**

Source: Authors' computation (2026).

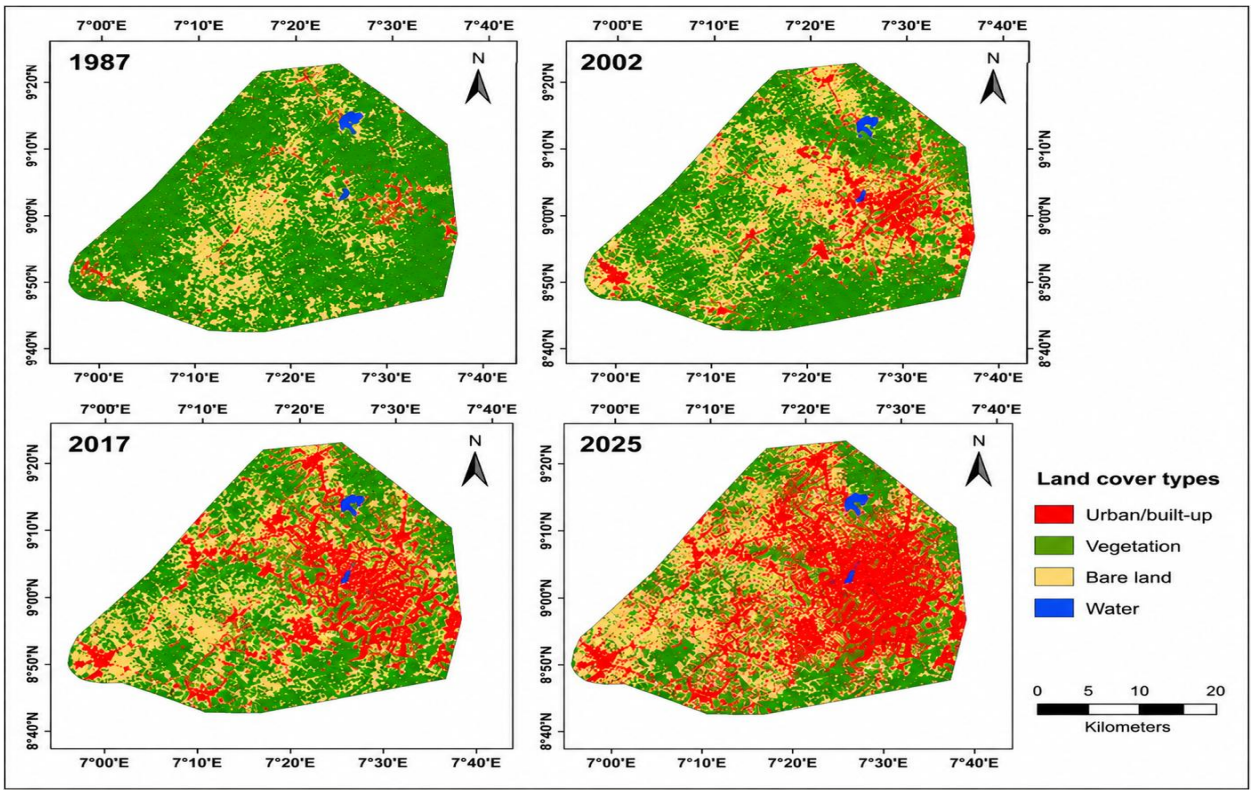


Figure 2: Land Use/Land Cover Pattern of the Abuja City-Region from 1987 to 2025

https://doi.org/10.5281/zenodo.23024859

4.2 Net Land Use/Land Cover Change in Abuja City-Region (1987–2025)

The net change analysis in Table 3 quantifies the absolute and relative transformation of the Abuja City-Region between 1987 and 2025. Built-up land recorded the largest gain (+261.6 km²), reflecting rapid urban growth driven by population increase, infrastructure development, and economic expansion. Vegetation experienced the greatest loss (−324.5 km², a 62.4% decline), signifying extensive conversion of natural landscapes to urban uses. Bare land increased moderately (+54.5 km²), while water bodies showed a notable increase (+8.4 km²). The sharp rise in water area between 2017 and 2025 is atypical and may reflect classification artefacts arising from seasonal imagery differences, reservoir construction, or misclassification; this anomaly warrants further verification. Overall, these net changes demonstrate the growing pressure of urbanisation on environmental resources and highlight the need for sustainable land-use planning and environmental conservation measures.

Table 3: Net Land Use/Land Cover Change in Abuja City-Region (1987–2025)

Land Cover Class	1987 (km²)	2025 (km²)	Net Change (km²)	% Change
Urban/Built-up	6.0	267.6	+261.6	+4,360%
Vegetation	519.7	195.2	−324.5	−62.4%
Bare Land	75.6	130.1	+54.5	+72.1%
Water Body	3.7	12.1	+8.4	+227.0%
Total	**605.1**	**605.1**	**0.0**	—

Source: Authors' computation (2026)

Discussion

The findings reveal a clear shift from a predominantly vegetated landscape to an increasingly urbanised environment. The substantial increase in built-up land and corresponding reduction in vegetation confirm the rapid pace of urban expansion within Abuja. This pattern is consistent with urban growth trends reported in rapidly developing cities where increasing demand for housing, infrastructure, and commercial activities drives land conversion and environmental change (Enoguanbhor et al., 2019; Okoduwa & Amaechi, 2024). The results underscore the importance of integrating environmental sustainability considerations into urban planning to minimise the adverse effects of continued urban expansion.

4.3 Drivers of Urban Growth in Abuja: Stakeholder Perspectives

Complementing the geospatial analysis, stakeholders were asked to identify the major factors influencing urban growth in Abuja. The responses indicate that population growth, housing demand, infrastructure development, commercial activities, employment opportunities, and private real estate investment are the most significant drivers of urban expansion. These factors collectively contribute to increasing demand for land and the continuous conversion of vegetation and open spaces into built-up areas. The findings suggest that Abuja's growth is largely driven by its role as Nigeria's administrative and economic centre, which continues to attract migrants,

businesses, investors, and government institutions. Consequently, the increasing demand for residential accommodation, transportation infrastructure, and commercial facilities has accelerated land-use transformation and urban sprawl. Similar observations have been reported in previous studies, which identified demographic growth, economic development, and infrastructure provision as major determinants of urban expansion within the Abuja city-region (Enoguanbhor et al., 2019; Okoduwa & Amaechi, 2024).

Table 4: Major Drivers of Urban Growth in Abuja

Driver	Implication for Urban Growth
Population Growth	Increased demand for housing and services
Housing Demand	Expansion of residential development
Commercial Activities	Growth of business and commercial centres
Employment Opportunities	Attraction of migrants and labour force
Infrastructure Development	Expansion of urban development corridors
Government Investment	Increased public facilities and urban services
Private Real Estate Development	Conversion of land for housing and commercial uses

Source: Field Survey and Authors' analysis (2026)

Figure 3: Conceptual Representation of Urban Growth Drivers in Abuja



Source: Authors' conceptualisation (2026)

Discussion

The identified drivers highlight the complex interaction between demographic, economic, and infrastructural factors in shaping urban growth. Population increase and housing demand create pressure for land development, while infrastructure investment and commercial expansion

https://doi.org/10.5281/zenodo.23024859

facilitate outward urban growth. Without effective planning and development control mechanisms, these growth drivers may contribute to environmental degradation, loss of vegetation cover, and increasing pressure on urban ecosystems. Therefore, understanding these drivers is essential for designing sustainable urban growth management strategies capable of balancing development needs with environmental sustainability.

4.4 Exploratory Factor Analysis of Urban Growth and Sustainable Urban Development Variables

Exploratory Factor Analysis (EFA) was employed to identify the underlying dimensions influencing urban growth and environmentally sustainable urban development in Abuja (n = 250). The analysis reduced 31 observed Likert-scale variables into a smaller number of meaningful constructs. The overall KMO was 0.957 and Bartlett's test of sphericity was significant (χ^2 = 6766.7, $p < 0.001$). Three factors had eigenvalues greater than 1 and explained 71.7% of total variance; a five-factor solution forced for conceptual alignment explained 75.1%. The five dimensions that emerged are: Urban Growth Pressure, Infrastructure and Economic Development, Environmental Sustainability Challenges, Governance and Planning Control, and Sustainable Urban Growth Strategies. These dimensions collectively explain the major forces shaping urban development and environmental sustainability within the Abuja City-Region.

The extracted dimensions comprise Urban Growth Pressure, Infrastructure and Economic Development, Environmental Sustainability Challenges, Governance and Planning Control, and Sustainable Urban Growth Strategies. These dimensions provide a comprehensive understanding of the demographic, economic, environmental, institutional, and participatory factors influencing urban growth and constitute the foundation for the proposed environmentally sustainable urban growth framework.

Table 5: Rotated Factor Loadings (Varimax) for Urban Growth and Sustainable Development Variables (KMO = 0.957; five factors explain 75.1% of variance)

Variable / Dimension	F1	F2	F3	F4	F5
Population growth / employment / commerce (GROWTFAC, EMPLOYME, COMMERCI, PRIVATEE)	0.84	0.01	0.02	0.08	0.14
Road & public infrastructure (ROADCONS, PUBLICIN, IMPROVED, EXPANSIO)	0.84	0.03	0.02	0.14	0.08
Housing demand & government investment (HOUSINGD, GOVERNME, PRIVATEH, HOUSING)	0.84	0.02	0.03	0.12	0.07
Land allocation & politics (LANDALLO,	0.83	0.02	0.03	0.11	0.24

POLITICA, AVAILABI, Urbanexpansion)					
Vegetation / open-space conversion (CONVERSI, OPENSPAC, Urbandeve)	0.03	0.87	0.05	0.12	0.04
Environmental regulation & climate (Environmentalreg, Climatechange, Protectinggreen)	0.02	0.86	0.04	0.14	0.06
Nature-based & affordable housing (Naturebased, Affordablehousing, EnvironmentalImpact)	0.01	0.84	0.02	0.15	0.06
Weak development control / poor enforcement (WEAKDEVE, POORENFO)	0.03	0.04	0.88	0.05	0.06
Strict enforcement & monitoring (Strictenforcement, Regularmonitoring, Developmentcontrol)	0.03	0.02	0.86	0.02	0.06
Public participation (Publicparticipation)	0.03	0.03	0.85	0.12	0.19
% of variance explained	**35.9%**	**21.3%**	**14.5%**	**1.7%**	**1.7%**

Source: Field Survey and Authors' analysis (2026).

Factor 1: Urban Growth Pressure

This dimension reflects the demographic and economic forces responsible for urban expansion in Abuja. Population increase, housing demand, employment opportunities, and commercial activities emerged as the primary pressures driving the conversion of natural landscapes into built-up areas. The factor demonstrates that increasing demand for land and urban services remains a major catalyst of urban growth.

Factor 2: Infrastructure and Economic Development

This factor captures the influence of infrastructure provision and economic investment on urban development. Road construction, public infrastructure projects, government expenditure, and private sector real estate investments were identified as major contributors to spatial expansion and land-use transformation. The findings suggest that infrastructure development continues to shape urban growth corridors within the city-region.

Factor 3: Environmental Sustainability Challenges

This dimension highlights the environmental consequences associated with rapid urbanisation. Stakeholders identified vegetation loss, climate change concerns, ecosystem degradation, and open-space conversion as significant sustainability challenges resulting from urban expansion. The factor underscores the need to incorporate environmental protection measures into urban planning and development processes.

Factor 4: Governance and Planning Control

This factor emphasises the role of institutions and regulatory frameworks in managing urban growth. Development control mechanisms, environmental regulations, planning standards, and

https://doi.org/10.5281/zenodo.23024859

monitoring systems were identified as critical tools for ensuring orderly urban development and preventing unsustainable land-use practices.

Factor 5: Sustainable Urban Growth Strategies

The final factor focuses on approaches capable of promoting environmentally sustainable urban development. Public participation, stakeholder engagement, green infrastructure development, and nature-based solutions emerged as essential strategies for improving urban resilience, enhancing environmental quality, and supporting sustainable growth management.

Figure 4: Dimensions Influencing Environmentally Sustainable Urban Growth in Abuja



Source: Authors' conceptualisation (2026)

Discussion

The factor analysis demonstrates that urban growth in Abuja is shaped by a combination of demographic, economic, environmental, institutional, and participatory factors (see Figure 4). While population growth, housing demand, and infrastructure development stimulate urban expansion, environmental sustainability concerns and governance effectiveness determine the long-term implications of such growth. The findings therefore suggest that sustainable urban development cannot be achieved solely through physical planning interventions but requires integrated approaches that combine environmental conservation, effective governance, stakeholder participation, and evidence-based decision-making. These dimensions complement

the geospatial findings by explaining the underlying drivers responsible for the observed land use and land cover changes within the Abuja City-Region.

4.5 Environmental Implications of Urban Growth in Abuja

The land use and land cover analysis revealed that urban growth in Abuja has been accompanied by substantial environmental changes, particularly the continuous decline in vegetation cover and the expansion of built-up areas. Between 1987 and 2025, vegetation decreased significantly while urban land uses expanded rapidly, indicating increasing pressure on natural ecosystems and environmental resources. These changes suggest that urbanisation has become a major driver of landscape transformation within the Abuja City-Region. One of the most significant environmental consequences of urban expansion is the loss of vegetation and green spaces. Vegetation performs critical ecological functions, including carbon sequestration, climate regulation, biodiversity conservation, erosion control, and watershed protection. The continuous conversion of vegetated land into residential, commercial, and transportation infrastructure reduces the capacity of the urban environment to provide these ecosystem services, thereby increasing environmental vulnerability and reducing urban resilience.

The rapid increase in built-up surfaces has also contributed to the expansion of impervious areas, which can alter natural hydrological processes and increase surface runoff. As urban development replaces permeable surfaces with roads, buildings, and paved infrastructure, the capacity of the environment to absorb and retain stormwater declines. This condition may increase susceptibility to urban flooding, soil erosion, and drainage congestion, particularly during periods of intense rainfall. Furthermore, urban expansion has implications for climate resilience and environmental quality. The reduction of vegetation cover and open spaces may contribute to higher land surface temperatures and urban heat island effects, while increasing energy consumption and environmental stress. Stakeholders also identified climate change, environmental degradation, and open-space conversion as major sustainability concerns associated with rapid urbanisation, indicating growing awareness of the environmental risks linked to uncontrolled urban growth.

Table 6: Environmental Implications of Urban Growth in Abuja

Environmental Issue	Observed Implication
Vegetation Loss	Reduction in ecosystem services and biodiversity
Open Space Conversion	Decline in environmental quality and green infrastructure
Increased Built-up Area	Greater pressure on land and natural resources
Impervious Surface Expansion	Increased runoff and flood susceptibility
Environmental Degradation	Ecosystem disturbance and landscape fragmentation
Climate Change Concerns	Reduced urban resilience and adaptive capacity

Source: Geospatial Analysis and Stakeholder Assessment (2026).

https://doi.org/10.5281/zenodo.23024859

Discussion

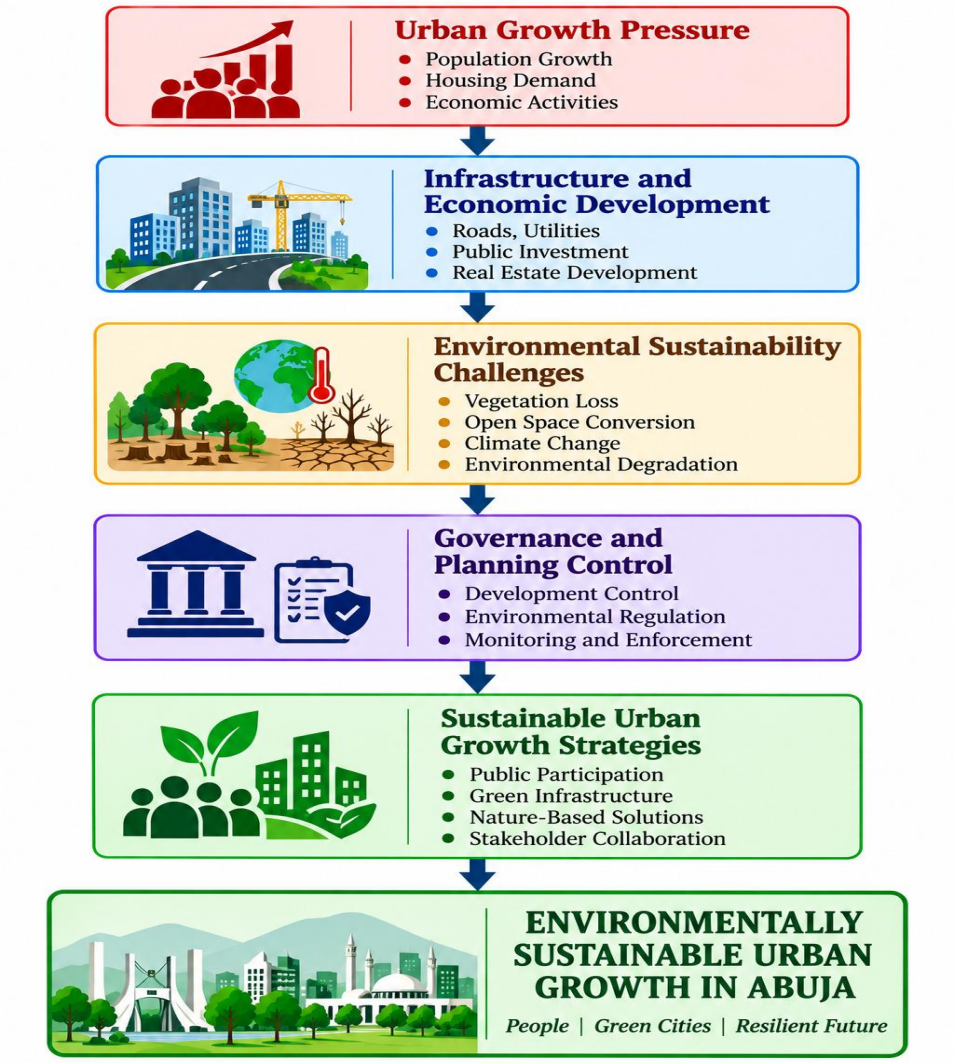
The findings demonstrate that the environmental consequences of urban growth extend beyond physical land conversion and increasingly affect ecosystem integrity, environmental quality, and urban resilience. The geospatial evidence and stakeholder perceptions consistently indicate that rapid urbanisation is contributing to vegetation depletion, environmental degradation, and sustainability challenges within the Abuja City-Region. These findings underscore the need for integrated planning approaches that combine development control, environmental protection, green infrastructure provision, and stakeholder participation to ensure that future urban growth occurs in a sustainable and environmentally responsible manner.

4.6 Development of an Environmentally Sustainable Urban Growth Framework for Abuja

The framework was developed by integrating findings from the land use and land cover (LULC) analysis, stakeholder perceptions, and the identified dimensions influencing urban growth and environmental sustainability. The framework provides a systematic approach for managing urban expansion while ensuring environmental protection, institutional effectiveness, and long-term urban resilience. It recognises that sustainable urban growth requires a balance between development needs and environmental conservation through coordinated planning, governance, and stakeholder engagement. The geospatial analysis revealed a substantial increase in built-up areas and a corresponding decline in vegetation cover between 1987 and 2025, indicating increasing development pressure on the urban environment. Similarly, stakeholder assessments identified population growth, housing demand, infrastructure development, environmental sustainability challenges, governance effectiveness, and participatory planning as the key factors influencing urban growth. The integration of these findings informed the development of a framework that addresses both the drivers and consequences of urban expansion.

The framework is organised around five interconnected components: Urban Growth Pressure, Infrastructure and Economic Development, Environmental Sustainability Challenges, Governance and Planning Control, and Sustainable Urban Growth Strategies. These components interact to influence urban development outcomes and collectively determine the sustainability of future urban growth within the Abuja City-Region.

Figure 5: Proposed Environmentally Sustainable Urban Growth Framework for Abuja



Source**:** Authors' conceptualisation (2026)

Components of the Framework

Urban Growth Pressure

This component represents the demographic and economic forces driving urban expansion, including population growth, housing demand, employment generation, and commercial development. These factors increase demand for land and urban services and serve as the primary catalysts of urban growth.

Infrastructure and Economic Development

This component reflects the role of infrastructure provision and economic investment in facilitating urban expansion. Road networks, public utilities, government projects, and private real estate developments influence the spatial distribution and intensity of urban growth**.**

https://doi.org/10.5281/zenodo.23024859

Environmental Sustainability Challenges

This component captures the environmental consequences of urbanisation, including vegetation loss, ecosystem degradation, open-space conversion, and climate-related risks. It highlights the environmental pressures that require continuous monitoring and management.

Governance and Planning Control

This component emphasises the importance of planning institutions, policy implementation, development control, environmental regulations, and enforcement mechanisms in guiding urban growth. Effective governance is essential for reducing uncontrolled development and ensuring compliance with planning standards.

Sustainable Urban Growth Strategies

This component focuses on interventions that promote sustainability, including stakeholder participation, green infrastructure development, nature-based solutions, environmental awareness, and collaborative planning approaches. These strategies provide practical pathways for balancing urban development with environmental conservation.

Discussion

The proposed framework demonstrates that environmentally sustainable urban growth depends on the interaction between development drivers, environmental conditions, governance structures, and sustainability interventions. Unlike conventional approaches that focus primarily on physical expansion, the framework adopts an integrated perspective that combines geospatial evidence, stakeholder insights, and sustainability principles. By linking urban growth pressures with governance mechanisms and sustainable planning strategies, the framework provides a practical basis for guiding future urban development within Abuja.

The framework also supports the objectives of sustainable urban development by promoting environmentally responsible land-use practices, enhancing urban resilience, protecting ecosystem services, and strengthening institutional capacity for growth management. Consequently, it offers a useful decision-support tool for planners, policymakers, environmental managers, and development agencies seeking to achieve balanced and sustainable urban growth in Abuja and other rapidly urbanising cities.

4.7 Framework Validation and Policy Implications

Framework Validation

The proposed Environmentally Sustainable Urban Growth Framework was evaluated based on its consistency with the empirical findings generated through geospatial analysis and stakeholder assessment. The framework successfully integrates the principal dimensions identified in the study, namely Urban Growth Pressure, Infrastructure and Economic Development, Environmental Sustainability Challenges, Governance and Planning Control, and Sustainable

Urban Growth Strategies. These dimensions collectively reflect the major drivers, consequences, and management requirements of urban growth within the Abuja City-Region.

The framework provides an integrated approach to understanding urban growth by recognising the interactions between demographic pressures, economic development, environmental sustainability concerns, institutional effectiveness, and participatory planning processes. By incorporating these interconnected elements, the framework offers a practical basis for guiding urban development decisions while promoting environmental protection and long-term urban resilience.

However, it is recognised that the framework has not undergone external validation through expert review panels, Delphi studies, or practical implementation within planning institutions. Consequently, the framework should be regarded as a preliminary decision-support model requiring further testing and refinement through future empirical applications and stakeholder engagement exercises.

Table 7: Validation of Framework Components against Study Findings

Framework Component	Evidence from Study
Urban Growth Pressure	Rapid increase in built-up area and stakeholder identification of population growth and housing demand as key drivers
Infrastructure and Economic Development	Expansion of transportation networks, public infrastructure, and urban development corridors
Environmental Sustainability Challenges	Significant vegetation loss and increasing environmental pressures associated with urbanisation
Governance and Planning Control	Stakeholder emphasis on development control, environmental regulation, and enforcement
Sustainable Urban Growth Strategies	Need for stakeholder participation, green infrastructure, and nature-based solutions

Source: Authors' synthesis (2026)

Policy Implications

The findings of this study have important implications for urban planning and environmental management in Abuja. First, the observed rate of urban expansion highlights the need for stronger land-use planning mechanisms capable of guiding development towards designated growth areas while protecting environmentally sensitive landscapes. Effective implementation of the Abuja Master Plan and strengthened development control measures are therefore essential for managing future urban growth. The substantial decline in vegetation cover underscores the importance of integrating environmental sustainability considerations into urban development policies. Urban planning authorities should prioritise the protection of green spaces, ecological corridors, urban forests, and environmentally sensitive areas to maintain ecosystem services and improve urban resilience.

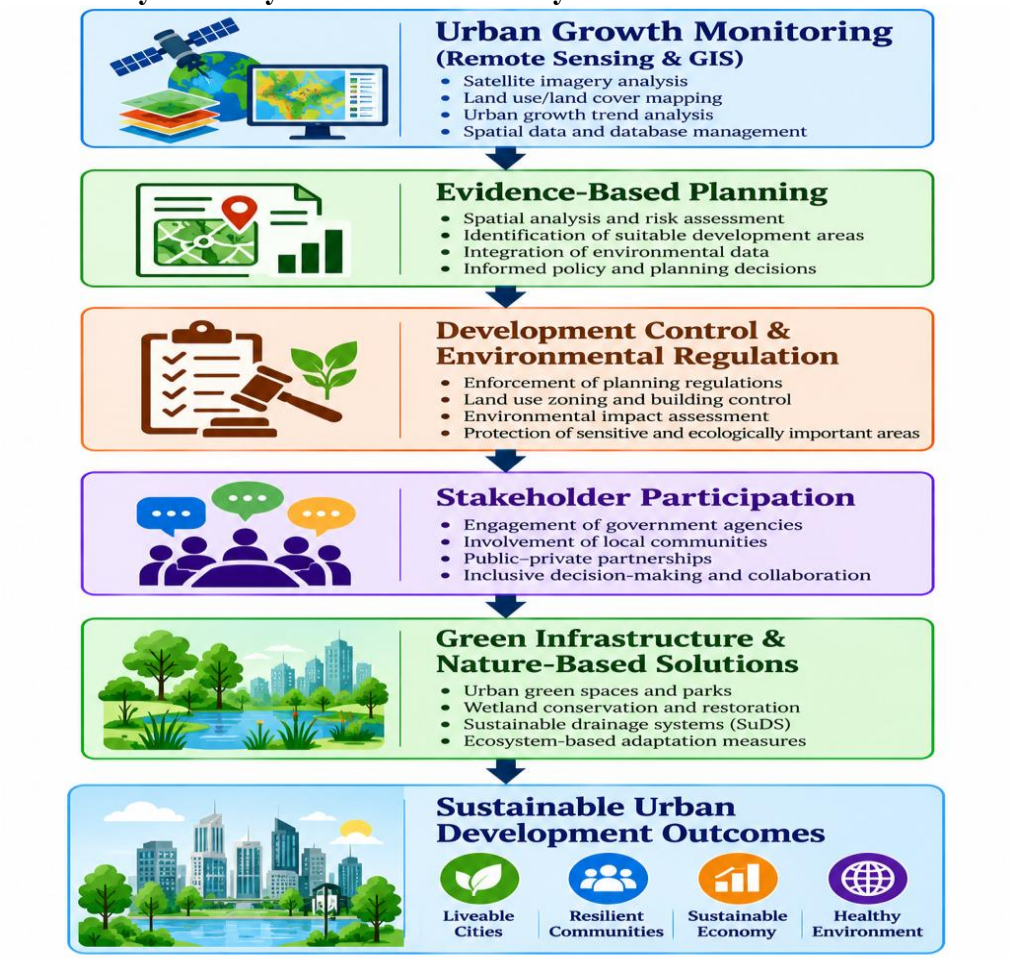
The findings emphasise the need for continuous geospatial monitoring of land use and land cover changes. The adoption of Remote Sensing, GIS, and cloud-based geospatial technologies such as

https://doi.org/10.5281/zenodo.23024859

Google Earth Engine can support evidence-based planning by providing timely information on urban growth trends and environmental change. Stakeholder participation should be strengthened within urban planning processes. The involvement of residents, community organisations, private-sector actors, environmental professionals, and planning institutions can improve decision-making, enhance policy acceptance, and promote more sustainable development outcomes.

Lastly, the adoption of nature-based solutions and green infrastructure approaches should form an integral component of future urban growth strategies. Such interventions can contribute to biodiversity conservation, climate adaptation, flood mitigation, environmental quality improvement, and sustainable urban resilience.

Figure 6: Policy Pathway for Environmentally Sustainable Urban Growth in Abuja



Source: Authors' conceptualisation (2026)

Discussion

The framework validation demonstrates that the proposed model adequately captures the key dimensions influencing urban growth and environmental sustainability in Abuja. The policy implications further indicate that sustainable urban growth cannot be achieved through physical

planning measures alone but requires coordinated actions involving environmental management, institutional strengthening, stakeholder engagement, and continuous monitoring. By integrating these elements, the framework provides a practical and adaptable approach for supporting environmentally sustainable urban development and enhancing urban resilience within the Federal Capital Territory.

4.8 Discussion of Findings

The study revealed significant land use and land cover transformation within the Abuja City-Region between 1987 and 2025. Built-up areas increased substantially, while vegetation cover declined considerably, indicating rapid urban expansion and increasing pressure on environmental resources. The findings demonstrate a progressive conversion of natural landscapes into residential, commercial, and infrastructural developments. Stakeholder assessment identified population growth, housing demand, commercial activities, infrastructure development, and real estate investment as the principal drivers of urban growth. The factor analysis further grouped these drivers into five major dimensions: Urban Growth Pressure, Infrastructure and Economic Development, Environmental Sustainability Challenges, Governance and Planning Control, and Sustainable Urban Growth Strategies.

The study also established that rapid urbanisation has contributed to vegetation loss, environmental degradation, ecosystem disruption, and increasing sustainability concerns within Abuja. These environmental challenges highlight the need for stronger planning controls, environmental protection measures, and sustainable development interventions.

Finally, the study developed an Environmentally Sustainable Urban Growth Framework that integrates geospatial evidence, stakeholder perspectives, governance mechanisms, and sustainability principles. The framework provides a practical guide for managing future urban growth while promoting environmental sustainability, resilience, and evidence-based planning within the Federal Capital Territory.

5.0 Limitations of the Study

Several limitations should be acknowledged. First, the remote-sensing analysis relied on medium-resolution imagery and a supervised classification approach; the absence of a formal accuracy assessment (confusion matrix, overall accuracy and kappa coefficient) means the reported LULC figures should be treated with appropriate caution. The unexpected increase in water-body area between 2017 and 2025 is a possible classification artefact that requires verification with higher-resolution or multi-seasonal data. Second, although a complete sample of 250 respondents (100% response rate) was achieved and basic demographic characteristics are reported, the study did not present a detailed cross-tabulation of responses by professional category, which limits assessment of potential response bias across stakeholder groups. Third, the proposed environmentally sustainable urban growth framework was evaluated only against the study's own findings rather than through independent expert review, Delphi rounds or practical application; further external validation is therefore required before the framework can be considered fully tested. Finally, the

https://doi.org/10.5281/zenodo.23024859

study area covers the approximately 605.1 km² Abuja City-Region rather than the entire Federal Capital Territory; generalisation of the results to the wider FCT should be undertaken carefully.

6.0 Conclusion and Recommendations

The study assessed urban growth and land use/land cover dynamics in the Abuja City-Region between 1987 and 2025 using geospatial analysis and stakeholder assessment. The findings indicate that Abuja has undergone substantial urban expansion characterised by a significant increase in built-up areas and a corresponding decline in vegetation cover. This transformation reflects growing demographic, economic, and infrastructural pressures associated with the city's rapid development.

The study further revealed that urban growth is influenced by a combination of population growth, housing demand, infrastructure expansion, environmental sustainability concerns, governance effectiveness, and stakeholder participation. While urbanisation has contributed to economic development and improved infrastructure, it has also intensified environmental challenges, including vegetation loss, ecosystem degradation, and increasing pressure on natural resources.

To address these challenges, the study developed an Environmentally Sustainable Urban Growth Framework that integrates urban growth drivers, environmental sustainability considerations, governance mechanisms, and sustainable planning strategies. The framework provides a comprehensive approach for guiding future urban development while balancing economic growth, environmental protection, and urban resilience. The study therefore concludes that sustainable urban growth in Abuja requires coordinated planning, effective development control, continuous environmental monitoring, and active stakeholder engagement.

Based on the findings, the study recommends that planning authorities strengthen development control mechanisms and ensure stricter compliance with the Abuja Master Plan to minimise uncontrolled urban expansion. Environmental protection policies should prioritise the conservation of vegetation, green spaces, and environmentally sensitive areas to safeguard ecosystem services and improve urban resilience. The study also recommends the institutionalisation of Remote Sensing, GIS, and Google Earth Engine technologies for continuous monitoring of urban growth and land use changes. Such technologies will enhance evidence-based planning and support timely decision-making. Furthermore, stakeholder participation should be strengthened in urban planning processes to improve transparency, inclusiveness, and policy effectiveness. Finally, greater investment should be directed towards green infrastructure and nature-based solutions to mitigate environmental degradation and promote environmentally sustainable urban development within the Abuja City-Region.

Reference

Enoguanbhor, E. C., Gollnow, F., Nielsen, J. O., Lakes, T., & Walker, B. B. (2019). Land cover change in the Abuja City-Region, Nigeria: Integrating GIS and remotely sensed data to support land use planning. *Sustainability, 11*(5), 1313.

Enoguanbhor, E. C., Gollnow, F., Walker, B. B., Nielsen, J. O., & Lakes, T. (2021). Key challenges for land use planning and its environmental assessments in the Abuja City-Region, Nigeria. *Land, 10*(5), 443.

Federal Capital Development Authority. (1979). *The Abuja master plan*. Federal Capital Development Authority.

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. *Remote Sensing of Environment, 202*, 18–27.

Goodwin, S., Olazabal, M., Castro, A. J., et al. (2023). Global mapping of urban nature-based solutions for climate change adaptation. *Nature Sustainability, 6*(4), 458–469.

Iheaturu, C., Okolie, C., Ayodele, E., Egogo-Stanley, A., Musa, S., & Speranza, C. I. (2024). Combining Google Earth historical imagery and UAV photogrammetry for urban development analysis. *MethodsX, 12*, 102785.

Kabisch, N., Korn, H., Stadler, J., & Bonn, A. (Eds.). (2021). *Nature-based solutions to climate change adaptation in urban areas*. Springer.

Meerow, S., & Newell, J. P. (2019). Urban resilience for whom, what, when, where, and why? *Urban Geography, 40*(3), 309–329.

Okoduwa, A. K., & Amaechi, C. F. (2024). Exploring Google Earth Engine, machine learning, and GIS for land use land cover change detection in the Federal Capital Territory, Abuja, between 2014 and 2023. *Applied Environmental Research, 46*(2), 029.

Okoduwa, A. K., Amaechi, C. F., & Enuneku, A. A. (2024). Soil adjusted vegetation index, normalized difference buildup index, and land surface temperature between 1987 and 2023 in Abuja Municipal Area Council, Nigeria. *Journal of Applied Sciences and Environmental Management, 28*(3), 665–674.

Sharifi, A. (2021). Urban sustainability assessment: An overview and bibliometric analysis. *Ecological Indicators, 121*, 107102.

United Nations. (2022). *World urbanization prospects 2022: Summary of results*. United Nations Department of Economic and Social Affairs.

https://doi.org/10.5281/zenodo.23024859

United Nations Human Settlements Programme (UN-Habitat). (2023). *World cities report 2023: Envisaging the future of cities*. UN-Habitat.

Wulder, M. A., Coops, N. C., Roy, D. P., White, J. C., & Hermosilla, T. (2022). Land cover 2.0. *International Journal of Remote Sensing, 43*(16), 5957–5968.