GIS-Based Assessment of Urbanization Impact on Green Space Dynamics in Awka, Nigeria (1990–2020)

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Abstract

This research project focuses on assessing the impact of urbanization on green spaces in Awka Urban City, Nigeria, utilizing Geographic Information Systems (GIS). The study spans the years 1990 to 2020 and employs Landsat satellite imagery for geospatial analysis. The primary objectives include mapping and quantifying the extent of urbanization, analyzing changes in green space distribution, and assessing ecological consequences. Despite limitations in data availability and challenges with Landsat 2010 scan lines, the study utilizes a comprehensive methodology involving data acquisition, preprocessing, image classification, and change detection. The results reveal a significant decline in green spaces, accompanied by a rise in built-up areas and bare lands. The ecological and environmental consequences of urbanization are discussed, emphasizing the importance of preserving green spaces for biodiversity, air and water quality, climate change mitigation, and overall human well-being.

Keywords: Urbanization, Green space, GIS, Remote sensing, Land use/land cover change, Landsat, Awka, Nigeria.

1. Introduction

Urban areas are now home to more than half of the world's population, and Sub-Saharan Africa is urbanizing faster than any other region, with the United Nations projecting that two-thirds of the global population will live in cities by 2030 (UN, 2018). While urbanization drives economic growth and improved infrastructure, it has come at a substantial ecological cost, as the rapid conversion of natural land cover into built environments has led to widespread loss and degradation of urban green spaces (Lindley et al., 2018; Paudyal et al., 2019). Green spaces, including parks, forests, wetlands, residential gardens, and street vegetation, are essential components of urban ecosystems, supporting biodiversity, regulating climate, and sustaining human well-being (IPBES, 2019; Cheng et al., 2017).

The consequences of green space loss are well documented. Reduced vegetation cover intensifies urban heat islands, increases per capita greenhouse gas emissions, and undermines urban thermal resilience (Kabisch et al., 2017; McPhearson et al., 2015; Sun, 2017). Some of the most severe historical heat events, including the 2003 European heatwave, have been linked to inadequate urban green cover (Kosatsky, 2005). In Sub-Saharan Africa specifically, the conversion of peri-urban agricultural land into residential and commercial development has compounded food insecurity, water shortages, and localized heat stress (Amlor and Alidza, 2016). Despite this evidence, urban green space in emerging economies continues to receive comparatively little research and policy attention (Teimouri and Yigitcanlar, 2018).

Nigeria illustrates this tension acutely. As Africa's most populous country, it is undergoing one of the world's most rapid urban transitions, with its urban population projected to grow by over 226 million people by 2050 (United Nations, 2014). Awka, the capital of Anambra State, has experienced one of the fastest population growth rates in the country (UN-HABITAT, 2009), driven by its administrative status and the expansion of Nnamdi Azikiwe University. This growth has been accompanied by road construction, residential development, and the attendant loss of natural land cover (Nzoiwu et al., 2017). Yet the scale and spatial pattern of this loss have not been systematically quantified.

Traditional ground-based land use mapping has been identified as labor-intensive, time-consuming, and performed only rarely, making it difficult to track changes and conduct time series analysis (Olorunfemi, 1989). Remote sensing and GIS have therefore proven to be effective and dependable techniques for monitoring such changes. However, few studies use GIS technology specifically to analyze the impact of urbanization on green spaces in Awka, Anambra State.

This study addresses that gap. Using Landsat imagery spanning 1990 to 2020, it applies GIS-based classification and post-classification change detection to (i) map and quantify the extent of urbanization in Awka, (ii) analyze changes in green space distribution and coverage over the study period, and (iii) assess the ecological and environmental consequences of that change to inform recommendations for sustainable urban development and green space preservation in Awka.

2. Materials and Methods

2.1 Study Area

Awka is the capital of Anambra State, Nigeria, located between latitudes 6°12′N and 6°17′N and longitudes 7°04′E and 7°08′E, covering an estimated land area of 60.2 km². The city lies on the low-lying western plain of the Mamu River at approximately 333 m above sea level, within the Awka-Orlu upland (Ezenwaji et al., 2013). Awka's population grew from 301,657 in 2006 to an estimated 617,000 by 2021 (Okeke-Ogbuafor and Ezenwaji, 2018), driven by its administrative role, commercial activity, and infrastructural investment. This growth has been accompanied by rising vehicular traffic, air pollution, and inadequate waste management (Okoye, 2016).

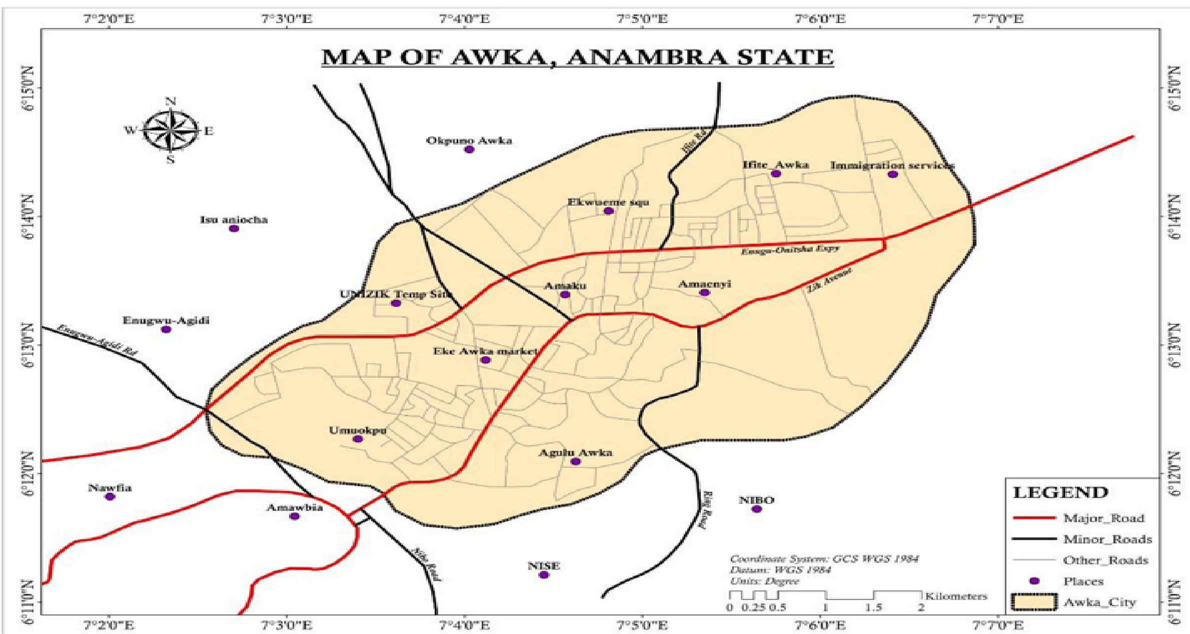

Fig. 1. Map of Awka Urban City (Source: Modified from Administrative Map of Nigeria).

2.2 Research Design and Data

This study adopted an experimental research design based on multi-temporal geospatial analysis of satellite imagery to determine the rate and impact of urbanization on green spaces in Awka. Secondary data comprised Landsat satellite imagery and Anambra State administrative shapefiles. Landsat imagery was selected for its low cost, medium spatial resolution, and demonstrated reliability in environmental change detection. Four images spanning 40 years at approximately 10-year intervals were obtained from the United States Geological Survey (USGS) Earth Explorer archive (Table 1).

Table 1. Satellite data used in the study

Data	Sensor	Acquisition Date	Source	Resolution	Bands
Landsat 5	TM (Thematic Mapper)	22 December 1990	USGS Earth Explorer	30 m	8
Landsat 7	ETM+ (Enhanced Thematic Mapper Plus)	28 July 2000	USGS Earth Explorer	30 m	4
Landsat 7	ETM+ (Enhanced Thematic Mapper Plus)	13 December 2010	USGS Earth Explorer	30 m	8
Landsat 8	OLI (Operational Land Imager)	20 March 2020	USGS Earth Explorer	30 m	4

All imagery was pre-corrected by USGS to Level 1G, using Digital Elevation Models and Ground Control Points to remove Earth-, satellite-, and sensor-related distortion and georeferenced to the WGS 1984 datum, UTM Zone 32N. Given uniform atmospheric conditions across the acquisition dates, no additional atmospheric correction was applied. Standard pre-processing included radiometric correction, geometric registration, and noise removal.

2.3 Image Classification

A False Color Composite (FCC) was generated for each image in ArcGIS 10.5 and clipped to the Awka study area boundary. Supervised classification was performed using the maximum likelihood classification algorithm, based on training samples derived from spectral signature curves and visual interpretation. Land cover was classified into four to five categories depending on data availability: Agriculture, Dense Vegetation, Bare Land, Built-up Area, and Water Bodies (Table 2).

Table 2: Land use/land cover classification scheme

Class	Description
Vegetative Cover (Agriculture / Dense Vegetation)	All plants, forests, reserves, and farmland
Built-up	Impervious surfaces preventing water infiltration, including settlements and road networks
Bare Land	Open ground that is neither vegetated, built-up, nor tarred
Water Bodies	Rivers, streams, and lakes

2.4 Change Detection and Accuracy Assessment

Post-classification comparison was used to quantify land use/land cover change across the four time periods (1990, 2000, 2010, 2020). This method was selected because it bypasses difficulties associated with comparing images acquired in different seasons or by different sensors and yields higher change-detection accuracy than single-date approaches (Zhang et al., 2007). Classification accuracy was assessed against reference points using overall accuracy and the Kappa coefficient following the threshold established by Anderson et al. (1976) and later refined by Eastman (2009), which recommends an overall accuracy above 85% for land use/cover mapping.

2.5 Limitations

Landsat imagery for 2010 was affected by scan-line corrector (SLC) failure, introducing data gaps (striping) across the scene. This constrained the depth of classification and change-detection analysis possible for that year relative to 1990, 2000, and 2020 and is treated as a limitation of the dataset rather than of the classification method.

3. Results and Discussion

3.1 Land Use/Land Cover Change, 1990-2020

In 1990, Awka was still a town in the former Anambra State. It had not yet become the capital at that time, so there were many green spaces. As observed in Fig. 2. below, the The level of urbanization was relatively low, with green spaces covering about 2213 hectares. which is approximately 73.5% of the study area. The bare lands and urbanized regions covered about 26.6%. Additionally, the landscape was mostly characterized by forests, grasslands, and agricultural areas.

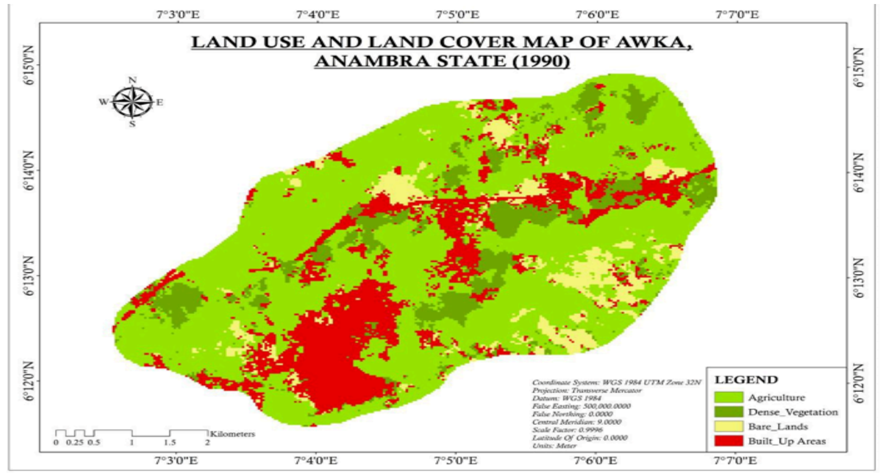

Fig. 2. Land use/land cover map of Awka, 1990. Source: Author's Analysis (2023)

By the year 2000, Awka had already been designated as the capital city of the new Anambra State. Additionally, the establishment of Nnamdi Azikiwe University was still almost a decade away, and this significantly influenced the pattern of land use during this period. Despite this, the level of urbanization remained relatively low. As depicted in Fig. 3 below, the level of urbanization was still relatively low, with green spaces covering about 1747 hectares, which is approximately 58% of the study area, in contrast to the 73.5% covered in 1990. The remaining area was comprised of bare lands, water bodies, and urbanized regions, which covered about 41.9%.

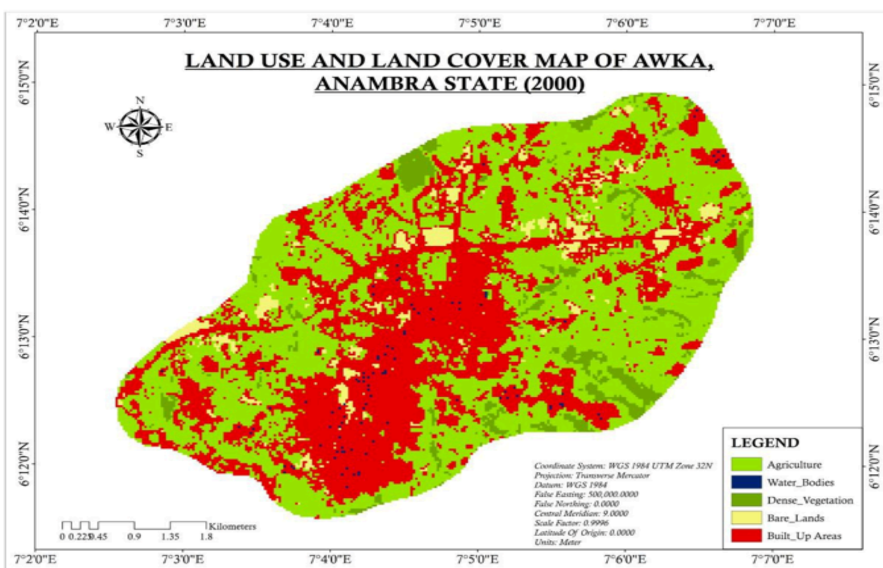

Fig. 3. Land use/land cover map of Awka, 2000. Source: Author's Analysis (2023)

By 2010, Awka was witnessing a significant influx of immigrants, attributed to its status as the administrative hub of the state and the rapid expansion of Nnamdi Azikiwe University. However, the presence of scan lines in the Landsat dataset hampered the ability to fully conclude the classification analysis for this year, adding a layer of complexity to the study (Fig. 4).

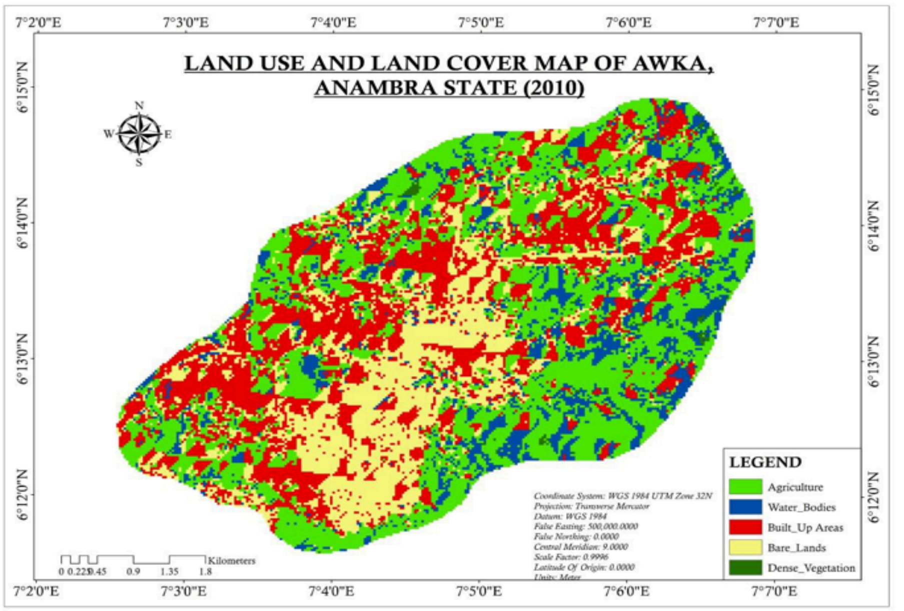

Fig. 4. Land use/land cover map of Awka, 2010. Source: Author's Analysis (2023)

By the year 2020, the spatial extent of the built-up area in Awka had already expanded to encompass over half of the study area. The green space in Awka City had decreased by half between 2000 and 2020, now covering just 484 hectares, which is approximately 16.1% of the entire study area. Additionally, bare lands experienced a significant increase during this period, covering about 946 hectares, which is about 31.4% of the study area. The built-up areas (urbanized areas) grew rapidly to about 1464 hectares, approximately 48.6% of the total area, while water bodies covered only 117 hectares, approximately 3.9%. This transformation reflects the substantial urbanization and land use changes that have occurred in Awka over the past two decades.

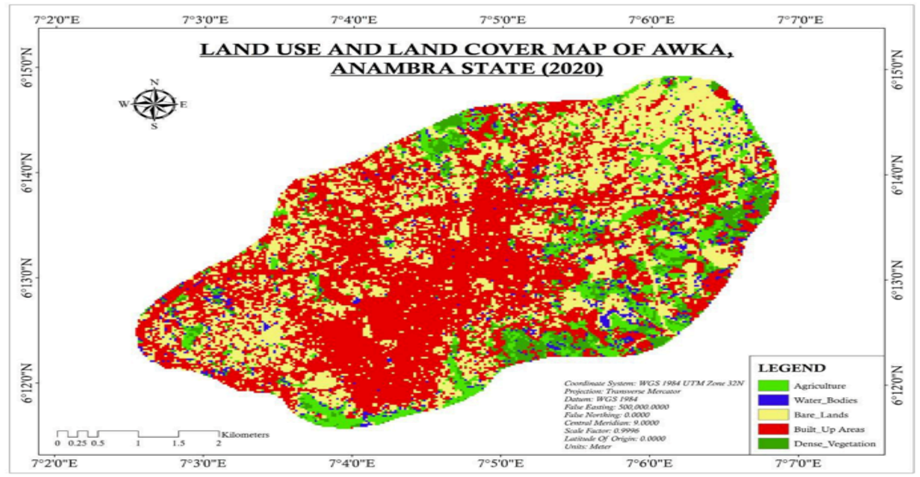

Fig. 5. Land use/land cover map of Awka, 2020. Source: Author's Analysis (2023)

Table 3. Land use/land cover distribution, 1990, 2000, and 2020

Class	**1990 (ha)**	**1990 (%)**	**2000 (ha)**	**2000 (%)**	**2020 (ha)**	**2020 (%)**
Agriculture	1882	62.5	1606	53.3	286	9.5
Dense Vegetation	331	11	141	4.7	198	6.6
Bare Land	222	7.4	1142	37.9	946	31.4
Built-Up Areas	577	19.2	115	3.8	1464	48.6
Water_Bodies	-	0.2	7	0.2	117	3.9

Source: Author's Analysis (2023)

3.2 Change Detection, 1990-2020

Table 4 summarizes the change detected across the study period. Green space declined by approximately 466 ha (15.5% of the study area) between 1990 and 2000 and by a further 1,263 ha (41.9%) between 2000 and 2020. Bare land increased by approximately 920 ha (30.5%) between 1990 and 2000 before declining slightly (-6.5%) between 2000 and 2020. Built-up area contracted by about 462 ha (15%) between 1990 and 2000, then expanded rapidly by 1,349 ha (44.8%) between 2000 and 2020.

Over the full study period, agricultural land alone declined by approximately 53%, while bare land and built-up area expanded by approximately 24% and 29.4%, respectively.

Table 4. Change detection analysis, 1990-2020

Class	1990-2000 (ha)	1990-2000 (%)	2000-2020 (ha)	2000-2020 (%)	Total change (ha)	Total change (%)
Agriculture	-276	-9.2	-1320	-43.8	-1596	-53.0
Dense Vegetation	-190	-6.3	57	1.9	-133	-4.4
Bare Land	920	30.5	-831	-6.5	1751	24.0
Built-Up Areas	-462	-15.4	1349	44.8	887	29.4
Water_Bodies	7	0.2	110	3.7	117	3.9

Source: Author's Analysis (2023)

3.3 Accuracy Assessment

Classification accuracy was assessed for 1990, 2000, and 2020 using overall accuracy and the Kappa coefficient. Overall accuracy was 94% (Kappa = 0.91) for 1990, 96% (Kappa = 0.92) for 2000, and 97% (Kappa = 0.95) for 2020, each exceeding the 85% threshold recommended by Anderson et al. (1976) and Eastman (2009), supporting the reliability of the classification results.

Table 5. Accuracy Assessment

Year	Overall Accuracy	Kappa Coefficient
1990	94%	0.91
2000	96%	0.92
2020	97%	0.95

Source: Author's Analysis (2023)

3.4 Ecological and Environmental Consequences

The expansion of the built-up area to accommodate Awka's growing population and infrastructure has had several ecological and environmental consequences.

Biodiversity loss. Habitat fragmentation and destruction associated with built-up expansion has disrupted the interconnected habitats that support plant and animal species in the study area. As green space is replaced by impervious surfaces, the study area's capacity to sustain diverse ecosystems is reduced, with implications for food webs, nutrient cycling, and ecosystem resilience.

Air and water quality and the urban heat island effect. Green spaces act as natural filters for air pollutants and support water quality by absorbing and filtering stormwater runoff. Vegetation also moderates temperature by providing shade, offsetting the urban heat island effect in which built-up areas experience higher temperatures than surrounding areas. The decline in green space in Awka reduces this regulatory capacity, with implications for air quality, temperature, and energy demand for cooling.

Erosion and flooding. As natural vegetation is replaced by impervious surfaces such as roads and buildings, the land's capacity to absorb and retain water is diminished, increasing surface runoff, soil erosion, sedimentation, and flood risk. Increased runoff can also carry pollutants into water bodies, degrading water quality and posing risks to aquatic ecosystems.

Social, psychological, and climate mitigation impacts. Beyond their ecological role, green spaces support recreation, community interaction, and mental well-being. Green spaces also serve as natural carbon sinks; their decline reduces the study area's carbon sequestration capacity, an important consideration for climate change mitigation.

4. Conclusion and Recommendations

This study provided a comprehensive examination of changes in land use and land cover within Awka city between 1990, 2000, 2010, and 2020, using GIS-based classification and change detection to uncover significant alterations in land use patterns, particularly the conversion of green spaces into developed areas and other land cover categories. The accuracy of the classifications for 1990, 2000, and 2020 was assessed to confirm the reliability of the produced maps, and the ecological and environmental impacts of this urbanization on green spaces were discussed, covering effects on biodiversity, air and water quality, the urban heat island phenomenon, erosion and flooding, social well-being, and climate change mitigation.

The rapid urbanization rate in the area has created unprecedented consequences by diminishing the quality of the environment. To mitigate the effects of urbanization on green space in Awka city, the following recommendations are made:

1. **Sustainable Urban Planning.** Implementing sustainable urban planning strategies is essential to balance the need for development with the preservation of green spaces. This includes zoning regulations, green infrastructure initiatives, and the integration of open spaces in urban design.
2. **Biodiversity Conservation.** Initiatives for biodiversity conservation should be integrated into urban development plans. This may involve creating urban green corridors, establishing protected areas within the city, and promoting sustainable landscaping practices.
3. **Environmental Impact Assessment (EIA).** Incorporating rigorous environmental impact assessments into development projects can help anticipate and mitigate potential negative consequences. This should be a standard practice for all major infrastructure developments.
4. **Community Engagement.** Engaging the local community in urban planning and decision-making processes fosters a sense of ownership and ensures that development aligns with community needs and values. This may involve public consultations, awareness campaigns, and participatory urban design.
5. **Green Infrastructure Investment.** Investing in green infrastructure, such as parks, green roofs, and sustainable drainage systems, can enhance urban resilience, improve air and water quality, and provide recreational spaces for residents.
6. **Policy Integration.** Integrating land use and environmental policies at the local, regional, and national levels ensures a holistic approach to urban development. Policies should aim to balance economic growth with environmental sustainability.

By implementing these recommendations, Awka City can strive for a more sustainable and resilient urban future, maintaining a balance between development and environmental conservation. The findings of this study underscore the critical need for proactive measures to address the adverse impacts of urbanization on green spaces in Awka city, and it is imperative for stakeholders and decision-makers to prioritize the implementation of these recommendations to safeguard the ecological integrity and environmental well-being of Awka city for future generations.

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