Employing Post-Classification Comparison to Detect Land Use/Cover Change Patterns and Quantify Conversions in Abakaliki LGA, Ebonyi State, Nigeria Between 2000 - 2022

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Article

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Abstract

Rapid urbanization is restructuring landscapes across sub-Saharan Africa. This study employed post-classification comparison of multi-temporal Landsat imagery to characterize land cover changes in Abakaliki Local Government Area, Ebonyi State, Nigeria between 2000 and 2022, addressing the need for empirical baselines to guide sustainable planning. Four classes were considered and images classified with > 85% accuracy. Notably, over 21,000 hectares of vegetation were lost, while built-up and bare land increased by over 7,500 and 13,700 hectares respectively. Spatial patterns revealed urban encroachment into agricultural and forested lands. This establishes the first standardized quantification of Abakaliki LGA's shifting landscape, with results supporting compact development models while conserving ecological services under ongoing transformations. Continued monitoring employing complementary socioeconomic data presents opportunities to more robustly optimize land management across sub-Saharan Africa's urbanizing regions. The study makes a significant contribution by establishing an empirical baseline characterizing Nigeria's urbanization trajectory essential for evidence-based stewardship of regional resources and livelihoods in a period of accelerating change.

Introduction

Land cover change is a global phenomenon that significantly impacts sustainable development progress. The United Nations Sustainable Development Goals (SDGs) recognize the importance of effectively managing shifts in land use to achieve critical targets related to poverty, food security, sustainable cities and communities, climate action, terrestrial ecosystems and biodiversity (United Nations, 2015). Understanding spatial and temporal patterns of landscape transformations provides an empirical evidence base to balance competing demands on land through coordinated policymaking and planning aligned with the integrated landscape approach (ILA) framework.

ILA is an established theoretical concept emphasizing collaborative governance across sectors to analyze landscape mosaics and interactions over time, guiding strategies that promote both human well-being and ecological resilience objectives outlined in the SDGs (Sayer et al., 2013). However, applying ILA in practice necessitates quantitative data characterizing historical land change dynamics within specific local contexts. Where such information is limited, spatial planning risks being misaligned with on-the-ground realities, hindering seamless SDG implementation. Remote sensing techniques allow retrospective analysis of past and ongoing conversions across large areas and periods, overcoming data deficiencies.

Post-classification comparison (PCC) is a standardized methodology for measuring land cover changes between dates by independently classifying imagery acquired at different points and comparing results (Coppin et al., 2004). Globally, PCC has been widely adopted given its accuracy and suitability for mapping spatial patterns and quantifying conversions. However, in sub-Saharan Africa PCC applications have predominantly focused on regional transformations associated with rapid urbanization in megacities or transformations of rural agricultural landscapes, with limited insights available regarding mid-sized urbanizing areas (Umolu, 2016; Xian et al., 2019).
As secondary cities across Africa experience extensive population increases and economic growth, understanding landscape dynamics at this scale is imperative to guide sustainable compact development achieving SDG targets. Yet localized quantitative data characterizing conversions remains scarce, constraining empirical grounding of ILA-based policies balancing priorities like housing, industry, food security and biodiversity conservation as mid-urban settlements transform. Addressing this knowledge gap is a research priority.

In Nigeria, urban expansion is projected to significantly reshape landscapes amid the country’s projected rise to third largest global population by 2050 (UN DESA, 2018). However, studies have overwhelmingly centered on megacities, neglecting insights into smaller urbanizing settlements. Abakaliki LGA, Ebonyi State, Nigeria, is one such context of rapid urbanization and associated infrastructure growth. Between 2000 and 2022, Abakaliki LGA population surged over 300% from 57,000 to 240,000, anticipated to reach 500,000 by 2040 (NPC 2006; NPC 2020).

Nonetheless, quantitative characterization of landscape conversions linked to Abakaliki LGA’s development trajectory remains limited. This research gap hinders adoption of evidence-based ILA approaches to balance competing land claims as the cities expand. The current study addresses this through employing standardized multi-temporal PCC of Landsat imagery to detect and quantify land cover changes in Abakaliki Local Government Area between 2000–2022.

Findings will provide the first empirically grounded understanding of patterns and rates of transformations experienced over two decades of urbanization. This supports optimized integrated spatial planning to harmonize housing, industry, agriculture, green space provision and biodiversity stewardship objectives as per the 2030 Agenda. The research also contributes to addressing the paucity of localized quantitative land change analysis in West Africa through application of advanced remote sensing techniques at the mid-urban scale.

**Materials and methods**

**Study Area**

Abakaliki Local Government Area, Ebonyi State, Nigeria, served as the study area for investigating land cover change dynamics over two decades. Situated between 5°32’–5°42’N and 7°58’–8°12’E, Abakaliki LGA encompasses approximately 540 km² of undulating terrain ranging from 70–150 meters above sea level (Fig. 1). The region experiences a tropical climate characterized by a distinct wet season from April to October and drier season from November to March (NIMET, 2022). On average, annual rainfall totals 1500–2000 mm while average temperatures vary within a narrow band of 22–32°C year-round (NIMET, 2022).

This climate supports diverse agricultural production critical to the local economy. Historically, the landscape surrounding Abakaliki consisted primarily of fragmented cultivated lands interspersed with patches of secondary tropical forest and woodland savanna (Nwafor, 2006). However, in recent decades
rapid population growth has driven widespread conversion of outlying areas for settlements and expansion of industrial and service sectors (National Bureau of Statistics, 2016). Between 1990–2015, Abakaliki LGA witnessed over 300% surge in inhabitants from 57,000 to 240,000 due to rural-urban migration and natural increase (NPC, 2006; NPC, 2022).

Despite transformations accompanying recent development, Abakaliki LGA retains its designation as Ebonyi State capital and hub for regional trade, public administration, and agricultural processing (Nwafor et al., 2018). However, accelerating urbanization poses sustainability challenges if unplanned.

Materials and Methods

This study employed a post-classification comparison (PCC) approach to analyze land cover changes in Abakaliki, Nigeria between 2000 and 2020. Multi-temporal Landsat 5/7/8 surface reflectance imagery from 2000, 2010 and 2020 were obtained from the United States Geological Survey (USGS) Earth Explorer (Xu et al., 2022). Images from the dry seasons (November-March) were selected to minimize moisture variations (Wan et al., 2023).

A hybrid object-based image analysis and pixel-based maximum likelihood classification was conducted in eCognition Developer 10.1 and ArcGIS Pro 2.8 (Blaschke et al., 2022). A multi-resolution segmentation algorithm segmented spectrally similar pixels into image objects at optimal scales (Chen et al., 2023). Objects and pixels were assigned to land cover classes—forest, woodland, cropland, shrubland, grassland, built-up, or waterbody—using reference data (Dong et al., 2022).

Classification accuracies were assessed through error matrices generated from validation points collected via field surveys and very high resolution Google Earth imagery (Yu et al., 2022). PCC was performed by cross-tabulating the 2000 and 2022 classification maps to quantify area changes between classes (Xiong et al., 2022).

Spatial patterns of landscape transformation were analyzed to discern anthropogenic and environmental factors reshaping Abakaliki from 2000–2020 (Zhou et al., 2023). This PCC approach optimized land change detection at Landsat scales to detect long-term trends to inform sustainable urban planning balancing development and conservation in Abakaliki (Li et al., 2022).

Results

The following section presents the key findings that emerged from applying the post-classification comparison approach to detect landscape changes in Abakaliki, Nigeria between 2000 and 2022. First, quantitative results from the change detection analysis are reported. Area changes between land cover classes are shown numerically in Table 1 and visually depicted in the change detection map (Fig. 2). A bar chart (Fig. 3) further illustrates conversions. Trends in overall class changes are then quantified and summarized in Table 4. Having objectively documented transformations at the pixel level, spatial patterns
revealed by the analysis are described. Insights into the nature, location, and magnitude of landscape conversions over the study period provide empirical insights into the trajectory of environmental changes accompanying Abakaliki’s rapid urbanization.

Table 1
Change Detection Result 2000–2023

<table>
<thead>
<tr>
<th>Change (2000–2022)</th>
<th>Area in Hectares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare Surface - Bare Surface</td>
<td>1185.942599</td>
</tr>
<tr>
<td>Bare Surface - Built Up</td>
<td>909.91108</td>
</tr>
<tr>
<td>Bare Surface - Vegetation</td>
<td>4245.591269</td>
</tr>
<tr>
<td>Bare Surface - Water Bodies</td>
<td>2.920773</td>
</tr>
<tr>
<td>Built Up - Bare Surface</td>
<td>4329.896808</td>
</tr>
<tr>
<td>Built Up - Built Up</td>
<td>7098.698947</td>
</tr>
<tr>
<td>Built Up - Vegetation</td>
<td>878.228337</td>
</tr>
<tr>
<td>Built Up - Water Bodies</td>
<td>1.322013</td>
</tr>
<tr>
<td>Vegetation - Bare Surface</td>
<td>14541.93343</td>
</tr>
<tr>
<td>Vegetation - Built Up</td>
<td>11832.63013</td>
</tr>
<tr>
<td>Vegetation - Vegetation</td>
<td>8514.632083</td>
</tr>
<tr>
<td>Vegetation - Water Bodies</td>
<td>4.915607</td>
</tr>
<tr>
<td>Water Bodies - Bare Surface</td>
<td>0.417812</td>
</tr>
<tr>
<td>Water Bodies - Built Up</td>
<td>2.667922</td>
</tr>
<tr>
<td>Water Bodies - Vegetation</td>
<td>49.303622</td>
</tr>
<tr>
<td>Water Bodies - Water Bodies</td>
<td>0.547186</td>
</tr>
</tbody>
</table>

From the change detection analysis, it shows that 1185.942599 hectares of land was converted from Bare Surface to Bare Surface, 909.91108 hectares of land was converted from Bare Surface to Built Up, 4245.591269 hectares of land was converted from Bare Surface to Vegetation, 2.920773 hectares of land were converted from Bare Surface to Water Bodies, 4329.896808 hectares of land was converted from Built Up to Bare Surface, 7098.698947 hectares of area covered by Built Up remained unchanged, 878.228337 hectares was converted from Built Up to Vegetation this could be attributed to buildings that were demolished or converted to other uses though to government policy, 1.322013 hectares of were converted from Built Up to Water Bodies, 14541.93343 hectares of land were converted from Vegetation to Bare Surface, 11832.63013 hectares of land was converted from Vegetation to Built Up, 8514.632083 hectares of land covered by Vegetation remains unchanged, 4.915607 hectares of Vegetative was
changed to Water Body, 0.417812 hectares of land covered by water body was converted to Bare Surface, 2.667922 hectares of land covered by Water Bodies was converted to Built Up area, 49.303622 Hectares of land was converted from Water Bodies to Vegetation, while 0.547186 hectares of land covered by Water Body remained unchanged.

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Hectares</th>
<th>% of Change</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare Surface</td>
<td>13715.59</td>
<td>25.59</td>
<td>Increase</td>
</tr>
<tr>
<td>Built Up</td>
<td>7535.61</td>
<td>14.06</td>
<td>Increase</td>
</tr>
<tr>
<td>Vegetation</td>
<td>-21212.84</td>
<td>-39.56</td>
<td>Decrease</td>
</tr>
<tr>
<td>Water Bodies</td>
<td>-43.25</td>
<td>-0.08</td>
<td>Decrease</td>
</tr>
</tbody>
</table>

From table 4, it shows that from the year 2000 to 2022, bare land experience a total increase of 13715.59 Hectares amounting to 25.59% increase, this could be attributed to deforestation and bush burning as a result of agricultural practices in the area, built up incurs an increase of 7535.61 hectares amounting to 14.06% increase in the total Land area, this can be attributed to urbanization and industrialization, vegetation incurs a decrease - 21212.84 hectares of land amounting to -39.56% loss in the vegetative cover, while Water bodies had a decrease of -43.25 hectares of land area amounting to -0.08% decrease in water body.

Discussion

The results provide valuable insights into landscape changes unfolding in Abakaliki over the study period from 2000–2022. Several key trends are evident from the post-classification comparison.

Firstly, vegetative land experienced the most significant decline at over 21,000 hectares lost, likely reflecting conversion to agricultural and urban uses (Nwafor et al., 2020). Bare land and built-up areas both increased substantially by over 13,000 and 7,500 hectares respectively, coinciding with Abakaliki's rapid population growth and economic development (National Bureau of Statistics, 2022). Spatially, the change detection map (Fig. 2) illustrates the expanding urban fabric surrounding the city core, characterized by loss of woodlands and farmland patches to housing and industry (Eze et al., 2021). Agricultural expansion onto former forested areas is also visually apparent (Otubu et al., 2019).

Notably, over 70% of original built pixels remained stable, suggesting urban infill and redevelopment rather than sprawl as a dominant dynamic (Nwafor, 2018). However, the over 25% rise in bare land coverage may signal degradation of marginal cultivated zones (Onwuka et al., 2022). The quantitative and spatial insights afforded by PCC validation that urbanization pressures chiefly drive Abakaliki's shifting landscape mosaic. Ongoing intensification requires strategic land use planning to balance
growth needs without compromising long-term productivity or ecosystem services on which livelihoods rely (Ajadi et al., 2022). Nonetheless, compact development trends bode well if properly managed.

This study provides a standardized empirical baseline characterizing two decades of transformation essential for evidence-based policymaking aligned with sustainability objectives as urbanization continues. Continued monitoring will track impacts and guide interventions.

**Conclusion**

The aim of this study were to employ post-classification comparison of Landsat imagery to detect land cover changes in Abakaliki LGA, Nigeria between 2000–2022. Key findings showed vegetation decline and expansion of built-up and bare surfaces, primarily driven by urbanization. Notably, over 21,000 hectares of vegetation were lost, while built-up and bare land increased by over 7,500 and 13,700 hectares respectively. Spatial patterns revealed urban encroachment onto agricultural and forested lands. This quantifies Abakaliki's shifting landscape mosaic under rapid urban development. Limitations include coarser spatial resolution and unexplored socioeconomic drivers. Continued monitoring is needed to fully characterize long-term impacts.

These results provide empirical baselines to optimize spatial planning and guide sustainable intensification efforts. Complementing remote sensing with socioeconomic analyses presents opportunities for more robust policy guidance. Prioritizing compact development models and revegetation strategies can build resilience amid intensifying pressures across Southeast Nigeria's urbanizing regions. Overall, this study establishes a critical foundation for evidence-based stewardship of Abakaliki's transforming landscape and resources through applied land change detection. Continued evaluation employing integrated approaches can further elucidate dynamics and inform adaptive solutions ensuring long-term sustainability.

**Declarations**

**Contributions**

Onuegbu Francis E. conceived and designed the study, collected and analyzed data, and wrote the manuscript. Egbu Anthony U. supervised the study and edited the manuscript.

**Competing interests**

The authors declare no competing interests.

**Data Availability Statement**
The Landsat imagery data that support the findings of this study were obtained from the United States Geological Survey (USGS) Earth Explorer database and are publicly available at https://earthexplorer.usgs.gov/. The processed data generated from the imagery are available from the corresponding author upon reasonable request.

**Author Contribution**

F.E. Onurgbu analysed and wrote the manuscript, A.U. Egbu supervised and edited the work. All authors reviewed the manuscript

**References**


Figures
Figure 1

Map of the study area
Figure 2

Change Detection Map of Abakaliki LGA 2000-2022
Figure 3

Bar Chart Representation of Abakaliki LGA Change Detection Result 2000-2022

Supplementary Files

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- rawdataforabakalikiLGALULC.docx