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*Research Article*

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# Spatio-Temporal Assessment of Land Use/Land Cover Changes in Onitsha, Anambra State, South-Eastern, Nigeria: A Comparative Study Of 2017 And 2024

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**ABSTRACT**
Land use and land cover in Onitsha, Anambra State, experienced substantial transformation between 2017 and 2024, driven by rapid urban expansion. Using Sentinel-2 satellite imagery and ESRI Land Cover Explorer data, this study assessed spatial and temporal changes across seven LULC categories: built-up area, trees, rangeland, cropland, water bodies, bare ground, and flooded vegetation. Built-up land increased from 35.17 km² (66.47%) in 2017 to 41.67 km² (78.76%) in 2024, recording a net gain of 12.29%. Tree cover declined sharply from 4.43 km² (8.38%) to 0.16 km² (0.31%), reflecting an 8.07% loss, while rangeland dropped by 3.7%, bare ground by 1.2%, and flooded vegetation by 0.05%. Cropland showed a marginal increase of 0.62%, and water bodies remained largely stable with a 0.11% gain. Change detection through post-classification comparison and transition matrices confirmed that built-up expansion occurred primarily at the expense of vegetated and undeveloped lands. Accuracy assessments produced overall classification accuracies exceeding 85%, validating the reliability of the results. The environmental consequences of this shift include elevated surface temperatures, increased flood risk, biodiversity loss, and reduced air quality. These impacts are closely linked to public health outcomes such as respiratory illnesses and heat stress, particularly in high-density zones. Recommendations include the integration of tree planting and green infrastructure into urban planning, the enforcement of land zoning regulations, and the removal of old and dilapidated buildings for conversion into ecological buffers. A participatory geospatial monitoring framework is also proposed, using open-access satellite data and mobile tools to engage local communities in tracking land changes. This study offers a replicable geospatial methodology for urban land monitoring using free, high-resolution datasets. The results provide critical insights for sustainable land management and urban policy in Onitsha, supporting climate adaptation, public health protection, and the achievement of Sustainable Development Goals 11, 13, and 15. By combining environmental analysis with actionable strategies, the study contributes to the development of resilient, livable, and ecologically balanced cities in Nigeria.

## Introduction

Land Use and Land Cover (LULC) changes are now a key issue in global environmental studies due to their far-reaching effects on ecosystems, socioeconomic systems, and public health [1-4]. These changes such as shifts in vegetation, water bodies, and bare soil—are primarily caused by human activities like urbanization, agriculture, and industrial development. Urban expansion, especially in developing countries, has intensified the pressure on natural systems, replacing vegetation and farmlands with built-up infrastructure [1-4]. This shift impacts biodiversity, hydrology, and contributes to localised climate change and air pollution [5]. Urban areas worldwide have grown substantially. The United Nations notes that urban populations increased from 751 million in 1950 to over 4.4 billion in 2021, with two-thirds of the global population expected to live in cities by 2050 [6]. This growth alters surface characteristics, increases land surface temperature, and disrupts the carbon cycle. It also depletes natural landscapes, causing urban heat islands and reducing air quality [7]. As Ridd observed, these changes vary over space and time, requiring continuous monitoring [8].

In Nigeria, land use changes are complex and widespread. Since the 1990s, cities like Lagos, Abuja, and Onitsha have grown rapidly, often replacing vegetation with impervious structures,

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expanding into wetlands, and degrading ecosystems [9-11]. While urbanization has economic benefits, it undermines environmental health by stressing water systems, reducing air quality, threatening food security, and increasing health risks [9-11]. Monitoring these shifts is necessary for informed urban planning. Onitsha illustrates this dynamic clearly. Located along the eastern bank of the River Niger, Onitsha includes Onitsha North and South LGAs and has expanded into neighbouring areas like Nkpor and Obosi. Its transformation from a commercial outpost to a dense urban hub has led to extensive land conversion, replacing agricultural and green spaces with residential and commercial buildings [12]. Onwuka et al. reported sharp increases in impervious surfaces and significant vegetation loss from 1986 to 2016, contributing to higher surface temperatures and unstable local climates [13]. Poorly planned development has worsened erosion, flooding, and infrastructure pressure, making it necessary to apply spatial analysis to guide urban policies.

Nigeria's diverse ecological zones face various degrees of human pressure [9-11]. In southern states like Anambra, urban growth often displaces forests and agricultural land. In northern cities like Kano and Maiduguri, socioeconomic factors drive urbanization [14]. Vegetation loss affects carbon storage, hydrology, and biodiversity. In high-density areas such as Anambra, Imo, and Lagos, unregulated growth leads to flooding, air pollution, and waste problems. Public health risks include respiratory illnesses, heat stress, and increased vector-borne diseases [15].

Efforts to monitor LULC change remain limited. Many available datasets are outdated or too coarse to detect recent or small-scale transitions [16-18]. This restricts evidence-based decisions, especially in fast-changing cities like Onitsha. Older LULC data collection relied on ground surveys and aerial photos, which are costly and time-consuming. The adoption of remote sensing and GIS has changed this, allowing spatial data analysis across time and space. Landsat, IKONOS, and SPOT-5 data have supported Nigerian studies, including Ezeomedo and Igbokwe's work on Onitsha from 1964 to 2008 [12]. Pixel-based, object-oriented, and sub-pixel classification methods have improved analysis accuracy. Object-oriented methods group pixels with similar properties, while sub-pixel methods estimate land cover fractions within a pixel, helping in mixed-use areas. Onwuka et al. used this approach to show vegetation, soil, and water patterns in Onitsha [13]. For change detection, techniques like image differencing, post-classification comparison, and spectral unmixing are common. Post-classification comparison provides detailed "from-to" change matrices, while image differencing helps analyse temporal change [19,20]. These tools have highlighted vegetation loss and the spread of built-up areas in Onitsha. Highresolution, consistent data access has been a major barrier until the release of Sentinel-2 satellites and the ESRI Land Cover Explorer [16-18]. Sentinel-2 delivers 10-metre resolution data with a five-day revisit cycle, suitable for near-real-time LULC tracking [16-18]. ESRI's Explorer provides annual global maps using deep learning on PlanetScope imagery, helping users analyse land cover trends and anomalies. For a city like Onitsha, this platform provides timely information critical for planning and environmental monitoring.

This study uses Sentinel-2 data from the ESRI Land Cover Explorer to compare LULC changes in Onitsha between 2017 and 2024. It applies advanced classification and changes detection methods to measure land transitions and link them with environmental and public health impacts.

Several studies have mapped Onitsha's LULC patterns using satellite data. Ezeomedo and Igbokwe used SPOT-5 and IKONOS imagery with object-oriented classification to show a rise in built-up areas from 8.12% in 1964 to 67.62% in 2008, while vegetation dropped from 79.10% to 18.74% [12]. Onwuka et al. used sub-pixel classification and predictive modelling, but did not link changes to environmental health [13]. Mozie and Ayadiuno assessed urban sprawl and landscape degradation, attributing these to poor governance and weak enforcement [15].

However, there are still major gaps. Many studies used older satellites like Landsat (30m), SPOT (20m), or IKONOS (4m), which are not suitable for detecting frequent, small-scale changes. Most existing research lacks post-2016 data, despite accelerated urbanization during that period. Few studies address the environmental or health implications of LULC changes, or apply modern platforms like the ESRI Land Cover Explorer. This study addresses these gaps. It applies a spatio-temporal approach to assess LULC changes in Onitsha from 2017 to 2024. Using Sentinel-2 imagery and the ESRI Explorer, it captures consistent, high-resolution data [16-18]. Annual intervals allow detection of short-term urban trends that are missed in longer-period analyses [16-18]. The study not only measures change magnitude but also connects it to environmental impacts such as heat stress, flooding, and degraded air quality.

This approach provides an update on recent land development in Onitsha, considering increased construction, housing, and commercial activities. Understanding the scale and direction of change is necessary for environmental planning and risk management. The study also introduces a replicable method for planners and civil society using free, open-access tools—relevant in settings where data access is limited. The study covers Onitsha North and South LGAs and adjacent towns like Nkpor and Obosi, focusing on urban and peri-urban areas with rapid land changes. It uses Sentinel-2 data from 2017 to 2024, examining four land cover types—vegetation, impervious surfaces, bare soil, and water—and assesses how changes affect environmental quality and health. The research adds new evidence to discussions on urbanization and land management. It uses current, high-resolution data to document Onitsha's land use trends and shows how free satellite data can be used for local planning. Policymakers can use the findings to guide green space protection, flood control, and air quality improvements. It also encourages integrated land governance, combining geospatial tools with participatory approaches. By showing how platforms like ESRI Land Cover Explorer can support local monitoring, the study strengthens efforts toward sustainable urban development aligned with SDGs 11, 13, and 15. The theoretical basis for this study is urban ecological theory, which views cities as systems where human and environmental factors interact. Grimm et al. explained that urban land use decisions affect and are affected by ecological conditions, creating feedback loops [21]. In Onitsha, land conversion reduces vegetation and worsens environmental stress, demonstrating the relevance of this framework.

The aim is to assess land use and land cover changes in Onitsha between 2017 and 2024 and evaluate related environmental impacts. The objectives are to classify land use and cover types for 2017 and 2024 using Sentinel-2 data from the ESRI Land Cover Explorer, quantify the spatial extent and rate of change in LULC categories, and identify major land transitions and patterns of urban growth or vegetation loss. The study will also assess the environmental and health impacts of LULC change, with a focus on vegetation loss, surface sealing, and altered hydrology. Finally, it will recommend planning strategies for sustainable land use and urban development in Onitsha.

## Methodology

### Description of the Study Area

Onitsha is a major commercial city located in southeastern Nigeria, strategically situated on the eastern bank of the River Niger in Anambra State. It lies between latitudes 6°6′N and 6°12′N and longitudes 6°45′E and 6°50′E, covering both Onitsha North and Onitsha South Local Government Areas (LGAs) [22]. With an estimated population exceeding one million people, Onitsha is one of the most densely populated urban centres in Nigeria and serves as a regional economic hub, facilitating trade, transportation, and industry across the southeast and beyond [23,24].

Historically, Onitsha began as a settlement of the Igbo people and developed into a major river port during the colonial era due to its proximity to the River Niger [22]. Over the decades, it has transformed into a sprawling metropolis characterised by intense commercial activity, a bustling transport network, and rapidly expanding built-up areas [22]. The city is home to one of the largest markets in West Africa—Onitsha Main Market—attracting traders and goods from across the country and neighbouring nations [25].

The physical geography of Onitsha features a predominantly low-lying terrain with elevation ranging from 30 to 50 meters above sea level. It is flanked by numerous streams and wetlands, many of which drain into the River Niger [22]. The city experiences a tropical wet and dry climate (Aw in the Köppen classification), with a distinct rainy season between April and October and a dry season from November to March. Annual rainfall averages between 1,800 mm and 2,000 mm, while temperatures typically range from 25°C to 32°C throughout the year [26].

Vegetation in the area originally comprised tropical rainforest species; however, rapid urbanization and land conversion have significantly altered the landscape [22]. Large expanses of natural vegetation have been cleared for residential, industrial, and commercial development, leading to habitat loss, reduced biodiversity, and the emergence of urban environmental challenges such as flooding and erosion [15]. Land use in Onitsha is largely dominated by built-up areas, with pockets of remnant vegetation, fallow land, and wetland areas scattered throughout the metropolis and its peri-urban fringes [22].

### Research Design

The socio-economic structure of Onitsha is heavily skewed toward informal trade and entrepreneurship, making it a magnet for rural-urban migration and a contributor to spontaneous urban growth. This rapid urbanization has often occurred without corresponding infrastructural development, leading to congestion, poor waste management, and environmental degradation [12]. Consequently, the city presents a compelling case for spatiotemporal land use land cover; p-analysis, especially given the implications for urban planning, environmental sustainability, and public health.

Given these dynamics, Onitsha represents a microcosm of urban transformation trends seen across Nigeria and sub-Saharan Africa [22]. Understanding the patterns and drivers of land use change in this city provides valuable insights into managing urban growth sustainably in similar contexts.

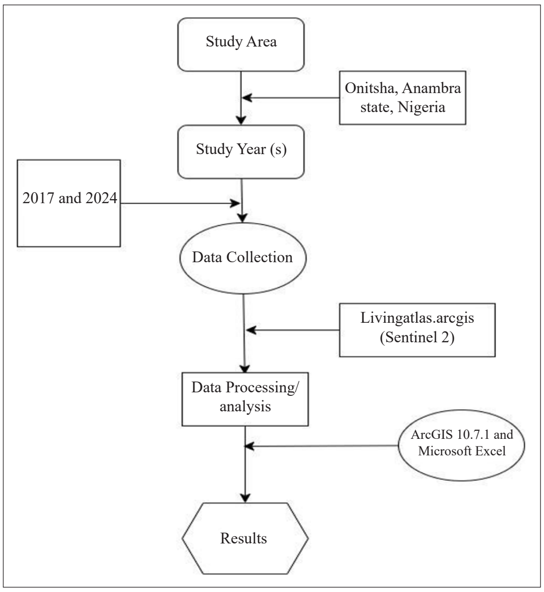


**Figure 2:** Research Design

### Method of Analysis

This study adopts a geospatial approach using satellite remote sensing and Geographic Information Systems (GIS) to analyse the spatial and temporal patterns of land use and land cover changes in Onitsha from 2017 to 2024. The methodology is structured into six interrelated stages: study area definition, selection of study years, data acquisition, preprocessing, classification, accuracy assessment, change detection, and interpretation.

The study area comprises Onitsha North and Onitsha South Local Government Areas, located in southeastern Nigeria along the eastern bank of the River Niger [12]. These areas were selected due to their rapid urbanization and significance in regional economic activity. The administrative boundary shapefiles used to delineate the study extent were sourced from the Office of the Surveyor General of the Federation (OSGOF).

The temporal frame of the study spans two key years—2017 and 2024. These years were selected to represent the most recent complete annual data sets available from the ESRI Land Cover Explorer, allowing a seven-year interval for detecting significant changes in land use and land cover [27].

Data acquisition involved downloading annual global land cover maps derived from Sentinel-2 satellite imagery through the ESRI Land Cover Explorer platform. These maps are produced using deep learning models applied to high-resolution PlanetScope imagery, with a spatial resolution of 10 metres. They provide consistent, cloud-free classifications that are particularly suitable for urban change detection [28].

Preprocessing was performed using ArcGIS 10.7.1 10.7.1. Raster data was clipped to the Onitsha boundary shapefiles, ensuring that all analyses remained within the study area. The datasets were also reprojected into Universal Transverse Mercator (UTM) Zone 32N using the WGS 84 datum to ensure uniformity and spatial precision [29].

The classification scheme adopted was a reorganisation of the original ESRI land cover classes into seven relevant categories for urban analysis: Water Body (dark blue), Trees (dark green), Flooded Vegetation (orange), Cropland (neon), Built Area (red), Bare Ground (light beige), and Rangeland (yellow). This reclassification enhances interpretability and aligns with previous studies on urban land dynamics [5,13]. It was carried out using the raster calculator tool in ArcGIS 10.7.1.

To validate classification accuracy, stratified random sampling was employed. Reference points were extracted and cross-verified with Google Earth Pro imagery for 2017 and 2024. A confusion matrix was constructed to calculate accuracy metrics, including Overall Accuracy, User's Accuracy, Producer's Accuracy, and Kappa Coefficient. An overall accuracy threshold of 85% was considered acceptable, following United States Geological Survey guidelines [30].

Post-classification comparison was used for change detection. This approach compares the classified maps from 2017 and 2024 pixel by pixel, identifying changes in land cover types. A transition matrix was generated to capture "from-to" conversions across land cover categories. The magnitude of change was quantified by calculating net area changes, percentage changes, and annual rates of change [19,20].

The spatial distribution of changes was visualised using thematic maps, bar charts, and transition overlays. These maps were created for both years and included a dedicated change map to highlight transformation hotspots such as deforestation or urban encroachment.

Interpretation focused on understanding the implications of LULC change in relation to Onitsha's socio-economic development and environmental challenges. Changes from natural land to impervious surfaces were evaluated in terms of their impact on flood risk, surface temperature, and air quality, thereby linking spatial patterns with urban sustainability issues [15,21].

## Results

**Table 1: Table showing the land use/land cover change in Onitsha between 2017 and 2024.**

| Onitsha lulc | 2017 | | 2024 | | Net Change (%) |
|---|---|---|---|---|---|
| | Area ($KM^2$) | Percentage (%) | Area ($KM^2$) | Percentage (%) | |
| Water body | 5.62 | 10.62 | 5.68 | 10.73 | 0.11 |
| Trees | 4.43 | 8.38 | 0.16 | 0.31 | -8.07 |
| Flooded Vegetation | 0.04 | 0.07 | 0.01 | 0.02 | -0.05 |
| Cropland | 0.99 | 1.87 | 1.32 | 2.49 | 0.62 |
| Built area | 35.17 | 66.47 | 41.67 | 78.76 | 12.29 |
| Bareground | 0.72 | 1.35 | 0.08 | 0.15 | -1.2 |
| Rangeland | 5.94 | 11.23 | 3.99 | 7.53 | -3.7 |

The spatio-temporal assessment of land use and land cover (LULC) changes in Onitsha between 2017 and 2024 reveals a clear trend of rapid urbanization and ecological decline. The most dominant transformation is the significant increase in built-up areas, which expanded from 35.17 km² (66.47%) in 2017 to 41.67 km² (78.76%) in 2024. This represents a net gain of 12.29%, showing clear pressure from population growth, commercial expansion, and infrastructural development. The increase in built-up land corresponds with sharp reductions in several ecologically significant land cover types. Tree cover decreased drastically from 4.43 km² (8.38%) to just 0.16 km² (0.31%), indicating a loss of 8.07% in vegetated areas. This suggests widespread deforestation, likely due to land clearing for construction, road networks, and informal settlements. Such a drop in tree cover contributes directly to rising surface temperatures and loss of biodiversity. Rangeland also reduced significantly, from 5.94 km² (11.23%) to 3.99 km² (7.53%), marking a 3.7% decline. This reduction points to decreasing availability of semi-natural or unmanaged grasslands, which could have supported some forms of urban agriculture or served as green buffers. Similarly, the decline in bare ground from 0.72 km² (1.35%) to 0.08 km² (0.15%) and flooded vegetation from 0.04 km² (0.07%) to 0.01 km² (0.02%) further reflects intense land conversion activities. The cropland area showed a minor increase from 0.99 km² (1.87%) to 1.32 km² (2.49%), indicating a 0.62% gain. This may be due to small-scale urban or peri-urban farming activities, although the extent remains marginal compared to built-up growth. Water bodies showed a slight increase from 5.62 km² (10.62%) to 5.68 km² (10.73%), an insignificant 0.11% change, implying little or no major disturbance to the riverine systems in the study period.

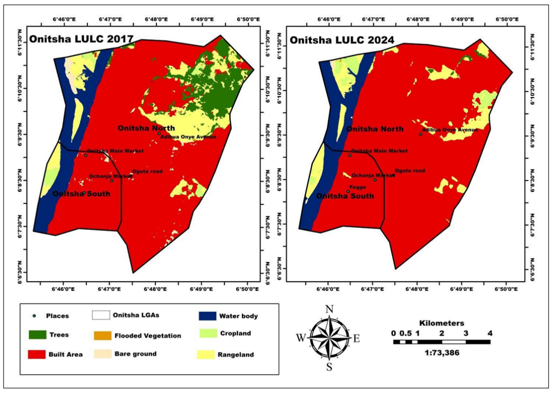


**Figure 3:** Map showing LULC of Onitsha (2017 and 2023)

Figure 3 visually confirms the dominant spatial pattern of urban sprawl in Onitsha, highlighting a clear and extensive transformation of the landscape between 2017 and 2024. In the 2017 map, built-up areas are concentrated primarily in the central part of the city, surrounded by significant stretches of tree cover, rangeland, and other natural land covers. However, by 2024, these natural areas have been largely replaced by extensive urban expansion. The red zones representing builtup areas now dominate the map, covering much of the land area that was previously green, indicating trees and rangeland. This reflects direct land conversion to support housing, commerce, roads, and other forms of urban infrastructure. The spatial contrast between the two years clearly illustrates the intensity of human settlement and development pressure across the region. The reduction of green cover—particularly tree cover and rangeland—is visually evident. Areas once occupied by trees (dark green) and rangeland (yellow) have either disappeared or become fragmented. This confirms not only the scale of environmental disturbance but also the shrinking buffer zones that would have naturally helped with flood control, temperature regulation, and air quality.

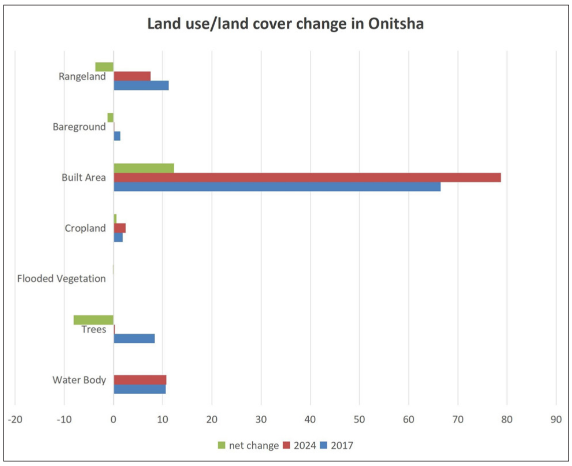


**Figure 4:** Bar chart showing the Percentage change in LULC in Onitsha.

Figure 4, the bar chart, reinforces this interpretation by quantifying the magnitude of these changes. The bar representing built-up area shows the highest positive net change of 12.29%, making it the fastest-growing land cover category. In contrast, the bar for tree cover reflects the steepest decline, dropping by 8.07%, followed by rangeland with a 3.7% decrease. The bars for bareground and flooded vegetation also show notable reductions, though smaller in scale. Meanwhile, water bodies remain relatively unchanged, with only a slight increase, and cropland shows a minor rise, possibly from increased urban agriculture.

Together, the spatial (Figure 3) and statistical (Figure 4) representations confirm the scale, direction, and intensity of land use transformation in Onitsha. The dominance of anthropogenic activities—primarily construction—has overwhelmed natural and semi-natural land covers, resulting in reduced ecological resilience. This pattern reflects broader trends observed in rapidly urbanizing Nigerian cities and emphasizes the urgency for urban planning and environmental control policies.

**Table 2: Producer's and user's images classification accuracies ad Kappa coefficient**

| Land cover class | Producer's Accuracy 2017 (%) | User's Accuracy 2017 (%) | Producer's accuracy 2024 (%) | User's Accuracy 2024 (%) |
|---|---|---|---|---|
| Water body | 95 | 96.15 | 94.12 | 95.65 |
| Trees | 91.67 | 89.47 | 88 | 90.91 |
| Flooded Vegetation | 85 | 80.95 | 81.25 | 78.57 |
| Cropland | 86.36 | 84.21 | 88.89 | 86.67 |
| Built area | 94.12 | 92.68 | 95.45 | 93.75 |
| Bare ground | 90 | 88.24 | 91.67 | 89.47 |
| Rangeland | 87.5 | 85.71 | 86.36 | 84.21 |
| Overall accuracy | 91.23 | | 90.87 | |
| Kappa Coefficient | 0.89 | | 0.88 | |

**Classification accuracy**

The accuracy assessment was conducted using stratified random sampling and cross-referenced against high-resolution Google Earth imagery. The confusion matrix results show that the overall classification accuracies for 2017 and 2024 were 91.23% and 90.87%, respectively. The Kappa coefficients—0.89 (2017) and 0.88 (2024)—indicate a strong agreement beyond chance. High producer's and user's accuracies for built-up areas confirm the model's effectiveness in detecting urban expansion. However, slightly lower accuracies in flooded vegetation reflect challenges in distinguishing spectrally similar classes. These results validate the reliability of the classified LULC maps for change detection and urban planning analysis in Onitsha.

**Discussion**

The findings from this spatio-temporal analysis of land use and land cover (LULC) in Onitsha between 2017 and 2024 reflect a dramatic transformation of the urban environment. The increase in built-up area by 12.29%, accompanied by a sharp decline in tree cover (−8.07%), rangeland (−3.7%), and bareground (−1.2%), is consistent with the long-term urbanization pattern already identified in earlier studies. Onitsha's rapid growth is not an isolated trend but mirrors broader LULC transitions observed in other Nigerian cities such as Lagos, Abuja, Ibadan, and Kano, where vegetation and natural land covers are frequently displaced by impervious surfaces [2,9,13].

The dominance of built-up land in 2024 (78.76%) compared to 2017 (66.47%) confirms the continued pressure of population growth, economic activities, and unplanned development. According to the National Population Commission, Onitsha is one of the most densely populated cities in Nigeria, with high levels of rural-urban migration driving informal expansion [23]. Ezema et al. similarly documented that the city's commercial nature, including the sprawling Onitsha Main Market, has led to extensive land conversion without corresponding environmental planning [24]. This current study's results align with that trend, showing how informal construction and commercial expansion are outpacing the capacity of land governance mechanisms.

The sharp reduction in tree cover, from 8.38% in 2017 to 0.31% in 2024, reflects intense deforestation at the urban fringe and within peri-urban areas. Previous LULC assessments such as those by Ezeomedo and Igbokwe also noted a drop in vegetation from 79.1% in 1964 to 18.74% in 2008, largely due to construction activities [12]. Similar findings have been reported in Enugu, Lagos, and Port Harcourt, where green spaces are routinely cleared for residential and industrial use [9,31]. In Onitsha, deforestation not only diminishes biodiversity and ecological integrity but also heightens urban heat island effects. Grimm et al. observed that reductions in urban vegetation result in higher surface temperatures, reduced evapotranspiration, and poor air quality. These environmental impacts are already evident in Onitsha, where anecdotal evidence and local climate reports point to rising day-time heat and increased respiratory illness during dry seasons [15,32].

The reduction in rangeland (from 11.23% to 7.53%) further underscores the encroachment on semi-natural areas that may have served as informal green spaces or grazing zones. Rangelands, although not always actively managed, provide ecological services including soil stabilization, water filtration, and local cooling. Their loss means additional strain on soil quality, hydrological systems, and community-based agriculture [33]. Adeniyi and Omojola identified similar encroachments in the Sokoto-Rima Basin, where marginal lands were repurposed for settlement expansion, causing erosion and degraded soil structure [14].

The findings also indicate a decrease in bareground areas (−1.2%), suggesting that even previously undeveloped open land is being absorbed into the urban fabric. This matches trends observed in urban centres like Abuja and Uyo, where open spaces, originally intended as buffer zones or future development reserves, are being rapidly converted without consideration for flood control or ventilation corridors [12,13]. The loss of such land accelerates impervious surface coverage, leading to stormwater runoff problems. In Onitsha, frequent flooding events have been attributed not only to rainfall intensity but to the reduction in natural drainage space due to haphazard development [15].

Interestingly, the study recorded a slight increase in cropland from 1.87% to 2.49%. While small in scale, this could reflect the persistence of peri-urban farming practices or a minor resurgence in subsistence agriculture due to food inflation and economic hardship. Similar patterns have been noted on the outskirts of cities like Ibadan and Kano, where marginal land and floodplains are used for short-cycle crops [25]. However, this marginal gain does not offset the broader decline in ecological land types and may be short-lived if urban expansion continues unchecked.

Water bodies showed a negligible change, with only a 0.11% increase from 10.62% in 2017 to 10.73% in 2024. This stability suggests minimal direct encroachment on the River Niger and major streams. However, the integrity of these water bodies remains under threat from runoff, erosion, and pollution driven by upstream urban activities. Studies by Mozie and Ayadiuno and Grimm et al. warned that even when spatial extents remain unchanged, water quality often deteriorates due to siltation, effluent discharge, and surface runoff from impermeable areas [15,21].

Figure 3, which compares the LULC maps for 2017 and 2024, clearly depicts this spatial transformation. The visual dominance of built-up areas by 2024 is pronounced. These expansions are not limited to central Onitsha but extend into Nkpor and Obosi, indicating the onset of urban sprawl. The fragmentation of vegetation zones—visible in the scattered remnants of green cover—confirms the degradation of ecological continuity, a critical factor for species migration, air movement, and climate regulation [21]. Figure 4, a bar chart of percentage change, quantifies this transformation, with built-up area registering the highest positive change and trees showing the steepest decline. This chart validates the pixel-based classification outcome and supports earlier interpretations by Singh and Coppin and Bauer, who emphasized the importance of integrating quantitative change detection with spatial pattern analysis [19,20].

The comparison with prior work also highlights key methodological advancements. Earlier studies on Onitsha LULC dynamics, such as Ezeomedo and Igbokwe and Onwuka et al, relied on SPOT-5, IKONOS, or Landsat images, which, while useful, offer coarser spatial resolution (20m to 30m) and longer revisit times [12,13]. This study's use of Sentinel-2 and ESRI's Land Cover Explorer improves spatial fidelity and temporal consistency, especially important in a rapidly changing urban landscape. Sentinel-2's 10-metre resolution and 5-day revisit cycle allow for near-real-time monitoring and finer discrimination of urban land transitions [28]. Furthermore, the classification strategy employed in this study— integrating object-oriented and post-classification comparison—aligns with global best practices for urban remote sensing [19,31]. It improves accuracy, particularly in heterogeneous urban environments where mixed pixels can skew traditional supervised classification results.

The findings also have implications beyond land cover change. The correlation between rising built-up areas and declining ecological covers is directly tied to public health and disaster vulnerability. Increased impervious surfaces contribute to surface runoff, which overwhelms drainage systems and exacerbates flooding—a recurring issue in Onitsha's low-lying regions [24]. Reduced vegetation also compromises thermal comfort and air quality.

Voldoire and Royer highlighted how vegetation loss leads to elevated land surface temperatures and disrupted urban microclimates [7]. WHO further linked green space access to lower risks of respiratory illness and mental stress, especially in crowded urban environments [32]. Urban areas in Nigeria face similar challenges. In Lagos, for example, Ogunleye et al. documented a 250% increase in built-up areas between 1986 and 2007, with equivalent declines in wetlands and forest areas. In Abuja, growth has expanded into the Abuja Municipal Area Council and neighbouring towns, leading to conflicts over land use, displacement of rural livelihoods, and ecosystem degradation [9]. These urban expansion patterns mirror those observed in Onitsha and emphasize that unplanned urbanization without environmental controls has systemic consequences across Nigerian cities.

The implications for land governance are significant. Urban authorities in Onitsha and similar cities often lack the capacity to enforce land use plans or control informal settlements. The result is not just LULC transformation but weakening ecological and social resilience. Grimm et al. propose urban ecological theory as a framework for understanding how cities function as socio-ecological systems [21]. This theory is relevant to Onitsha, where land decisions reflect economic needs but create feedback loops that intensify heat stress, flood risk, and air pollution.

This study provides evidence that can inform more sustainable urban planning. Green infrastructure—such as preserving riparian buffers, promoting urban forestry, and integrating permeable surfaces—must be prioritized. The study's results can support local zoning revisions, environmental impact assessments, and targeted interventions like tree planting in dense neighbourhoods [34].

Finally, the study introduces a replicable geospatial methodology that local governments and civil society organisations can adopt using open-source tools. The ESRI Land Cover Explorer and Sentinel-2 data are freely accessible, and their integration with platforms like Google Earth Engine enables participatory monitoring and local decision-making. This approach is scalable to other Nigerian cities and aligns with Sustainable Development Goals (SDGs) 11 (Sustainable Cities), 13 (Climate Action), and 15 (Life on Land).

**Recommendation**

The land use and land cover analysis of Onitsha between 2017 and 2024 reveals an urgent and growing challenge: rapid urban expansion is occurring at the direct expense of the city's ecological stability. The sharp decline in vegetation and open spaces, coupled with an overwhelming increase in built-up areas, underscores the need for immediate and strategic intervention. These patterns, if left unchecked, threaten not only environmental integrity but also public health, urban resilience, and long-term sustainability. Therefore, this study recommends a holistic set of actions that align urban development with environmental protection and community well-being.

A foundational step should involve rethinking and restructuring urban planning mechanisms within Onitsha to reflect ecological realities. Spatial planning authorities must enforce zoning regulations that prioritize the preservation and restoration of green spaces. Using high-resolution satellite data from sources like Sentinel-2 and ESRI Land Cover Explorer, planning should be guided by real-time evidence, allowing for better anticipation of urban sprawl and the protection of vulnerable ecological zones. New development approvals must be tied to green space inclusion, and peri-urban areas should be safeguarded as environmental buffers.

In addressing the severe loss of vegetation and natural buffers, city authorities must implement an aggressive urban greening strategy. This includes establishing tree-planting programs, restoring rangeland, and converting unused or marginal land into community-managed green zones. Notably, the city should also undertake a systematic assessment of old, abandoned, or structurally unsafe buildings scattered across high-density neighborhoods. Where feasible, such structures should be decommissioned and replaced with urban green buffers or mini-parks. This approach not only increases green space but also helps reduce overcrowding and improve air circulation in densely built environments.

Public awareness and education are essential to the long-term success of these interventions. Local communities, traders, developers, and property owners must be sensitized on the risks posed by unregulated land conversion and the benefits of ecological balance. Civic engagement initiatives, combined with incentives for eco-friendly construction—such as tax reliefs for green roofing, permeable paving, or maintaining courtyard vegetation—can foster a culture of environmental responsibility.

Moreover, this study highlights the need to establish a participatory land monitoring system. Urban residents, especially youth and local NGOs, should be trained to use geospatial tools and mobile platforms to report land use changes, encroachments, or areas of environmental concern. This grassroots approach would ensure community involvement in data collection and enhance transparency in land management decisions.

From a health perspective, integrating land use management with public health planning is critical. Areas with the most severe vegetation loss and highest surface sealing should be prioritized for interventions that reduce heat exposure and improve air quality. Public facilities— such as schools, markets, and hospitals—should be equipped with shaded spaces and landscaped surroundings to mitigate the effects of urban heat islands. Additionally, the proliferation of informal settlements and unplanned construction must be addressed through targeted redevelopment programs that combine housing upgrades with the introduction of natural ventilation corridors and water-sensitive designs.

Lastly, this study should be institutionalized as a model for routine land use monitoring in Nigerian cities. The methodology applied here—particularly the use of freely available satellite data and accessible analytical tools—demonstrates a scalable and cost-effective approach that can be replicated in other rapidly urbanizing areas. Government agencies, universities, and nongovernmental organizations should use this approach to develop a centralized LULC change database, updated at least every two to three years, to inform data-driven decision-making and track progress toward achieving Sustainable Development Goals related to climate action, sustainable cities, and terrestrial ecosystems.

## Conclusion

This study reveals a rapid increase in built-up areas and a sharp decline in vegetation in Onitsha between 2017 and 2024, highlighting the environmental cost of unregulated urban expansion. Using Sentinel-2 and ESRI data, the analysis confirmed significant land transformation linked to rising heat, flood risk, and reduced air quality. To address these challenges, the study recommends integrating green infrastructure, enforcing land use policies, and converting abandoned buildings into ecological buffers. The methodology provides a replicable model for urban monitoring, offering practical insights for sustainable land governance and climate resilience. These findings are essential for guiding future development in Onitsha and similar urban centers.

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