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Object-Based Landcover/Landuse Change Detection and Analysis of Onitsha and Its Environs Using Multi-Scale Image Fusion

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Abstract - *This study investigates the landcover and land use changes in Onitsha and its environs between 2000 and 2020 using object-based analysis and multi-scale image fusion. The analysis reveals significant transformations driven by rapid urbanization. The built-up area expanded dramatically from 39.64% in 2000 to 62.54% in 2020, highlighting the city's growth as a commercial and residential hub. Concurrently, vegetation cover decreased from 38.86% to 25.06%, and open spaces declined from 14.23% to 5.74%, indicating substantial environmental impacts including increased temperatures, reduced air quality, and biodiversity loss. Water bodies also saw a slight reduction, emphasizing the need for sustainable water resource management. The study underscores the critical need for sustainable urban planning that balances infrastructure development with environmental conservation. By integrating green infrastructure, preserving open spaces, and managing water resources, policymakers can mitigate the adverse effects of urbanization. The findings provide valuable insights for achieving balanced and resilient development in Onitsha, ensuring that economic growth does not compromise environmental sustainability.*

Keywords: *Built-up areas, Environmental impacts, Land use changes, Onitsha, Remote sensing, Sustainable urban planning, Urbanization*

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I. Introduction

Change detection is the process of identifying differences observed at different times (Bruzzone, 2000). In the past decades, remotely sensed images have become a major data source for various applications of change detection. Numerous change detection methods have been developed (Listner, 2011). Some of the most commonly used traditional change detection techniques include image differencing, principal component analysis, post-classification comparison, and change vector analysis (Yonghong et al., 2016). These techniques have typically been applied and evaluated using medium spatial resolution satellite images such as Landsat TM.

However, when studying landscape change detection for high-resolution images, the aforementioned methods have some drawbacks. Traditional pixel-based change detection methods are based on the assumption that neighboring pixels are relatively independent of each other. In high-resolution images, several adjacent pixels combine to form significant geographical objects (Yonghong et al., 2016). Experiments have shown that for images with a resolution higher than 10 meters, object-oriented change detection methods outperform traditional ones. Traditional remote sensing image change detection methods built on the pixel level primarily analyze spectral information and seldom consider the shape and structural features of ground objects.

High-resolution remote sensing images have brought significant advancements to remote sensing technology, clearly displaying the structure, texture, and detailed information of the landscape. In addition to capturing spectral features, object-based methods can also capture the structure, shape, and texture information of surface objects, making it easier to address issues in high-resolution remote sensing image change detection. Thus, studying object-based change detection techniques for high-resolution images is of great significance.

There have been numerous object-oriented change detection methods for high-resolution images (Listner, 2011; Niemeyer, 2011). The fundamental idea of the object-oriented approach is to segment the image and regard objects as the basic unit of operation. Most existing object-oriented change detection methods tend to segment the image at a single scale. However, in high-resolution images, different land-cover types have different scales, and objects of the same type also vary in scale. Single-scale segmentation cannot adequately reflect the characteristics of different objects in images.

Therefore, this study intends to perform object-based landcover/landuse change detection and analysis of Onitsha and its environs using multi-scale image fusion. This method leverages the characteristics of high-resolution images to achieve better results than traditional methods for detecting changes from high-resolution remote sensing images. Change detection in complex landscapes is challenging (Yonghong et al., 2016) due to the complexity of landscapes, which are composed of numerous heterogeneous components that interact non-linearly and exhibit adaptive properties through space and time.

Complex systems display emergent properties, multi-scale hierarchical interactions, unexpected behavior, and self-organization, producing characteristic patterns that change depending on the scale of observation. This is the case with Onitsha and its environs, where the landscape is highly complex, and traditional change detection techniques often lead to mis-registration/misrepresentation of features, resulting in poor outcomes due to varying scale patterns in the landscape. To properly analyze the change dynamics in the landscape of Onitsha and its environs, considering the rule of scale is critical.

Analyzing data at multiple scales addresses the problem of data misrepresentation and helps determine the optimal analysis area for individual objects. Many studies have utilized multi-scale analysis in literature (Carvalho et al., 2003, 2005; Desclée et al., 2006; Hall and Hay, 2003; Youjing and Hengtong, 2007; Duveillera et al., 2008), although few studies on multi-scale image fusion and change detection have been conducted in Onitsha and its environs.

This study aims to perform object-based landcover/landuse change detection and analysis of Onitsha and its environs using multi-scale image fusion. The goal is to provide an approach that yields better change dynamics results than traditional methods, thereby offering quality data for planning, management, and sustainable development in Onitsha and its environs.

II. Materials and Methods

2.1 Study Area

Onitsha is a city located on the eastern bank of the Niger River, in Nigeria's Anambra State (see figures 1 and 2). A metropolitan city, Onitsha is known for its river port and as an economic hub for commerce, industry, and education. It hosts the Onitsha Main Market, the largest market in Africa in terms of geographical size and volume of goods.

In the 2006 Nigerian census, Onitsha had an estimated city proper population of over quarter of million people. The indigenous people of Onitsha are Igbo and speak the Igbo language. Onitsha is located between longitudes 6 45’ 00” E and 6 48’ 00” E and latitudes 6 03’ 00” N and 6 09’ 00” N (see figure 3).

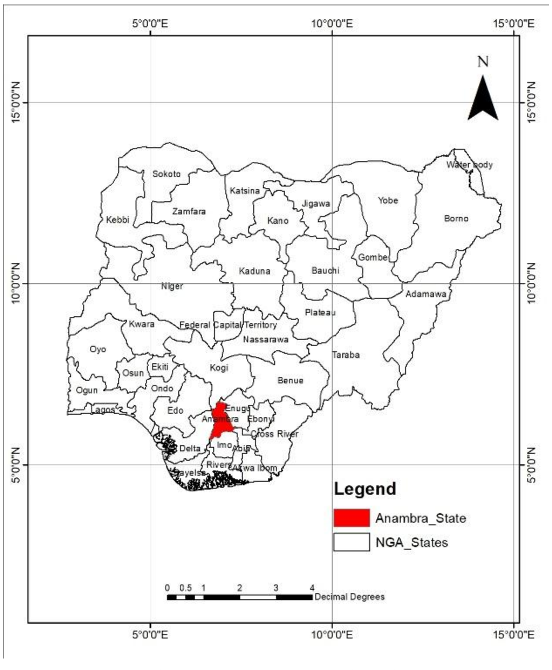


Figure 1: Map of Nigeria

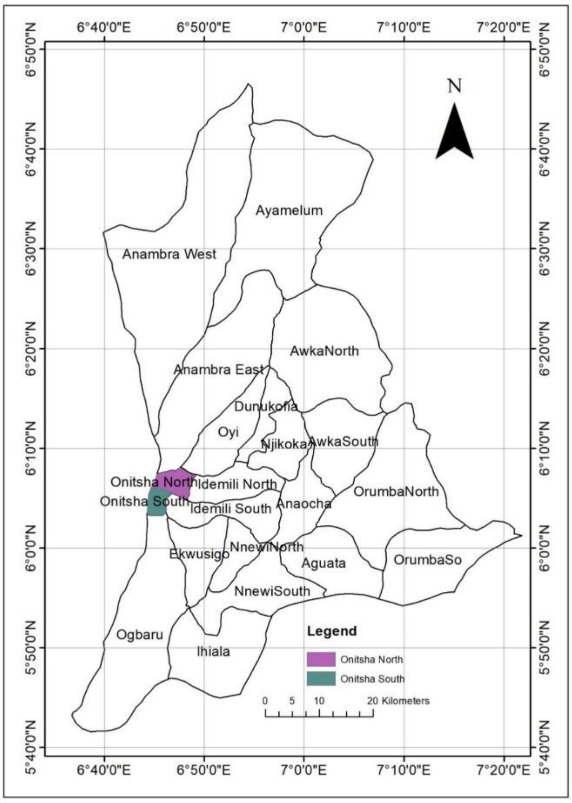


Figure 2: Map of Anambra State

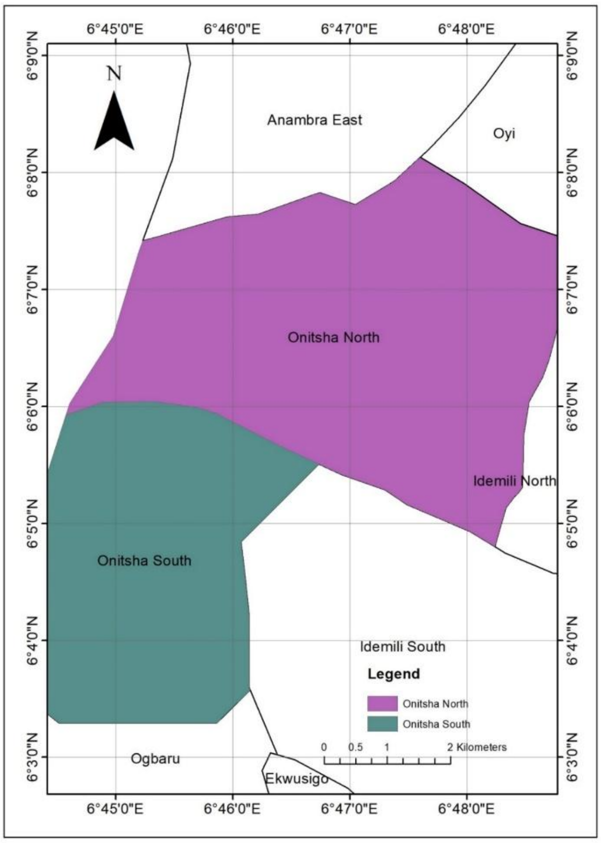


Figure 3: Map of Study Area

Onitsha lies at a major east-west crossing point of the Niger River and occupies the northernmost point of the river regularly navigable by large vessels. These factors have historically made Onitsha a major centre for trade between the coastal regions and the north, as well as between eastern and western Nigeria. Onitsha possesses one of the very few road bridge crossings of the mile-wide Niger River and plans are in place to add a second bridge near it. Rapid urbanization in recent years negatively affects natural vegetation and local landscape.

2.2 Methodology

The methodology involved acquiring high-resolution imagery of the study area for the years 2000, 2010, and the methodology for this study was designed to comprehensively analyze landcover and land use changes in Onitsha and its environs over a twenty-year period, utilizing advanced remote sensing techniques. The detailed steps are as follows:

a) **Data Acquisition**:

High-resolution satellite imagery for the years 2000, 2010, and 2020 was obtained from reliable sources. These images provided the necessary spatial and spectral resolution to accurately capture the landscape changes in the study area.

b) **Preprocessing**:

Image Fusion: Multi-scale image fusion was performed to enhance the spectral and spatial quality of the acquired images. This process involved combining images from different sensors and scales to create a single image with improved detail and clarity, thereby facilitating more accurate analysis.

Image Subset Extraction: The area of study was extracted from the fused images using a subset extraction technique. This step ensured that only the relevant portions of the images, corresponding to Onitsha and its environs, were used for further analysis.

c) **Object-Based Image Analysis (OBIA)**:

Segmentation: The pre-processed images were segmented into meaningful objects using object-based segmentation techniques. This process involved dividing the images into homogenous segments or objects based on spectral and spatial characteristics.

Classification: The segmented objects were then classified into distinct landcover/landuse classes. Object-based classification methods were employed to categorize the objects into predefined classes such as built-up areas, vegetation, open spaces, water bodies, and sand.

d) **Accuracy Assessment**:

The classification results were evaluated to assess the accuracy and extent of coverage of each landcover/landuse class. Accuracy assessment involved comparing the classified images with ground truth data or reference data to determine the precision of the classification process.

e) **Trend Analysis**:

Change Detection: The extent of coverage for each landcover/landuse class was analyzed for the years 2000, 2010, and 2020. Change detection techniques were applied to quantify the changes in area and percentage for each class over the specified periods.

Rate of Change: Trend analysis was conducted to establish the rate of change for the extracted classes. This analysis involved calculating the annual rate of change and identifying significant trends in landcover/landuse transformations.

f) **Data Interpretation and Visualization**:

The results of the classification and trend analysis were interpreted to understand the spatial and temporal dynamics of landcover and land use changes in Onitsha. The findings were visualized using maps, graphs, and tables to effectively communicate the extent and nature of the changes observed.

III. Results

3.1 Landcover/landuse mapping

a. Landcover/landuse mapping of Onitsha in 2000

The landcover/landuse distribution of Onitsha in 2000 as shown in Figure 4 and Table 1 indicate that built up area, accounted for the largest land cover/use of about 39.64% and an area of about 2736.85 hectares. vegetation had 38.86% and a coverage area of 2683.46 hectares. Open space, water body and sand had the lowest turnout with 14.23%, 6.45% and 0.83% with an area of 982.51hectares, 445.07 hectares and 57.12 hectares respectively.

Table 1: Landcover/Landuse distribution for 2000

Class	Area (Hectares)	Percentage (%)
Water Body	445.07	6.45
Vegetation	2683.46	38.86
Built up area	2736.85	39.64
Open space	982.51	14.23
Sand	57.12	0.83
Total	6905.01	100.00

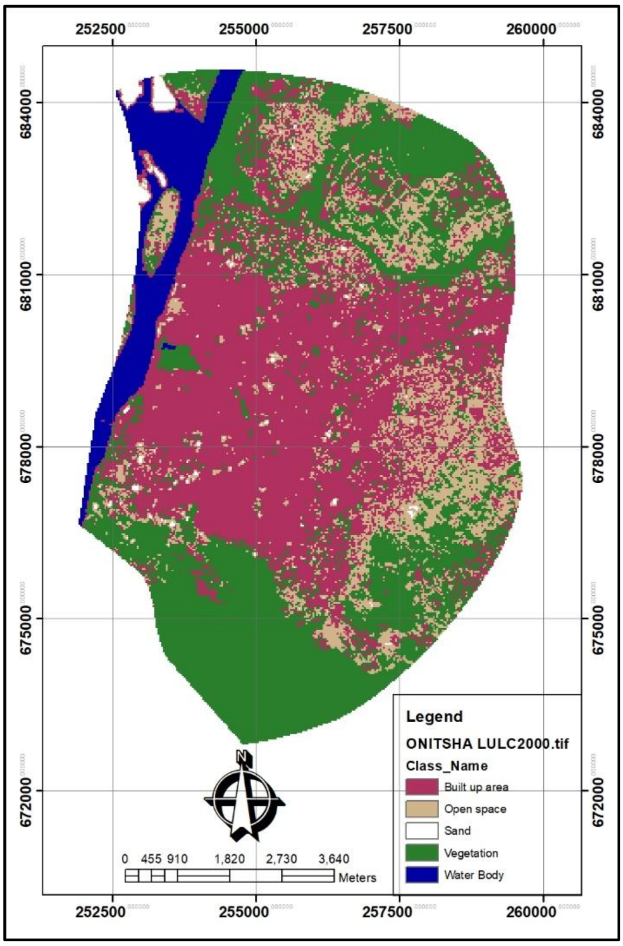


Figure 4: Landcover/landuse map of Onitsha in 2000

b. Landcover/landuse mapping of Onitsha in 2010

The landcover/landuse distribution of Onitsha in 2010 as shown in Figure 5 and Table 2, indicated that built up area had a percentage coverage of 49.19% and an area of about 3396.46 hectares. vegetation had 36.06% and a coverage area of 2490.03 hectares. Open space, water body and sand had the lowest turnout with 7.56%, 6.25% and 0.94% with an area of 522.17 hectares, 431.69 hectares and 64.66 hectares respectively.

Table 2: Landcover/Landuse distribution for 2010

Class	Area (Hectares)	Percentage (%)
Water Body	431.69	6.25
Vegetation	2490.03	36.06
Built up area	3396.46	49.19
Open space	522.17	7.56

Sand	64.66	0.94
Total	6905.01	100.00

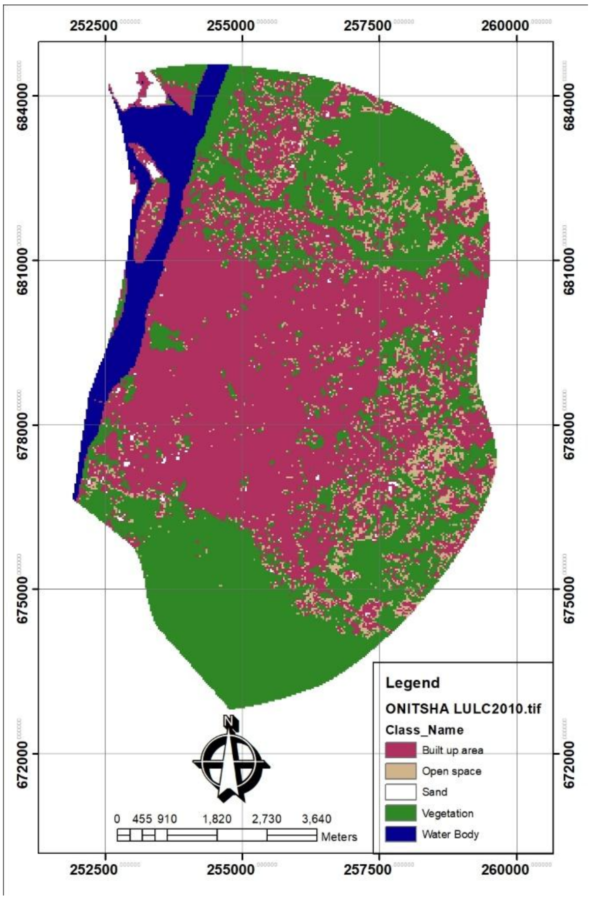


Figure 5: Landcover/landuse map of Onitsha 2010

c. Landcover/landuse mapping of Onitsha in 2020

The landcover/landuse distribution of Onitsha in 2010 as shown in Figure 6 and Table 3, indicated that built up area had a percentage coverage of 62.54% and an area of about 4318.63 hectares. vegetation had 25.06% and a coverage area of 1730.27 hectares. Open space, water body and sand had the lowest turnout with 5.74%, 5.73% and 0.93% with an area of 396.04 hectares, 395.77 hectares and 64.3 hectares respectively.

Table 3: Landcover/Landuse distribution for 2020

Class	Area (Hectares)	Percentage (%)
Water Body	395.77	5.73
Vegetation	1730.27	25.06
Built up area	4318.63	62.54
Open space	396.04	5.74
Sand	64.3	0.93
Total	6905.01	100.00

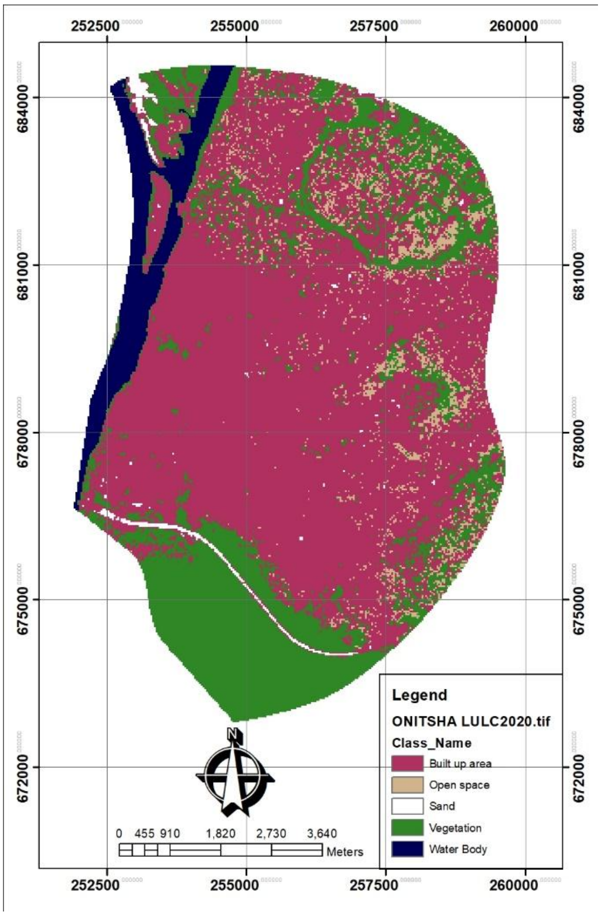


Figure 6: Landcover/landuse map of Onitsha in 2020

3.2. Trend Analysis and Landcover/landuse Transition

i. Trend Analysis

In this study, between 2000 and 2020, the difference in area for water body was -13.38 hectares and -35.92 hectares from 2000 to 2010 and 2010 to 2020 respectively. Vegetation had a difference in area of -193.43 hectares and -759.76 hectares from 2000 to 2010 and 2010 to 2020 respectively.

Built up area had a difference in area of 659.61 hectares and 922.17 hectares from 2000 to 2010 and 2010 to 2020 respectively. Open space had a difference in area of -460.34 hectares and -126.13 hectares from 2000 to 2010 and 2010 to 2020 respectively. Sand had a difference in area of 7.54 hectares and -0.36 hectares from 2000 to 2010 and 2010 to 2020 respectively. As shown in Table 4.

Table 4: Difference in area between 2000 and 2020

Class	2000 – 2010 (Hectares)	2010 – 2020 (Hectares)
Water Body	-13.38	-35.92
Vegetation	-193.43	-759.76
Built up area	659.61	922.17
Open space	-460.34	-126.13
Sand	7.54	-0.36

The total area for water body was 876.76 hectares and 827.46 hectares from 2000 to 2010 and 2010 to 2020 respectively. Vegetation had a difference in area of 5173.49 hectares and 4220.3 hectares from 2000 to 2010 and 2010 to 2020 respectively.

Built up area had a difference in area of 6133.31 hectares and 7715.09 hectares from 2000 to 2010 and 2010 to 2020 respectively. Open space had a difference in area of 1504.68 hectares and 918.21 hectares from 2000 to 2010 and 2010 to 2020 respectively. Sand had a difference in area of 121.78 hectares and 128.96 hectares from 2000 to 2010 and 2010 to 2020 respectively. As shown in Table 5.

Table 5: Total area between 2000 and 2020

Class	2000 – 2010 (Hectares)	2010 – 2020 (Hectares)
Water Body	876.76	827.46
Vegetation	5173.49	4220.3
Built up area	6133.31	7715.09
Open space	1504.68	918.21
Sand	121.78	128.96

The trend of change for the class features between 2000 and 2020 was given as -1.53 % for water body between 2000 and 2010, and -4.34 % between 2010 and 2020. The trend of change for vegetation was given as -3.74% between 2000 and 2010, and -18.00% between 2010 and 2020. The trend of change for built up area was given as 10.75% between 2000 and 2010, and 11.95% between 2010 and 2020. The trend of change for open space was given as -30.59% between 2000 and 2010, and -13.74% between 2010 and 2020. Then lastly, the trend of change of sand was given as 6.19% between 2000 and 2010, and -0.28% between 2010 and 2020. as shown in Table 6 and Figure 7.

Table 6: Trend of change between 2000 and 2020

Class	2000 – 2010 (%)	2010 – 2020 (%)
Water Body	-1.53	-4.34
Vegetation	-3.74	-18.00
Built up area	10.75	11.95
Open space	-30.59	-13.74
Sand	6.19	-0.28

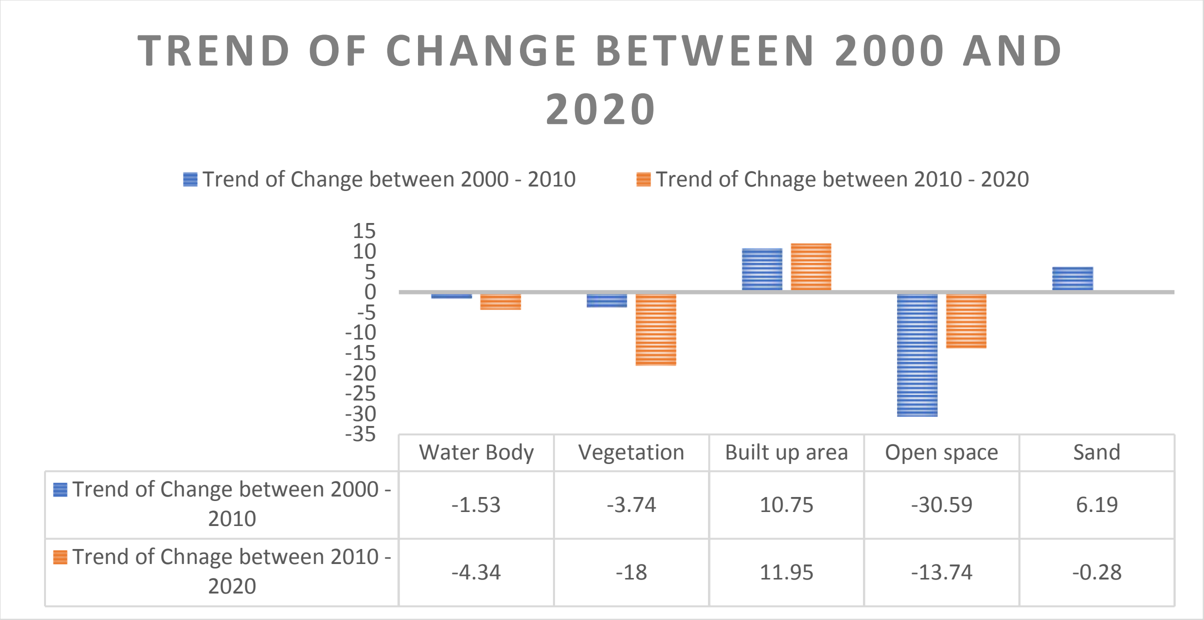
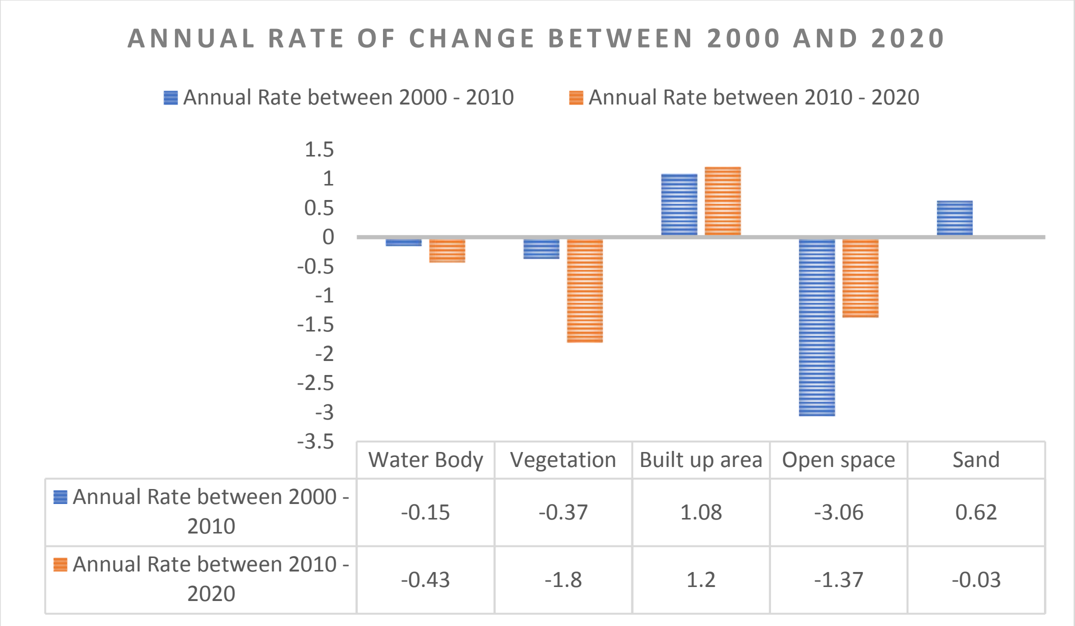


Figure 7: Trend of change between 2000 and 2020

The annual of change for the class features between 2000 and 2020 was given as, -1.53 % for water body between 2000 and 2010, and -4.34 % between 2010 and 2020. The trend of change for vegetation was given as -3.74% between 2000 and 2010, and -18.00% between 2010 and 2020. The trend of change for built up area was given as 10.75% between 2000 and 2010, and 11.95% between 2010 and 2020. The trend of change for open space was given as -30.59% between 2000 and 2010, and -13.74% between 2010 and 2020. Then lastly, the trend of change of sand was given as 6.19% between 2000 and 2010, and -0.28% between 2010 and 2020. as shown in Table 7 and Figure 8.

Table 7: Annual rate of change between 2000 and 2020

Class	Annual Rate between 2000 – 2010 (%)	Annual Rate between 2010 – 2020 (%)
Water Body	-0.15	-0.43
Vegetation	-0.37	-1.80
Built up area	1.08	1.20
Open space	-3.06	-1.37
Sand	0.62	-0.03



	Water Body	Vegetation	Built up area	Open space	Sand
🟦 Annual Rate between 2000 - 2010	-0.15	-0.37	1.08	-3.06	0.62
🟧 Annual Rate between 2010 - 2020	-0.43	-1.8	1.2	-1.37	-0.03

Figure 8: Annual rate of change between 2000 and 2020

IV. Discussion of Results

The landcover and land use changes in Onitsha from 2000 to 2020 reveal significant transformations in the region's landscape, driven primarily by urban expansion and other anthropogenic activities. The analysis provides a comprehensive overview of these changes and their implications, focusing on built-up areas, vegetation, open spaces, water bodies, and sand.

In 2000, built-up areas accounted for 39.64% of the landcover, covering approximately 2736.85 hectares. By 2010, this had increased to 49.19%, representing 3396.46 hectares. In 2020, the built-up area further expanded to 62.54%, covering 4318.63 hectares. This substantial increase in built-up areas, with a 10.75% rise from 2000 to 2010 and an 11.95% rise from 2010 to 2020, underscores the rapid urbanization in Onitsha. This growth reflects the city's development as a commercial and residential hub, leading to a higher demand for infrastructure and services.

Vegetation, which covered 38.86% of the area (2683.46 hectares) in 2000, decreased to 36.06% (2490.03 hectares) in 2010 and further to 25.06% (1730.27 hectares) in 2020. The reduction in vegetation cover, with a 3.74% decrease between 2000 and 2010 and a significant 18.00% decrease between 2010 and 2020, highlights the environmental impact of urban expansion. The loss of vegetation can lead to increased temperatures (urban heat island effect), reduced air quality, and loss of biodiversity, which underscores the need for sustainable urban planning practices.

Open spaces, which covered 14.23% (982.51 hectares) in 2000, reduced significantly to 7.56% (522.17 hectares) in 2010 and further to 5.74% (396.04 hectares) in 2020. This decline, with a 30.59% reduction between 2000 and 2010 and a 13.74% decrease between 2010 and 2020, reflects the conversion of open spaces into urban infrastructure. This trend impacts recreational areas and contributes to overcrowding and reduced quality of life.

Water bodies, which covered 6.45% (445.07 hectares) in 2000, saw a slight decrease to 6.25% (431.69 hectares) in 2010 and further to 5.73% (395.77 hectares) in 2020. The reduction in water bodies, with a 1.53%

decrease between 2000 and 2010 and a 4.34% decrease between 2010 and 2020, may be attributed to land reclamation and pollution. Preserving water bodies is crucial for maintaining local ecosystems and water quality.

Sand areas remained relatively stable over the two decades. In 2000, sand covered 0.83% (57.12 hectares) of the area, increasing slightly to 0.94% (64.66 hectares) in 2010 and maintaining a similar coverage of 0.93% (64.30 hectares) in 2020. These changes are minimal compared to other landcover types but are still important for understanding sedimentation and erosion processes in the region.

The landcover and land use changes in Onitsha from 2000 to 2020 have profound implications. The significant increase in built-up areas necessitates improved urban planning to ensure sustainable development. This includes better infrastructure, public services, and housing to accommodate the growing population. The substantial loss of vegetation underscores the need for green infrastructure initiatives, such as urban forests, parks, and green roofs, to mitigate the adverse effects of urbanization, such as heat islands and air pollution.

The reduction in water bodies calls for concerted efforts to protect and restore these critical resources. Policies aimed at reducing pollution and promoting sustainable water use are essential for maintaining the health of aquatic ecosystems. The decline in open spaces highlights the need to preserve and create recreational areas to improve the quality of life for residents. These spaces are vital for community well-being, providing areas for recreation and social interaction.

Changes in land use can affect the local economy, influencing sectors such as agriculture, real estate, and tourism. Understanding these dynamics can help policymakers develop strategies to balance economic growth with environmental sustainability. In conclusion, the landscape changes in Onitsha between 2000 and 2020 reflect rapid urbanization and its associated challenges. Addressing these challenges requires a multi-faceted approach that integrates sustainable urban planning, environmental conservation, and socio-economic considerations to ensure balanced and resilient development.

V. Conclusion

The study of landcover and land use changes in Onitsha between 2000 and 2020 reveals significant transformations primarily driven by rapid urbanization. The built-up area increased dramatically from 39.64% in 2000 to 62.54% in 2020, reflecting the city's expansion as a commercial and residential hub. This growth, while indicative of economic development, has come at the cost of reduced vegetation cover and open spaces, which declined by 13.80% and 8.49%, respectively, over the same period. These changes highlight the environmental impacts of urban expansion, including increased temperatures, reduced air quality, and loss of biodiversity.

The slight reduction in water bodies further underscores the need for sustainable water resource management to maintain local ecosystems and water quality. The relatively stable area of sand, despite minimal changes, also points to the importance of understanding sedimentation and erosion processes in the region.

The findings emphasize the critical need for sustainable urban planning that balances infrastructure development with environmental conservation. Initiatives such as green infrastructure, urban forests, and parks are essential to mitigate the adverse effects of urbanization. Furthermore, preserving and creating recreational spaces can enhance the quality of life for residents, providing areas for social interaction and recreation.

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