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Effects of Urbanisation on Land Use and Land Cover Changes in Ibadan and Owerri Metropolitan Cities in Rainforest Ecological Zone of Nigeria

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ABSTRACT

This study assessed the effect of urbanisation on land use/land cover changes, Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built up Index (NDBI) in Ibadan and Owerri Metropolis located in the Rainforest Ecological Zone of Nigeria. Landsat imageries of the two cities from 1990 to 2019 were acquired from the Earth Explorer and Global Visualizations (GLOVIS) database of the United States Geological Survey (USGS), processed and analysed using the maximum likelihood supervised classifier algorithm of the Idrisi Terrset., while the NDVI and NDBI for the locations were computed using ArcMap 10.8. The study established that in Ibadan, built-up increased by 726.64km^2 from 312.90km^2 in 1990 to 1039.54km^2 in 2019 while bare surfaces increased by 134.26km^2 from 155.0km^2 in 1990 to 289.27km^2 in 2019. Forest cover, light vegetation, agricultural lands and water bodies decreased from 712.66km^2, 1316.21km^2, 891.51km^2 and 14.70km^2 respectively in 1990 to 253.05km^2, 1092.51 km^2, 715.55km^2 and 12.73km^2 respectively in 2019. In Owerri, built-up and agricultural lands increased from 70.32km^2, and 78.79km^2 respectively in 1990 to 209.16km^2 and135.94km^2. Forest, bare surfaces, light vegetation and water bodies decreased in areal coverage from 70.16km^2, 59.98km^2, 255.09km^2 and 9.11km^2 respectively in 1990 to 21.35km^2, 29.12km^2, 141.52km^2 and 6.19km^2 in 2019. The study also revealed that Owerri had a higher mean NDVI value (0.1137) than Ibadan (-0.0422), while Ibadan had a higher mean NDBI value (0.1578) than Owerri (0.0589). The study concluded that urbanisation occurs rapidly in both cities to the detriment of other land cover types and has resulted in drastic depletion in vegetal cover and alterations in other biophysical parameters of the cities as a result of rapid urbanisation. The study therefore suggests strict implementation of the development plans of the cities, and adoption of urban improvement measures.

Keywords: Ibadan, LULC, NDBI, NDVI, Owerri, Rain Forest, Urbanisation.

1. INTRODUCTION

Over the past three to four decades, Sub-Saharan African cities and towns have experienced annual unprecedented growth rate of approximately four percent (Henderson *et al*., 2017). As a result of this unprecedented urbanisation, more than half of the global population currently resides in urban areas, and this figure is expected to continue rising. The prevalence of urbanisation in developing countries is attributable to the fact that cities, especially capital cities, serve as focal points for a significant portion of contemporary productive endeavours. Several factors have been attributed to the rapid urbanisation in Nigerian urban areas, among which include the pull factor of urban centres due to perceived opportunities offered by these urban centres (Ohwo and Abotutu, 2015; Aliyu and Amadu, 2017). The process of urbanisation results in land use/land cover changes and the transformation of natural land cover into modern non-evaporating impervious surfaces (Polydoros *et al*., 2018; Paranunzio *et al.*, 2019). Land use and land cover changes (LULCC), aside from altering the physical dimension of the spatial extent of the various land cover classes, also influence many of the secondary processes which lead to the eventual degradation of the ecosystems and reduction in vegetation cover (Roy and Roy, 2010). The loss of a vegetal cover consequently leads to several deleterious effects which include climate change (Niyogi *et al*., 2009; Iwuji *et al*., 2017; Namugize *et al*., 2018, Alemayehu *et al*. 2019). The unprecedented deforestation happening in the Rainforest Ecological Zone (RFEZ) of West Africa not only results in the loss of biodiversity but also the degradation of the land. Furthermore, LULCC in the RFEZ may worsen the climate change occurring globally. Understanding the spatial distribution and expansion of urban centres and its implications on other biophysical parameters is therefore vital for sustainable urban planning and improvement of the urban environment. Unfortunately, very little of such current assessments exist for the study locations, especially putting the sizes of the cities into consideration. This study therefore assessed the current LULCC and associated biophysical parameters of Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Built-up Index (NDBI) in a densely populated city and a moderately populated one in the RFEZ.

2. MATERIALS AND METHODS

2.1 Description of the study Area

The RFEZ is classified as Koppen's Tropical Humid (Af) Climate. The area is highly inhabited and covers almost 9.7% of Nigeria's whole land area. The mean annual precipitation in this ecological zone is approximately 2500mm in the southern region and around 1220mm in the northern outskirts. The average yearly relative humidity is approximately 76.05% (Adepoju and Salami, 2017; Gbiri *et a*l., 2019). The region experiences a prolonged period of precipitation from March/April to November, followed by a dry spell from December to March (Adepoju and Salami, 2017). The zone exhibits a monthly mean minimum temperature of approximately 22.49°C and a monthly mean maximum temperature of around 31.24°C. Additionally, it maintains an average annual temperature of about 26.6°C (Adepoju and Salami, 2017). The zone exhibits the highest level of richness regarding the composition, abundance, and diversity of tree and animal species (Adaohuru *et al*., 2012; Akpan-Ebe, 2017). Ibada and Owerri are both located within this zone. Ibadan is situated inside the Rainforest area of Nigeria, specifically between longitude 3°5' to 4°36' East of the Greenwich Meridian, and latitude 7°23' to 7°55' North of the Equator (Figure 1B). The city consists of eleven (11) Local Government Councils, with six located in

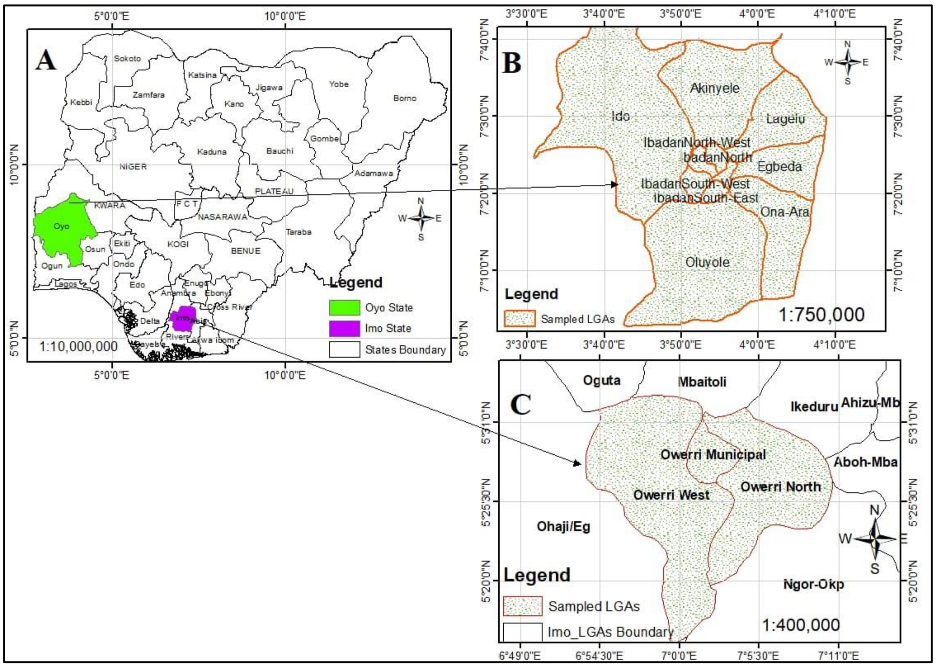


Figure 1: (A) Nigeria (B) Ibadan Metropolis (C) Owerri Metropolis

the outer areas: Akinyele, Lagelu, Egbeda, Ona-Ara, Oluyole, and Iddo.

The remaining five are situated in the inner city, which is the central area where the metropolis is located: Ibadan North East, Ibadan North, Ibadan North West, Ibadan South West, and Ibadan South East. The city of Ibadan is a densely populated urban area with a population of 3,383,000, as reported by the United Nations (UN, 2018). Owerri is situated within latitudes 5°20′ and 5°32′N, and longitudes of 6°51′ and 7°08′ E (as shown in Figures 1C). The area consists of Owerri Municipal, Owerri-west, and Owerri-north local government areas and parts of Mbaitoli and Ikeduru local government areas (Nwanya *et al*., 2019). Owerri serves as the administrative, commercial, and entertainment hub of Imo State (Okere *et al*., 2018). It houses the majority of government ministries, departments, and agencies, and is the focal point for all socio-economic and religious activities in the State (Okeke, 2015). The National Population Commission (NPC, 2007) reported that the estimated population of Owerri Metropolis in 2006 was 401,873, with 211,298 males and 190,575 females. The UN (2020) anticipated that the population of the Owerri metropolitan region was 873,000 in 2020.

2.2 Data Used

The study utilized cloud-free multi-temporal remotely sensed Landsat datasets. The data sets used consist of Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Operational Land Imager (OLI) images. These images were obtained from the Earth Explorer and Global Visualizations (GLOVIS) database of the United States Geological Survey (USGS) which are freely accessible to users (Table 1).

Table 1. Data used for the study

S/N	Location	Data Source	Path	Row	Acquisition Data
1.	Owerri	Landsat TM	188	056	12th December, 1990
		Landsat ETM+			17th December, 2000
		Landsat ETM+			16th December, 2010
		Landsat OLI			3rd February, 2019
2.	Ibadan	Landsat TM	191	055	27th December, 1990
		Landsat ETM+			7th March, 2001
		Landsat ETM+			3rd January, 2011
		Landsat OLI			1st January, 2019

2.3 Methods

2.3.1 Land use Land Cover Mapping

Training sites or regions of interest were established as a preliminary classification exercise on the layer stacked False Color Composite (FCC) images. This was done by utilizing the knowledge gained from ground-truth experience during the field visit and by utilizing high-resolution Google Earth photographs to construct spectral signatures. The process involved digitizing vector layers containing different polygons and overlaying them onto raster sceneries representing various land use types. The land cover was classified into five categories namely: forest cover, light vegetation, bare surfaces, built up regions, agricultural fields, and water bodies using the maximum likelihood supervised classifier of Idrisi Terrset. The software was used to extract the statistical coverage of the classes, which was then utilized to calculate the percentage changes involved in calculating the magnitude of change, calculating the trends, and computing the yearly rate of change. The nature of change was determined through the process of map overlay.

2.3.2 Mapping NDVI

The NDVI, the most commonly used satellite-based measure of vegetated regions was used to determine the vigour or health of vegetation/vegetation abundance. NDVI allows for comparing images over time to assess ecologically significant changes. The formula for computing NDVI is given below:

$$\mathrm{NDVI} = \frac{\mathrm{NIR-RED}}{\mathrm{NIR+RED}} \quad (1)$$

Where NIR and RED are reflectance's in the near-infrared band (0.76-0.90μm) and the red band (0.63-0.69 μm) respectively for Landsat TM, ETM+ and OLI. The NDVI values vary from -1 to 1. Vegetated areas typically have high values because they reflect more near-infrared light and less visible light. On the other hand, water, built-up areas, and bare surfaces reflect more visible light than near-infrared light, resulting in negative index values. The Multi-temporal NDVI layers for all cities underwent re-classification using the mean-standard deviation method as described by Bozorgi and Nejadkoorki (2019). The NDVI layers were categorized into five interval classes: low NDVI, secondary low-NDVI, medium NDVI, secondary high-NDVI, and high NDVI locations.

2.3.3 Mapping NDBI

The Normalized Difference Built-up Index (NDBI) is a valuable metric for quantifying the degree of impermeability based on satellite imagery (Bhatti and Tripathi, 2014). The calculation was performed for all of the chosen cities. The distribution of urban surfaces can be effectively highlighted by their increased reflectivity in the short-wave infrared band compared to the near-infrared band. The calculation was performed using the Equation developed by Limin and George (2003):

$$\text{NDBI} = \frac{\text{SWIR} - \text{NIR}}{\text{SWIR} + \text{NIR}} \quad (2)$$

Where; $SWIR$ is the short-wave infrared band ranging from 1.57 - 1.65μm, while NIR is the near-infrared band ranging from 0.85 to 0.88μm.

The NDBI layers for all cities at different time periods were reclassified using the mean-standard deviation method, following the approach described by Bozorgi and Nejadkoorki (2019). The NDBI layers were classified into five interval classes: low NDBI, secondary low-NDBI, medium NDBI, secondary high-NDBI, and high NDBI areas.

3. RESULTS AND DISCUSSION

3. 1 LULC Changes in Ibadan

3.1.1 LULC trends in Ibadan from 1990 to 2019

The outcomes of the land use and land cover (LULC) classification of Ibadan from 1990 to 2019 are displayed in Figures 2 and 3. The findings demonstrate a gradual rise in built-up areas from 1990 to 2019. The data indicates that the built-up areas encompassed a total of 312.90km^2, or approximately 9.19% of the overall coverage area. In 2001, it had a land area of 479.45km^2 of the total land area. The area expanded to 755.29km^2 in 2011, and subsequently grew to 1,039.54km^2 in 2019. The findings are comparable to the outcomes of Edobor and Bello's work (2017) which showed a progressive increase in built up in Ibadan from 107 km^2 in 1972 to 192 km^2 and 381 km^2 in 1986 and 2000 respectively. The data indicates a gradual decline in the extent of forested areas between 1990 and 2019. Forests occupied a total area of 712.66km^2 in 1990. In 2001, the total area covered by woods was 408.28km^2. In 2011, the forest cover decreased to 278.55km^2. By 2019, the forest cover further declined to 253.05km^2. Except for the year 2001, when there was a higher amount of light vegetation, Ibadan consistently suffered a decline in light vegetation from 1990 to 2019. In 1990, the metropolitan area was comprised of 1316.21km^2 of light vegetation. In 2001, the extent of vegetation cover expanded, encompassing 1367.78km^2, which accounted for 40.19% of the metropolitan area. In 2001, the extent of light vegetation in the metropolitan region reduced to 1,298.88km^2.

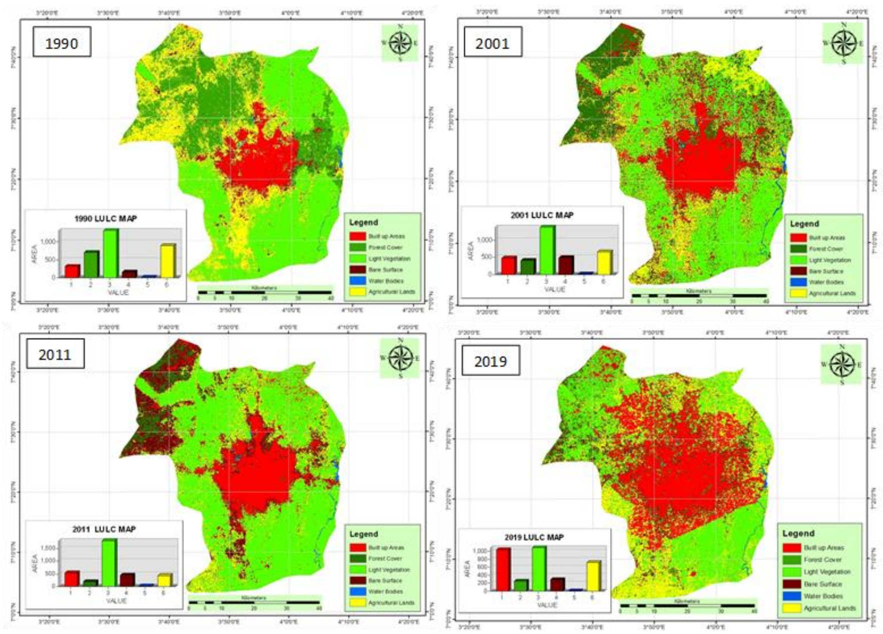
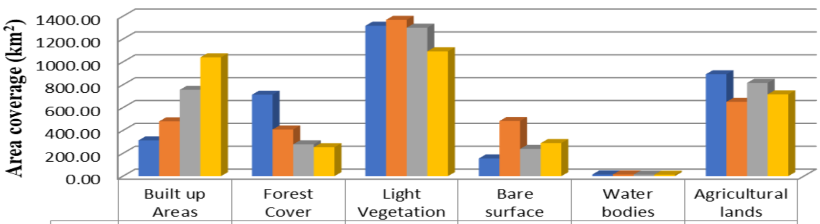


Figure 2: LULC of Ibadan 1990-2019



	Built up Areas	Forest Cover	Light Vegetation	Bare surface	Water bodies	Agricultural lands
1990	312.90	712.66	1316.21	155.01	14.70	891.51
2001	479.45	408.28	1367.78	482.62	14.80	650.14
2011	755.29	278.55	1298.88	238.32	13.63	815.9364
2019	1039.5369	253.0521	1092.51	289.2708	12.7251	715.5513

Figure 3: LULC coverage of Ibadan 1990-2019

Subsequently, it further declined to 1,092.51km^2. Throughout the study period, the bare surfaces did not display any discernible pattern, nor did they undergo any notable changes.

In 1990, an area measuring 155.01km^2 was encompassed. In 2001, the area covered by them was 482.62km^2, which represented 14.18% of the total land cover. In 2011, the area covered by them decreased to 238.32km^2. In 2019, the total area of uncovered surfaces was 289.27km^2. The limited alteration in the barren terrain can be ascribed to its predominantly rocky outcrops and exposed riverbed sand, which are only discernible when devoid of plant or surface water. This was observed during field visit to the location in the dry season, during which most non-perennial rivers and water bodies had dried up and vegetal cover was at its minimal. In 1990, water bodies covered 14.70km^2 of the total area, whereas in 2001, 2011, and 2019, they covered 14.80km^2, 13.63km^2, and 12.73km^2 correspondingly. Consequently, the water body remained rather stable without undergoing any notable changes during the whole duration of the study. In 1990, agricultural grounds spanned an area of 891.51km^2. By 2001, this area had decreased to 650.14km^2. In 2011, agricultural lands covered 815.94km^2. Finally, in 2019 the area of agricultural lands was 715.55km^2, making up 21.03% of the total land area.

3.1.2 Assessment of classification accuracy of LULC in Ibadan

The categorization accuracy for the four periods of 1990, 2001, 2011, and 2019 in Ibadan was 82.65%, 84.31%, 83.62%, and 85.00% accordingly (refer to Table 2). This achieved a satisfactory level of accuracy, making it suitable for subsequent change detection and analysis. The user achieved accuracy rates ranging from 62.03% to 92.00% for various land cover categories, whereas the producer achieved accuracy rates ranging from 68.49% to 90.99%. The overall Kappa coefficient was also computed for each of the classified maps in order to assess their accuracy. The Kappa statistics for the four periods, 1990, 2001, 2011, and 2019, were 0.80, 0.84, 0.82, and 0.84, respectively. The Kappa coefficient for the four eras falls within the range of strong agreement to practically perfect agreement on the kappa scale, suggesting that it is a reliable measure.

3.1.3 The magnitude and percentage change in LULC in Ibadan from 1990-2019

Table 3 depicts the changes in magnitudes and percentages of Land Use and Land Cover (LULC) in Ibadan from 1990 to 2019. The table demonstrates that, with the exception of built up and bare surfaces which had a continuous increase in size over the specified time frame, all other land use and land cover (LULC) categories showed a decrease. The built-up area increased by 726.64km^2 from 312.90km^2 in 1990 to 1039.54km^2 in 2019. The persistent expansion of urban development can be ascribed to the swift rise in urban population resulting from the migration of rural inhabitants to urban and suburban regions in pursuit of lucrative employment opportunities and a perceived elevated quality of life. Consequently, there is an increased need for housing in metropolitan areas, necessitating the spread of urban development. During the period, the extent of forested land declined by -459.61km^2, going from 712.66km^2 in 1990 to 253.05km^2 in 2019. The gradual decline in forest cover can be

Table 2: Accuracy Assessment of Ibadan LULC Imageries (1990, 2001, 2011 and 2019)

Class Name	1990 Producer's Accuracy (%)	1990 User's Accuracy (%)	2001 Producer's Accuracy (%)	2001 User's Accuracy (%)	2011 Producer's Accuracy (%)	2011 User's Accuracy (%)	2019 Producer's Accuracy (%)	2019 User's Accuracy (%)
Built-up areas	82.76	89.50	92.35	98.00	83.60	83.10	79.92	86.09
Forest cover	88.29	70.47	80.15	86.20	80.51	92.00	90.10	74.76
Light Vegetation	81.37	86.48	84.74	93.37	87.54	62.03	87.84	80.97
Bare Surface	80.21	78.61	93.20	86.01	84.31	85.5	75.78	87.65
Water Bodies	81.00	85.76	82.70	69.40	81.81	83.40	90.99	70.00
Agricultural lands	81.98	83.67	79.12	80.07	84.19	90.43	68.49	80.53
Overall Classification Accuracy (%)	**82.65**		**84.31**		**83.62**		**85.00**	
Overall Kappa	**0.801**		**0.837**		**0.823**		**0.844**	

Table 3: Magnitude and percentage Change in LULC of Ibadan between 1990 and 2019

LULC Class	1990 Extent (km^2)	2019 Extent (km^2)	Magnitude of Change (km2)	percentage of Change	Annual Rate % Change
Built up	312.90	1039.54	726.64	42.19	12.24
Forest cover	712.66	253.05	-459.61	-26.69	-7.74
Light Vegetation	1316.21	1092.51	-223.7	-13.57	-3.94
Bare surface	155.01	289.27	134.26	7.79	2.26
Water body	14.70	12.73	-1.97	-0.11	-0.03
Agricultural lands	891.51	715.55	-175.96	-10.22	-2.96
Total	3402.98	3402.98	1722.14	100	

linked to the increasing demand for fuel wood, the clearing of land for urban infrastructure development, the proliferation of educational institutions, and the expansion of urban agriculture. From 1990 to 2019, the extent of light vegetation declined by -223.70km^2, going from 1316.21km^2 in 1990 to 1092.51km^2 in 2019. The area of bare surfaces had a significant rise of 134.26km^2 between 1990 and the present, growing from 155.01km^2 to 289.27km^2. Overall, the size of water bodies declined by 1.97km^2 (0.11%) from 14.70km^2 in 1990 to 12.73km^2 in 2019. The area of agricultural lands decreased by -175.96km^2 (-10.22%) from 891.51km^2 in 1990 to 715.55km^2. The decline in agricultural land can be linked to its conversion into developed surfaces as a result of urban growth.

3. 2 LULC Changes in Owerri

3.2.1 LULC trends in Owerri Metropolis from 1990 to 2019

Results of the LULC classification of Owerri between 1990 and 2019 are presented in Figures 4 and 5. The results revealed a progressive increase in built up areas from 1990 to 2019. They show that Owerri witnessed a progressive expansion into other land use classes from 1990 to 2010. The built-up areas occupied 70.32km^2, 166.55km^2, 170.55km^2, 209.16 km^2 of the coverage area in 1990, 2000, 2010 and 2019 respectively. This is analogous to the research conducted by Echebima *et al*. (2019), which examined some regions of Owerri and found that the expansion of developed areas occurred at a yearly rate of 0.65% relative to the whole land area from 1986 to 2016. The economic and industrial activities in Owerri, supported by its well-established road infrastructure, the growth of tertiary institutions, and the high level of activity in the city, have been recognized as factors that contribute to rural to urban migration (Emeribeole and Iheaturu, 2016) and subsequently lead to an increase in urban development. The extent of forested areas experienced a progressive decline from 1990 to 2019. The data indicates that the area covered by forests was 70.16km^2, 17.00km^2, 21.43km^2, and 21.35km^2 in the years 1990, 2000, 2010, and 2019, respectively. Similarly, there was a gradual decline in the amount of sparse plant life from 1990 to 2019. In 1990, the area occupied by light vegetation covering was 255.09km^2 of the total area. By 2000, this area decreased to 179.75km^2. In 2010, it further decreased to 157.08km^2. Finally, in 2019, the area of light vegetation coverage was 141.52km^2. These figures indicate a continuous decline in light vegetation coverage over time. The ongoing reduction in light vegetation covering may be attributed to the encroachment of developed regions. Echebima *et al.* (2019) found that forests and sparse vegetation experienced an annual drop of 0.73% and 0.05% correspondingly, over a three-year period. According to Echebima *et al*. (2019), if the current rate of converting vegetation into built surfaces in the Owerri metropolitan area continues without any reduction, there is a possibility that the area may completely lose its plant cover by 2039. This loss of vegetation may have significant effects on the local climate of the city. Bare surfaces did not follow a definite pattern between 1990 and 2019. Analysis shows that bare surfaces occupied 58.98km^2, 19.30km^2, 29.24km^2 and 29.12km^2 in 1990, 2000, 2010 and 2019 respectively. Water bodies decreased progressively between 1990 and 2010 but increased slightly in 2019. It occupied 9.11km, 8.55km^2, 5.56km^2 and 6.19km^2 in 1990, 2000, 2010

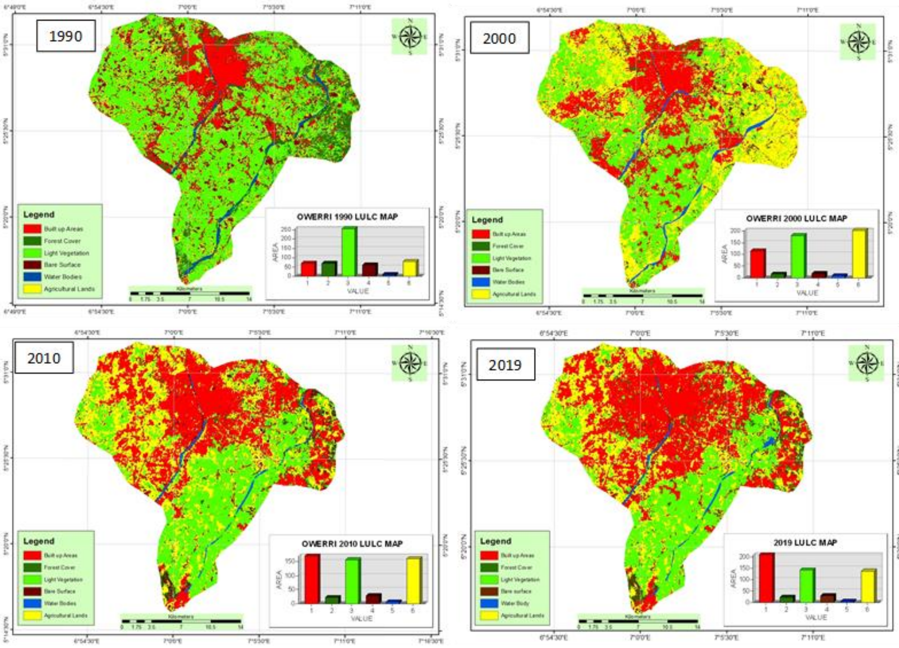


Figure 4: Land use / land cover of Owerri Metropolis 1990 – 2019

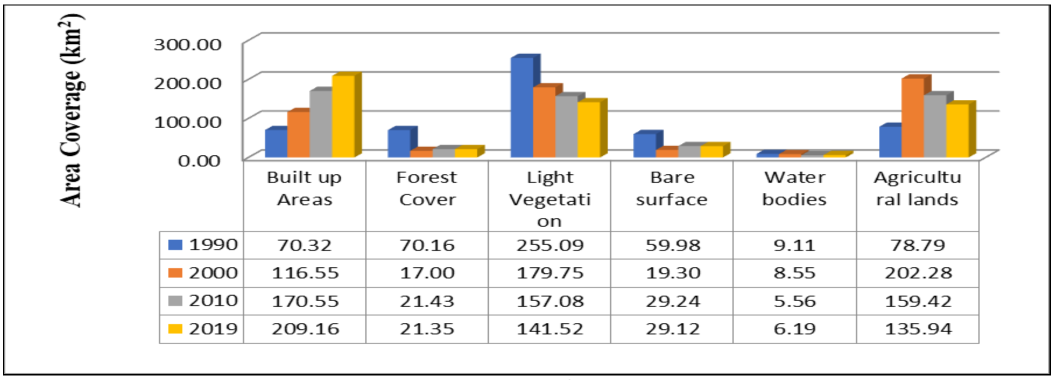


Figure 5: LULC coverage of Owerri 1990-2019

and 2019 respectively. The continuous decrease in coverage by water surfaces may have been as a result of encroachment on wet/marsh lands by urban infrastructures. Agricultural lands increased progressively during the study period, except for the decrease in 2019. They occupied 78.79km^2, 202.28km^2, 1.59km^2 and 135.94km^2 in 1990, 2000, 2010 and 2019 respectively. Rising food insecurity in urban areas may have resulted in intensification of agricultural activities as a means of augmenting food supply.

3.2.2 Assessment of classification accuracy of LULC in Owerri

The accuracy of classification for the four periods of 1990, 2001, 2011 and 2019 for Owerri showed an overall accuracy of 81.45%, 82.62%, 84.70% and 85.21% respectively (See Table 4). This was considered a decent overall accuracy and, therefore acceptable for the succeeding detection of change and analysis. The user's accuracy for different land cover categories ranged between 72.29% and 93.73% while the producer's accuracy ranged between 73.60% and 93.55%.

The overall Kappa was also calculated for each of the classified maps to determine their accuracy. The results of the four periods 1990, 2001, 2011 and 2019 revealed Kappa statistics of 0.78, 0.80, 0.82 and 0.81 respectively. The Kappa coefficient for the four periods ranges from substantial agreement to almost perfect agreement on the kappa scale, an indication that it is usable.

3.2.3 The magnitude and percentage change in LULC of Owerri from 1990-2019

The magnitude and percentage change in LULC in Owerri from 1990 to 2019 are presented in Table 5. The table shows a net increase in built up areas/settlements and agricultural lands while over the period while other land use/ land cover recorded a decrease in coverage. Between 1990 and 2019 built up areas in Owerri increased in magnitude by 138.84km^2 (35.14%), from 70.32km^2 in 1990 to 209.16km^2 in 2019. The persistent increase in the urban built-up may be attributed to urban population explosion occasioned by the influx of rural dwellers to the urban and suburban areas in search of white-collar jobs and presumed better quality of life which

Table 4: Accuracy Assessment of Owerri LULC Imageries (1990, 2000, 2010 and 2019)

	1990		2000		2010		2019	
Class Name	Producer's Accuracy (%)	User's Accuracy (%)	Producer's Accuracy (%)	User's Accuracy (%)	Producer's Accuracy (%)	User's Accuracy (%)	Producer's Accuracy (%)	User's Accuracy (%)
Built-up areas	83.32	93.50	90.35	93.73	73.60	83.10	80.87	84.82
Forest cover	81.20	72.29	81.95	88.24	79.96	91.19	66.43	87.95
Light Vegetation	79.71	83.10	80.74	92.38	91.33	75.63	85.11	80.69
Bare Surface	85.25	82.61	90.76	88.67	82.84	85.58	79.98	83.85
Water Bodies	82.29	84.13	85.70	83.50	93.55	80.40	91.68	83.25
Agricultural lands	80.11	82.99	79.01	82.47	85.10	89.43	80.75	92.52
Overall Classification Accuracy (%)	**81.45**		**82.62**		**84.70**		**85.21**	
Overall Kappa	**0.78**		**0.802**		**0.82**		**0.81**	

Table 5 Magnitude and Percentage Change in LULC of Owerri between 1990 and 2019

LULC Class	**1990 Extent (Sq. km)**	**2019 Extent (Sq. km)**	**Magnitude of Change (Sq. km)**	**Percentage of Change**	**Annual Rate of Change %**
Built up	70.32	209.16	138.84	35.14	10.19
Forest cover	70.16	21.35	-48.81	12.45	3.61
Light Vegetation	255.09	141.52	-113.57	28.96	8.40
Bare surface	59.98	29.12	-30.86	7.87	2.28
Water body	9.11	6.19	-2.92	0.74	0.21
Agricultural lands	78.79	135.94	57.15	14.57	4.23
Total	**543.45**	**543.45**	**392.15**	**100**	

puts demand on urban residential houses, necessitating the expansion in the urban coverage. On the contrary, forest cover recorded a net decrease in coverage as it diminished in magnitude by -41.81km^2 from 70.16km^2 in 1990 to 21.35km^{2,} in 2019. The progressive decrease in forest cover may be attributed to demand for fuel wood, land clearance for urban infrastructural development, proliferation of educational institutions, and urban agriculture expansion. Light vegetation decreased in magnitude by -113.57km^2 from 255.09km^2 in 1990 to 141.52km^2 in 2019. The general trend in Owerri between 1990 and 2019 is that bare surfaces decreased in magnitude by -30.86km^2 (7.87%) from 59.98km^2 in 1990 to 29.12km^2. The general decrease in bare surfaces may be attributed to the incursion of built-up areas into it. Furthermore, during the period, water bodies decreased in magnitude to -2.92km^2 from 9.11km^2 in 1990 to 6.19km^2 in 2019. Lastly, agricultural lands increased in magnitude by 57.15km^2 from 78.79km^2 in 1990 to 135.94km^2 in 2019. Summarily, in Ibadan, built-up surfaces increased in percent coverage by 332.43% from 9.19% in 1990 to 30.55 percent in 2019. In contrast, Owerri Metropolis recorded lower increase in built-up surfaces, as it increased by 297.53% from 12.94% in 1990 to 38.50% in 2019.

3.3 NDVI of Ibadan metropolis 1990-2019

NDVI images of Ibadan Metropolis from 1990 to 2019 are presented in Figure 6. Results showed that the maximum recorded NDVI of the city was 0.97, 0.25, 0.12 and 0.42 in 1990, 2001, 2011 and 2019 respectively, while the minimum was -0.95, -0.65, -0.39 and -0.02 in 1990, 2001, 2011 and 2019 respectively. The mean NDVI values of -0.08, -0.13, -0.08 and 0.24 were recorded in 1990, 2001, 2011 and 2019 respectively; indicating that the highest mean value was recorded in 2019, while the lowest mean value was recorded in 2001. For standard deviation, recorded values were 1.85, 0.09, 0.07, and 0.07 in 1990, 2001, 2011 and 2019 respectively, indicating that 1990 had the highest standard deviation. The high NDVI points were concentrated around the non-urbanized locations of the city such as thick and light vegetation areas of the city, which possessed insignificant concentrations of built-up surfaces, while the lowest NDVI values were concentrated in the built areas, bare surfaces, and water surfaces which were devoid of vegetal cover. Figure 7 shows the statistics of re-classified NDVI images of Ibadan in 1990, 2001, 2011 and 2019 respectively. The results showed that in 1990, low, secondary low, medium, secondary high and high NDVI areas covered 253.64km^2, 6.06km^2, 958.37km^2, 205.39km^2 and 389.61km^2 of the total area respectively. This implied that in 1990, high and secondary high NDVI areas collectively occupied 1595.00km^2 and covered 46.87% of Ibadan. Low and secondary low NDVI areas collectively occupied 849.70km^2 and covered 24.97% of the Metropolis, revealing that higher NDVI values dominated the scene of Ibadan Metropolis in 1990.

In 2001, low, secondary low, medium, secondary high and high NDVI areas occupied 920.63km^2, 869.35km^2, 37.90km^2, 57.07km^2, and 418.12km^{2}of the metropolis respectively. This implied that in 2001, high and secondary high NDVI areas collectively covered 975.19km^2 of Ibadan Metropolis, indicating a coverage area decrease of 18.21% from 46.87% in 1990 to 28.66% in 2001. Similarly, medium NDVI areas decreased in percentage coverage by 9.42% from 28.16% in 1990 to 18.74% in 2001. On the contrary low and secondary low NDVI areas collectively covered 1,789.98km^2, indicating a coverage area increase of 27.63% from 24.97% in 1990 to 52.60% in 2001.

In 2011, low, secondary low, medium, secondary high and high NDVI areas covered 1279.38km^2, 961.06km^2, 546.00km^2, 406.67km^2 and 209.96km^2 area of the city respectively. This implied that in 2011, high and secondary high NDVI areas collectively occupied 616.63km^2 Metropolis, indicating a progressive coverage area decrease of 10.54% from 28.66% in 2001 to 18.12% in 2011. Similarly, medium NDVI areas decreased progressively in percentage coverage by 2.02% from 18.74% in 2001 to 16.04% in 2011. In 2019, low, secondary low, medium, secondary high and high NDVI areas covered 749.73km^2, 977.33km^2, 771.45km^2, 82.00km^2 and 322.55km^2 area of the city respectively. This further revealed that in 2019, high and secondary high NDVI areas covered 904.55km^2 and covered 26.58% of Ibadan Metropolis, indicating a coverage area higher than 2011 by 8.46%. Similarly, medium NDVI areas increased in percentage coverage by 6.63% from 16.04% in 2011 to 22.67% in 2019. On the contrary, low and secondary low NDVI areas collectively occupied 1727.06 km^2 and covered 50.75% of the Metropolis, indicating a lower coverage area of 15.09%, from 65.84% 2011 to 50.75% in 2019. This result therefore demonstrated an association between land use/land cover in Ibadan city and vegetation over the study period, and was corroborated with results of previous studies (Kasim *et al*., 2020; Seun *et al*., 2022). The persistent increase in areas with very low and low NDVI values indicated that increase in built and bare surfaces during the study period resulted in reduced coverage areas of vegetal cover due to heightened anthropogenic activities.

3.4 NDVI of Owerri metropolis 1990-2019

NDVI images of Owerri Metropolis from 1990 to 2019 are presented in Figure 8. Results showed that the maximum recorded NDVI of the city was 0.42, 0.28, 0.42 and 0.27 in 1990, 2000, 2010 and 2019 respectively, while the minimum was -0.12, -0.32, -0.17 and -0.01 in 1990, 2000, 2010 and 2019 respectively. For standard deviation, recorded

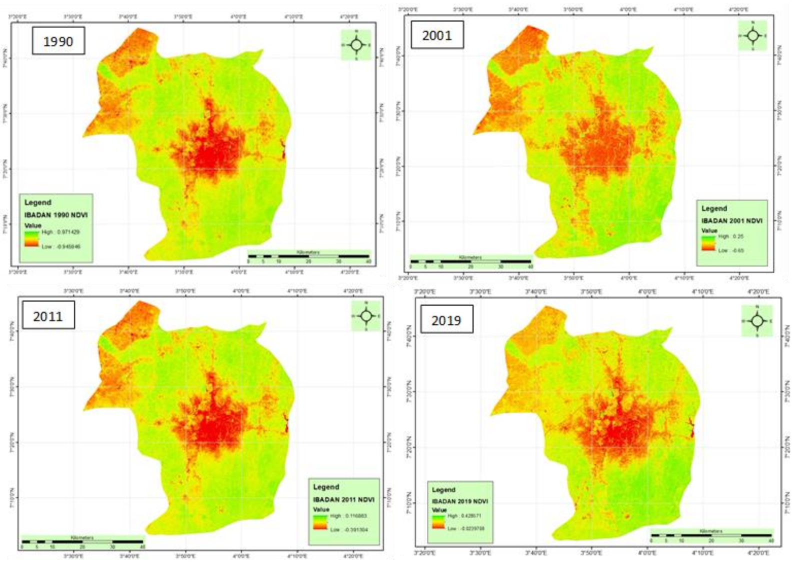
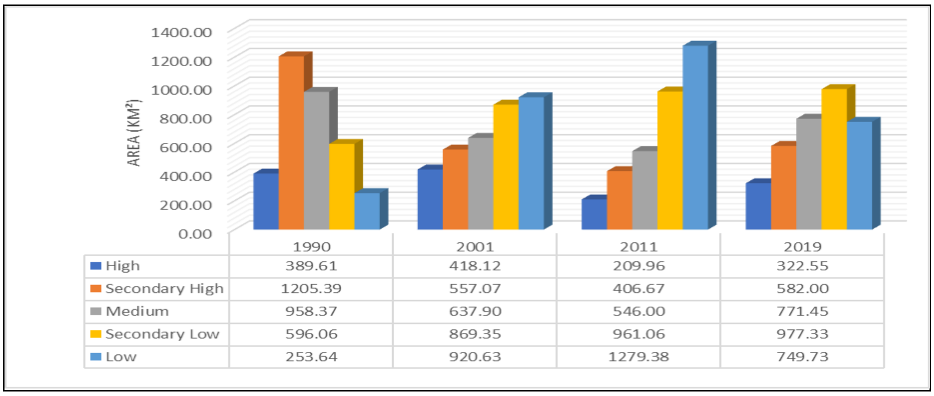


Figure 6: NDVI images of Ibadan Metropolis 1990 – 2019



	1990	2001	2011	2019
High	389.61	418.12	209.96	322.55
Secondary High	1205.39	557.07	406.67	582.00
Medium	958.37	637.90	546.00	771.45
Secondary Low	596.06	869.35	961.06	977.33
Low	253.64	920.63	1279.38	749.73

Figure 7: Ibadan NDVI classes 1990 – 2019

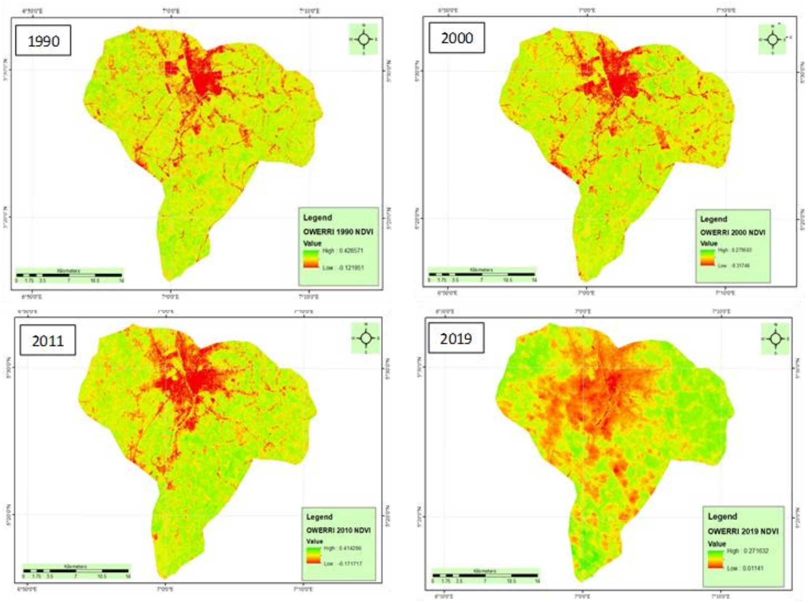
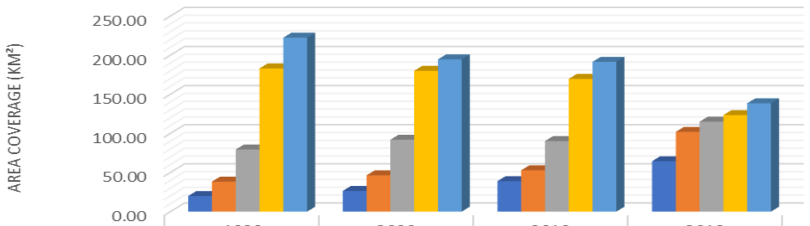


Figure 8: NDVI of Owerri metropolis 1990-2019

values were 0.05, 0.08, 0.09, and 0.04 in 1990, 2000, 2010 and 2019 respectively. The low NDVI points are concentrated around the city areas which have the highest percentage of built-up area and vegetal cover. Figure 9 shows the statistics of re-classified NDVI images of Owerri in 1990, 2000, 2010 and

2019 respectively. The statistics showed that in 1990, low, secondary low, medium, secondary high and high NDVI areas occupied 19.95km^2, 38.41km^2, 79.45km^2, 183.15km^2 and 222.45km^2 respectively. This implied that in 1990 high and secondary high NDVI areas collectively occupied 405.60km km^2 of Owerri Metropolis, whereas low and secondary low NDVI areas collectively occupied 58.37km^2. In 2000, low, secondary low, medium, secondary high and high NDVI areas occupied 26.53km^2, 46.42km^2, 91.94km^2, 180.06km^2 and 94.63km^2 respectively. It also implied that in 2000, high and secondary high NDVI areas collectively occupied 374.69 km^2 and covered 69.44% of Owerri Metropolis, indicating a coverage area lower than 1990 by 5.20%. On the contrary, low and secondary NDVI areas (72.95km^2) increased slightly in percentage coverage by 2.78% from 10.74% in 1990 to 13.52% in 2000.

respectively. The high NDVI areas occupied 191.54km^2 (32.25%). This implied that in 2010, high and secondary high NDVI areas collectively occupied 361.28km^2 and covered 66.48% of Owerri Metropolis, indicating a coverage area lower than 2000 by 2.96%. Similarly, medium NDVI areas decreased in percentage coverage from 17.04% in 2000 to 16.61% in 2010. On the other hand, low and secondary low NDVI areas collectively occupied 91.87km^2 and covered 16.91% of the Metropolis, indicating a coverage area higher than year 2000 by 3.39%. In 2019, low, secondary low, medium, secondary high and high NDVI areas occupied 64.45km ^{2}, 102.01km^2, 15.02km^2, 23.43km^2 and 38.51km^2 of the total area respectively. This further showed that in 2019, high and secondary high NDVI areas collectively occupied 261.95km^2 and covered 48.20% of Owerri Metropolis, indicating a coverage



	1990	2000	2010	2019
Low	19.95	26.53	38.99	64.45
Secondary low	38.41	46.42	52.90	102.01
Medium	79.45	91.94	90.26	115.02
Secondary High	183.15	180.06	169.74	123.43
High	222.45	194.63	191.54	138.51

Figure 9: Owerri NDVI classes 1990 – 2019

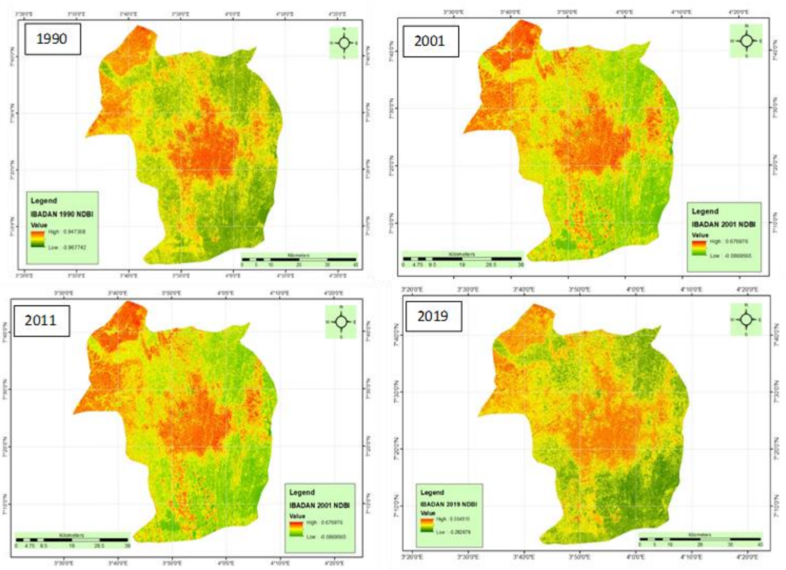
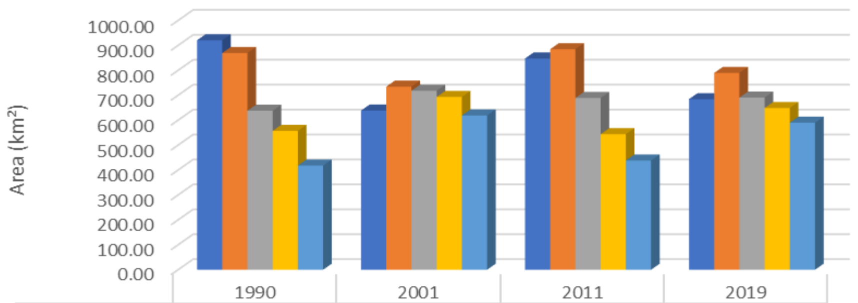


Figure 10: NDBI of Ibadan 1990 – 2019

Similarly, medium NDVI areas increased in coverage from 79.45km^2 (14.62%) in 1990 to 91.94km^2 (17.04%) in 2000, a difference of 2.42%. In 2010, low, secondary low, medium, secondary high and high NDVI areas covered 38.99km^2, 2.90km^2, 90.26km^2, and 169.74km^2 of the city

area lower than 2010 by 18.28%. On the contrary, low and secondary low NDVI areas collectively covered 166.46km^2 and covered 30.63% of the Metropolis, indicating an increase in percentage coverage by 13.72% from 16.91% in 2010 to 30.63% in 2019. Similarly, medium NDVI areas increased in percentage coverage from 16.61% in 2010 to 21.17% in 2019. As in the case of Ibadan, the study demonstrated an association between land use/land cover in Owerri metropolis during the period, and corroborated the results of Kasim *et al.* (2020) and Seun *et al.* (2022). The city also witnessed a persistent increase in areas with very low and low NDVI values; indicating that increase in built and bare surfaces during the period resulted in reduced coverage areas of vegetation.

respectively. The mean NDBI values of 0.12, 0.19, 0.12 and -0.07 were recorded in 1990, 2001, 2011 and 2019 respectively; indicating that the highest mean value was recorded in 2001, while the lowest value was recorded in 2019. For standard deviation, recorded values were 0.09, 0.09, 0.08, and 0.08 in 1990, 2001, 2011 and 2019 respectively. The high NDBI points were concentrated around the urbanized areas of the city, particularly the core local government areas which have significant



	1990	2001	2011	2019
Low NDBI	920.63	638.42	847.34	684.27
Secondary Low	869.34	734.52	884.73	789.49
Medium	637.90	717.95	689.05	690.54
Secondary High	557.07	693.34	543.82	648.84
High	418.12	618.84	438.12	589.93

Figure 11: Ibadan NDBI classes 1990 – 2019

By way of contrast, Tukey pairwise comparison test revealed that Owerri had a higher mean NDVI value (0.1137) than Ibadan (-0.0422) over the period which was also statistically different at five percent confident level. It therefore implied that the smaller town (Owerri) recorded a higher mean NDVI value than the larger city (Ibadan); depicting urbanisation effects on NDVI. In summary, the NDVI values fluctuated within the two locations on an annual basis, with a consistent decrease in areas exhibiting high NDVI in both locations. The areas with the highest NDVI values were located within the sub-urban sections of the cities, where there was a greater concentration of vegetation, including woods, light vegetation, and agricultural fields. Conversely, places with bare surfaces, water bodies, which were devoid of vegetation had the lowest NDVI values. The decrease in the number of areas with high values over time may be attributed to the increasing urbanisation. The findings align with the study conducted by Kasim *et al*. (2020), which also observed a higher Normalized Difference Vegetation Index (NDVI) in suburban areas of Ibadan with denser vegetation cover in 2009.

3.5 NDBI of Ibadan metropolis 1990-2019

NDBI images of Ibadan Metropolis from 1990 to 2019 are presented in Figure 10. Results showed that the maximum recorded NDBI of the city was 0.95, 0.68, 0.65 and 0.50 in 1990, 2001, 2011 and 2019 respectively, while the minimum was -0.09, -0.39, -0.25 and -0.28 in 1990, 2001, 2011 and 2019

concentrations of built-up areas. Figure 11 shows the statistics of re-classified NDBI images of Ibadan metropolis in 1990, 2001, 2011 and 2019 respectively. The statistics showed that in 1990, low, secondary low, medium, secondary high and high NDBI areas occupied 920.63km^2, 869.34km^2, 637.90km^2, 557.07km^2 and 418.12km^2 of the total area respectively. This implied that in 1990, high and secondary high NDBI areas collectively occupied 975.19km^2 and covered 28.66% of Ibadan. Low and secondary low NDBI areas collectively had occupied 1789.98km^2 and covered 56.20% of the Metropolis.

This implied that low NDBI values dominated the scene of Ibadan Metropolis in 1990. In 2001, low NDBI areas occupied 638.42km^2 of the total area; lower than 1990 by 8.29%. The secondary low NDBI areas occupied 734.52km^2, lower than 1990 by 3.97%. The medium NDBI areas occupied 717.95km^2, higher than 1990 by 2.36%.m The secondary high NDBI areas occupied 693.34 km^2, higher than 1990 by 4.01%. The high NDBI areas covered 618.84km^2, 5.89% higher than 1990. This implied that in 2001, high and secondary high NDBI areas collectively occupied 1,312.17km^2 and covered 38.56% of Ibadan, indicating a coverage area increase of 9.9% higher than 1990. Similarly, medium NDBI areas increased in coverage area by 2.36%. On the contrary low and secondary low NDBI areas collectively 1,372.94km^2 and covered 40.34% of the Metropolis, which was 15.86% lower than 1990. In 2011, low, secondary low, medium, secondary high and high NDBI areas occupied 847.34km^2, 884.73km^2, 689.05 km^2, 543.82km^2 and 438.12km^2 of the total area respectively. It further showed that in 2011, high and secondary high NDBI areas collectively occupied 981.94km^2 and covered 28.85% of Ibadan Metropolis. The low and secondary low NDBI areas collectively occupied 1,732.08km^2 (50.90%). 1n 2019, low, secondary low, medium, secondary high and high NDBI areas covered 684.27km^2, 789.49km^2, 690.54km^2, 648.84km^2, and 589.93km^2 respectively. This implied that in 2019, high and secondary high NDBI areas collectively occupied 1.238.77km^2 and covered 36.40% of Ibadan Metropolis, indicating a coverage area higher than 2011 by 7.74%. Similarly, medium NDBI areas increased in percentage coverage by 1.55% between 2011 and 2019. On the contrary low and secondary low NDBI areas collectively covered 1,473.76km^2 and covered 43.31% of the Metropolis, indicating a coverage area decrease of 9.29% between 2011 and 2019.

3.6 NDBI of Owerri 1990-2019

NDBI images of Owerri Metropolis from 1990 to 2019 are presented in Figure 12. Results showed that the maximum recorded NDBI of the city was 0.47, 0.60, 0.36 and 0.13 in 1990, 2000, 2010 and 2019 respectively, while the minimum was -0.12, -0.25, -0.48 and -0.26 in 1990, 2000, 2010 and 2019 respectively. The mean NDBI values of 0.09, 0.19, 0.07 and -0.09 were recorded in 1990, 2000, 2010 and 2019 respectively. For standard deviation, recorded values were 0.08, 0.08, 0.08, and 0.05 in 1990, 2000, 2010 and 2019 respectively. The high NDBI points were concentrated around the urbanized areas of the city, particularly the core three local government areas which have significant concentrations of built-up areas. Figure 13 shows the statistics of re-classified NDBI images of Ibadan metropolis in 1990, 2001, 2011 and 2019 respectively.

The results showed that in 1990, low, secondary low, medium, secondary high and high NDBI areas covered 157.85km^2, 60.79km^2, 04.30km^2 6.70km^2 and 43.77km^2 of the total area respectively. This implied that in 1990 high and secondary high NDBI areas collectively occupied 120.47km^2 (22.17%), whereas low and secondary low NDBI areas covered 318.65km^2 (58.64%). In 2000, low, secondary low, medium, secondary high and high NDBI areas covered 65.57km^2, 53.77km^2, 94.56km^2, 86.50km^2 and 38.52km^2 of the area of the city respectively. This implied that in 2000, high and secondary high NDBI areas collectively occupied 125.02km^2 (23.20% of Owerri Metropolis); indicating a coverage area higher than 1990 by 1.03%. Similarly, low and secondary NDBI areas (319.34km^2) increased slightly in percentage coverage by 0.62% from 58.64% in 1990 to 59.26% in 2000. On the contrary medium NDBI areas reduced in coverage from 104.30km^2 (19.19%) in 1990 to 94.56km^2 (17.55%) in 2000, a difference of 1.64%. In 2010, low, secondary low, medium, secondary high and high NDBI areas covered 74.39km^2, 138.50km^2, 105.62km^2, 83.51km^2 and 41.4km^2 of the total area respectively. This further implied that in 2010, high and secondary high NDBI areas collectively occupied 124.91km^2 (22.99%) of Owerri Metropolis; indicating a coverage area lower than 2000 by 0.21%. Similarly, low and secondary low NDBI areas collectively occupied 312.90km^2 and covered 57.58% of the Metropolis; indicating a coverage area lower than year 2000 by 1.68%. On the contrary, medium NDBI areas (99.09km^2)

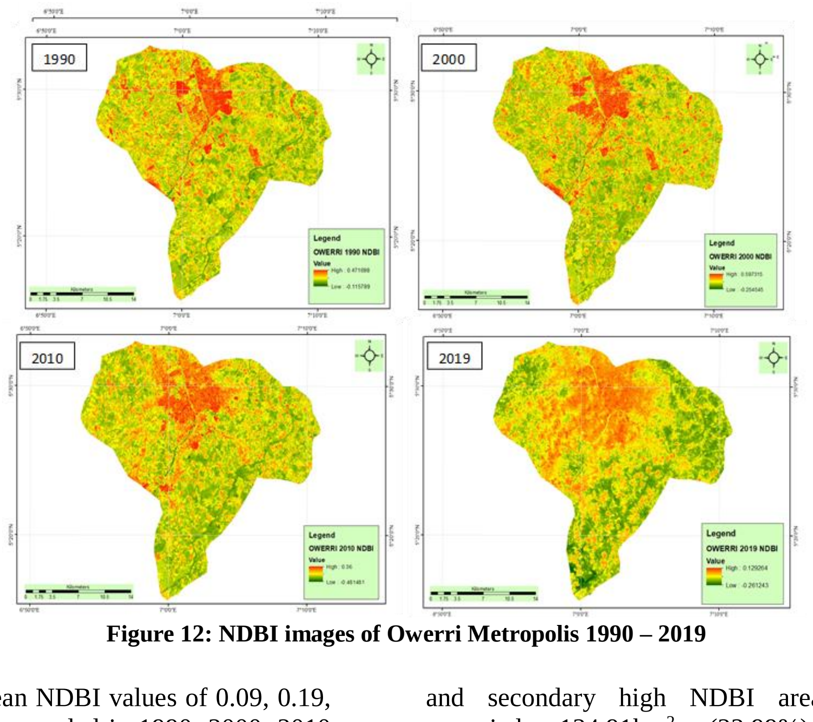
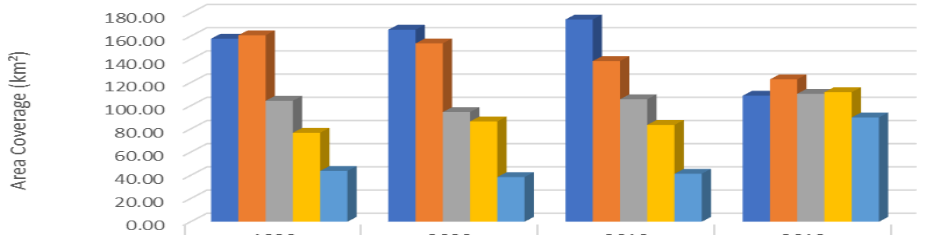


Figure 12: NDBI images of Owerri Metropolis 1990 – 2019

increased in percentage from 17.55% in 2000 to 19.44% in 2010.

In 2019, low, secondary low, medium, secondary high and high NDBI areas covered 108.67km ^{2}, 122.77km^2, 110.33km^2, 111.72km^2 and 89.94 km^2 of the city respectively. This implied that in 2019, high and secondary high NDBI areas collectively occupied 201.65km^2 (37.11%), indicating a coverage area higher than 2010 by 14.12%. Similarly, medium NDBI areas increased in percentage coverage from 19.44% in 2010 to 20.30% in 2019. On the contrary, low and secondary low NDBI areas collectively occupied 231.44km^2 (42.59%) of the Metropolis, indicating a decrease in percentage coverage by 14.99 % from 57.58% in 2010 to 42.59% in 2019. The Tukey pairwise comparison test revealed that over the period, Ibadan, with a mean NDBI value of 0.1578 recorded a higher value than Owerri (0.0589). This work therefore revealed the relationship between urbanisation and NDBI. It revealed that Ibadan, which has a high population density recorded the highest mean NDBI than Owerri which is much smaller in terms of landmass. Summarily, in both cities, the highly urbanized central areas had high/positive NDBI values, indicating a lack of vegetation. Conversely, the suburban areas had the lowest negative NDBI values, indicating the presence of vegetation or water bodies. This pattern is consistent with a previous study conducted by Kasim *et al*. (2020). The implication of urbanisation in the two cities therefore is the threat it poses to the natural environment vis-a-viz greenhouse gases emission, loss of biodiversity, flash flooding and air pollution. Therefore, there is a need to adopt strategies that will ameliorate their urban environments.



	1990	2000	2010	2019
Low	157.85	165.57	174.39	108.67
Secondary low	160.79	153.77	138.50	122.77
Medium	104.30	94.56	105.62	110.33
Secondary High	76.70	86.50	83.51	111.72
High	43.77	38.52	41.40	89.94

Figure 13: Owerri NDBI classes 1990 – 2019

4. CONCLUSION

Conclusively, the study shows that Owerri Metropolis recorded lower increase in built-up surfaces than Ibadan Metropolis. It increased by 297.53% from 12.94% in 1990 to 38.50% in 2019 compared to Ibadan, where built-up surfaces increased in percentage coverage by 332.43% from 9.19% in 1990 to 30.55% in 2019. The study also clearly demonstrated urbanisation effects on NDVI and NDBI over the study period. This may have attendant implications on the urban environment, one of which includes urban heat island effect. The study therefore suggests increased funding and vigorous implementation of urban developmental plans, strengthening of capacity for an appreciable implementation of afforestation/greening programmes through proper landscaping, as well as the adoption of urban agriculture and green infrastructures in the two cities to improve their liveability through improving air quality, and mitigating urban temperature in the face of daunting challenges of a changing climate.

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