

Dynamics of Land Use Land Cover Change in Enugu City of Enugu State, Nigeria

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Abstract

As far as urban expansion is concerned, there is no city in the world that is static. One of the effects of this expansion is vegetation loss and its attendant ecosystem disequilibrium. The aim of this paper is to analyze urban expansion and loss of vegetation cover in Enugu city in Enugu State. Land use and land cover (LULC) in Enugu city has undergone constant change over the past few decades due to major changes caused by anthropogenic and natural factors and the impacts of their activities on the environment and climate of the city. This study used techniques of Remote Sensing and GIS to identify the rate of urban expansion and the degree of vegetal loss using the Landsat imageries of 1989, 1999, 2009 and 2019. The maximum likelihood classification algorithm in IdrisiSelva software was used to extract three major land cover classes i.e. Built up, Vegetation and Non-vegetation. The average rates of change were elicited for each of the land cover types.

Vegetation had diminished from 430.75km² (77.26%) in 1989 to 313.18km² (56.17%) in 2019. Conversely, built-up areas had increased from 67.28 km² (12.07%) in 1989 to 170.71km² (30.62%) in 2019. Non-vegetation increased from 59.53km² (10.68%) in 1989 to 73.67km² (13.31%) in 2019. Results also revealed changes in temperature with respect to vegetation changes. The temperature has increased from average of 27°C in 1989 to average of 29.1°C in 2019. This has led to an increase of about 2.1°C. Therefore, the State Development of Environments and other relevant agencies should as a matter of urgency, start working with planners to establish urban greenery as mitigating measure against vegetation loss, environmental and climate change.

1. Introduction

The multi-directional spreading out of a city and its fringes toward non-built-up areas can be termed urban expansion. Urbanization is the process that refers to the growth both in size and numbers of urban centers. This accelerated growth has been monumental from the beginning of the 20th century (Ifatimehin and Musa, 2006), especially in developing countries such as Nigeria. It is predicated on anthropogenic activities amongst other factors. Increase in population over time, results in sprawling development that consequently manifest in form of socio- economic, health and environmental challenges. These drawbacks also reflect in the poor physical planning of Enugu city as an integral part of a state. The negligence of urban planners to properly situate peri-urbanization landscape during land use planning decisions at various levels, can accentuate future unsustainable land use changes (Grimm et al., 2008).

While land use refers to the way in which land has been used by humans and their habitat, usually with an emphasis on the functional role of land for economic activities, land cover simply means all biophysical characteristics of earth's surface e.g. vegetation, water and other physical characteristics of the land. LULC dynamics are widespread, accelerating, and significant processes majorly impelled by human actions and at the same time resulting to changes that impact human livelihood. LULC change is a major issue of concern with regards to change in the global environment (Qian, et al., 2007). Rapid growth and expansion of urban centers, increasing population growth, increasing scarcity of land, increasing demand for industrial products, technological advancements are among the drivers of LULCC in our society today. The environmental implications of rapidly growing urban areas are unquantifiable, they partly manifest by consistent displacement of agricultural land and vegetal loss in the peripheral areas of cities by residential and manufacturing layouts (Martellozo et al., 2014). Looking at urban expansion from global perspective. It was revealed that in the year 2000, urban built-up area in the world consumed about 400,000 square kilometers, which amounted to about 0.3% of the total land area of the world. The research projected that by 2030, about 1,100,000 (about 0.85%) shall be urbanized if the same growth rate is maintained (Angel et al., 2005).

Land use affects land cover and changes in land cover affect land use. A change in either, however, is not necessarily the product of the other. Changes in land cover by land use do not necessarily imply degradation of the land (Fabiya 2006 and Dami et al., 2011). However, many shifting land use patterns driven by a variety of social causes result in land cover changes that affect biodiversity, water and radiation budgets, trace gas emissions and other processes that come together to affect climate and bio-sphere (Kasim, 2012).

This work is premised on Hoyt Homer's Sector Model based on the assumption that common low-income households are usually found near railroad lines, and commercial establishments. In 1939, Hoyt modified the concentric zone model to account for major transportation routes. He postulated that most major cities evolved around the nexus of several important transport facilities such as roads railroads, sea ports, and trolley lines that emanated from the city's center. Hoyt theorized that cities would tend to grow in wedge-shaped patterns, or sectors, emanating from the Central Business District (CBD) and centered on major transportation routes (Hoyt, 1939). Deforestation rate or loss of vegetation in Nigeria is about 3.5 percent which implies a loss of 350,000– 400,000 hectares per annum. Between 1990 and 2005 alone, Nigeria lost 21% of her forests (Ladipo, 2010). The indicators of these changes can be clearly seen in the current major global concerns such as increasing concentrations of carbon dioxide (CO₂) in the atmosphere, loss of **biological** diversity, conversion and fragmentation of natural vegetation areas and accelerated emission of greenhouses gases (Steffen and Tyson, 2001). The depletion of vegetal cover adversely affects various ecosystems by way of biodiversity loss, wildlife habitat, food supply, medicinal herbs, pollution, erosion and drought. In recent times, geospatial technologies (remote sensing and geographical information system have proven to be the most cost effective and time-saving tools for monitoring land use/cover change at large spatial and temporal (Agbor et al., 2012 and Shao et al, 2017). The importance of

vegetation in the environment cannot be underestimated when considered against the backdrop of the role it plays as a major carbon sink, microclimate moderation and for aesthetics (Ige et al., 2017). Therefore, this study would attempt to map the status of land use land cover change (LULCC) of Enugu city in Enugu state over a 30 year period (1989-2019) to estimate the rate of vegetal cover loss as a result of urban expansion. Also, this study would venture into scrutinizing the impact of deforestation on temperature in Enugu city.

2. Objective

The objectives of this study are to detect the changes in Enugu City metropolis from 1989-2019, determine the change in temperature from 1989-2019 and model forest change using temperature.

3. Materials And Methods

3.1 The Study Area

Enugu city is the capital of Enugu State. It is located in southeastern Nigeria. The. The name *Enugu* is derived from the two **lgbo** words *Énú* *Ūgwŭ* meaning "hill top" denoting the city's hilly geography. The city was named after **Enugwu Ngwo**, under which coal was found. There are three local government areas in the city namely Enugu East, Enugu North and Enugu South. It is between longitude 6°.23' N and 6°.38' N and latitude 7°25'Eand 7° 39'N of the equator. It is bordered in the east by Nkanu East local government area and west by Udi Local Government Area respectively, in the south by the Nkanu west, and towards the north by Igbo Eti local government area of Enugu State. It spans across an area of about 560km². According to 2006 census, the total population is 722,664(NPC,2006). Its elevation is about 590ft (180m). It is significant for its coal mining activities.

The Ekulu, Asata, Ogbete, Aria, Idaw and Nyaba rivers are the six largest rivers located in the city. The Ekulu River is the largest body of water in Enugu urbanand its reservoir contributes to part of the city's domestic water supply. Enugu is located in a tropical rain forest zone with a derived savannah. The city has a tropical savanna climate. It's climate is humid and this humidity is at its highest between March and November. For the whole of Enugu State the mean daily temperature is 26.7 °C (80.1 °F) (Sanni, 2007)

3.2 MATERIALS

3.2.1 Data used and source

Landsat satellite images of the study area for 1989, 1999, 2009,2019 were obtained from USGS Earth Explorer official website. Another important data used is the road network of the study area.

Table 1: Data and their sources

S/N	Data Type	Source	Resolution
1	Landsat (TM) 1989	http://earthexplorer.usgs.gov/).	30m
2	Landsat (TM)1999	http://earthexplorer.usgs.gov/).	30m
3	Landsat (TM+)2009	http://earthexplorer.usgs.gov/).	30m
4	Landsat (OLI)2019	http://earthexplorer.usgs.gov/).	30m

3.2.2 Software used (Shao et al, 2017)

- i. ArcGIS 10.5 software (ESRI) was used to generate various thematic layers.
- ii. Microsoft Office package came very handy for the correlation analysis and the presentation of the work.

3.3 Methodology

3.3.1 Image Processing

Geometric rectification is critical for producing spatially corrected maps of land use/cover changes through time. The Landsat TM, ETM+ and OLI images were in UTM projection (Zone 31N) on WGS84. Therefore, the images of the study area were geometrically corrected. The color composites for the four images were generated from Landsat TM, ETM+ and OLI bands 2, 3, 4, and 5. These color composites were selected

to for training sites for land use/land cover extraction. The images were classified using supervised classification i.e. maximum likelihood classifier algorithm, which provides a consistent approach to parameter estimation problem. It can be applied in reliability analysis to censored data. From the classified images, the land use/land cover (LULC) maps were extracted and the requisite statistics generated thereafter. The classification scheme utilized only three land use classes representing built-up area, vegetation and water body. The post interpretation phase included preparation of land use maps and detection of their changes. A greater part of the analysis was predicated on the post-classification comparison approach. It was employed for analyzing land use/cover changes, by comparing independently produced classified land use/cover maps. The main advantage of this method is that it has capability to provide descriptive information on the nature of changes that occurs (Mundia and Aniya, 2005., Alboody et al., 2008).

3.4 Temperature Retrieval from Satellite Thermal Bands for the Study Period:

3.4.1 Conversion from Digital Number to Radiance

All the image bands are quantized as 8 bit data except Landsat 8 which is 16 bit, thus; all information is stored in DN which will then be converted to radiance with a linear equation (Giannini *et al*, 2015).

$$Y = mx + b$$

Where

Y=TOAr (Top of Atmosphere) radiance - the radiance measured by the sensor

m= Radiance multiplicative value

x= Raw band

b= Radiance additive value

3.4.2 Conversion from Radiance to Surface Temperature

The inverse of the Planck function was applied, thermal bands radiance values was converted to brightness temperature value using equation (Giannini *et al*, 2015). This is satellite temperature in Kelvin.

$$B_t = \left(\frac{K_2}{\ln\left(\frac{K_1}{TOAr} + 1\right)} \right) - 273.15$$

where

B_t = ° Kelvin

TOAr =Top of Atmosphere radiance

K1 = calibration constant 1 (607.76 for TM), (666.09 for ETM+) and (774.89 for OLI band 10)

K2 = calibration constant 2 (1260.56 for TM), (1282.71 for ETM+) and (1321.08 for OLI band 10).

3.4.3 Average Rate of Change

The average rate of change describes the rate at which one quantity is changing with respect to something else changing. In other words, it calculates the amount of change in one item divided by the corresponding amount of change in another item

$$\text{Average rate of change (ARC)} = \frac{f(x) - f(a)}{(x - a)}$$

Where:

$f(x) - f(a)$ = the change in the function "f" as the input changes from "a" to "x"

$x - a$ = the change in the input of the f function.

3.4.4 Correlation Analysis

Most of the changes in land use land cover depend on certain factors like roads, commerce, topography, population e.t.c. This study considered the contributions of expansion rate of the study area over the years. Vegetation was considered dependent variable while temperature was considered independent variable. Correlation analysis was carried out to assess the degree of relationship among the variables.

4. Results And Discussion

The results are presented in this chapter in form of maps, and statistical tables. They include the land cover types, change statistics and weather variable such as temperature, and the relationship that exist between temperature and vegetation cover over the years.

4.1 Analysis of Land Use Changes and Dynamics of Urban Expansion in Enugu

The urban change analysis is based on the statistical data extracted from the three-different land use and land cover maps of the classified images (Figures 2). As at 1989, vegetation accounted for the largest landcover type in the area which is 430.76 km², representing (77.26%) of the total landcover of the study area. Built-up area was 67.283 (12.07%) of the total land cover of the study area. By 2019, the landcover had changed tremendously consequent upon accumulated anthropogenic activities. Vegetation had diminished from 430.76 (77.26%) in 1989 to 261.53km² (46.91%) in 2019. Conversely, built-up areas had increased from 67.283 (12.06%) in 1989 to 272.81 km² (48.93%) in 2019. Non vegetation reduced from 59.52km² (10.68%) in 1989 to 23.21km² (4.16%) in 2019 (see table 2)

Table 2. LULC Distribution of Enugu in 1989, 1999, 2009 and 2019.

LULC CLASSES	1989		1999		2009		2019	
	AREA	%	AREA	%	AREA	%	AREA	%
BUILT UP	67.2831	12.06746	126.8064	22.74317	170.7084	30.61715	272.817	48.93069
NON-VEGETATION.	59.5233	10.67571	43.902	7.873978	73.6695	13.21288	23.2146	4.16362
VEGETATION	430.7517	77.25683	386.8497	69.38285	313.1802	56.16997	261.5265	46.90569
TOTAL	557.5581	100	557.5581	100	557.5581	100	557.5581	100

Table 2.b: Comparison of area and rates of change of LULC between year 1989 - year 2018.

LULC	1989		1999		2009		2019		AVERAGE RATE OF CHANGE (1989-2019)	
	AREA	%	AREA	%	AREA	%	AREA	%		
BUILT UP	67.2831	12.06746	126.8064	22.74317	170.7084	30.61715	272.817	48.93	68.53	11.56
NON-VEGETATION	59.5233	10.67571	43.902	7.873978	73.6695	13.21288	23.2146	4.164	-12.10	-6.51
VEGETATION	430.7517	77.25683	386.8497	69.38285	313.1802	56.16997	261.5265	46.90569	-56.38	10
TOTAL	557.5581	100	557.5581	100	557.5581	100	557.5581	100		

Using the average rate of change from 1989 – 2019 it was observed (Table 2) that vegetation as a land cover reduced at an average rate of about 8%per year in a 30-year period. It also explains the average rate of increase of the built-up area which was increased at an average rate of about 9%) per year. This connotes a very high rate of urban expansion in the study area (Chukwuka et al., 2017)

Table 3: Differences in LULC: Area/Percentage gained (+) or lost (-) between year 1989 - year 2019

LULC	DIFF (1989-1999)		DIFF (1999-2009)		DIFF (2009-2019)	
	(+ gain, – loss)		(+ gain, – loss)		(+ gain, – loss)	
	AREA	%	AREA	%	AREA	%
BUILT UP	67.28-126.81 (-59.53)	12.07-22.74 (-10.76)	126.80-170.71 (-43.91)	22.74-30.62 (-7.88)	170.71-272.82 (-102.11)	30.62-48.93 (-18.31)
NON VEGETATION	59.53-43.90 (+15.63)	10.68-7.87 (+2.81)	43.90-73.67 (-29.77)	7.87-13.21 (-5.34)	73.67-23.21 (+50.46)	13.31-4.16 (+9.15)
VEGETATION	430.75-386.85 (+43.9)	77.26-69.38 (+7.88)	386.85-313.18 (+73.67)	69.38-56.17 (13.21)	313.18-261.53 (51.65)	56.17-46.91 (9.26)

In Table 3, between 1989 and 1999, about 10.26% of other land cover types transitioned to built up areas and this increased to 18.31% between 2009 and 2019. The total difference of loss in vegetal cover between 1989 and 2019 is just about 1.38% while the total gained by built up area between 1989 and 2019 (30year period) is 7.6%.

Also, the vegetation loss was just about 7.88% between 1989 and 1999 and rose to 9.26% between 2009 and 2019. This could be an effect of urbanization in the area.

4.2 Temperature Pattern of the Enugu city

In (Table 3), the vegetation loss was just about 7.88% between 1989 and 1999 and rose to 9.26% between 2009 and 2019. This could be an effect of urbanization. Between 1989 and 1999, about 10.26% of other land cover types transitioned to built up areas and this increased to 18.31% between 2009 and 2019. The total difference of loss in vegetal cover between 1989 and 2019 is about 1.38% while the total gained by built up area between 1989 and 2019 (30year period) is 7.6%. This further validates the fact that what was lost in vegetation was gained by built-up.

Table 4: Average temperature of Enugu between 1989 and 2019

Year	Temperature (°c)	Change in temperature (°c)
1989	27	-
1999	27.6	0.6
2009	28.1	0.5
2019	29.1	1

The temperature map from the analysis shows the temperature distribution of Enugu city in pixels (30x30). The non vegetation area has the lowest temperature while the built up area has the highest temperature. Also, both temperature and vegetation graphs show that the area experienced decrease in vegetation cover over the course of years, while temperature was in the increase. Also, area of low vegetation has high temperature and vice versa from the temperature images.

Figure 3.1 to 3.4 shows that Enugu City has experienced a considerable high temperature over the years. A major factor responsible for this is the loss of vegetation cover in the course of years.

While in figure 4.1 to 4.4, it shows that the relationship between the vegetation cover and temperature by analyzing the vegetation distribution of the study area in a vegetation index form

Temperature and Vegetation Relationship in Enugu city

This has been determined by carrying out Correlation Analysis between temperature and NDVI. Table 4 shows their correlation coefficients. Non vegetation were excluded from the regression analysis. This was done due to the fact that studies have shown that surface temperature and NDVI have a negative correlation with non vegetation, meaning that excluding such surfaces would increase the accuracy of the regression between mean surface temperatures and mean NDVI, values for vegetations. The correlation coefficients of surface temperature and NDVI are 0.09219, 0.44912, 0.65606, and 0.68606 for 1989, 1999, 2009 and 2019 respectively.

Table 4: Temperature and vegetation correlations

	1989 NDVI	1989 TEMP	1999 NDVI	1999 TEMP	2009 NDVI	2009 TEMP	2019 NDVI	2019 TEMP
1989 NDVI	1							
1989 TEMP	-0.09219	1						
1999 NDVI	0.124737	-0.044912	1					
1999 TEMP	-0.44771	0.65606	-0.65606	1				
2009 NDVI	0.44912	-0.52172	0.410333	-0.68606	1			
2009 TEMP	-0.41321	0.502679	-0.44062	0.65792	-0.919	1		
2019 NDVI	0.534496	-0.52172	0.44033	-0.07625	1	-0.68606	1	
2019 TEMP	0.855832	0.502679	-0.44062	0.855832	-0.919	1	0.68606	1

5. Conclusion And Recommendation

From the analysis, we can deduce that what was lost in vegetation was gained by built-up and that urbanization and industrialization are major factors of loss of green vegetation. Density of roads and elevation showed positive relationships with urban expansion between 1989 and 2019. Planners and policy-makers should put more premiums on the increase in land consumption rate and pattern when looking at urban morphology. They can achieve this by critically evaluating the spaces for future urban expansion, encouraging the construction of high-rise buildings, and the opening of the peri-urban through the construction of access roads.

Also, the results obtained from this study should raise strong concerns for environmental managers involved with the mitigation of the effect climate change in and around Enugu city. With increasing percentage of built up areas through industrialization and urbanization, the temperature of the city will also continue to be on the rise. The future urban land use planners, the analysts and the policy makers in the state should consider urban space management for land allocation in the future. They study can provide important insights on why it's essential to encourage urban forestry as a way to mitigate the effect of vegetation loss.

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Figures

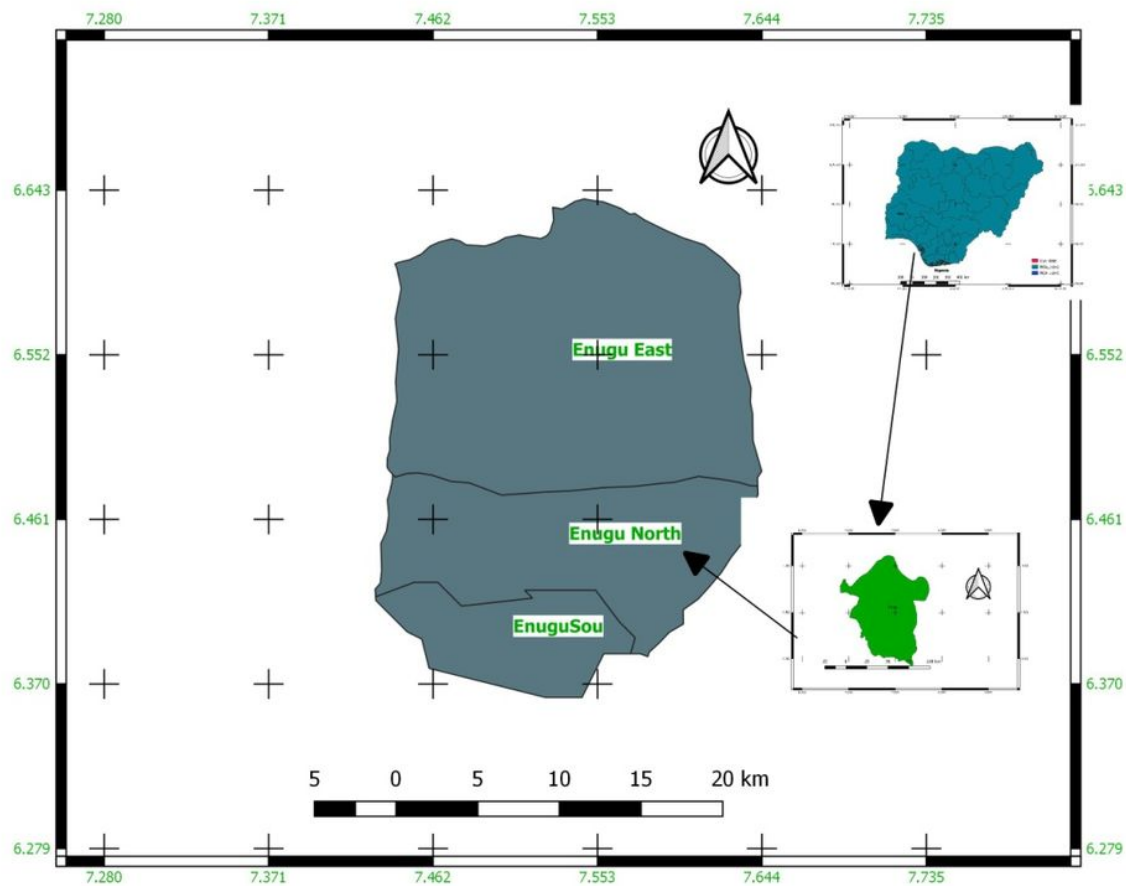


Figure 1

Map of the Enugu City in Enugu State Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

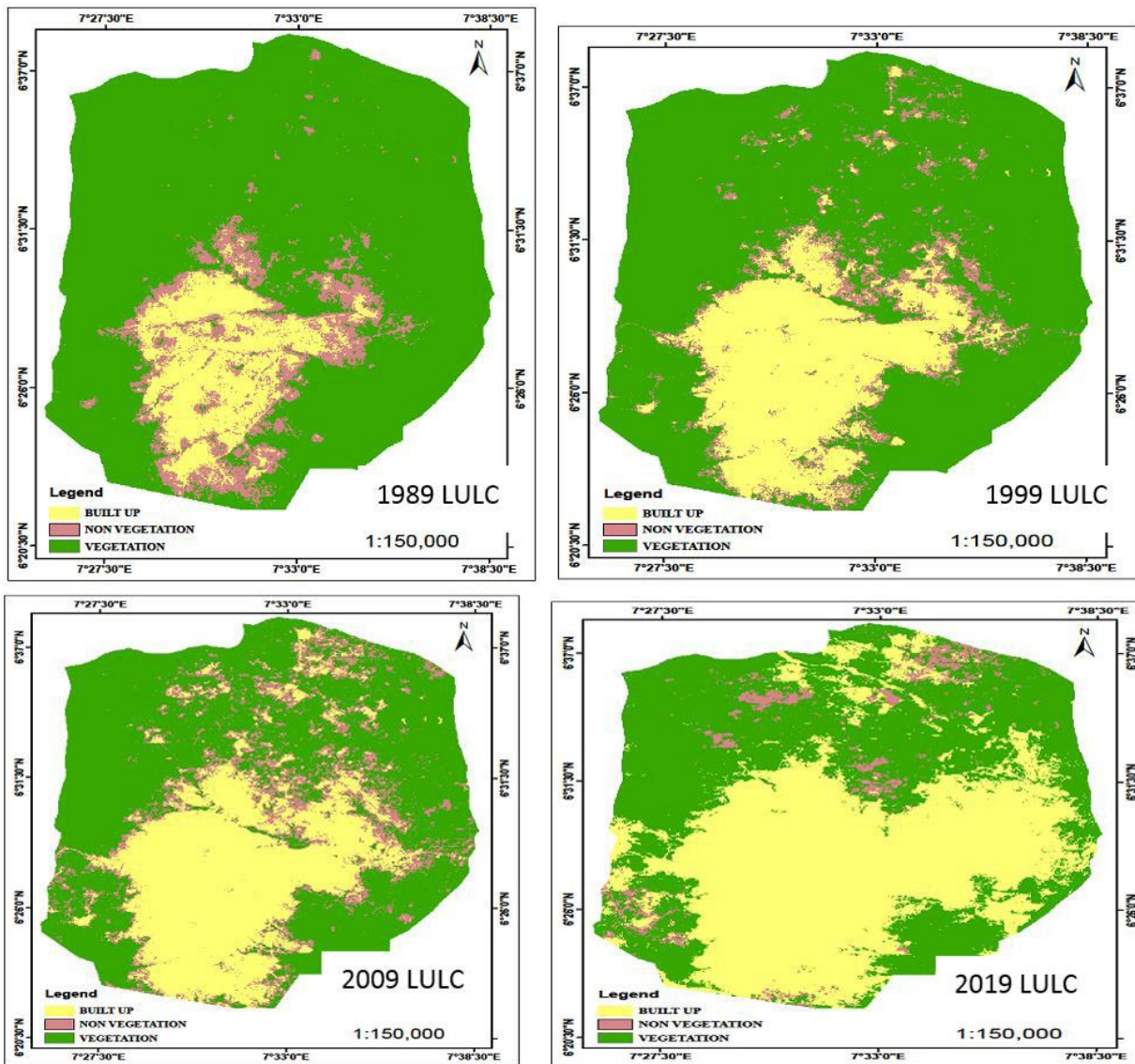


Figure 2

LULC map between 1989 and 2019 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

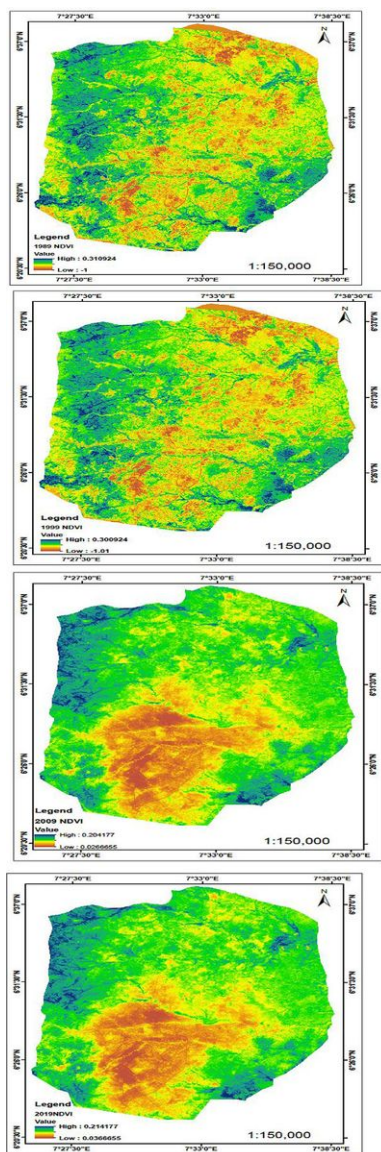


Figure 3

NDVI map between 1989 and 2019 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

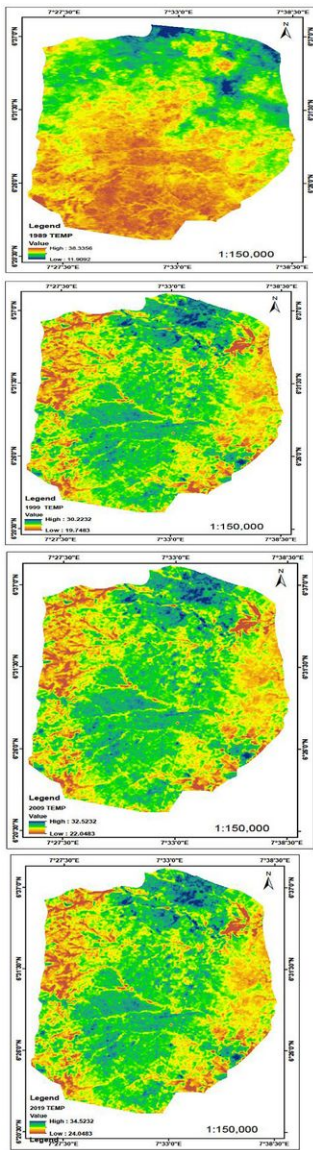


Figure 4

Temperature map of Enugu city between 1989 and 2019 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.