Original Research Article

Spatial Assessment of Temperature, Rainfall and Land Cover Change as Climate Change Monitoring Techniques in Okigwe and its Environs

Abstract:

Climate change is an alarming global environmental change phenomena constituting serious threat on natural, social, cultural, and human systems. Its associated risks requires a wide range of policy responses and techniques at all levels from local to global. The study sought to evaluate the changes in climatic parameters over three decades as monitoring techniques in Okigwe, Imo State, Nigeria, based on evaluated land cover and temperature variation using Landsat 5 TM, Landsat 7 ETM+ and Landsat 8 ETM+ satellite data of 1986, 2003, and 2020 respectively. This in combination with precipitation data from 1990-2020 of the study area was used to evaluate rainfall variation as climatic change parameters in the area over three decades. Results of the geospatial analysis indicates that climate change has become a fallout from development activities in Okigwe, which obviously is impacting on all facets of human activities thereby militating against sustainable development. Implicitly, changes in built-up areas or surfaces significantly produced a corresponding effect in escalating urban heat in the city. This study recommends the enforcement of adequate land use planning via adopting green city planning techniques in infrastructural development.

Keywords: Land surface temperature, Rainfall, Land Cover Change, Climate Change, Satellite Imageries, Change Detection

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1. INTRODUCTION:

Natural and anthropogenic activities are fingered to be contributing factors to changing global climate [1]. In the past few decades, climatic changes have been witnessed globally, and in Nigeria, the changing climate is evident from temperature increase, rainfall variability. These changes can be quite alarming when juxtaposed with some important climatic indices such as temperature, rainfall, and humidity, as shown in many studies such as [2]. Climate change as a global issue has affected environmental sustainability due to its negative effects on the ecosystem. Research conducted by [3] reports that jointly, land and ocean temperatures have increased at an average rate of 0.13°F (0.08°C) per decade since 1880;

however, the average rate of increase since 1981 (0.18℃ / 0.32°F) has more than doubled that rate. Also research shows that Nigeria has witnessed several inter-annual fluctuations in the mean annual variability and trend of rainfall over the past six decades, and these have been blamed for such extreme climate events as droughts and floodings in several parts of the country [4;5;6]. Other climatic indices have also been known to exhibit notable variations. The Inter-Governmental Panel on Climate Change (IPCC) has reported global average temperature increase of at least 0.6℃ in the past few decades. There have also been arguments in the science community that average temperature has increased by 0.3℃ – 0.7℃ globally over the last century with an estimated increase of about 1.4℃– 5.8℃ by the end of the 21st 4entury [7;8].

Research conducted by (9) had observed that climatic changes impacts on precipitation and believes that continual fluctuations in weather and climate, will result in rainfall fluctuation. This variability has been recorded globally and regionally within the tropics, in Nigeria, and Sub-Saharan Africa. Nigeria's climate has been changing over the years, this is evident in; temperature increases; distorted rainfall pattern; sea level rise and flooding events across the country; drought and desertification recorded; land degradation; recurring extreme weather events; impacted freshwater resources and biodiversity loss[10].

Thus, this paper aimed at evaluating the changes in climatic parameters over three decades. The aim would be achieved through processing and analyzing satellite imageries to detect changes in land use and land cover over three decades (1986, 2003, and 2020) in Okigwe; analyzing climatological data to ascertain changes in climatic parameters. And also spatially revealing the dynamics of temperature, rainfall and land use land cover in Okigwe. Hence, recommending environmental management plans to aid sustainable development in the study area.

2. MATERIALS AND METHOD:

Description of Study Area; Okigwe Local Government Area (LGA) of Imo State, Nigeria, comprises twelve communities and many villages. It is located between Longitude 7° 26' 24" of and 7° 15' 36" Greenwich Meridian and Latitude 5° 18' 0" and 5° 34' 12" of the Equator. (See Fig. 1). The area occupies a landmass of about 360km^2 and has a population of about 132,237 people [11]. It shares common boundaries in the North with Umuahia South Local Government Area in Abia State, and with Onuimo Local Government Area of Imo State in the East, the South is bordered by Umunneochi Local Government Area of Abia State and the West by Isuikwuato Local Government Area, Abia State. Okigwe enjoys a tropical climate with an annual rainfall of between 1800mm-2000mm, and a mean temperature range of about 28 - 42 and relative humidity of 65%. There are two dominant seasons comprising of the dry season November-April, and the rainy season May-October [12].

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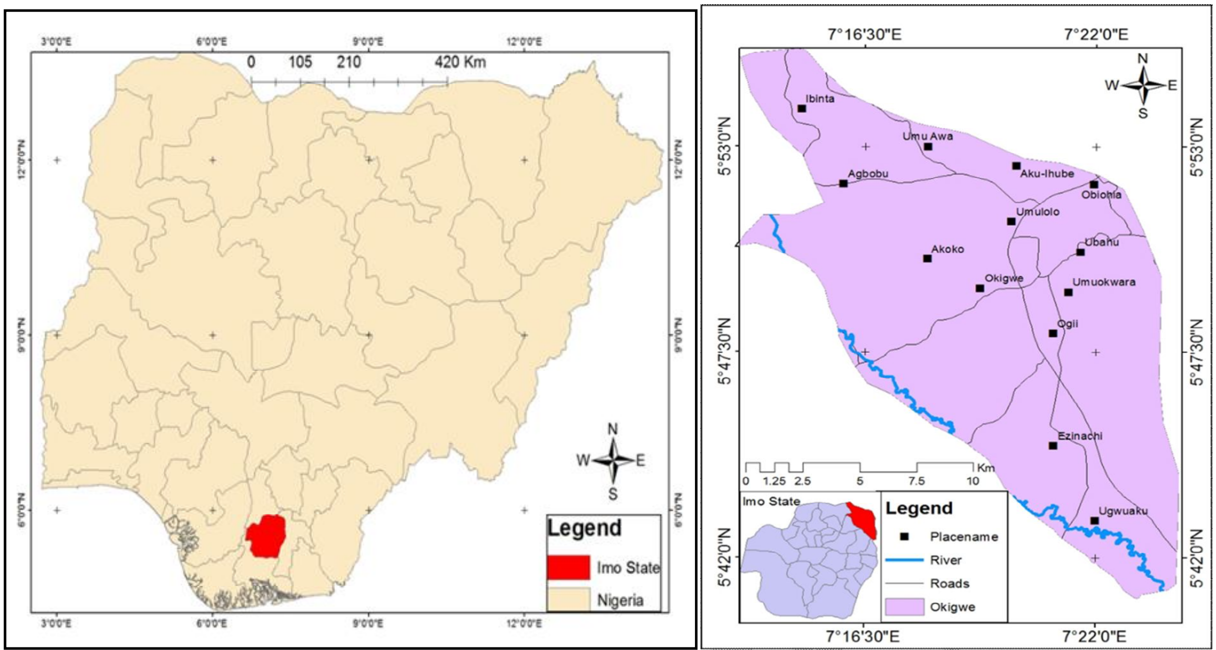

Figure 1: The study area.

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Primary and secondary data used include Landsat satellite data used for assessing the land use and land cover changes. Thermal bands of Landsat satellite imageries were used to determine the spatial land surface temperature (LST) of the study area for the selected duration of available data. Precipitation data was used for temporal trend analysis of the study area. Others data include the visual assessment and geographic coordinate data acquired during the field reconnaissance survey. The three Landsat satellite data used for the analysis of land use and land cover as well as land surface temperature were acquired from the USGS Earth Explorer website hosted by the United States Geological Survey. The rainfall data used for temporal trend analysis was obtained from the Nigerian Meteorological Agency (NIMET).

Method of Data Acquisition

Table 1: Properties of Data and Source

S/N	Type of Data	Date of data	Scale of Data	Source

1.	Landsat 8	2020	28.5m ETM+	USGS
2.	Landsat 7	2003	30m TM	USGS
3.	Landsat 5	1986	30m TM	USGS
4.	Rainfall data	1990 -2020	Not applicable	NIMET

Techniques of Data Analysis.

Landsat-8 data listed in table 1 above was resampled to 30m resolution. The satellite images in bands were combined adopting a false colour combination with A RGB of Band 432 composite. Thus, the satellite image was masked to delineate the area of interest defined for the study. The classification scheme was developed based on visual inspection of the images and the study area. The class scheme included Primary Forest Cover, Built-up Cover, Bare Surface cover, Rock outcrops, and Secondary Forest cover. This was followed by a supervised classification of LULC using the maximum likelihood classifier. The Land-use cover classified maps are displayed in the result session. The rainfall data analysis was done with MS Excel to average annual precipitation density data showing the trends of the three decades. The land surface temperature (LST) was obtained using the thermal bands of Landsat's data for the different years of the study. The LST calculation was done using the Algebraic toolbox of the ArcMap and calculating the Radiance, BT, and conversion of the surface temperature from Kelvin to Degree Celsius. [13;14]. See Figure 2. The geospatial and image processing analysis was done using ArcMap 10.0.

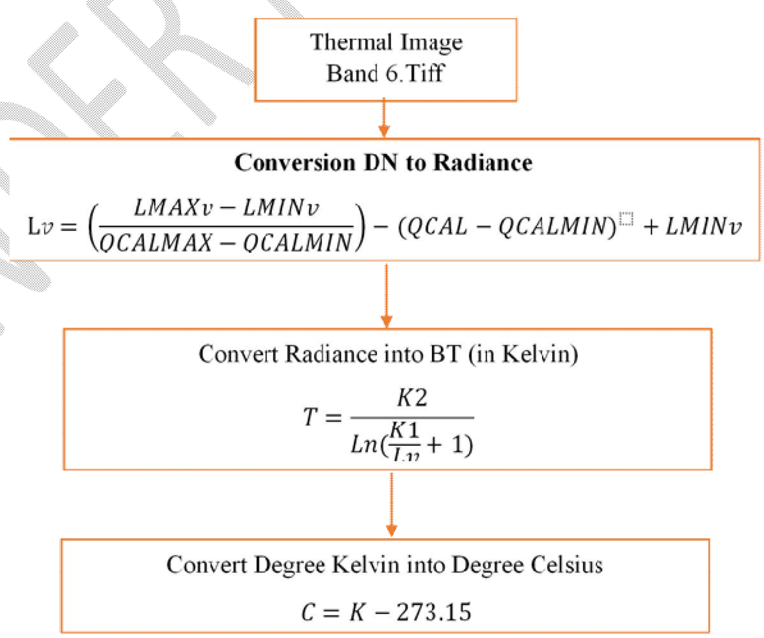

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Figure 2: Formulas for estimating land surface temperature (LST)

Where,

$L\lambda$ = Spectral radiance

QCAL = Quantized Calibrated pixel value in DN

$LMAX\lambda$ = Spectral radiance scaled to QCALMAX in (Watts/ (m2 * sr *µm))

$LMIN\lambda$ = Spectral radiance scaled to QCALMIN in (Watts/ (m2 * sr *µm))

QCALMIN = Minimum quantized calibrated pixel value (corresponding to $LMIM\lambda$) in DN

QCALMAX = Maximum quantized calibrated pixel value (corresponding to $LMAX\lambda$) in DN

Where:

T = Effective at- satellite temperature in Kelvin

K2 = Calibration constant 2

K1 = Calibration Constant 1

$L\lambda$ = Spectral radiance in (Watts/(m2 * sr *µm))

Table 2: Thermal Value of the selected Bands used for Land Surface Temperature

Satellite Sensor	**Constant 1 – K1 (Watts/(M2 * SR *MM))**	**Constant 2 – K2 Kelvin**
Landsat 7 ETM+	669.09	1282.71
Landsat 5 TM	607.76	1260.56
Landsat 4 TM	671.62	1284.3

NDVI Analysis using NDVI Tool Box in ArcGIS 10.0

$$\text{NDVI} = \frac{\text{Near-Infrared} - \text{Red}}{\text{Near-Infrared} + \text{Red}} = \frac{\text{Band 5} - \text{Band 4}}{\text{Band 5} + \text{Band 4}}$$

NDVI's results were revealed in two dimensions; and ranges from -1.0 to +1.0, negative and the positive dimension from the vegetation abundance of the study location. The NDVI raster result from the calculations signifies that negative values indicate vegetation loss and the positive values signify vegetation gain [15].

Land Surface Temperature Analysis Flow:

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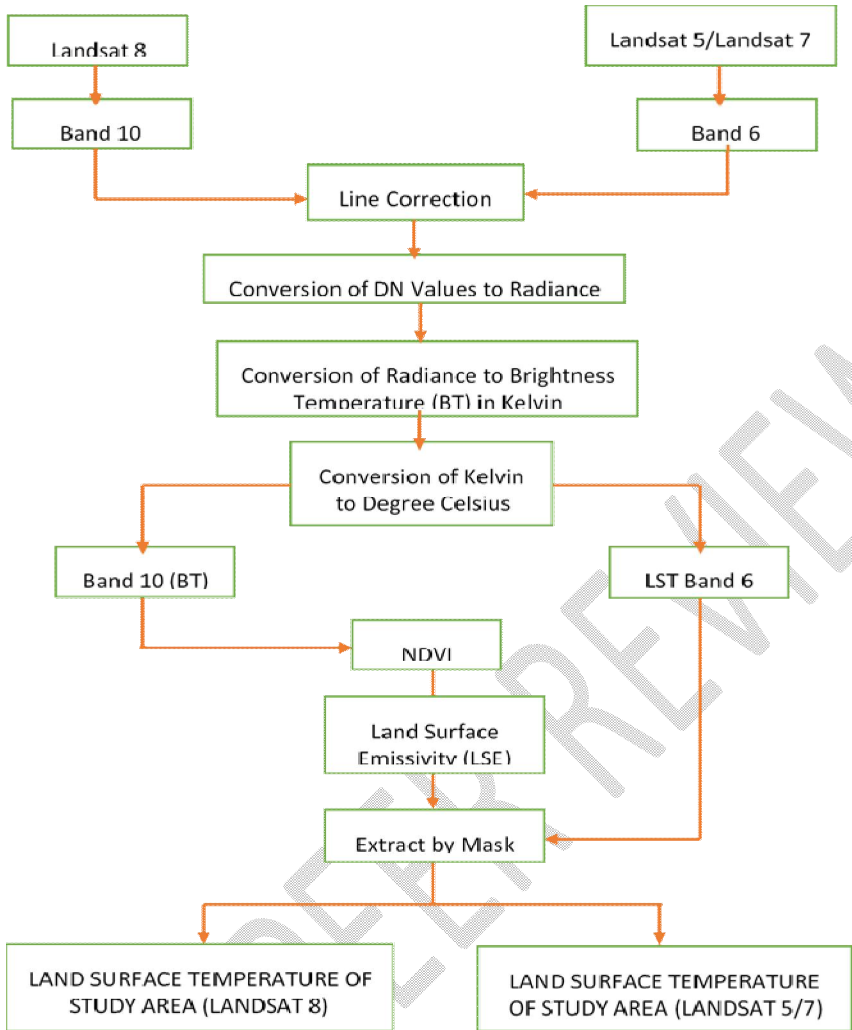

Figure 3: Land Surface Temperature Analysis Flow (source????)

The multi-temporal Landsat satellite data was acquired from Landsat 5 TM (1986), Landsat 7 ETM+ (2003), and Landsat 8 ETM+ (2020). A suitable land surface temperature algebraic algorithm was selected to calculate the Land Surface Temperature. The land use and land cover classification scheme was generated using the maximum likelihood classifier on the ArcGIS software. A total of six land use and cover classes were identified in the study area.

3. RESULTS AND DISCUSSION

LULC Maps of the study area

The analysis of land use and land cover was useful for identifying the land cover types evidenced in the area and the different identified LULC types were used to develop the signatory land cover samples for classifying the LULC using the supervised maximum likelihood classification. Each year of Landsat

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satellite image analyzed turned up six classes of land use and land covers: built-up areas, Primary Forest (Thick Forest cover including all matured forest layers of the mycelial, or mushroom, layer–the overstory, the understory, the shrub layer, the herbaceous layer, the root layer, the ground cover layer, and the vine layer), Secondary Forest (Grassland/all other young forest regrowing covers), bare surface, River and rock outcrops. The land use and land cover classification results are depicted in (Figures 4 - 6). The land-use classification, accuracy assessment and land surface temperature classification of the satellite images of the study area covered a total of 26,590.47 hectares. The Change detection tables in the various LULC and maps of the Built-up area were generated.

In 1986 as shown in (Figure 4), the LULC map generated revealed that Secondary Forest cover was the highest land cover in the study area with an average land area of 11370.44 hectares, making up a total of 42.76 percent of the total study area assessed. Primary Forest cover is the second-largest land cover of the study area in 1986, with about 6123.28 Hectares making up about 23 percent of the total land area. These other land covers followed sequentially with a bare surface, rock outcrops and built-up area as the third, fourth, and fifth largest land cover respectively. The waterbody was barely detected because the riparian Secondary Forest surrounded the undulating river channels in the study area.

Temporal trend of precipitation in the study area

The data acquired from the Nigerian Meteorological Agency (NIMET) was used to investigate the spatial and temporal variability and trends in precipitation on annual basis for Okigwe L.G.A, Imo State, Nigeria [12]. The analysis carried out was useful in identifying temporal trends of rainfall over the years under review. The temporal trends of precipitation are presented in (Figures 12 – 14). The precipitation density trend for the three decades of the study area was generated. The first decade 1990-1999 had decadal average precipitation of 205.406mm, being the decade with the highest precipitation over the years under review, it also recorded the year with the highest rainfall intensity 1997 with a total average annual precipitation of 224.283mm. The second decade 2000-2009 had a decadal average of 196.683mm and the third decade 2011-2020 had a decadal average of 177.919mm, which showed that 2011-2020 was the decade with the lowest rainfall intensity. The statistical analysis carried out shows a decreasing trend in rainfall in the study area within the years under review.

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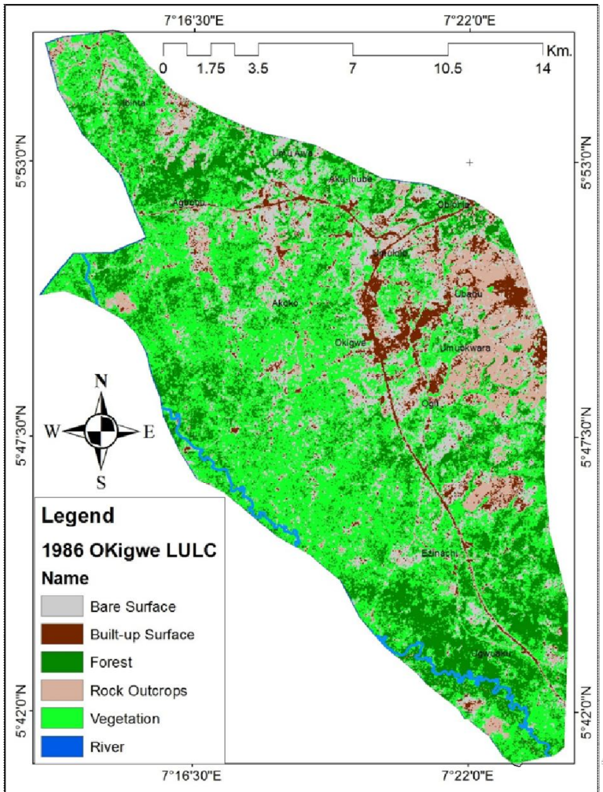


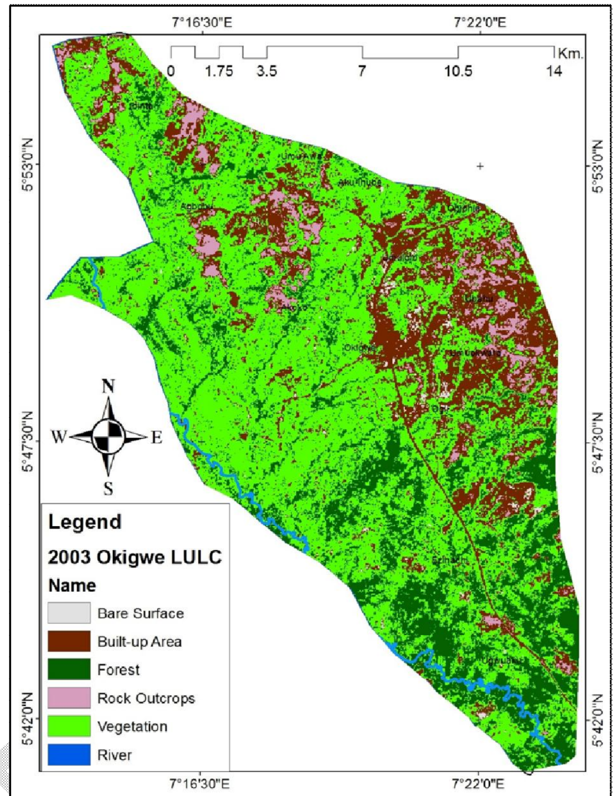
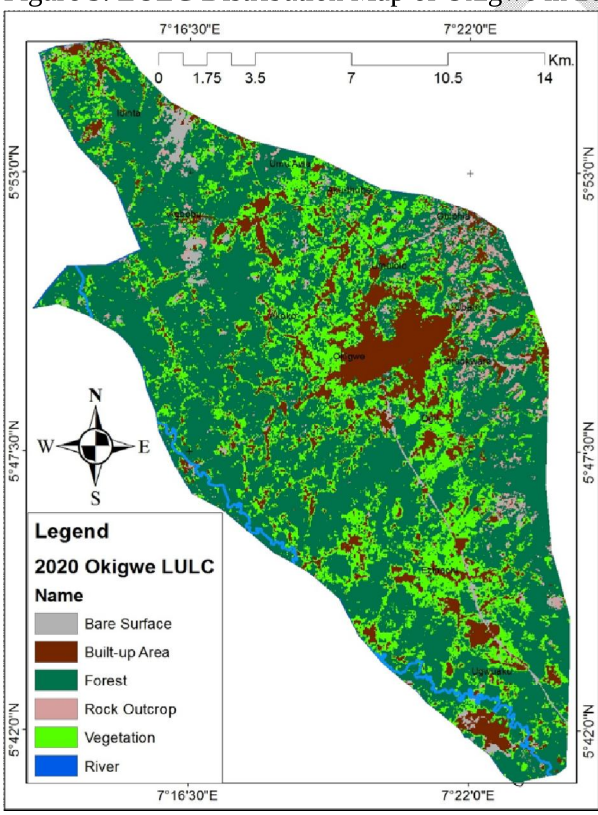


Figure 4: LULC Distribution Map of Okigwe in 1986

Figure 5: LULC Distribution Map of Okigwe in 2003



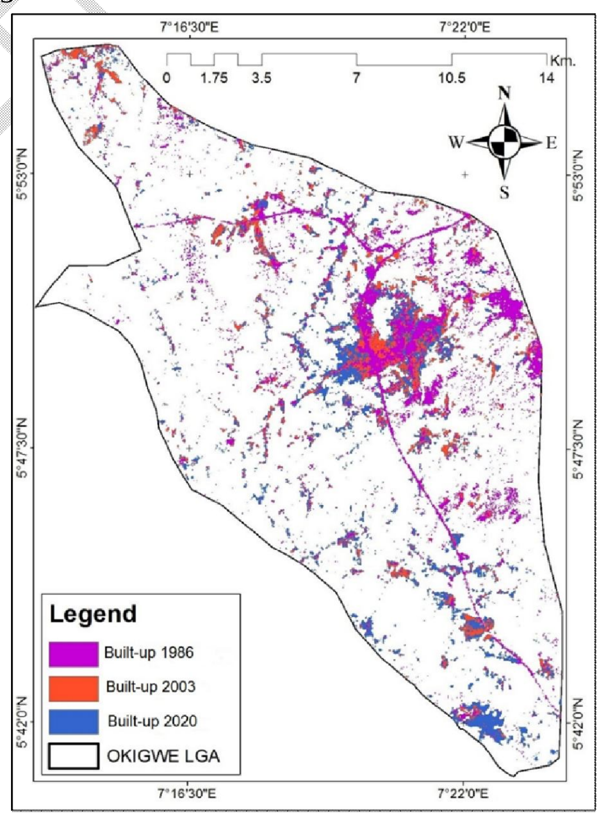


Figure 6: LULC Distribution Map of Okigwe in 2020

Figure 7: LULCBuilt-up Change Detection Map of Okigwe 1986-2003-2020

Table 3: Area Distribution Map of Okigwe in 1986

Name	Pixel Count	Area (M2)	Area (Ha)	Area (%)
Bare Surface	50472	40995882	4099.59	15.42
Built-up Surface	19591	15912790	1591.28	5.98
Primary Forest	75388	61233903	6123.39	23.03
River	12083	9814417	981.44	3.69
Rock Outcrops	29847	24243226	2424.32	9.12
Secondary Forest	139987	113704441	11370.4	42.76
Total	**327368**	**265904658**	**26590.5**	**100**
Accuracy Assessment		Overall Accuracy: 0.751	Kappa Coefficient: 0.728	

Table 3: revealed an overall accuracy of 0.75 and a Kappa coefficient of 0.72.

Figure 5 is the LULC map revealing the LULC classified covers in the study area in 2003. The delineation of signatory class helped to prevent the thermal reflection of Rock Outcrops and Paved Surfaces for Built-up areas bearing similar count pixel class across the years of classified LULC maps.

In 2003, Secondary Forest occupied the largest land area with about 39.1 percent, representing 11529.36 hectares of the total study area, Primary Forest cover was identified to occupy the second largest cover of about 6518.52. While built-up area covered 18.4% and was identified as the third-largest cover, representing about 5411.16 hectares.

Table 4: LULC Distribution in Okigwe for 2003.

Name	Pixel Count	Area (M2)	Area (Ha)	Area (%)
Bare Surface	26532	23878800	2387.88	8.1
Built-up Surface	60124	54111600	5411.16	18.4
Primary Forest	72428	65185200	6518.52	22.1
River	13003	11702700	1170.27	4.0
Rock Outcrops	27177	24459300	2445.93	8.3
Secondary Forest	128104	115293600	11529.36	39.1
Total	327368	294631200	29463.12	100.00
Accuracy Assessment	Overall Accuracy: 0.751	Kappa Coefficient: 0.728		

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Bare surface cover, rock outcrops, and waterbody were identified to cover 8.1 %, 8.3 %, and 4.0 % respectively. Figure 6 shows that in 2020, the Built-up area covered the highest land cover with a total of 37.4 % of the entire area, representing about 11013.84 Hectares. The second-largest cover of the study area is Primary Forest cover resulting in about 31.8 % representing a total of 9355.14 Hectares. The third-largest land cover identified from the LULC result is Secondary Forest cover occupying a total of 19.8 & of the entire study area making up to 5839.02 Hectares of land cover. Bare surface, river/water bodies, and rock outcrops were identified to occupy 4.8 %, 4.0 %, and 2.2 % respectively.

Table 5: LULC Distribution of Okigwe in 2020

Name	**Pixel Count**	**Area (M2)**	**Area (Ha)**	**Area (%)**
Bare Surface	15864	14277600	1427.76	8.1
Built-up Surface	122376	110138400	11013.84	18.4
Primary Forest	103946	93551400	9355.14	22.1
River	12977	111679300	1167.93	4.0
Rock Outcrops	7327	6594300	659.43	8.3
Secondary Forest	64878	58390200	5839.02	39.1
Total	327368	294631200	29463	100.00
Accuracy Assessment		Overall Accuracy: 0.751	Kappa Coefficient :0.728	

This result shows that there is increasing demand on land use for built-ups and Secondary Forest by the sprawled population due to increased rural-urban migration and the outburst of economic activities in the study area.

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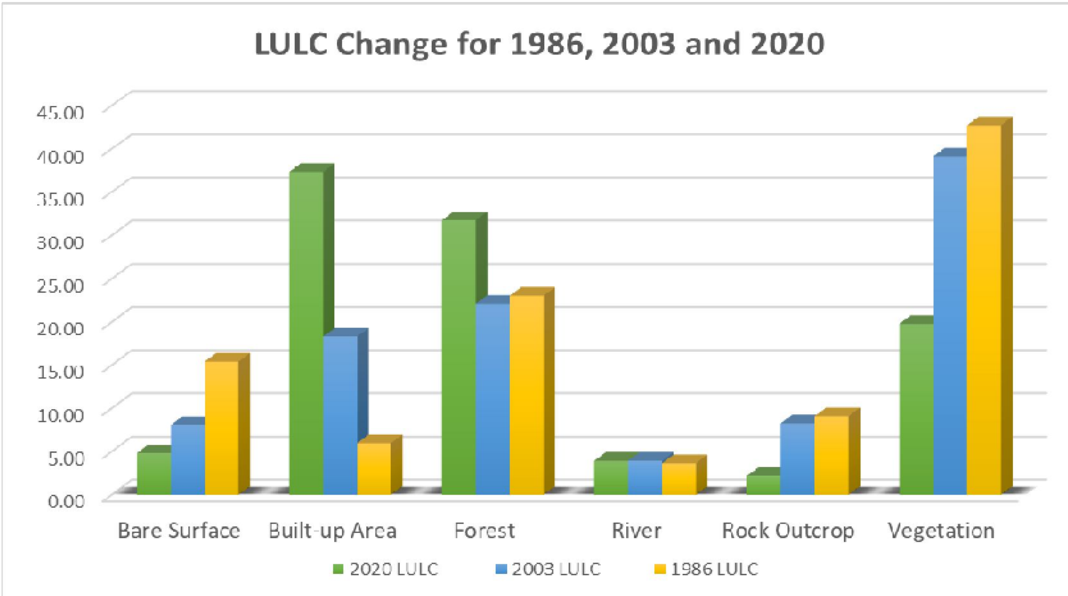


Figure 8: Trends of LULC Change Distribution Chart in 1986-2003-2020

Figure 8 revealed the trends of land use and cover classes assessed for the years under review. Bare surface, Secondary Forest, and rock outcrops followed a pattern of decrease. Whereas the built-up surface and Primary Forest cover followed a pattern of increase with a significant percentage.

LULC Change Detection for Built-up Cover Results

The comparison of Built-up cover across the years of the assessment was shown in Figure 7: it revealed the change detection in built-up area cover from 1986 to 2003 and 2020. This significant land cover changes within 34 years. However, the results demonstrated a statistically substantial increase in only a built-up area and maintained slightly stable Secondary Forest area cover. The built-up area showed an overall increase with emerging percentage change of 12% and 18% from 1986 to 2003 and 2003 to 2020 respectively. The increase however was significantly higher in 2020 with 37.4% cover of the total area compared to 2003 and 1986 which occupied about 18.4 % and 5.98 % respectively.

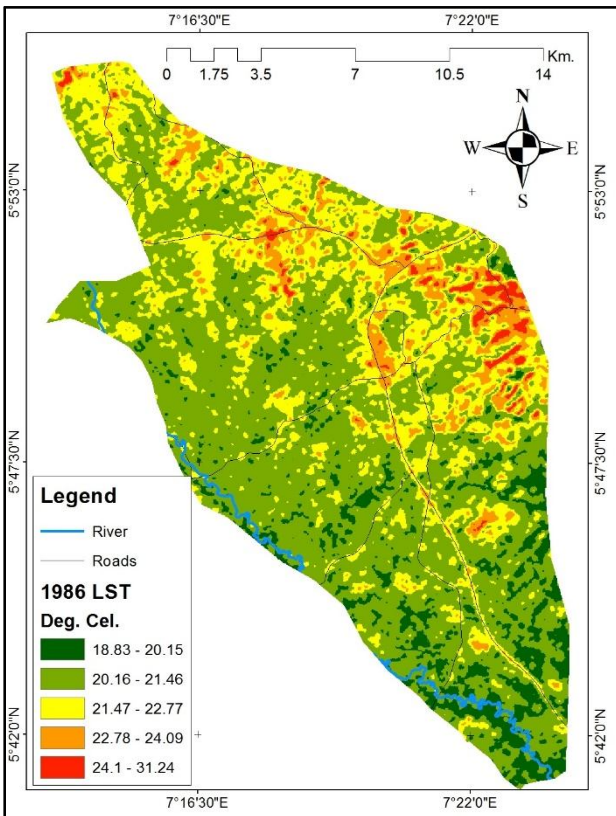
Table 6: Area Distribution of the Built-up area of Okigwe over the three decades

LULC Name	Count	Area (M2)	Area (Ha)	Area (%)
1986 Built-up Area	19591	17631900	1763.19	5.98
2003 Built-up Area	60124	54111600	5411.16	18.4
2020 Built-up Area	122376	110138400	11013.84	37.4

4.4 Land Surface Temperature Analysis of the Study Area

The spatial distribution of surface temperature within the study area is shown for the years 1986, 2003 and 2020 in Figures 9, 10, and 11 respectively. The LST ranged from 19°C in 1986 to 50°C in 2020. A slight difference is noticed which might be attributed to a radiometric error of the satellite platform. In 1986, it was evident that the temperature was higher between 23°C and 31°C within the peri-urban center of Okigwe local government area of Imo State compared to the rural fringes of the local government area.

Other areas that were indicated to be covered by rock outcrops were observed to exhibit very high temperatures as well, implying the occurrence of Urban Heat Island (UHI) with obvious intensity. There were significant increasing trends over the 34 years of analysis. This was observed in LST results which revealed the same trends with increasing changes detected on the LULC maps. For all the years, built-up areas and Rock outcrop areas exhibited the highest land surface temperature with very high intense temperature within the rocky land covers of the study area. This is attributable to the high emission capacity of rocks and other paved surfaces.



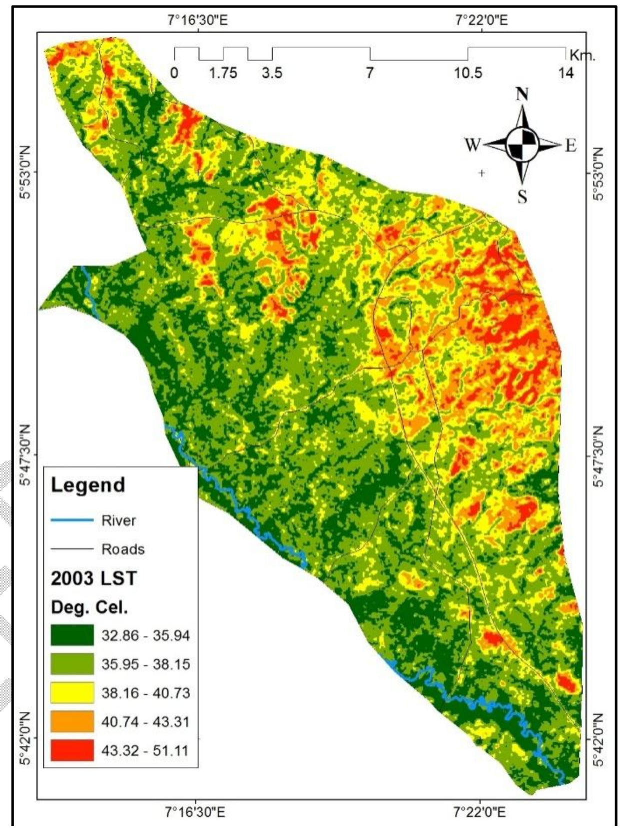


Figure 9: Spatial Distribution of Land Surface Temperature in 1986.
Figure 10: Spatial Distribution of Land Surface Temperature in 2003.

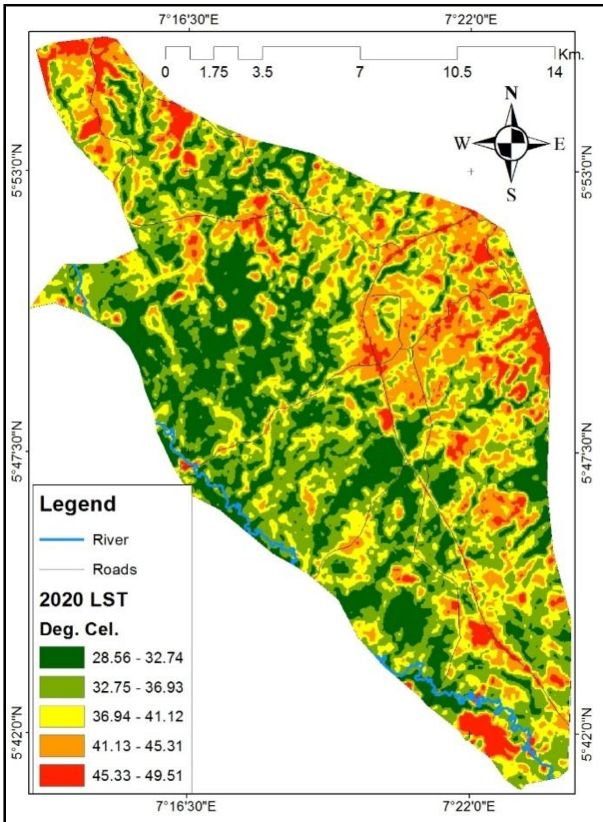


Figure 11: Spatial Distribution of Land Surface Temperature in 2020.

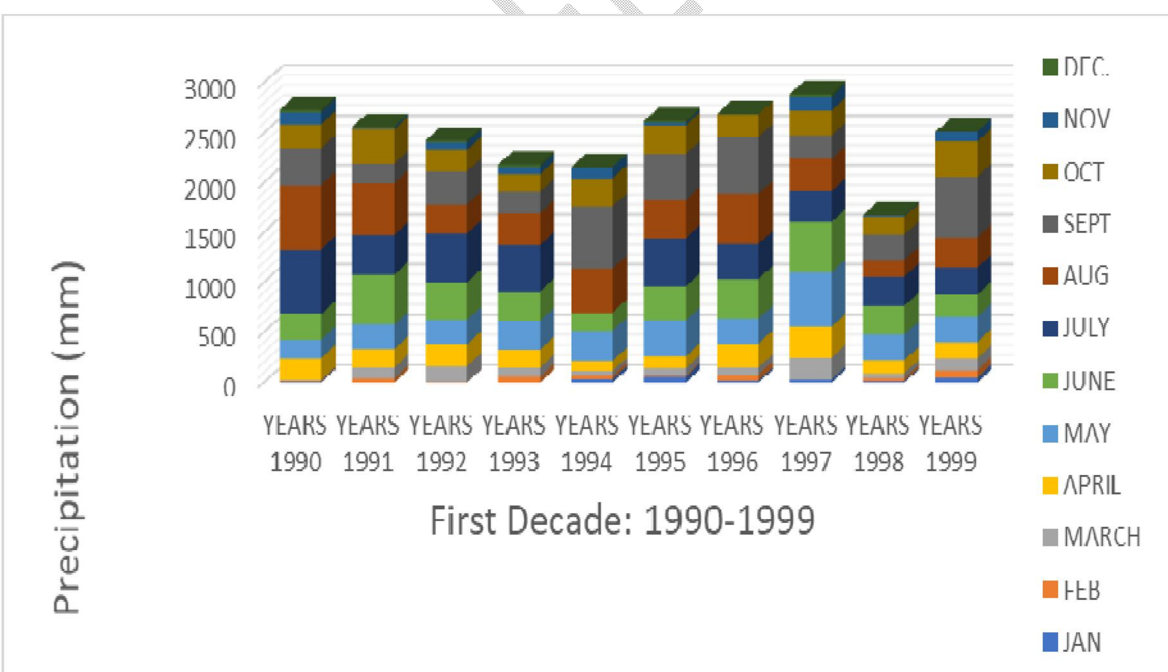


Figure 12: Temporal Trends of Precipitation for the study area 1990 – 1999.

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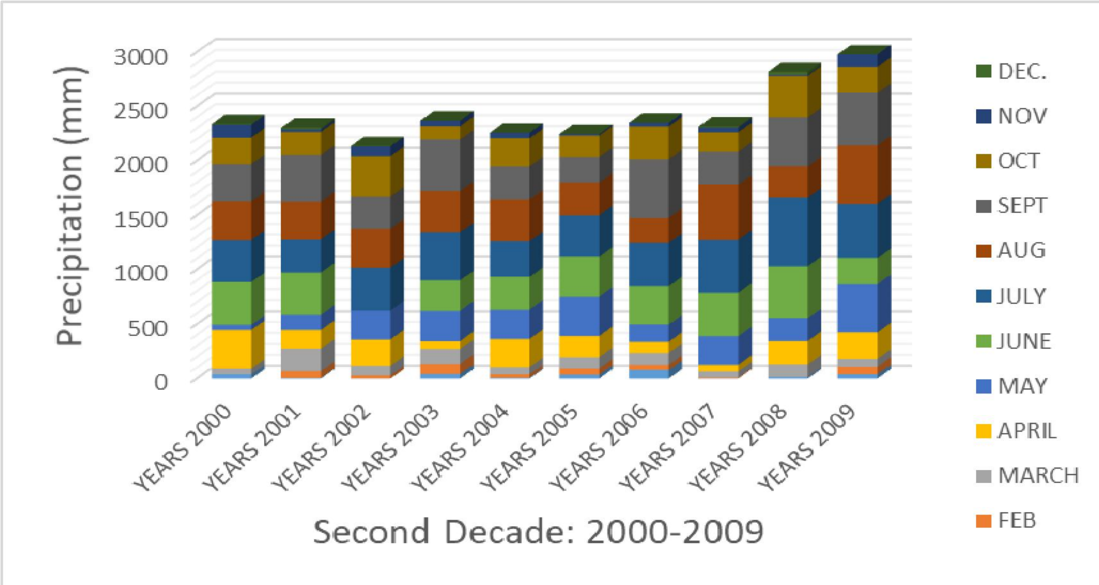

Figure 13: Temporal Trends of Precipitation for the study area 2000 – 2009

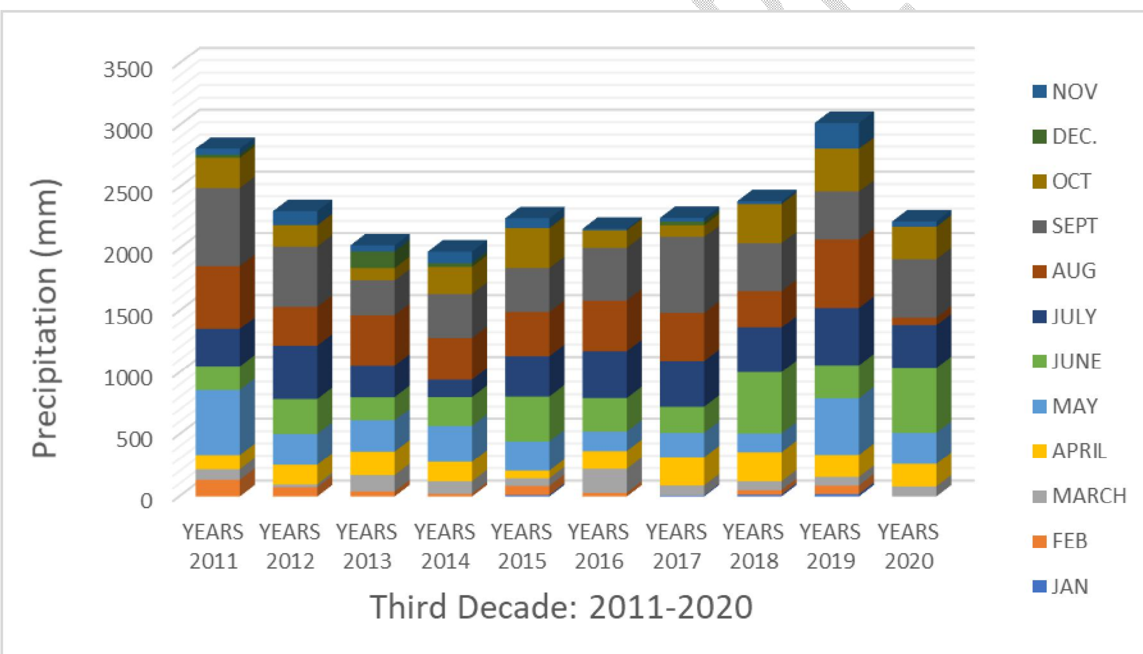

Figure 14: Temporal Trends in Precipitation for the study area 2011 – 2020.

Figure 12 revealed that 1997 was the year in the first decade with the highest rainfall intensity, with a total average annual precipitation of 224.283 mm, it also revealed that 1998 was the year with the lowest rainfall intensity in the first decade, with a total average annual precipitation of 139.3mm. Figure 13 revealed that 2009 was the year in the second decade with the highest rainfall intensity, with a total average annual rainfall of 248.2583 mm, it also revealed that 2002 was the year with the lowest rainfall intensity in the second decade, with a total average annual precipitation of 192.025mm.

Figure 14 revealed that 2019 was the year in the third decade with the highest rainfall intensity, with an average annual rainfall of 251.7083mm, it also showed that 2020 was the year with the lowest rainfall intensity in the second decade, with an average annual precipitation of 164.7833mm. The precipitation density shown in the annual precipitation distribution is very similar to the LULC distribution of the area

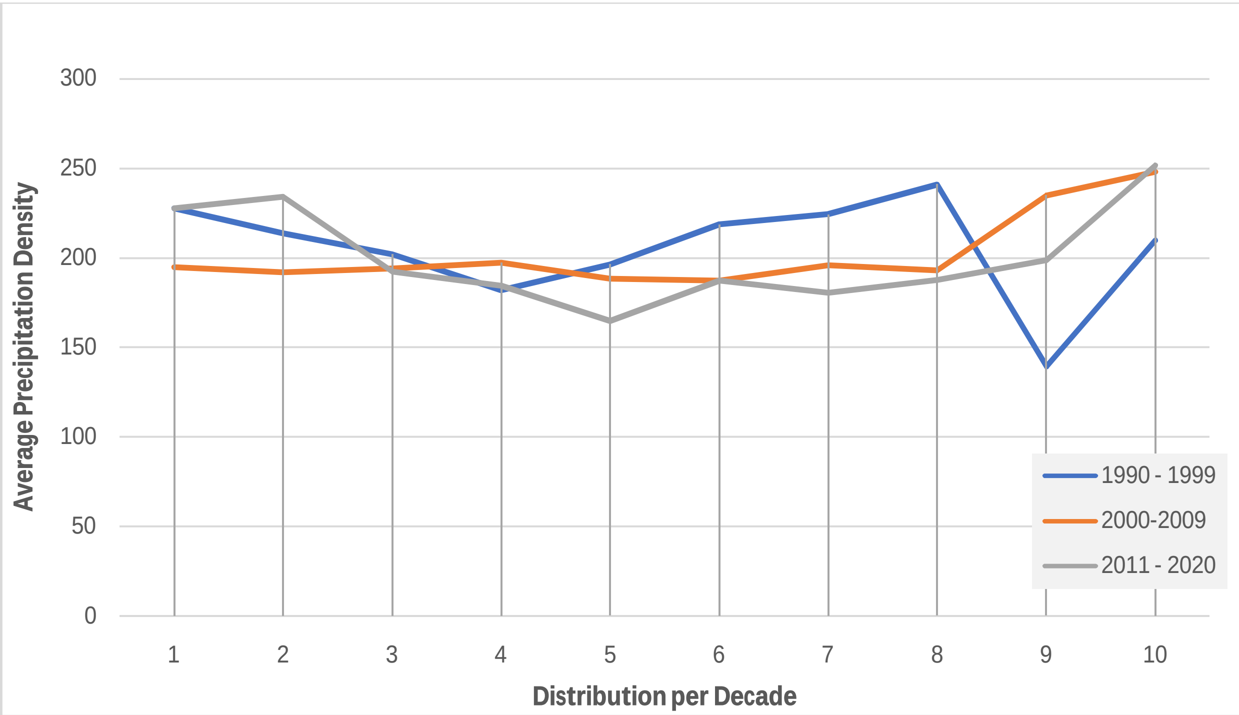

Figure 15: Three decadal trends of Precipitation density in the study area.

The three decades of precipitation review in Okigwe showed a consistent trend in the annual precipitation density. 1990-1999 had its lowest average rainfall in 1998 and the highest average precipitation was observed in 2019 with approximately 251.7mm. The trends revealed above indicate agreement with dynamics in other assessed variables like LULC (Figure 8)and surface temperature as shown in Figure 9,10 and 11 above.

Figure 7 showed the LULC change for 1986, 2003, and 2020 which shows the built-up area as the land cover with the most significant change. Figure 8 indicates that the built-up area changed from 5.98% which is a sum of 1591.28Ha in 1986 to 18.4% of the total land cover in 2003 making up a sum of 5411.16Ha. This also changed to 37.4% with a land cover of about 11013.84Ha in 2020. According to the United States Geological Survey (USGS's) land-use land-cover classification system, built-up area refers to the presence of buildings (roofed structures), urban environment, or human footprints such as paved surfaces (roads), commercial and industrial sites, and urban green spaces. The increase in built-up is attributed to the development and an increase in population density. According to [11], Okigwe L.G.A recorded a population of 132,701 people in the 2006 census, and in 2016 a population projection of 182,700 people was made. Accordingly, the L.G.A has had an average population growth rate of 3.3% per annum from the 2006 population census to the 2016 population projection, implying an increase in population density.

Figures 9, 10 and 11 show the spatial distribution of land surface temperature from 1986 to 2020. With temperature ranging from 19℃ - 31℃ in 1986 and 29℃ - 50℃ in 2020, showing an increase in temperature over the years under review, this change is attributed to change in a built-up area and increase in population and urbanization of the study area.

Figure 15 shows the decadal trends of precipitation density for the study area. The first decade 1990-1999 had average precipitation of 205.406mm, the second decade 2000-2009 had average precipitation of 196.683mm and the third decade 2011-2020 had average precipitation of 177.919mm, showing a downward trend in precipitation in the study area. This change was attributed to development, increase in land surface temperature and LULC change in the study area.

4. CONCLUSION AND RECOMMENDATIONS

This section should be shorter and clearer and be able to answer the purpose of this research.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Equally publication ethics such as issues of misconduct, fabrication and falsification of data, duplication of publication and, or submission, have been duly considered by the authors.

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