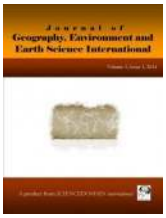

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Spatial Assessment of Temperature and Land Cover Change as Climate Change Monitoring Strategies in Owerri, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author KOEU designed the study and performed the remote sensing and geo statistic analysis. Authors MCI and GTA wrote the protocol and wrote the first draft of the manuscript. Author CCU reviewed and discussed further the implications of the result on the environment. Author IEO managed and reported various implications to the global climate and environmental sustainability. All authors read and approved the final manuscript

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ABSTRACT

Climate change is one of the alarming global environmental changes likely to have deleterious effects on natural, social, cultural and human systems. The risks associated with it call for a broad spectrum of policy responses and strategies at local, regional, national and global levels. This study seeks to explore the nexus between geospatial techniques in assessing climate change and sustainable development, discussing evidenced effects of climate change with considerations into sustainable development efforts in Owerri, Nigeria. This study uses Landsat 5, Landsat 7 and Landsat 8 satellite data of 1986, 2000 and 2016 respectively to evaluate land cover and temperature variation as climatic change in the study area over three decades. The results from the adopted geospatial analysis revealed that climate change resulted from development activities in

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urban cities, and is evidently affecting every sector of human activities and limiting life expectancy, thus working against sustainable development. This confirms that changes in impervious surfaces significantly produce corresponding effect in increasing urban heat in the city. This study recommended that adequate land use planning be enforced by adopting green city planning techniques.

Keywords: Climate change; sustainable development; land cover; urban vulnerability; urban heat island.

1. INTRODUCTION

In the past few decades, there has been global climatic and weather changes. These changes are alarming when focusing on important climatic factors such as temperature, rainfall, humidity etc., which have shown notable variability in many regions. Climate change is one of the global cases affecting environmental sustainability due to its deleterious effects on ecosystem [1]. The Inter-Governmental Panel on Climate Change (IPCC) [2] reports that global average temperature has increased by at least 0.6^{o}C in the past few decades. Some scientists have also argued that the global average temperature has increased by 0.3℃ – 0.7℃ over the last century and have also estimated an increase of about 1.4℃ – 5.8℃ by the end of the 21^{st} century. Other climatic variables have also shown significant variations. Some researchers [3,4] have verified if there is any variation in rainfall and other climatic features in Nigeria. They observed that climatic changes affect precipitation and are of the opinion that as weather and climate continue to fluctuate, rainfall will continue to fluctuate and this variability has been recorded globally and regionally within the tropics, the sub-Saharan Africa, and Nigeria. These changes in weather and climatic variables in sub-Saharan West Africa have been researched by [5-7].

1.1 Statement of Problem

Climate change has resulted in alterations of most anthropogenic and natural activities. Climate change and its effects lead to destruction of major ecological zones and the wildlife they support. According to [8] In many parts of Nigeria, tropical forests and rangelands are already under threat from population pressure and land use systems. This can affect the planning techniques adopted for developmental strategies in the region [2]. Also, as a consequence of climate change, some areas will receive heavy and more steady rainfall, and such areas will experience increased rainfall-induced erosion. Conversely, in the arid northern Nigeria, higher temperatures contribute to dry conditions which underlie accelerated wind erosion. These are very serious situations given that soil erosion is a catastrophic phenomenon in Nigeria [9,10]. Sea level is also accelerating, resulting from climate change. This involves overflow of ocean water body which adversely affect residential and industrial layouts, surface and underground water resources, cropland, transportation, land–based recreational activities on the shores of the ocean or and numerous other land use activities which has noted impacts on the environment and its sustainability [11]. Global warming leads to increased frequency of drought in the Northern Nigeria [12]. In addition to temperature increase and heightened human activities, drought will lead to desertification. Thus, this study examines the rate of change of climate parameters, specifically the Land Surface Temperature (LST) of Owerri in relation to development of infrastructure of paved surfaces in the city, with a view to recommending climate change mitigation techniques as part of sustainable urban development strategy [13].

1.2 Aim and Objectives

The aim of the research is to assess the changing climatic features inherent in the city and recommend a climate change mitigation technique thus, developing sustainable urban development strategy.

The aim was achieved through the following objectives;

a) To process and analyze the satellite imageries to detect the changes in land use land cover over four decades in Owerri.
b) To analyze the climatological data acquired to assess changes in climatic features.
c) To adopt a corresponding geospatial analysis and evaluate changes in the land surface temperature of the city.

d) To integrate the results using geostatistic techniques to produce the results in maps to enable visual interpretation.
e) To make recommendations for the town planning authorities in the city for strategic plans towards sustainable urban development.

The research is envisaged to contribute to and promote the city's resilience to climate-related vulnerabilities and the sustainability in the development [14]. The research will be used to advance and disseminate knowledge and inform decision-makers and the general public about the climate change risks, increasing capacities to respond to climatic stress, to implement necessary adaptation measures and to strengthen the sustainable responsive capacity of the urban system [15].

1.3 The Study Area

Owerri is located between Latitudes 5°31'N and 5°20' N and Longitudes 6°54'E and 7°16'E. Owerri is made up of three Local Government Areas including Owerri Municipal, Owerri North and Owerri West. The city is bounded by Mbaitolu in the north, by a part of Ikeduru on the northeast, by Aboh Mbaise on the east and in the south by Ngor-Okpala, and by Ohaji/Egbema in the West. Rivers Otamiri and Nworie bisect the area, creating major drainage landmarks (Fig. 1).

The climate and vegetation of Owerri are as found in the southern part of Nigeria [16]. The study area is underlain by the Coastal Plain sands of the Benin Formation which is Late Tertiary in age. It is rather deep, porous, infertile and highly leached. In some parts, the soil consists of lateritic material under a superficial layer of fine grained sand. The soil would naturally be fertile but excessive leaching has removed much of the required plant nutrients.

According to the 2006 Nigeria National Census, the study area has an estimated population of 401,873 inhabitants, with 211,298 males, and 190,575 females comprising about 32,000 households [17]. The inhabitants are majorly

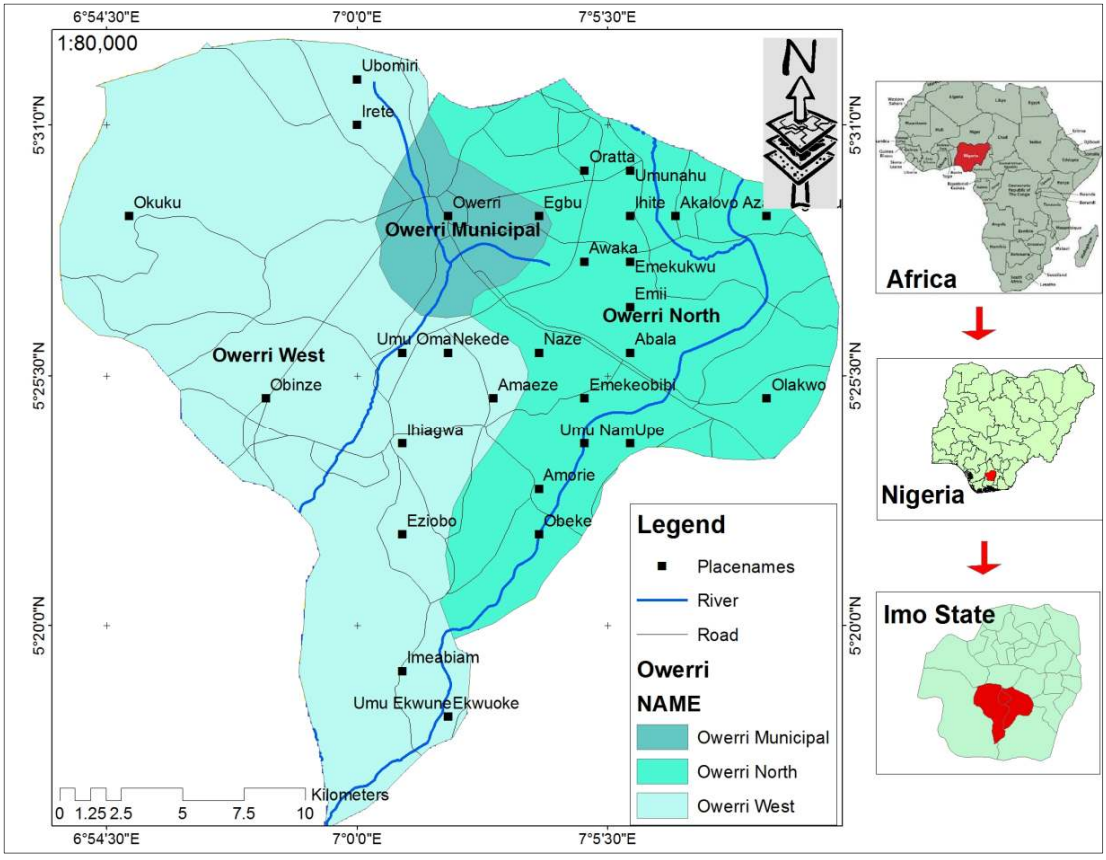

Fig. 1. Map of the study area

traders, few artisans, civil servants and famers. The city has few commercial centers. The agricultural is likely to retain its relative dominance in some communities of the study area [16].

2. METHODOLOGY

This study explored the nexus between geospatial techniques in assessing factors driving climate change for sustainable development in the study area. This study used Landsat 5, Landsat 7 and Landsat 8 satellite data of 1986, 2000 and 2016 respectively to evaluate land cover and temperature variations as climatic change sprawl in developing city for over three decades. Remote sensing data for the temporal period under investigation (i.e. 1986 and 2016) were acquired from USGS Earth Explorer website. 30 meters Landsat low resolution imageries was used to detect changes in land use/land cover. Images were pre-processed for geometrical correction and noise removal before being subjected to supervised classification, using Maximum Likelihood Classifier in ERDAS IMAGINE. The satellite image was further analyzed to investigate the changes in land surface temperature in the city. For the estimation of land surface temperature, band 6 from 1986 and 2000 Landsat data and band 10 and 11 from 2016 Landsat data were used as thermal bands to estimate the land surface temperature of the study area using ArcMap. Thus, converting the Digital Number (DN) to radiance using Spectral Radiance Scaling Method (SRSM): The LMin and LMax spectral radiance scaling factors were used to convert DNs to radiance.

The formula used in this process is as follows: (1b)

$$CV_{R1} = \left(\left(LMAX_{\lambda} - LMIN_{\lambda}\right)/\left(QCALMAX - QCALMIN\right)\right)*\left(QCAL - QCALMIN\right) + LMIN_{\lambda}$$

Where:

CV_{R1} is the cell value as radiance
QCAL = digital number
$LMIN_{\lambda}$ = spectral radiance scales to QCALMIN
$LMAX_{\lambda}$ = spectral radiance scales to QCALMAX
QCALMIN = the minimum quantized calibrated pixel value (typically = 1)
QCALMAX = the maximum quantized calibrated pixel value (typically = 255)

Then convert Radiance to Kelvin: After the DNs for the thermal bands was converted to radiance values, the study applied the inverse of the Planck function to derive temperature values. The formula to convert radiance to temperature is:

$$T = \frac{K_2}{\ln\left(\frac{K_1 * \varepsilon}{CV_{R1}} + 1\right)}$$

Where: T is degrees Kelvin

CV_{R1} is cell value as radiance (from Section 1), e is emissivity (typically 0.95—you use this value), also Landsat ETM; K1 = 666.09 and K2 = 1282.71 while Landsat TM; K1 =607.76 and K2 = 1260.56

2.1 Tools of Data Analysis and Data Processing

The analysis was carried out using ArcGIS 10.0 as one of the tools of data analysis, ArcMap and Arc Catalogue. These were used for the digital images analysis and extracting of the various features from the imageries to generate the map of Owerri. Arc Catalogue was used create a personal geo-database and shapefiles. The map of the study location was also obtained. The GPS coordinates of Area were obtained during field work using hand held Etrex Garmin Version 16.0 GPS, and imported into the Arc Map.

ERDAS Imagine was used to import the imageries and, to carry out color composites and for all necessary digital image processing. Erdas Imagine was used to classify the imageries using the Maximum Likelihood Classifier to generate the land use/ cover map of study area. The different classified land cover features were extracted on ArcMap. The impervious surface covering of the study area was estimated using the land use and cover classified map and for the spatial, spectral and radiometric enhancement of the imageries. Spatial enhancement was carried out using a resolution merge model.

2.2 GIS Approach

This study demonstrated the use of remotely sensed imagery and the integrated approach of remote sensing and GIS techniques in climate change variable analysis. Middle resolution imagery was required for a depiction of the extent of the impervious surface and the trend of the increase. The map of the study location was digitized from the LGA vector data archive of National Space Research and Development Agency. This data was then imported into ARCGIS as X, Y and Z data. Interpolation process was carried out, using the spatial analyst tool to create a digital terrain model.

3. DISCUSSION AND PRESENTATION OF RESULTS

Results of the LULC and temperature variations in City paved surfaces of Owerri and environs is revealed in this section. These results show the LULC variation of the City and increase in paved surfaces over 30 years.

The derived maps in Fig. 2 and 3 displayed the spatial and statistical variations of the classified land use and cover of 1986, 2000 and 2016 and the temperature variation. The result showed paved surface rising from 1986 values of 31,625.9 Ha to 47,979.1Ha in 2000 and further to 55297.3 Ha in 2016, implying approximately 31.1% in 1986, 47.2% in 2000 and 54.4% in 2016. There was a linear change in paved surface from 1986 – 2000 from 31.1% to 54.4%. This implies that land use land cover change was highly significant that forest and farm vegetation was converted to paved surface in the city between the periods. However, if this conversion was in line with green city plan it would not be this significant The trend of average percentage changes from 1986 to 2016 revealed an increase of 31.1%, 47.2%, and 54.4%. % for 1986, 2000 and 2013, respectively see Fig. 4.

Global warming produces increase in global temperature which impacts directly on human life and the natural environment. Increasing City temperature is having serious effects and consequences on the study area, evidently there is rising sea levels (Table 1, Figs 5 and 6), changes in urban temperature which have high fluctuation, change in the amount and pattern of precipitation, and more severe weather like warmer evening and increased heat waves. These were global manifestation of the changing climate in this region.

Table 1. LULC Distribution and coverage of the City from in 1986 – 2016

Owerri LULC	1986		2000		2016	
Land Cover	**Area (Ha)**	**Area (%)**	**Area (Ha)**	**Area (%)**	**Area (Ha)**	**Area (%)**
Bare Surface	290.4	0.3	144.0	0.1	486.7	0.5
Farm Vegetation	20427.8	20.1	21577.0	21.2	11956.5	11.8
Forest	48907.3	48.1	31470.7	31.0	33482.0	33.0
Paved Surface	31625.9	31.1	47979.1	47.2	55297.3	54.4
Water Body	370.6	0.4	453.4	0.4	390.4	0.4
Total	101622.0	100.0	101624.1	100.0	101612.9	100.0

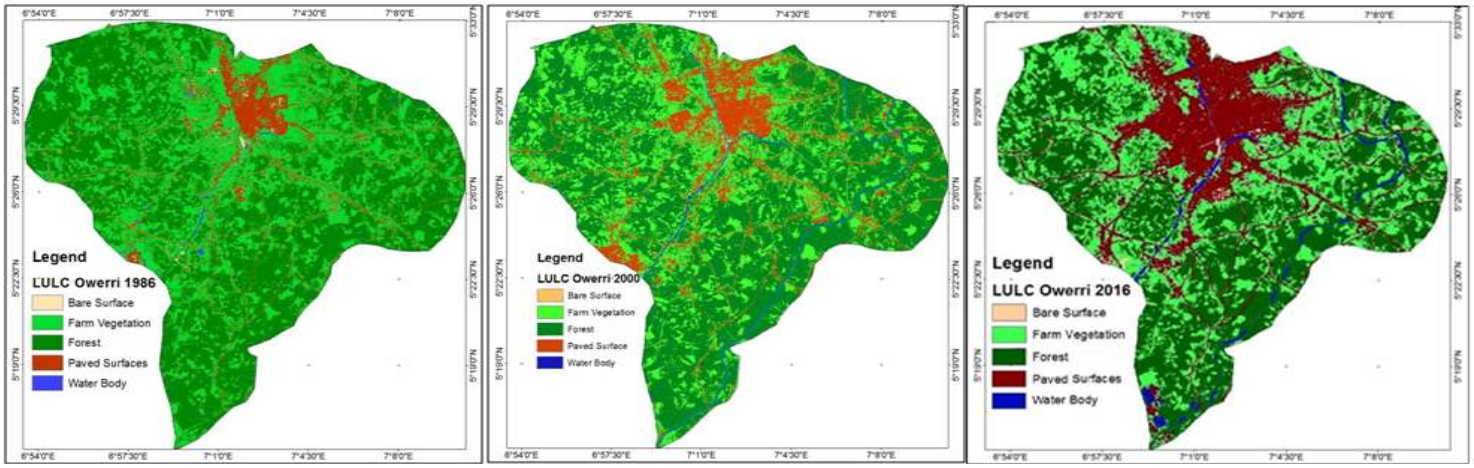

Fig. 2. Land Use Land Cover variation of the City from 1986 – 2016

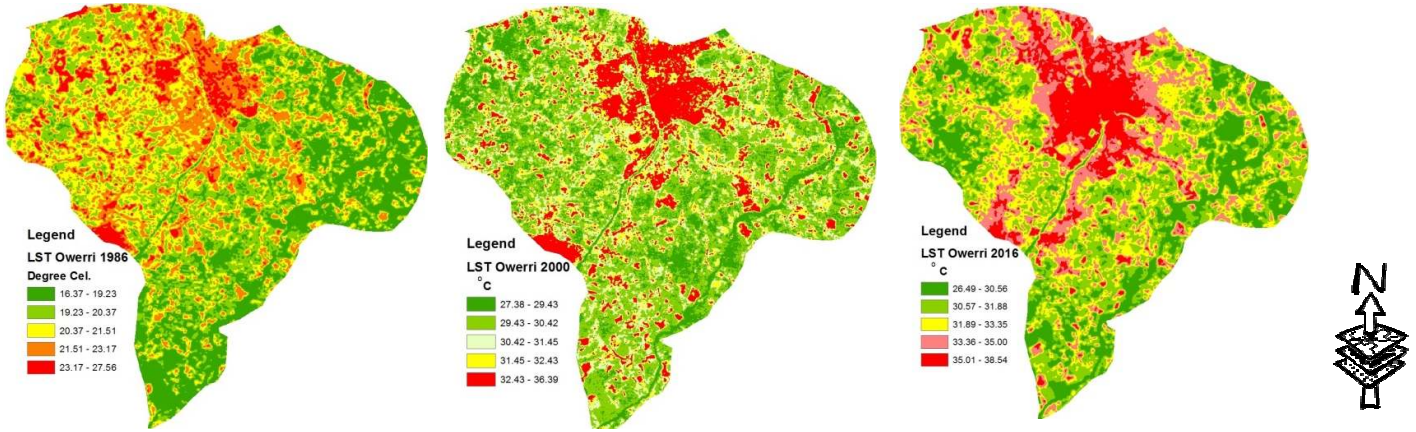

Fig. 3. Land surface temperature of the City from 1986 – 2016

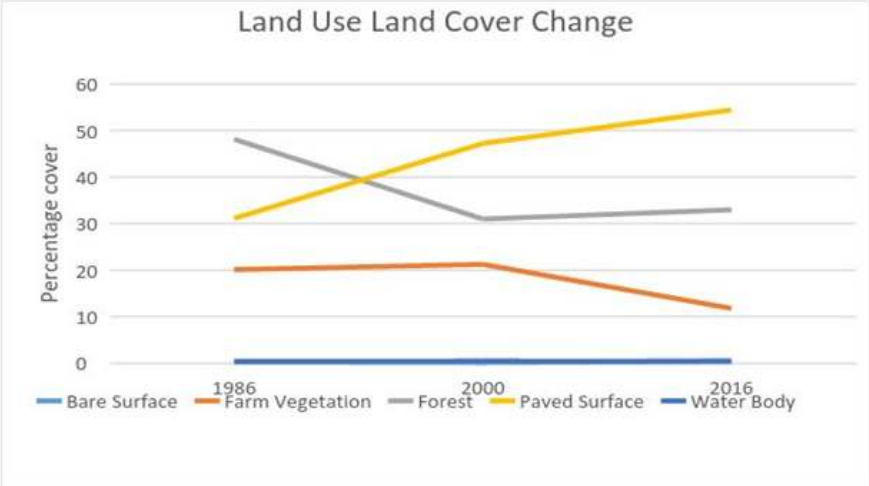

Fig. 4. LULC variation over the study year

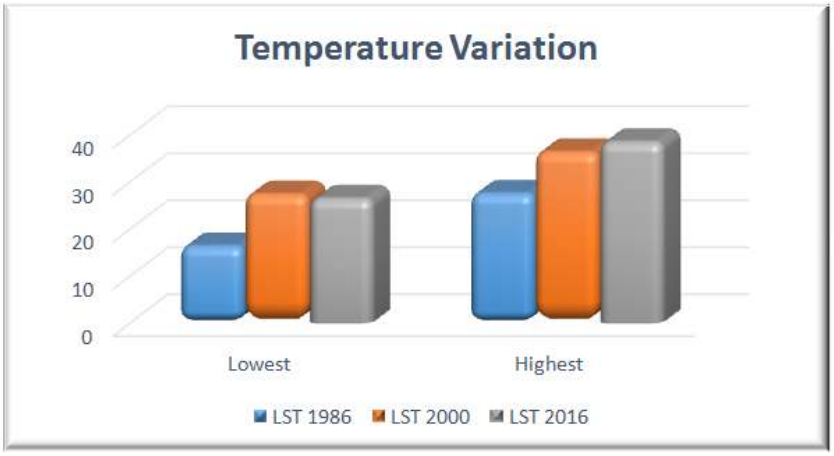

Fig. 5. Temperature variation over the study year

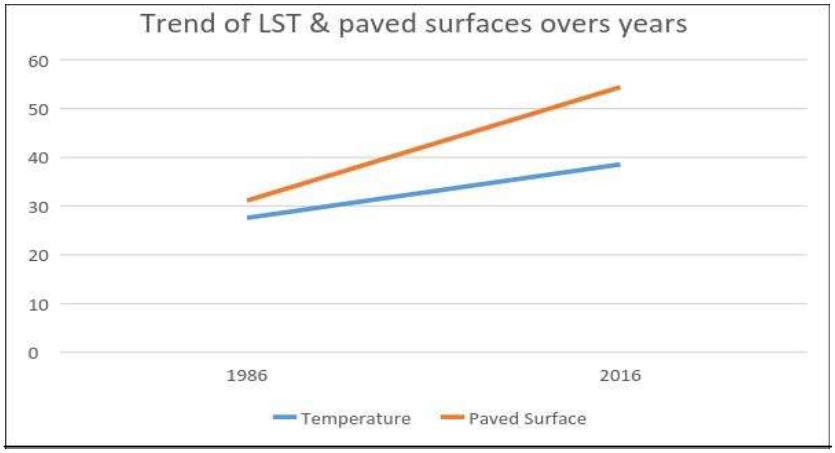

Fig. 6. Trend between the land surface temperature and paved surfaces in the city

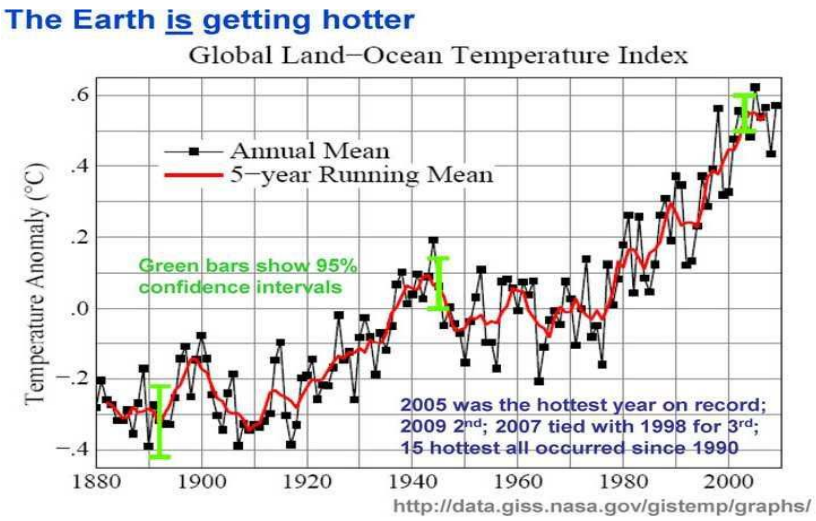

Fig. 7. Indicators of Global Warming
[Source: 18]

According to NASA in Fig. 7, Global warming as a result of increasing temperature has caused rise in sea level due to the fast melting of polar ice. The average temperature of the area is increasing simultaneous with the paved surfaces. [18] had submitted in his scientific studies that global warming is real and that human activities are causing the warming trend. Global temperatures have steadily risen over the last century.

4. CONCLUSION AND RECOMMENDA-TIONS

This study has not only shown the increasing trend in surface temperature but also revealed its significant relationship with increasing paved surfaces in the city. According to scientists, 2005 was the warmest year on record, and the warming trend is expected to continue through the 21st century and beyond. This study has estimated that average temperature of the City's paved surface fluctuated within the ranges of ±10.55℃ during the 30 years of Land surface temperature investigation ending in 2016.

The challenge facing the study area was planning as indicated in the statement of problem. This study reveals the need to make our cities greener without making them less dense. Green roofs and walls are important components in a greener city. All surfaces that do not have to be hard for a specific reason can be made green and converted into so-called green space areas. Large trees can be planted along streets, in schoolyards and in gardens and parks. It was thus, recommended in future development plan, the green plans be used in connection with urban transformations. According to [19] Grounds, courtyards, green plots and public parks could potentially become multi-functional green spaces for storm water management, enhanced biodiversity and recreation. If the implementation of green city is applied in the Owerri city planning, the trend of the land surface temperature will be reduced, and the plight over global warming will be reduced. Hence, this study recommends greening the entire city of Owerri especially the more area covered by paved areas.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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