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Geospatial Assessment Of Urban Heat Island In Warri, Delta State, Nigeria

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ABSTRACT
The detrimental effects associated with anthropogenic air pollution have raised concerns globally. Thus, the geospatial assessment of urban heat in Warri was examined. The data used for this study were generated from Thermal Remote Sensing satellite sensors. For the purpose of this research, the Landsat satellite data of 2018, 2020 and 2022 in the study area were obtained as base data for analysis. A spectrometer that measures the reflection of sunlight by the Earth's atmosphere known as Sentinel-5P equipped with the TROPOMI instrument was used to detect and quantify various atmospheric gases. Google Earth Engine was used to extract Carbon dioxide, Methane, Nitrogen dioxide and Sulphur dioxide. The results obtained from the study showed that the concentration value of 4403.34ppm for CO_2 was fair as the mean concentration value was within 2,000-5,000ppm. The CH_4 value for Warri was 90.46ppm which is far below the threshold value of 1000ppm with no health implication. However, NO_2 concentration value within the study area was582.01ppm. This is far above the unhealthiest range of 201 to 300 as revealed by the air quality index thereby making resident exposed to varying concentration values of NO_2 that could exhibit human health challenges. With the mean SO_2 being 201.82ppb, the ambient air quality for SO_2 in Warri was considered poor. The study therefore recommends the planting of vegetation around buildings (green design), making modifications in the design and orientation of buildings amongst others.
Keywords: urban heat, anthropogenic air pollution, satellite sensors

1. INTRODUCTION

Urbanization is an extreme example of human land use modification which, does not only radically alter the physical properties of the earth's surface but also affect the thermal, radiative and aerodynamic character of the surface (Oke, 1987). United Nations [UN], (2010) reported that more than half of the world's population resides in the urban areas. Since such a high proportion of the World's population reside in urban areas, it is important to understand the processes determining urban climates and how both past and future urbanization patterns might affect climate at the local and regional scale.

In both industrialized and developing countries, urbanization trend constitutes new millennium challenges amongst which is thermal heat stress resulting from climate change. During the hot season, the Niger-delta's hot humid tropical environment is characterized with high intensity of solar radiation and low wind

velocity. Urban heat island effect and plant destruction amongst other environmental damages has no doubt resulted from the rapid development activities taking place within the past decades. City dwellers are experiencing continuous problems of heat stress due to the recent climate change phenomenon, thus the problem of thermal comfort in urban quarters needs to be addressed. Vegetation is an essential element of urban space planning, though benefits derived from its application include amelioration of urban microclimate through sunlight interception, shading, and control of wind velocity, as well as air purification by absorption and control of noise pollution (Yu and Hien, 2006). Thermal comfort within acceptable standards for urban dwellers living in the city could be aimed at by reducing solar heat and increasing and controlling wind direction as part of planning strategies.

According to Owen, (2009), people living in cities consume less energy compared to people living in suburbs, thus reducing the negative effects of environmental issues for human health and quality of life to pursue sustainable development is mandatory. Perini and Magliocco (2014) stated that vegetation increases the oxygen and moisture in the air, absorbs sun's radiation, gives shade, cools the surrounding environment and generally improves the microclimate of a given area. According to Thornson *et al.,* (2004), thermal conditions are influenced by buildings, surface conditions, open space obstacles and tree canopies causing climate from very hot to cool in the hot season. Therefore, considering the psychological issues and thermal variations, microclimate guidelines should be studied. This will in turn help to develop planning strategies in order to ensure outdoor human comfort in future urban design. Chandler (2001) categorized climate into various levels, which include macroclimate and microclimate. Macroclimate climate is obtained by using data from a number of standardized sites over a large area such as country, continent, and oceans. On the other hand, microclimate includes large areas with fairly uniform conditions which are influenced by air masses moving over earth surface within parameters that characterize a localized area with a geographic scale between 1sqm -100sqm. Surface temperature, relative humidity, wind speed, solar radiation and precipitation are considered as the main factors that modify microclimate.

The urban surfaces (e.g. concretes, pavements and roads) absorb heat and increase the temperature comparatively to the surrounding rural areas. An elevated urban temperature, known as urban heat island reduces human comfort, increases energy consumption in buildings and consequently leads to global warming. Temperatures for large cities like Lagos metropolis have been observed to be significantly increasing for the past three decades. In recent times, research has also showed the effectiveness of urban heat island in changing the urban microclimate which could result to changes of intensity and frequency of rainfall as observed by Noorazuan (2007). One of the most obvious examples of human modification of the earth's surface is urban area**.** Although, Lamptey et al. (2005) and Shepherd (2005) asserted that urban areas cover only 1.2 percent of the earth's surface, it was estimated that in 2003 about 48 percent of the world's population resided in urban settlements and by 2030 it is expected that 61 percent of the world's population will be living in urban areas (UN, 2004).

Basically, there are two main ways to evaluate the UHI phenomenon: conventional weather station automatic temperature measurements (Tzavali et al., 2015) or the Land Surface Temperature (LST) measurements given by Thermal InfraRed (TIR) remote sensing data (Weng, 2002; Voogt, 2003; Mushore et al., 2017; Jiménez-Muñoz et al., 2014; Cristobal et al., 2018). Many authors have investigated the relation between satellite measured LST and other variables such as vegetation cover, land surface albedo, the urban spatial structure and its reflective patterns (Roth et al., 1993; Gallo et al., 1993; Bonafoni et al., 2017; Lo et al., 1997; Chen et al., 2006; Grover et al., 2015 and the review article: Voogt et al., 2003). Also wind speed affected by the urban texture (Yang et al., 2016), and the presence of water bodies have the ability to affect land temperatures (Moyer et al., 2017). Howard in 1810 studied the phenomenon of Urban Heat Island in an area of land that experiences consistent surges in surface temperature more than adjoining areas (Surawar and Kotharkar, 2017). Trends in global migration indicate a predisposition for urban areas because in an absolute short time as of 2018, the urban-based global population had surpassed 50% and it is expected to be at peak at 68 percent by 2050 (UN, 2018).. The impact of UHI is felt across every sphere of human endeavour especially in urban design and planning, health, comfort, energy management and air pollution amongst others in urban areas. The occurrence of UHI raises peak energy demand and energy consumption by obviously increasing energy demand for cooling systems which

indicates a 0.6^0C increase in the ambient air temperatures, electricity requirement for cooling increases by 1.5-2.0 percent at temperatures higher than 20^0C implying that 5.0-10.0 percent of the municipal demand for electricity goes into UHI compensation (Akbari and Konopacki, 2005). Other feasible impacts of UHI observed by Rinkesh (2019) include a sudden increase in air pollutants and greenhouse gases emissions, thermal pollution in the aquatic systems, discomfort, health risks, and local climate alterations such as wind and rainfall patterns, humidity, fog formation and impaired water quality.

The sudden rise in the form of UHI and its attendant challenges as affirmed by Phelan, et al., (2015) include air pollution, heat wave, greenhouse effect and increased energy consumption has been a source of concern to researchers recently. High concentrations of gases and particulates such as CO_2, CH_4 and hydrocarbons pollute the atmosphere, posing risks to both the environment and human health (Ediagbonya et al., 2015). Hence, effective control measures are crucial to address air pollution, which has become a significant environmental concern in the modern era. Vehicle emissions, generator fumes, and building site are stated as the significant sources of urban air pollution in Nigeria (Mopa et al., 2020). Recent studies on ambient air pollutants in Nigeria found higher concentrations of the frequent air pollutants in Lagos State, Ibadan, Kano, Kaduna, Port Harcourt, and the Niger Delta region (Abulude et al., 2021; Daful et al., 2020; Obisesan and Weli, 2019). In addition, such cities also constitute significantly higher PM levels than the World Health Organization's (WHO) hourly average standards (Abulude et al., 2021). It is difficult to assess the continuous spatiotemporal profile of air pollutants since most urban areas throughout the world lack comprehensive air quality monitoring networks (Rudke et al., 2023). In addition, the utilization of remote sensing to analyze the air quality of many developing African nations is a necessity where in-situ ground monitoring stations are limited (David-Okoro et al., 2020; Marais et al., 2014). While in-situ monitoring stations are commonly used to collect data on surface air pollution concentrations, this data is typically point-based rather than spatially continuous. It is observed that most pollutants are found in metropolitan environments and thus might be challenging to detect their geographic features using in-situ measurement techniques (Filonchyk et al., 2020; Zhang et al., 2018). As an alternative, satellite imagery offers the benefit of delivering geographically consistent information over extensive areas (Fernandes et al., 2019). It could play a crucial role in evaluating atmospheric trace gases (Lim et al., 2009). Anejionu et al. (2015) and Marais et al. (2014) also have utilized satellite data to detect air pollution in Nigerian cities. However, the environment in Nigeria is degrading and there are inadequate monitoring stations, and environmental legislation is less acknowledged (Adeniran et al., 2019). Therefore, the geospatial assessment of urban heat in the study area.is paramount.

Aim and Objectives of Study

This study is aimed at evaluating the geospatial assessment of urban heat in Warri with the following objectives:

i. To determine the extent of urbanization from 1992-2022 of Warri in Delta State.
ii. To evaluate the microclimatic elements in the study area.
iii. To determine the impacts of the evaluated microclimatic elements on the environment.

Hypotheses

i. There is no relationship between impact of urbanization on microclimatic elements and the environment.
ii. There is no relationship between microclimatic elements and human health.

Study Area

Delta state covers a landmass of about 18,050 km^2 (6,970m^2), of which more than 60% is land. The state lies approximately between 5°00' and 6°45' E and 5°00' and 6°30' (Ebewore, 2020). It is geographically located in Nigeria's Midwest, bounded in the north and west by Edo state, the east by Anambra, Imo, and Rivers states, southeast by Bayelsa state (Encyclopedia Britannica, 2021) and on the southern extreme is the Bight of Benin, which covers about 160km of the state's coastline. There are various seasons in Nigeria and it meteorological parameters vary from one location to another (Abaje and Oladipo, 2019). The issue of seasonal variation in Nigeria cannot be over -stretched. Delta state is generally low-lying without any remarkable hills. The state has a wide coastal belt inter-laced with rivulets and streams, which form part of the Niger Delta (Alabi, 2017). The 2006 National Population and Housing Census put the population of

Delta state and Warri with a population of 4,112,445 and 149,603 people respectively (NPC, 2006). The climatic condition of experiences moderate rainfall and moderate humidity for most part of the year. The climate is equatorial and is marked by two distinct seasons: the dry season and the rainy season. The dry season lasts from about November to April and is significantly marked by the cool "harmattan" dusty haze from the north-east winds. The rainy season spans May to October with a brief dry spell in August, but it frequently rains even in the dry season. The area is characterized by tropical equatorial climate with mean annual temperature of 32.8°C and annual rainfall amount of 2673.8mm. There are high temperatures of 20°C and 29.6°C. The natural vegetation is of rainforest with swamp forest in some areas. The forest is rich in timber trees, palm trees, as well as fruit trees.

Warri being formally the divisional headquarter for Shell Petroleum Development Co-operations (SPDC), is also a swamp location for exploration and production of oil for SPDC. Other oil companies as well as oil servicing companies are also situated in the town. Major industries in the area are oil mining, oil servicing, petro-chemicals and sculptural and bronze making establishments. Others include commerce, tourism, etc.

2. METHODOLOGY

2.1 Data Types and Sources

The type of data used in the course of this study included:

2.1.1 Administrative map sourced for from office of surveyor general of Delta State.

2.1.2 Microclimate Satellite Remote Sensing based sensors:

i. Satellite images: Thermal Remote Sensing satellite sensors are designed to offer surface temperature and emissivity information from land and sea surface from several spacecraft sensors, including Moderate Resolution Imaging Spectroradiometer (MODIS), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), and Advanced Very High Resolution Radiometer (AVHRR), in addition to raw Landsat thermal data. For the purpose of this research Landsat collection was sourced for and used. Landsat has the longest history of Earth Observation among the available Earth Observing Satellites, it started operations July 23, 1972 and expired, January 6, 1978, but the project has continued to improve itself with several follow-ups to Landsat 9 and afterwards is Landsat Next due in the year 2030, while Landsat 6 missed orbits. The epochs of interest were 2003, 2013 and 2023. Landsat Imagery; Landsat ETM+ for 2003 (USGS, 2023), Landsat ETM+ for 2013, and Landsat OLI for 2023 with Path 189 and Row 56 is determined by converting the Latitude and longitude from the USGS website (https://landsat.usgs.gov/wrs-2-pathrow-latitudelongitude-converter) of the study area based on Worldwide Reference System 2, or using KML/KMZ or shapefile (https://www.usgs.gov/media/files/landsat-wrs-2-scene-boundaries-kml-file), which can be loaded into Google Earth or any software that support shapefile respectively from necessary and available repositories.

Image analysis: The Landsat satellite data of 2018, 2020 and 2022 (a period of 2years interval) of the study area (Warri) was obtained as base data for analysis. The choice of these years was based on availability, consistency and reliability of data. The images were classified using supervised classification techniques. After the initial image processing and rectification, the images were enhanced in order to enable visual interpretation and better comprehend the tonal presentations, the nature, types and characteristics of the land use discernable from the images. Land use classification scheme was developed by careful modification of the Handerson classification scheme with particular reference to the peculiar characteristics of the study area. The refined land- use classification scheme was used as the input in the selection of the training sites that were used in the supervised classification using Erdas Imagery. With the aid of head on digitizer the classified image will be vectorised and the map for each year period will then be captured.

ii) Microclimatic element (Temperature) maps from 2003-2023 (a period of 20 years) of Warri was obtained. For air pollution or air quality monitoring over the study area, Sentinel–5P was considered for this research although it has less history of data collection in reference to other EOS, but with great resources in the recent times with better capability and capacity onboard the platform to determine aerosol, air quality/pollution parameters. Sentinel-5P (also known as Sentinel-5 Precursor) is a European Space Agency (ESA) Earth observation satellite launched in 2017. Its main mission is to monitor air pollution

and track the transport of pollutants in the atmosphere. Sentinel-5P is equipped with the TROPOMI (TROPOspheric Monitoring Instrument) instrument, which is a spectrometer that measures the reflection of sunlight by the Earth's atmosphere. This allows it to detect and quantify various atmospheric gases, such as: Nitrogen dioxide (NO_2), Ozone (O_3), Carbon monoxide (CO), Methane (CH_4), and Sulfur dioxide (SO_2). The data collected by Sentinel-5P is used for various applications, including air quality monitoring, climate modeling, weather forecasting, emission inventory creation and research and development of new atmospheric models. Sentinel-5P is a precursor to the Sentinel-5 mission, which is part of the European Space Agency (ESA's) Copernicus program. The Copernicus program aims to provide accurate and timely data and information services for Earth observation, climate change, and environmental monitoring.

2.1.3 Hardware and Software required for the research included;

1. Computer System and related accessories like mouse, printers
2. Internet
3. Microsoft excel for processing of field coordinates.
4. ARCGIS 10.8.2 software for digitizing the administrative map and image digital number conversion to temperature using Landsat ETM + band 4 and 5, Landsat 7 and 8, OLI band 10 and 11.
5. Google Earth Engine to extract Carbon dioxide, Sulphur dioxide, Methane and Nitrogen dioxide (see Appendix 1for the code)
6. Microsoft word for presentation of report
7. GPS for field coordinates.

2.2 Method of Data Analysis

Data obtained was analyzed using inferential statistical techniques. The inferential statistics, which included correlation analysis was used to examine the relationship between the impact of urbanization on environmental microclimatic elements and also if there is any relationship between microclimatic elements and human health in the study area.

2.2.1 Calculation of Urban Heat Island (UHI)

In other to generate the temperature for the study area, the impact of urban growth on surface temperature was examined. The essence of this was to reveal the microclimate changes over the reference period in the surface temperature from the study area as the built-up area keep on expanding. Then, the impact of the urban growth on surface temperature was assessed graphically and numerically. This is to confirm that the urban growth was the major factor that create the concept of urban heat island. In order to achieve this, the sequence of data processing is highlighted below:

Step 1: Conversion to Top of Atmospheric Radiance (ToAR)

$L_l = M_L Q_{CAL} + A_L$

where:

*L_l = ToAR spectral radiance (watts/(m2*srad*mm))*

M_L = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)

Q_{CAL} = Quantized and calibration standard product pixel values (DN)

A_L = Band-specific additive rescalling factor from the metadata

Step 2: Conversion to Top of Atmosphere Brightness Temperature

$$TB = \frac{ks}{\left(\frac{k1}{L\lambda} + 1\right)} - 273.15$$

T = Top of atmosphere brightness temperature (K)

*L_l = TOA spectral radiance (watts/(m2*srad*mm))*

K1 = Band-specfic thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where z is the thermal band number)

K2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the thermal band number)

Step 3: Calculating Emissivity

e = emissivity

e = 0.004*Pv+0.986

$Pv = ((NDVI-NDVI_{min})/(NDVI_{max}-NDVI_{min}))^2$

Step 4: conversion from At-Satellite Temperature to Land Surface Temperature

T = TB/ (1+(*l**TB/c2) *ln(e))

l = wavelength of emitted radiance (center wavelength of thermal band)

*c2 = h*c/s = 1.4388*10-2 mK = 14388 mK*

*h = Planck's constant = 6.626*10-34 Js*

*s = Boltzman constant = 1.38*1023J/K*

*c = velocity of light = 2.998*102m /s*

3. RESULTS AND DISCUSSION

3.1 Determination Of Urban Status For Warri Between 1992 And 2022

The built up area growth within this region seems small based on economic activities from 7.88 km^2 in 1992 to 9.75 km^2 in 2022 (Table 3.1 and Figure 3.1), the compactness of development was observed and the water body/river around this settlement at the southern and eastern part hindered the growth.

Table 3.1: Built up Area Between 1992 and 2022 in the Study Area

Settlement	1992		2022	
	Area (km^2)	Area (Hec)	Area (km^2)	Area (Hec)
Warri	7.88	787.83	9.75	974.64

Source: Author's Lab analysis

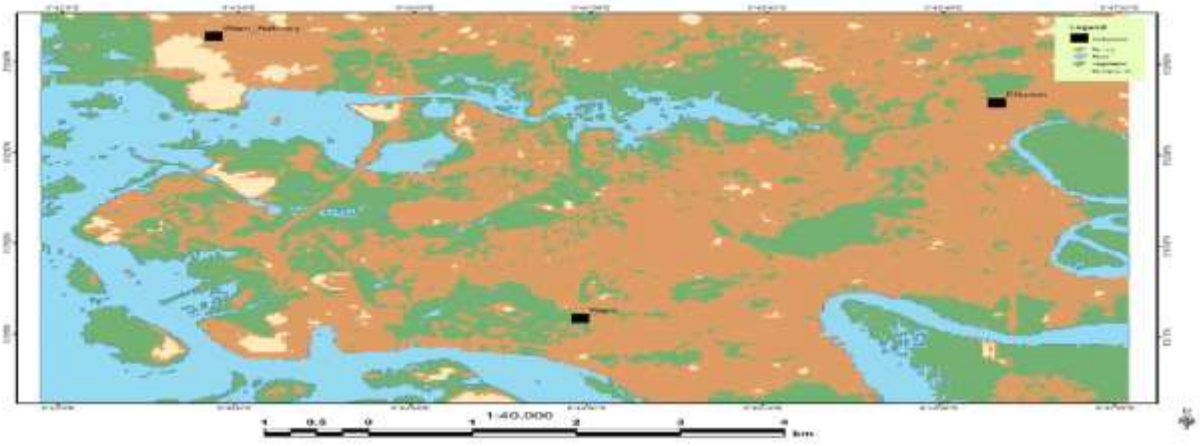

Fig 3.1: Urban Status of Warri in 1992

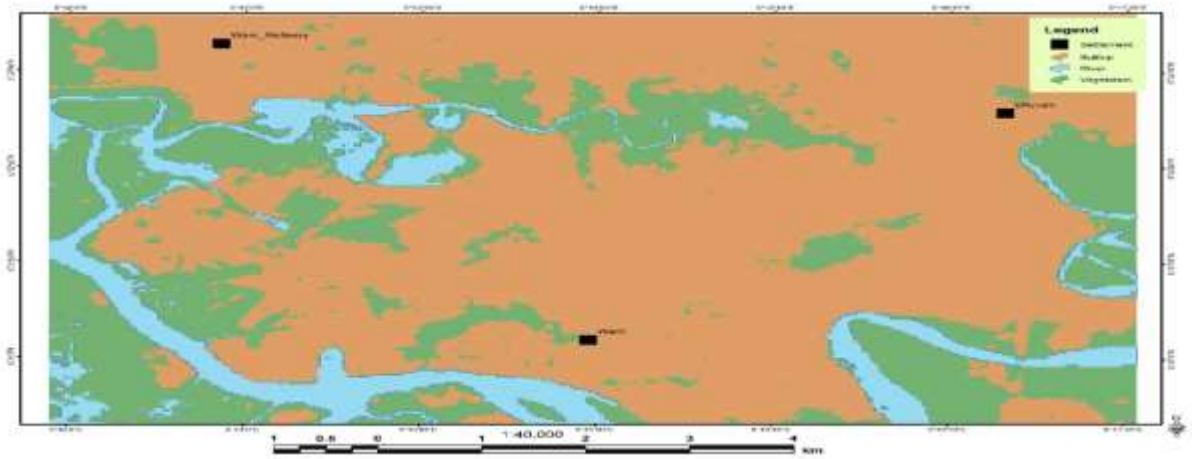

Fig. 3.2: Urban Status of Warri in 2022

3.2 Spatio-Temporal Analyses Of The Microclimatic Elements In The Study Area

The value of CO_2 in Warri was 4789.58ppm in 2018 (Table 3.2 and Figure 3.3). This value decreased to 4422.32ppm in 202 0(Table 3.2 and Figure 3.4) and further reduced to 3998.41ppm in 2022 (Table 3.2 and Figure 3.5). The rate of reduction was 367.29ppm and 423.91ppm from 2018 to 2020 and from 2020 to 2022 respectively. The reduction in the concentration of CO_2 might be due to the vegetation covers that flank the banks of rivers and stream that are common in Warri and its connobated towns like Agbarho, Usubi, Ugbomro and Ogbolokposo that could influence the CO_2 concentration. With a mean concentration of CO_2 of 4403.34ppm (Table 3.2) recorded in Warri, the ambient air quality could be said to be fair (Table 3.3), with the consequences of headaches, fatigue, stagnant, stuffiness, poor concentration, loss of focus, increased heart rate, nausea on the inhabitants.

Table 3.2: Mean concentration of Carbon dioxide in the Study Area

Settlement	CO_2 Value in ppm			Mean
	2018	2020	2022	
Warri	4789.58	4422.32	3998.41	4403.34

Source: Author's analysis

Table 3.3: Ambient Air Quality for Carbon Dioxide

Air Quality Category	Concentration (ppm)	Percentage by volume (%)	Description of indoor air quality
Excellent	400	0.04	Normal outdoor air
Very Good	400-1,000	0.04-0.1	Typical CO_2 levels found indoors
Good	1,000-2,000	0.1-0.2	Common complaints of drowsiness or poor air quality
Fair	2,000-5,000	0.2-0.5%	Headaches, fatigue, stagnant, stuffiness, poor concentration, loss of focus, increased heart rate, nausea
Poor	> 50,000	> 5%	Toxicity due to oxygen deprivation occurs
Extremely poor	> 100,000	> 10%	Oxygen deprivation in seconds: convulsions, coma, and death

Source:https://www.co2meter.com/blogs/news/carbondioxideindoorlevelschart

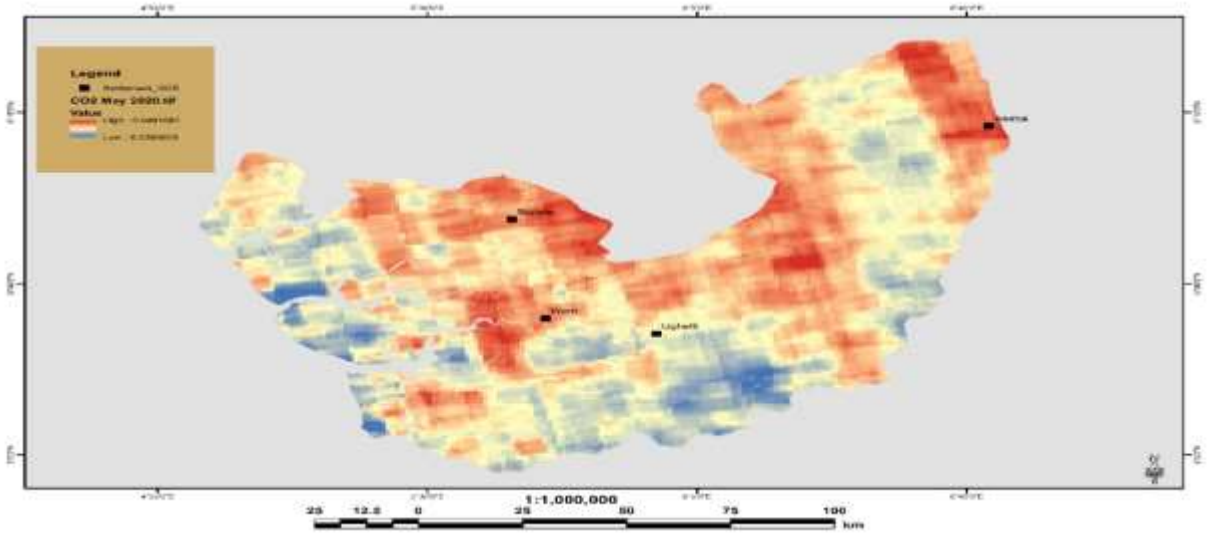

Fig 3.3: Carbon dioxide Concentration in the Study Area in 2018

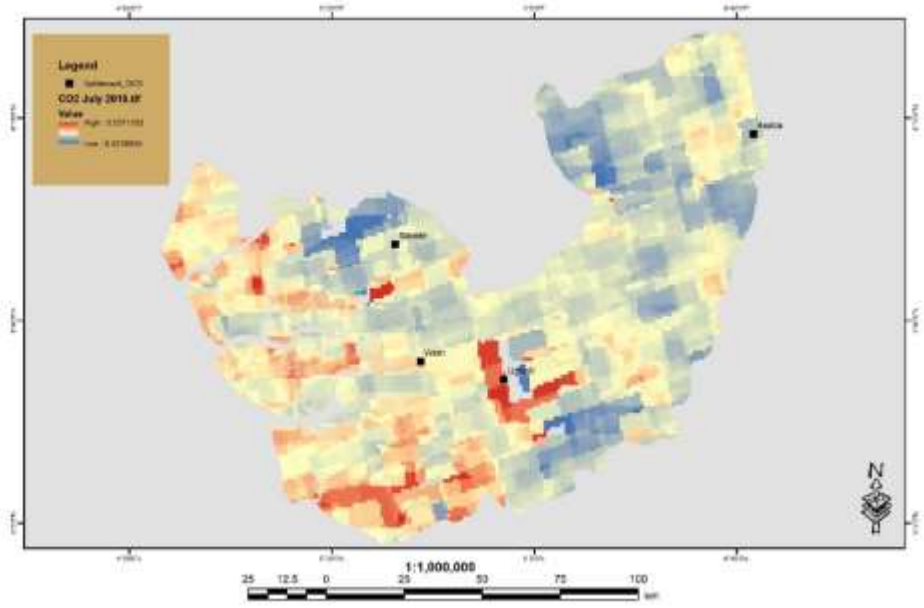

Fig 3.5: Carbon dioxide Concentration in the Study Area in 2022

3.2.2 Concentration of Methane in Warri

The value of CH_4 concentration in Warri was 263.88ppm in 2018 (Table 3.4 and Figure 3.6). This value decreased by 106.27ppm to 157.61ppm in 2020 (Table 3.4 and Figure 3.7) and further decreased by 67.15ppm to 90.46ppm in 2022 (Table 3.4 and Figure 3.8). The mean Methane value for Warri was 90.46ppm; this is far below the threshold value of 1000ppm (Table 3.5). The low concentration of methane in Warri could be due to the reduced activities and non-existence of some of the anthropogenic emission sources such as landfills, agricultural activities, oil and gas natural systems, coal mining, stationary and

mobile combustion, wastewater treatment and some industrial processes that are either non existing or at low level of operation in Warri.

Table 3.4: Mean concentration of Methane in the Study Area

Settlement	2018	2020	2022	Mean
Warri	263.88	157.01	90.46	170.45

Source: Author's analysis

Table 3.5: Ambient Air Quality for Methane

Exposure level (ppm)	Effect or symptom
1000	NIOSH 8-hours TLV*
50,000 to 150,000	Potentially explosive
500,000	Asphyxiation

* TLV = Threshold Limit Value

Source: Alberta Agriculture, food and rural development

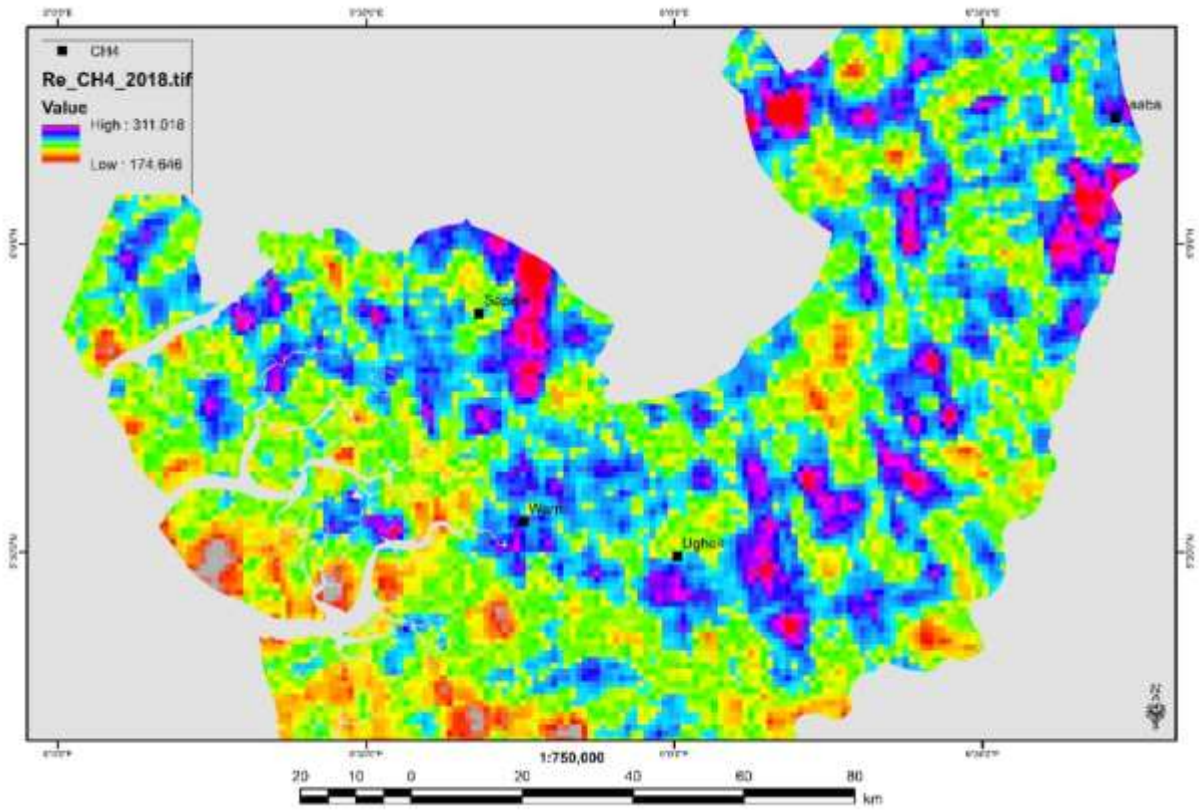

Fig 3.6: Methane Concentration in the Study Area in 2018

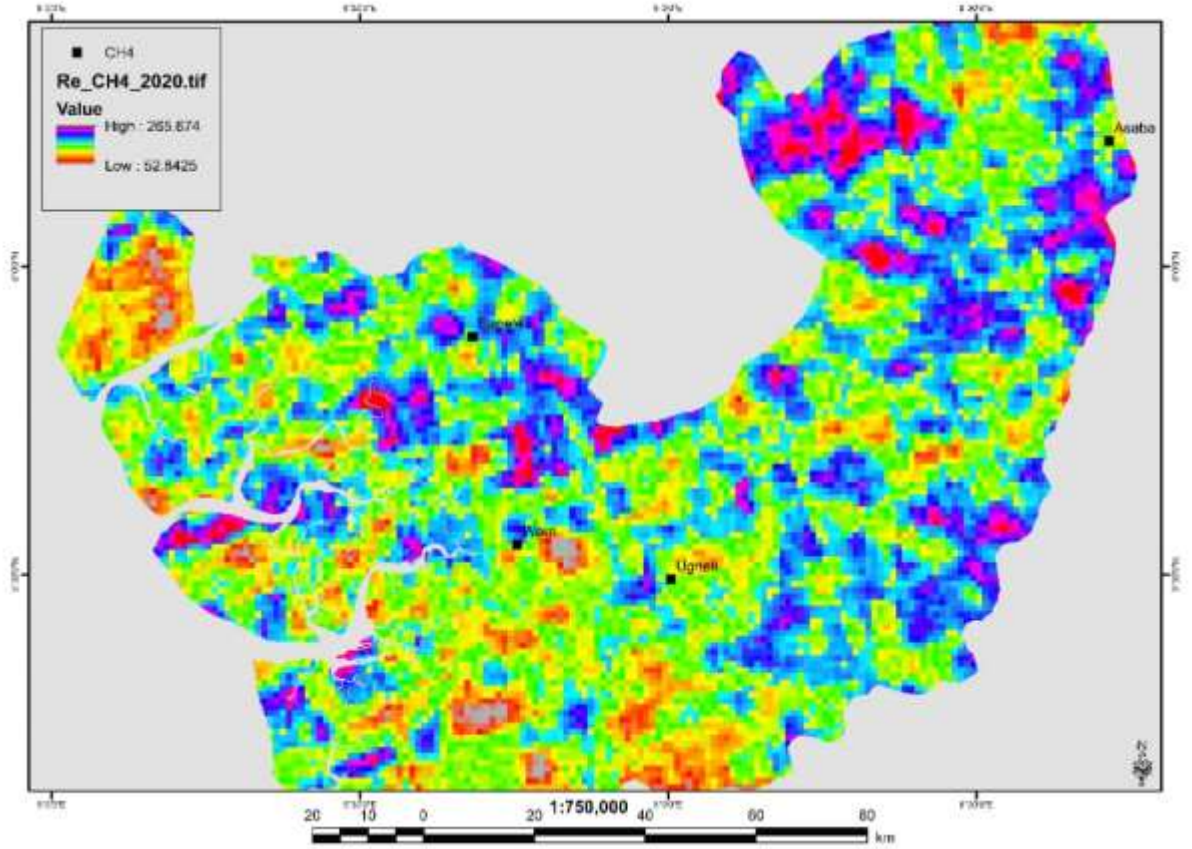

Fig 3.7: Methane Concentration in the Study Area in 2020

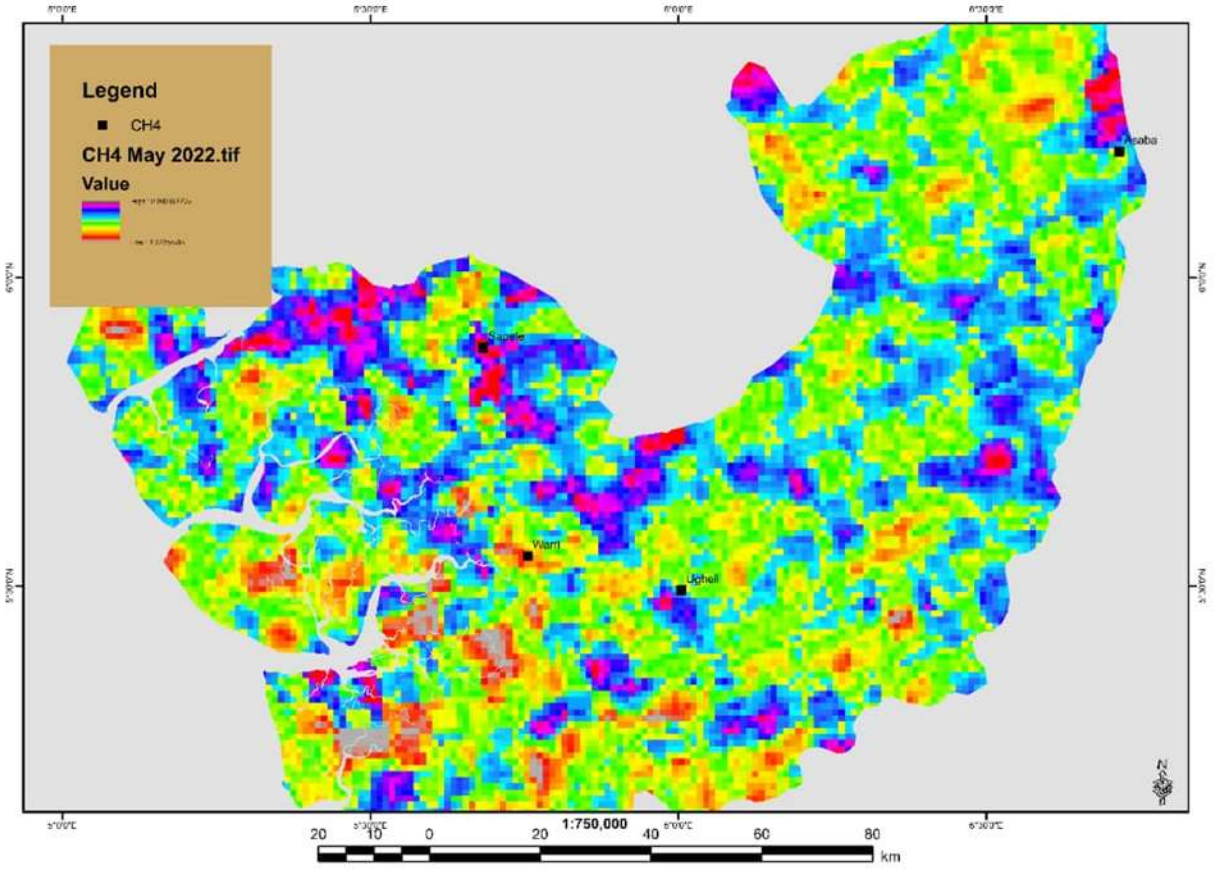

Fig 3.8: Methane Concentration in the Study Area in 2022

Table 3,6: Mean concentration of Nitrogen dioxide in the Study Area

Settlement	2018 (ppm)	2020 (ppm)	2022 (ppm)	Mean (ppm)
Warri	557.77	547.43	640.84	582.01

Source: Author's analysis

Table 3.7: Air Quality Guide for Nitrogen dioxide (NO_2)

Concentration (ppm)	Air Quality Index	Description of indoor air quality
0 -50	Good	No health impacts are expected when air quality is in this range
51 – 100	Moderate	Individuals who are unusually sensitive to nitrogen dioxide should consider limiting prolonged outdoor exertion
101 – 150	Unhealthy for Sensitive Groups	The following groups should limit prolonged outdoor exertion: I. people with long disease such as asthmatics ii. Children and adults
151 – 200	Unhealthy	The following groups should limit prolonged outdoor exertion: I. people with long disease such as asthmatics ii. Children and adults Everyone else should limit prolonged outdoor exertion
201 – 300	Very Unhealthy	The following groups should limit prolonged outdoor exertion: ii people with long disease such as asthmatics ii. Children and adults Everyone else should limit prolonged outdoor exertion

Source: EPA; United State Environmental Protection Agency

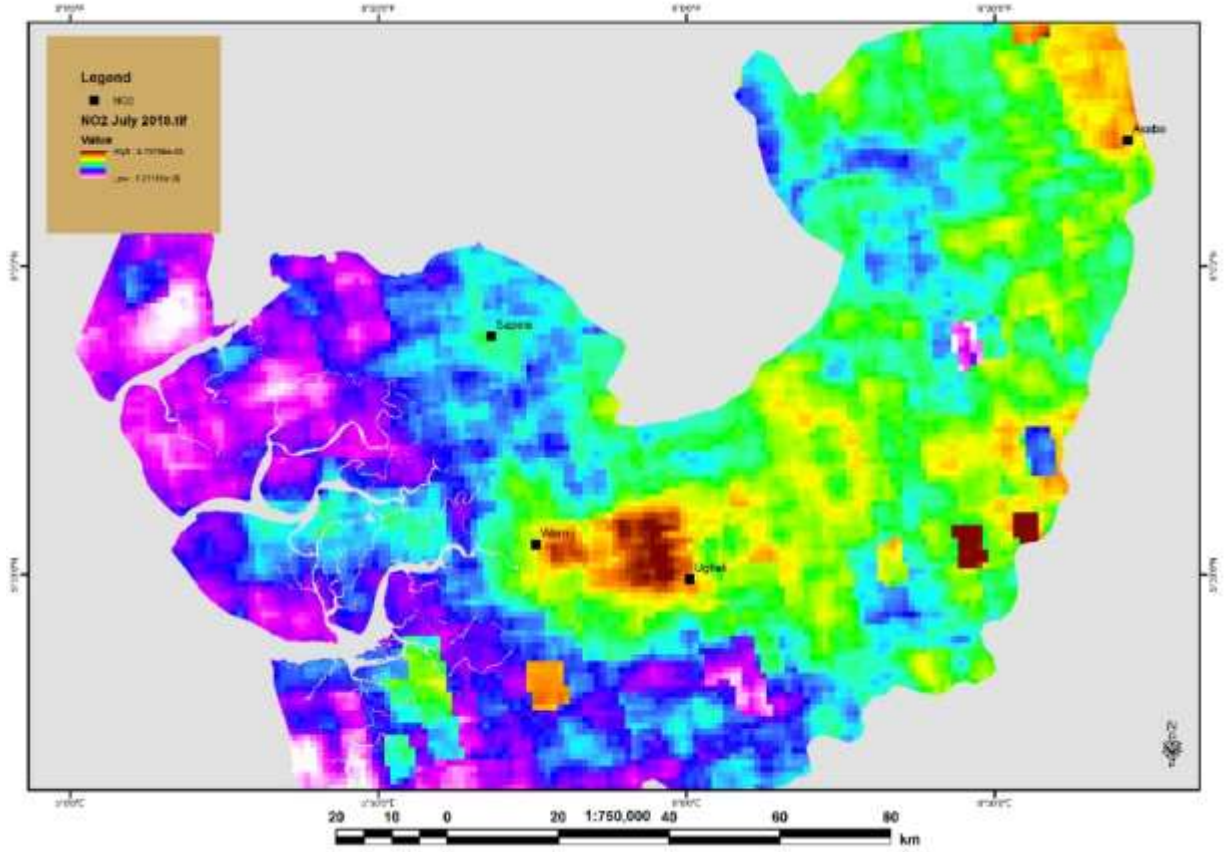

Fig 3.9: Nitrogen dioxide Concentration in the Study Area in 2018

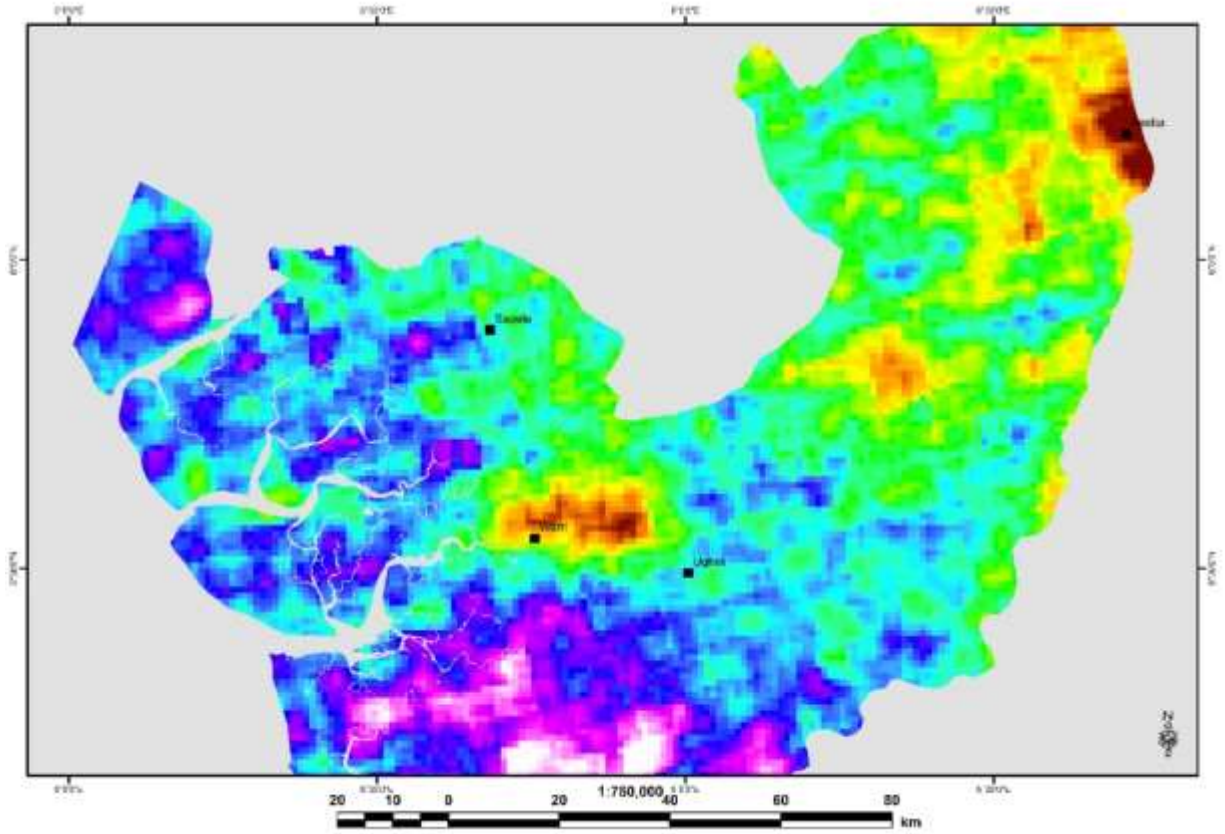

Fig 3.10: Nitrogen dioxide Concentration in the Study Area in 2020

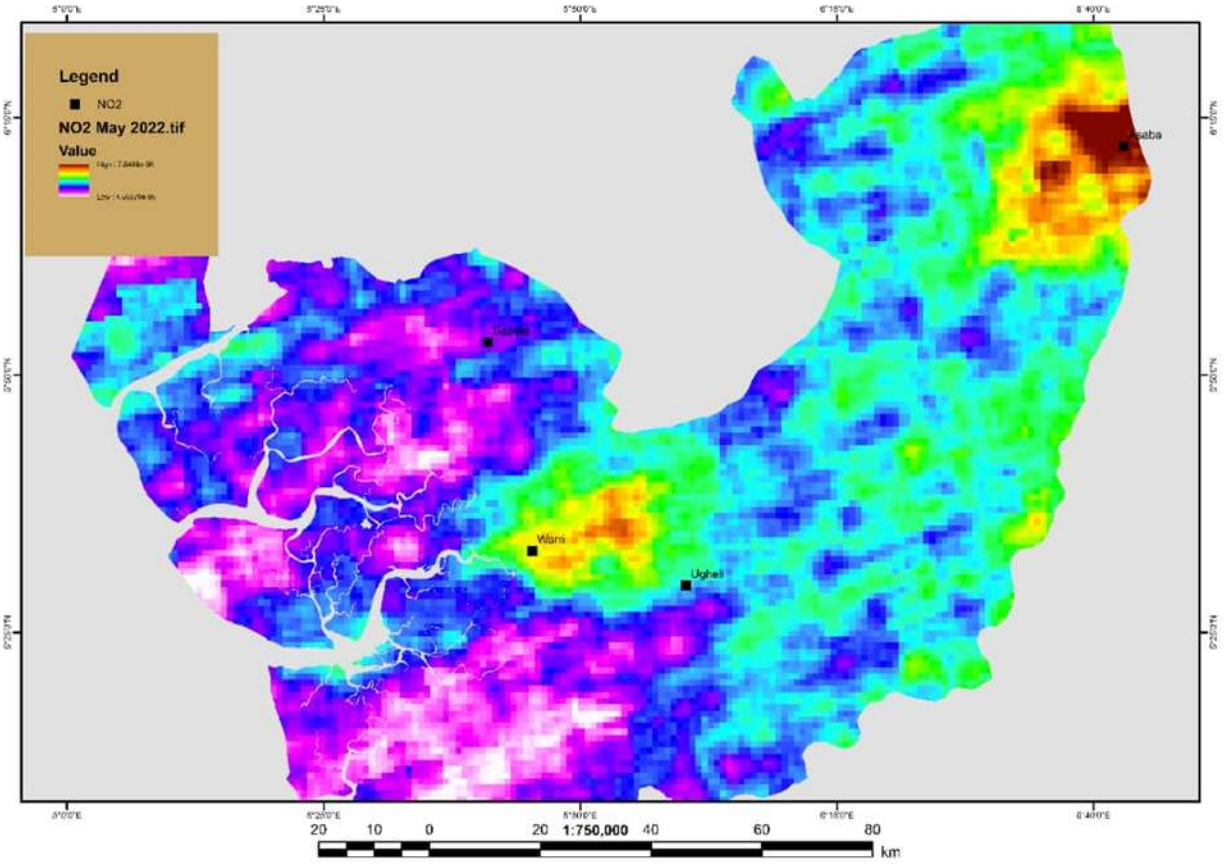

Fig 3.11: Nitrogen dioxide Concentration in the Study Area in 2022

3.2.4 Sulphur dioxide Concentration in Warri

The value of sulphur dioxide in Warri was 41.08ppb in 2018 (Table 3.8 and Figure 3.12). The value decreased to -66.10ppb in 2020 (Table 3.8 and Figure 3.13) and increased greatly to 226.84ppb in 2022 (Table 3.8 and Figure 3.14). The concentration of sulphur dioxide in 2018 and 2020 were below the threshold value of < 100 (Table 3.8), which is considered to be good with no caution to health of inhabitants but the concentration of sulfur-dioxide-in-the-air increased greatly to 226.84ppb which is considered to be poor (Table 3.9). The increase witnessed maybe attributed to industrial plants that rely on coal or fuel for operation which are major sources of release of sulphur dioxide into the environment. With the mean sulfur-dioxide-in-the-air being 201.82ppb (Table 3.8), the ambient air quality for sulphur dioxide in Warri is considered poor (Table 3.9).

Table 3.8: Mean Concentration of Sulphur Dioxide in the Study Area

Settlement	Concentration (ppb)			Mean
	2018	2020	2022	
Warri	41.08	-66.13	226.84	201.79

Source: Author's Lab analysis

Table 3.9: Ambient Air Quality for Sulfur dioxide (SO2)

Sulfur dioxide average over 1 hour (parts per billion)	Air Quality Category
< 100	Good
100 – 200	Fair
200 – 300	Poor
300 – 600	Very poor
> 600	Extremely poor

Source: https://www.epa.vic.gov.au/for-community/environmental-information/air-quality/sulfur-dioxide-in-the-air

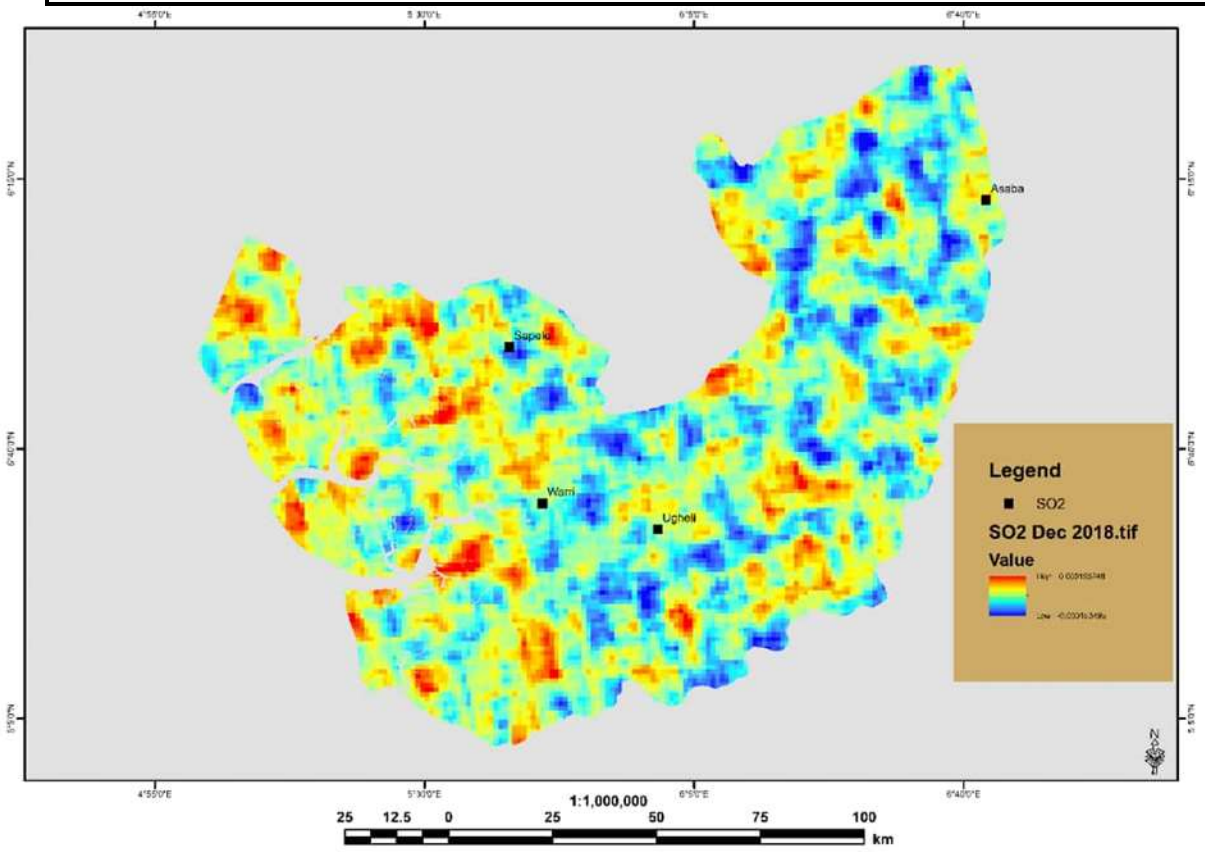

Fig 3.12: Sulphur dioxide Concentration in the Study Area in 2018

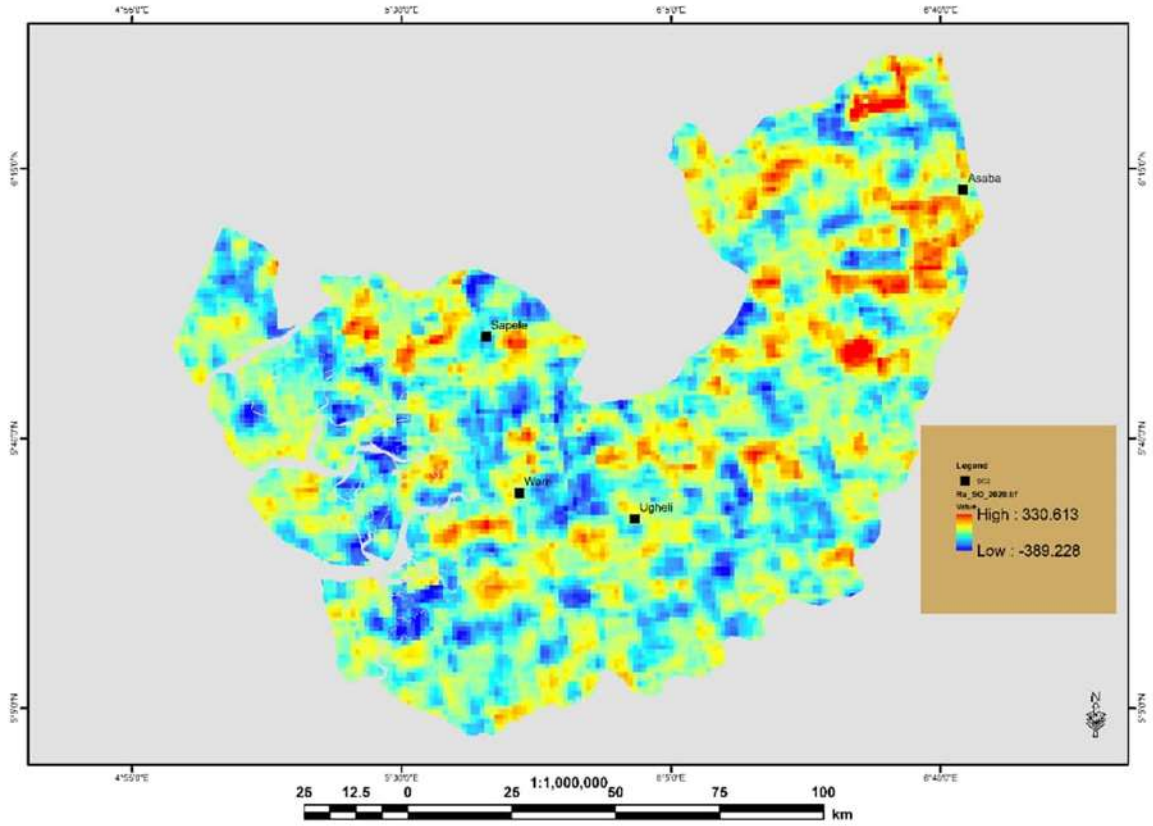

Fig 3.13: Sulphur dioxide Concentration in the Study Area in 2020

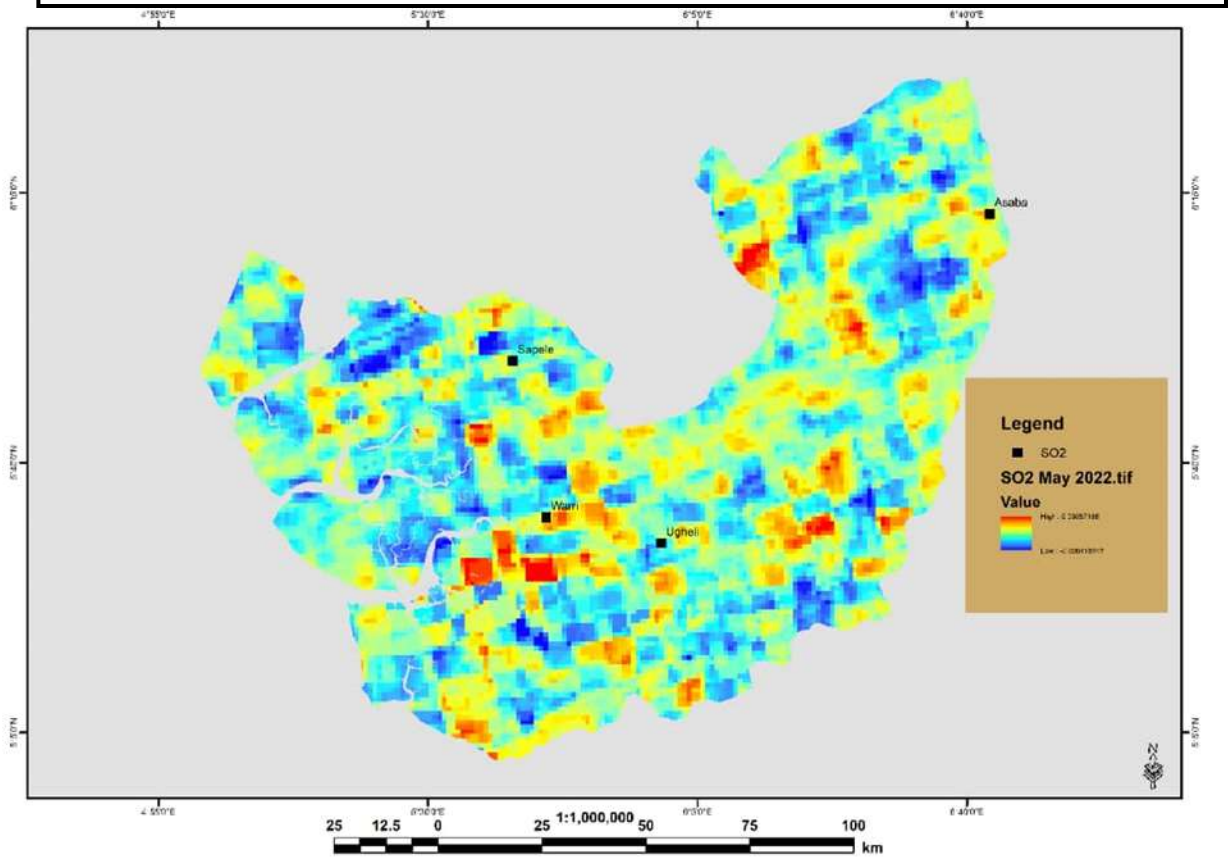

Fig 3.14: Sulphur dioxide Concentration in the Study Area in 2022

3.3 The Impact Of Urban Growth On Surface Temperature And The Urban Heat Island For The Study Area

The temperature in Warri 2003 was 45.21°C, which was considered very very hot (Table 3.10 and Figure 3.15). In 2013, bands 11 and 12 had 27.69°C and 25.10°C respectively, indicating feeling hot and warm to hot respectively (Table 3.10 and Figure 3.16). The temperature recorded in 2023 was 29.61°C and 27.19°C indicating feeling hot for bands 10 and 11 respectively (Table 3.10 and Figure 3.17). The temperatures from the base year 2003 were decreasing, this could be due to the awareness of the impact of increase in temperatures that has led to the transition from fossil based energy to energy sources that do not emit greenhouse gases such as solar that is common across the city and the moderating effects of the surrounding rivers on the temperature.

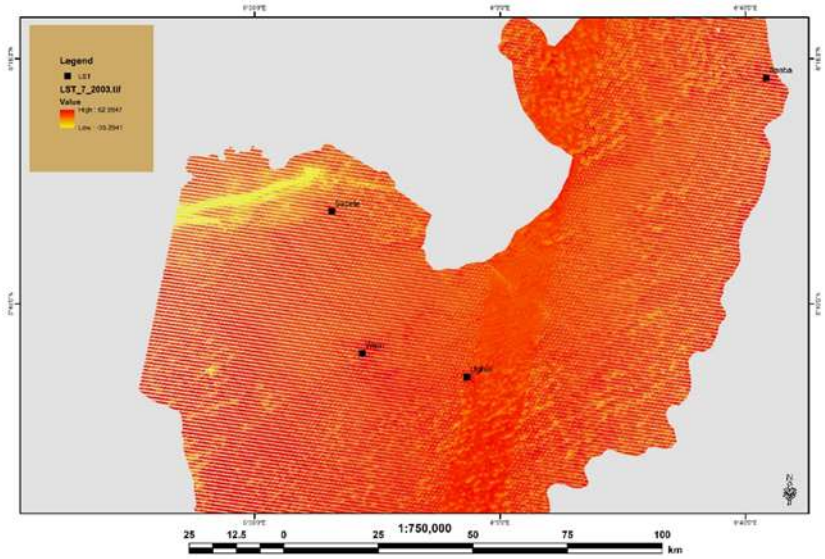

Fig 3.15: Land Surface Temperature for 2003

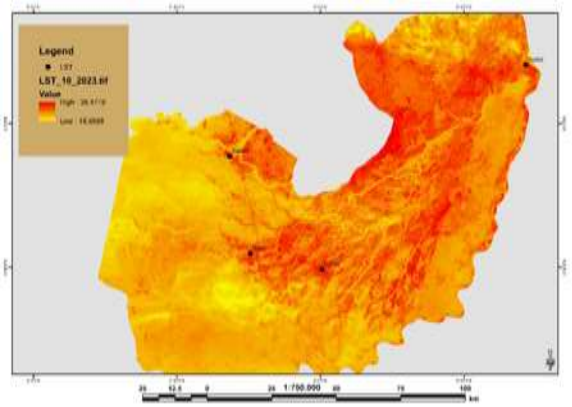

Fig 3.16: Land Surface Temperature for 2013

Table 3.10: Temperature variation within the study area between 2003 and 2023

Settlement	Temperature °C	How it feels	Temperature °C		How it feels		Temperature °C		How it feels	
	2003		2013		2023		2023			
	Band 6		Band 10	Band 11	Band 10	Band 11	Band 10	Band 11	Band 10	Band 11
Warri	45.21	Very very hot	27.69	25.10	Feeling hot	Warm to hot	29.61	27.19	Feeling hot	Feelin hot

Source: Author's Lab analysis

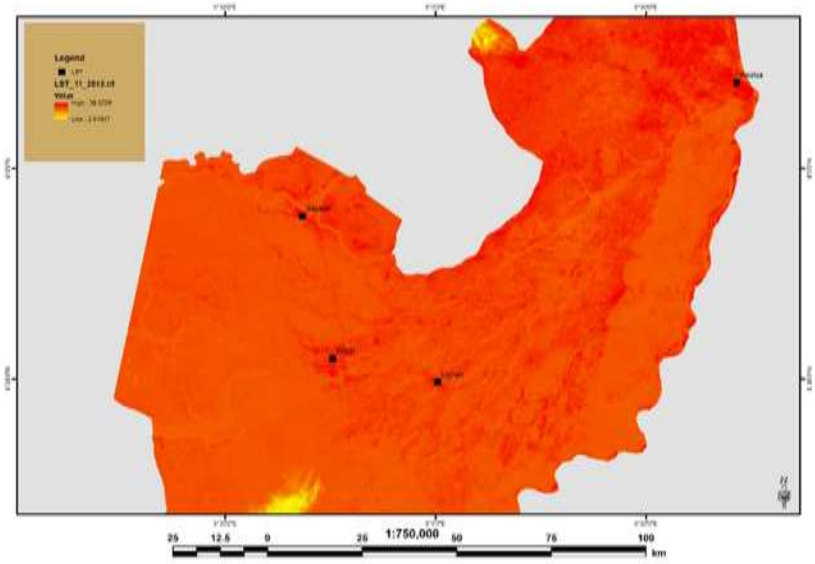

Fig 3.17: Land Surface Temperature for 2023

5. CONCLUSION

The result obtained from the study showed that with a mean concentration of 4403.34ppm (Table 3.2) for CO2 recorded in Warri, the ambient air quality could be said to be fair (Table 3.3), with the consequences of headaches, fatigue, stagnant, stuffiness, poor concentration, loss of focus, increased heart rate and nausea on the inhabitants. The mean Methane value for Warri was 90.46ppm which is far below the threshold value of 1000ppm (Table 3.5). With a mean concentration of 582.01ppm for NO2 in Warri, which is far above the unhealthiest range of 201 to 300, the following groups should limit prolonged outdoor exertion: i people with long disease such as asthmatics, ii. children and adults and everyone else should limit prolonged outdoor exertion (Table 3.7). However, the residents of the study areas are exposed to varying concentrations of NO2 that could exhibit human health challenges and as such irritate the lungs and lower resistance to respiratory infections. This is because the NO2 concentration was higher than the ambient air quality guidelines. This corroborates Atubi and Osoyibo, 2020. With the mean sulfur-dioxide-in-the-air being 201.82ppb (Table 3.8), the ambient air quality for SO2 in Warri is considered poor (Table

3.9). Hence, constant monitoring of the locations assessed should be enforced to prevent the aforementioned human health challenges associated with NO2 and SO2.

6. RECOMMENDATIONS

The recommendations from this study include:

i. The planting of vegetation around buildings also known as green design.
ii. Making modifications in the design and orientation of buildings.
iii. In order to ensure outdoor human comfort in future urban designs microclimate guidelines should be studied and adhered to strictly so as to develop planning strategies.
iv. Rising up to the challenges of urbanization through improved planning, monitoring and sensitization.

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