An Assessment of Heatwave Impact in Enugu Metropolis of Enugu State

Christian Chijioke Agu (christianagu820@gmail.com)
National Space Research and Development Agency https://orcid.org/0000-0002-9420-2062
Ikwuka Amarachi
National Space Research and Development Agency
Kamila Tukur
National Space Research and Development Agency
Hassan Omede
National Space Research and Development Agency
Blessing Kakushia Nwadike
National Space Research and Development Agency

Research

Keywords: Temperature, Rainfall, Relative Humidity and Change Detection

Posted Date: September 4th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-36863/v1

Abstract

Background

The context of this research the impact of heatwave within Enugu city center, with the aim to analyze the impact in the city metropolis of Enugu state which comprises of three local government areas namely Enugu East Enugu North and Enugu South.

Result

From the result, our findings showed the increase in lst over the period of years and over 50% inhabitants feel discomfort, while the vegetation index reduced in year 2020.

Conclusion

The summary of the research looked at the change detection, NDVI, LST, and thermal comfortablity index, the potential implication of the result shows that heatwave impact is more felt in the study area and, the city will become more hotter in the near future thereby making it unfavourable and un comfortable for people to live or habit.

1.1 Background

Within century (1906–2005) temperature linear movement of 0.74 °C is noticeably lesser than the associated trend of 1980 to 2012, which is 0.85 °C Intergovernmental Panel on Climate Change (IPCC) 2014. Indeed climate change has been affecting communities in different ways and climate extremes are aspect of the most confusing challenges of climate change. The changes in the climate implies changes in the spatial extent, in the frequency, the intensity, the duration, and the time frame of climate events and this can lead to ground-breaking extreme weather and climate events (IPCC 2012). There are different climate extremes that affect communities in different ways: storms, flooding, drought and heat waves. The latter may seem to be the less dangerous among them but the recorded impacts worldwide have been dreadful compared to the other ones during the last decades (Balogun et al. 2016; Ceccherini et al. 2016, Russo et al. 2014, 2015; Nkrumah et al. 2011).

From droughts to flooding rains and damaging frosts to heat waves, it is obvious that climate extremes are very important and must be considered in every society (Alexander 2016); especially in tropics (direct hit of sunshine) where the west Africa countries are located. Over the years, people’s exposures to heat wave as a result of climate change have attracted a lot of concern due its frequent occurrence globally. It is a period of marked unusual hot weather over a region persisting for at least three consecutive days (Dawson RJ, Johns Det al. 2016).Scientists have agreed that climate change is happening, and that it is largely due to anthropogenic emissions of greenhouse gases (GHGs) (IPCC 2007).

Heat waves occur when high pressure rise upward in the higher atmosphere above the earth, from 3000 to 7600 m, gain strength and stays over an area for days and sometimes weeks in the same place. This physical process is frequently observed in summer (in each of the hemispheres) as the jet stream motion with the sun [National Oceanic and Atmospheric Administration (NOAA), 2015]. Anticyclones with low-level thermal low (transient anticyclones) can alter the jet stream's normal path and block synoptic weather systems and allow heat waves to build in an area. This is a complex system that includes many factors such as tropical convection (Horton et al. 2016).

Human activities such as (industrialization, Urbanization and increased population) are capable of altering the carbon cycle by adding more Carbon dioxide (CO_2) into the atmosphere, and this emission of carbon dioxide comes from a variety of natural sources; but human-related emissions are responsible for the increase land atmospheric temperature that has occurred since the industrial revolution (USNCDC, 2013). Histories have it that extreme temperature events such as (heat wave, flood, drought and many more) are increasing in their frequency, duration, and magnitude globally. Between 2000 and 2016, it was observed that the number of people exposed to heat waves increased by around 125million globally (IPCC, 2014).

The effect of heatwave may be aggravated in the cities, due to the urban heat Island (UHI) effects, deforestations, anthropogenic heat release from industry, businesses and transport; reduced cooling due to hindrance to airflow from buildings, and absorption and release of energy by dark surfaces like roads. The livelihoods and wellbeing of non-urban communities can also be severely disrupted during and after periods of unusually hot weather (Santamouris *et al*, 2007; Akbari and Oke 1987).

According to World Health Organization (W.H.O), 2008; Heatwaves can burden food and livelihood security i.e. its occurrence can make farmers lose their crops and livestock due extreme heat. It can also burden Health and emergency services; increase strain on water, energy and transportation resulting in power shortages or even blackouts. The health impact of a heatwave depends on the intensity and duration of the temperature, the acclimatization and adaptation of the population, and the infrastructure and preparedness (Hulme*et al,* 2011).

Exposure to heatwave causes severe symptoms, such as heat exhaustion and heat stroke-a condition which causes faintness, as well as dry warm skin, due to the inability of the body to control high temperatures. Other symptoms include swelling in the lower limbs, heat rash on the neck, cramps, headache, irritability, lethargy and weakness. Heat can cause severe dehydration, acute cerebro vascular accidents and contribute to thrombogenesis (blood clots). People with chronic diseases that take daily medications have a greater risk of complications and death during a heatwave, most especially older people and children. (Miles2009; W.H.O, 2009)

Bringing it down to Africa, the continent is not left out of the severe impact of global warming, as it was deemed to be one of the most vulnerable regions to weather and climate variability despite having contributed little to its cause. Africa vulnerability to the dynamics of climate is as a result of its high exposure and low adaptive capacity (IPCC, 2014). In the past few decades Africa was said to have suffered 27% of the world reported fatalities from natural catastrophes(614,250 people) and experienced 1560 weather-related catastrophe such as heatwave, storms and floods(Munich Re 2011).

Land surface temperatures have increased in Africa by 0.5 degrees Celsius or more during the last 50-100 years. For instance, it was observed that in 2002 north-eastern Nigeria suffered one of the hottest and driest spells in living memory, with recorded temperatures above 50 degrees Celsius and dozens of people dying as results of the heat wave (http://news.bbc.co.uk/2/hi/africa/2038164).

Nigeria has been experiencing unprecedented climate change due to the way the country urbanizes coupled with the fact that Nigeria has a tropical climate with two precipitation regimes: low precipitation in the Northeast and high precipitation in the part of Southeast and Southwest. This can lead to aridity, drought and desertification in the north; and rise in sea level, heatwave, flooding and erosion in the southeast (Abdulkadir *et al;* Akande *et al*, 2017; ebele and Emodi 2016; Federal Ministry of Environment, 2014)

It was also highlighted that In Nigeria, When you have heatwave the body is dehydrated, the young, the elderly people that live sedated live-are the kind of people that will have immediate health reactions to heat wave said Environmental expert (Oluwafemi Akinbode 2020);

So since the study area (Enugu State) falls within the humid tropical rainforest belt of south-eastern Nigeria, there is every tendency that heatwave may affect the inhabitant of the Enugu. So therefore, there is every need for this research.

1.2 Statements of the Research problems

There will be over 200 million people living in Nigeria by the end of 2020 and one-half of them may be urban dwellers (Sada, 2015). With increased urbanization, temperatures tend to rise and this often has adverse effects on thermal comfort of people through the imposition of increased climate stress on such urban dwellers. The Intergovernmental Panel on Climate Change (IPCC) in their special report (Suzanne, 2018) suggests that risks with increased warming are particularly higher in urban areas due to the heat related effect. Today we hear frightening statements such as; intense heat-waves could become annual events by the year 2075.

Enugu metropolis is the centre of Enugu State, and it has recorded high increase in urbanization. The high tempo of temperature raise in Enugu metropolis is something to worry about because it affects the social life of the citizens within the urban (Adinna et al. 2009). The town is geographically positioned in the Tropical Rain forest area with high heat (Adinna et al. 2009). Also owing to the city's urbanization, factors that mostly contributed to the temperature's reduction of the region like plantation of tress and forest are gradually being removed due to deforestation and anthropogenic activities. The health of human beings and animals especially in Enugu metropolis is directly or indirectly influenced by the weather. Temperature, sunshine and oxygen have direct effects while the indirect effects are far greater (Odemoerbe, 2018). In Enugu, high temperatures combined with high humidity very often lead to the outbreak of "pricky heat" which is only cured by moving the person to a healthier environment, heat strokes occur when the temperatures become unbearable.

Climate change, population growth and urbanization are instrumental at increasing exposure to extreme temperatures. The effects of climate change are felt specifically in countries with tropical climate which are characterized by high humidity and very high temperatures. Countries in these regions especially in Africa are experiencing heavy urbanization and socio-economic development, leading to an explosion in the size of urban populations (Dao, 2012). A combination of these two factors is having a major impact on the living conditions of city dwellers in Enugu, especially in terms of exposure to extreme- or even-lethal temperatures. A critical threshold is usually considered to be 40.6 degrees centigrade taking humidity in to account (Guillaume 2019). High outdoor humidity levels can disrupt human ability to thermo-regulate with a potentially fatal consequences.

In Enugu heat is usually seen as normal. The general perception is that people are adapted to cope with it. One reason for this is that most elderly people may not see themselves as old and therefore don't recognize the increased risks to heat waves (Gwimi, 2010). Heat waves are among the most dangerous natural hazards, but rarely receive adequate attention because their death tolls and destruction are not always immediately obvious. Weather phenomena can cause mass fatalities in vulnerable groups such as the elderly, young children and out- door workers. Though heat-waves are easily predictable, heat is often a silent killer. Sadly too, when there is a combination of poverty and high heat, it can be deadly. We need to develop a conceptual approach to understand the consequences of Heatwave in the Enugu city center and reconsider city plan strategy and what are the implementation measures. Therefore the majority of citizens are suffering from outdoor environment discomfort and this issue has a deeper and problematic dimension in the study of Enugu, particularly in the metropolis. This research is an effort to recognize the radical effect of Heatwave in Enugu and will suggest some appropriate recommendations to solve this matter.

1.3 Aims

The research aim of this research is to examine the effect of Heatwave phenomenon on Enugu metropolis.

1.4 Objectives

The objectives of the research are:

- To investigate the change detection in the area over a period of time.
- To investigate climate change variables.
- To analyze the increase in surface and air temperature of the area over a period of time.
- To analyze the thermal comfort of the area.

1.5 Scope

The study investigated the impact of Heatwave in Enugu metropolis from 2000 and 2020 by means of remote sensing data, Landsat imagery gotten from the United States Geological Survey Site, and Air temperature, relative humidity and rainfall data from 2000 and 2019 which was procured from the Prediction of Worldwide Energy Resource (POWER) site (https://power.larc.nasa.gov/data-access-viewer/)

1.6 Significant of the Study

The purpose of this research is to study the impact of heat wave in the study area. Heat waves have always been a silent natural disaster but the most impactful, especially on health and agriculture (IPCC, 2007). Globally, extreme weather events such as heat wave have strong implications for socio-ecological, biophysical and human system (IPCC, 2007).

High intensity of land atmospheric temperature as a result of heatwave has led to the prevalence of diseases such as heat stroke, body dehydration, heat rashes, meningitis and other chronic diseases in the state. Due Poor health care system, lack of access to credit facilities, poverty, inequitable distribution of natural resources, cultural practices, violent conflict and low educational background; both the inhabitants and farmers in Enugu state lack the adaptive capacity to cope and adjust to the effect of heatwave in Enugu (Duncan, 2007).

Other physical weather event that have occurred in Enugu metropolis as a result of regional urbanization over the years includes; flood, increased temperature (heat wave), gully erosion, increase in frequency and intensity of storms, late and early cessation of rain and frequent dry spell during farming season. Such impacts combined with high dependence of poor healthcare system and poor farmers with natural resources and rain-fed agriculture exposes these farmers to high impact of heatwave.

This Study therefore is out to show that heat wave portent serious danger to the people of Enugu metropolis especially in the areas of life, food, health, water, and social infrastructural security. The insecurity posed by climate change means that Nigeria at large and Enugu state in particular must rise up to these challenges by building climate resilient country in ways of adopting efficient mitigation and adaptation measures.

1.7 Justification

The metropolitan City of Enugu provides an excellent environment for a study like this due to a number of reasons. First the City was an administrative headquarters of Nigeria’s Eastern provinces in 1929. The rise of Enugu as a modern city began with the penetration of the British Colonialists in the first quarter of 20th Century. The British mining Engineers discovered real sub-bituminous coal which led to the establishment of a colliery and railway line linking Enugu with the coast to transport mined coal (Ayaode, 2018). As a result of this, many people drifted to the new town in search of livelihood. Heat waves associated with an increase in temperature are on the increase in many parts of Nigeria and highly pronounced in the Eastern part of the country (Odgie, 2010). Recent studies (Russo, 2019) also revealed among other things that:

1. Enugu is one of the most spectacular classes of Nigerian cities which owed their growth and development to European influence.
2. Enugu is a typical African city in the South East of Nigeria with rapid rate of increase in socio-economic activities and problems alike.

- With increase in urbanization and expansion in cities around Enugu metropolis, there is high rate of deforestation, and bush burning and clearing where vegetation had largely been replaced by buildings and roads thereby altering the energy balance.

These therefore provide the justification of this research.

2.0 Literature Review

In recent times, there is limited literature on the potential impacts of extreme weather events such as heatwaves; most literatures have concentrated their efforts more on estimating global averages of temperature. This focus may result in part, from incomplete knowledge and uncertainties regarding the current and future impacts of heatwave as well as the exposure and vulnerabilities. Nonetheless, understanding current impacts can be important for decision makers preparing for future risks. The 21st century witnesses the abnormal increase of atmospheric temperature due to the overexploitation of the environment through deforestation, high consumption of fossil fuel etc. The heat wave has great potential and more dangerous as compare to other natural phenomenon like hurricanes, lightening, and tornadoes (Shakeel Anwar2019).

Heatwaves according to Perkins and Alexander, 2013 is a prolonged periods of anomalously warm temperatures; which Inflict disastrous impacts on human health, food security, infrastructure and ecosystems (Lindgren and McMichael 2011, Welbergen *et al* 2008, and Perkins 2015). Over the past few decades, increases in heatwaves have been observed over numerous regions (Russo *et al* 2014, Ding *et al* 2010). These marked progression in heatwaves are statistically significant extensively (Perkins *et al* 2012), and anthropogenic climate change is a main contributor in which projected future changes increases in trends consistently. Orlowsky and Seneviratne 2012, Cowan *et al* 2014, Russo *et al* 2014 were of the opinion that heatwaves are influenced by climate variability and only a handful of studies have investigated how internal this is.

Similarly, in 2013, Jamain Label, Pierre Gosline, Diane Balenger, Fateh Chibana investigated the health impacts of July 2010 heatwave in Quebec, Canada. It was marked to be one of the unprecedented heat waves in recent history. The purpose of their study was to estimate certain health impacts of this heat wave. The crude daily death and emergency department admission rates during the heat wave were analyzed in relation to comparison periods using 95% confidence intervals. From their result, the crude daily rates showed a significant increase of 33% for deaths and 4% for emergency department admissions in relation to comparison periods. No displacement of mortality was observed over a 60-days horizon.

In 2012, Derrick A. AkompabPeng, Susan Williams, Janet Grant, Iain A. Walker and Martha Augoustinos conducted a research on Awareness of and Attitudes towards heat waves within the Context of Climate Change among a Cohort of residents in Adelaide, Australia. Their study was aimed at examining the perception and attitudes towards heatwave in the context of climate change. A cross-sectional study was conducted in the summer of 2012 among a sample of 267 residents. The results of the survey found that television (89.9%), radio (71.2%), newspapers (45.3%) were the main sources which respondents received information about heatwave. The majority of the respondents (73.0%) followed news about heatwave very or somewhat closely. About 26.6% of the respondents were extremely or very concerned about the effects of heat wave on them personally.

In 2014, Frimpong, K., Oosthuizen, J. & Van Etten E. J. examined the extent of heatwave on Health and Sustainable Farming in Ghana –Bawku East. The purpose of their study was to undertake a preliminary investigation on the extent of heat stress on outdoor and indoor working and living areas of farmers respectively. In their method of data collection,heat monitoring equipment capable of recording readings every hour (Lascar EL USB temperature and humidity loggers) (Kjellstrom, Sabine Gabrysch et al., 2009; Pradhan et al., 2013) were used to measure temperature, relative humidity and dew point at the workplace of farmers in selected rural crops growing communities at (Pusiga) in Bawku East, of Northern Ghana. Also questionnaire developed by the HOTHAPS program was adapted and administered to a cohort of crop (legume, cereals, Vegetables) growing farmers in the study area (n=308) in order to elicit information related to their self-reported health status and the impact of heat on their day to day work activities. From their findings, during the dry season the dry bulb temperature rose as high as 45 ºC, while during the humid months of March and April WBGT rose to levels as high as 34 ºC. Farmers worked for nine hours a day during these hot periods with insufficient rest, which has adverse consequences on their health and productivity.

Jian Cheng, Hilary Bambrick, Laith Yakob, Gregor Devine, Francesca D. Frentiu, Do Thi Thanh Toan, Pham Quang, Zhiwei, Wenbiao(2020) looked at Heatwaves and dengue outbreaks in Hanoi, Vietnam: New evidence on early warning. The study aimed to compare the short-term temperature-dengue associations during different dengue outbreak periods, estimate the dengue cases attributable to temperature, and ascertain if there was an association between heatwaves and dengue outbreaks in Hanoi, Vietnam. The methods and findings of the research were to assign Dengue outbreaks to one of three categories (small, medium and large) based on the 50th, 75th, and 90th percentiles of distribution of weekly dengue cases during 2008–2016. Using a generalized linear regression model with a negative binomial link that controlled for temporal trends, temperature variation, rainfall and population size over time, they examined and compared associations between weekly average temperature and weekly dengue incidence for different outbreak categories. They discovered evidence of an association between heatwaves and dengue outbreaks, with longer delayed effects on large outbreaks (around 14 weeks later) than small and medium outbreaks (4 to 9 weeks later). They concluded that the short-term association between temperature and dengue risk varied by the level of outbreaks and temperature seems more likely affect large outbreaks. Moreover, heatwaves may delay the timing and increase the magnitude of dengue outbreaks.

Generally, very minimal research works have been done on heatwave globally, and as such the need to carry out further studies on its impact on the people of Enugu state cannot be over emphasized.

3.1 The study area

The study area Enugu State is located in south-eastern part of Nigeria which is approximately within latitude 6^{0}.00'N and longitude 7^{0}.00E and 7^{0}.45'E. Due to the discovery of coal in the state in large in a commercial large quantity in 1999, the state is called the coal city. The state shares boundary with benue to the Northeast, Abia State and Imo State to the south, Ebonyi State to the east, Kogi State to the northwest and Anambra State to the west. It is an hour's drive from Onitsha, one of the biggest commercial cities in Africa and 2 hours' drive from Aba, another very large commercial city Nigeria.

3.1.1 Climate of Enugu

The city has a tropical savannah climate, which falls within the humid tropical rainforest belt of south-eastern Nigeria. Enugu'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), just like the rest of West Africa, the rainy season and dry season are the only weather periods in Enugu. The average annual rainfall in Enugu is around 2,000 millimetres (79 in), which arrives intermittently and becomes very heavy during the rainy season. Other weather conditions affecting the city include Harmattan dusty trade wind lasting a few weeks of December and January. Like the rest of Nigeria, Enugu is said to be hot all year round.

3.2Data Used

The dataset used for this study was secondary data which contains spatial and non-spatial attributes. The dataset includes Landsat 7 Enhance Thematic Mapper (ETM+) and Landsat 8 Operational Land Imager (OLI) Images, topographic maps, Temperature, Rainfall, and Relative Humidity data. Software packages include; ArcGIS version 10.5, Idrisi.

Table 3.1: Data types and sources

Data list	Data type	Data	Data source	Resolution
1. Landsat 7	Secondary	Satellite imagery	Earth explorer	30m
2. Landsat8	Secondary	Satellite imagery	Earth explorer	30m
3. Temperature, Rainfall, and Relative Humdity data	secondary	Climate data	Prediction of worldwide energy resources, NASA	

The Landsat data was obtained from (URL; http://earthexplorer.usgs.gov). The images are, Landsat 7 ETM + image acquired on 6th February 2000 and Landsat 8 OLI acquired on 20th of February 2019 as revealed in Table 3.1. The satellite imagery has 30m spatial resolutions. ETM data have a spectral range of 0.45-2.35 micrometers with bands 1,2,3,4,5,6,7 and 8 while the OLI extends to band 12.

Climate data (Temperature, Rainfall and Relative Humidity) were acquired from Prediction of Worldwide Energy Resources (POWER) (https://power.larc.nasa.gov/data-access-viewer/) for a period of 2000 and 2019 annual data.

3.2.1 Software Used

The software used is as listed;

ArcGIS 10.5: The spatial plus statistical analyst extensions of the ArcGIS 10.5 version will be applied to take out both the spatial analyses and the spatial statistical analyses.

Idrisi: Supervised classification was being carried out by Idrisi the land change of the Idrisi was applied to examine the land-use/land-cover between the years of observation.

Microsoft Excel: is a spreadsheet program use to estimate and analyze numerical data. The software was being applied to transmit out the statistical investigation.

3.3 Methodology

To extract the study area, the topographic map covering the Enugu was georeferenced in ArcGIS environment. Subsequently carving out the area of interest delineated from the satellite image covering the study area. The area of interest was used to subset the study area map. The sub map was digitized, and personal geo-database (Tourism geo-database), feature dataset and feature class were created in Arc Catalog

The methodology adopted for this work was categorized into four stages (a) Normalized difference vegetation index (NDVI) generated. (b) Land Surface temperature (LST) generated (c) Land use/ Land cover (LULC). (d)Thermal comfort index was also generated.

A. Normalized Difference Vegetation Index

NDVI is used to compute vegetation greenness and beneficial to comprehend vegetation density and evaluating fluctuations in vegetal fitness.

NDVI= NIR-R

NIR+R

It is delivered a single-band product specified.

The spatial disparity of NDVI is not focused on the effect of vegetation quantity, likewise landscape, incline, lunar energy disposal, and further reasons. NDVI is normally used as a degree of terrestrial greenness built on the supposition that the NDVI significance is absolutely relative to the sum of green vegetation in an image pixel region. Theoretically, NDVI ethics are signified as a proportional tenanting in value from -1 to 1 likewise in repetition, great damaging values signify water, ethics nearby zero signify bare soil and ethics adjacent to one signify thick green vegetation.

B. Land surface Temperature.

Land surface temperature is the temperature of the land from solar radiation (Francois Becker and Zhao-liang Li) 2009.Apparent heat and emissivity at scales: Remote Sensing Reviews, Journal. https://doi.org/10. ArcGIS 10.5 was used to retrieve the land apparent Temperature.

C. Land use land cover:

IDRISI was used for Image Analysis this include:

Pre-processing - operations before the key statistics study and removal of evidence, are referred to as radiometric or geometric corrections.

Image Enhancement - increase the form of imagery to promote graphic understanding and examination. Spatial filtering enhances precise longitudinal configurations in an image.

Image Transformation - mutual processing of statistics from numerous spectral bands. Arithmetic procedures (i.e. deduction, tallying, duplication, partition) are achieved to syndicate and convert the unique bands into "different" images that enhanced presentation or focus assured topographies in the sight. Techniques: Spectral or band rationing and principal components analysis.

Image Sorting and Study – regularly executed on multi-channel statistics groups (A) this procedure consign small pixels in an image to a specific class or subject.

(B) Grounded on arithmetical features of the pixel intensity values. Supervised classification was employed. Classes are bare land, rocks, water body, vegetation, and built-up areas.

D. Thermal comfort ability/discomfort.

Air temperature and relative humidity data were used to analyze the thermal comfort/Discomfort of the study area. In spite of the achievement of a scientist through modern technology, the comfort of humans still influenced to an excessive level by these two thermal indices: temperature and humidity. Thermal comfort indices are diverse and generally relevant only in assured settings, as distinct by ecological arrays. This array of pertinent is though only stated for particular directories. Besides, studies of these directories conclude that they are valid in a much thinnerseries of conservational circumstances than appealing. Many thermal guides have been broadly used to prompt the anthropological relief level in extents or phases by the amalgamation of climatological and biological statistics based on conservational environments. Since accounts of earlier training and guides reflected for Nigeria, it was recommended that temperature-humidity index (THI) is significant as an index of thermal comfort in the tropics since it has the benefit of providing the mutual result of temperature and humidity on comfort within a thin array of conservational situations (Balogun et al, 2014). THI is similarly used to analyze human thermal environments to evaluate the affiliation amid climatological variables, like airborne heat and virtual moisture. Thom (1959), indicated that the actual temperature, completed an extensive array of its standards underneath open-air circumstances, can be estimated by a modest undeviating comparison joining the corporal constraints of airborne temperature (desiccated-bulb temperature) and (damp-bulb temperature).This suggested experimental index, which is, in detail, a modification of AT*, remains what he termed the temperature-humidity index (THI) otherwise the discomfort index (DI). Scientists have anticipated several balanced or experimental bioclimatic guides that designate the perception of temperateness that individual experiences based on acquaintance to diverse arrangements of factors that impact thermal comfort such as airborne heat, virtual humidity, airspeed, meteorological gravity, apparel, movement, etc. Excel was used for Statistical Analysis.

The thermal discomfort index (DI) was summarized from Thom's formula which is DI = T - (0.55-0.0055*RH) (T-14.5).where T= Temperature, RH=Relative Humidity.

Thom's table DI Series was used to regulate the proportion of the interested tourist to suffer from discomfort.

DI Classification	**DI range(0c)**
No Discomfort	DI<21
Under 50% of Populations feel discomfort	21≤DI <24
0ver 50% of Populations feels discomfort	24≤DI<27
Most of the population suffers discomfort	27≤DI<29
Everyone feels severe stress	29≤DI<32
State of a medical emergency	DI≥32

Table 3. Thom's' classification of DI ranges

4.0 Data Analysis, Results And Discussion

4.1 Change Detection

Each composed image was ordered into 5 area classes: built-up areas, vegetation, bare-surface, water body and rocks. The outcome of the classifications of land cover is found in the above Figure. The classification and quantification of images of the study zone (which covers an aggregate of land area of 4578.56 square kilometres (km^2) were necessary for the detection of changes in various LULC observed within the study area and over the study period. Thus, the fixed LULC dispersal for each study year was imitative above the three study years (2000, and 2020). The table reveals that as of 2000, Vegetation occupies the largest area with 1398.44 $km^2$of the entire study area, while built-up covered 1306.15 km^2, bare-surface covered 364.03 km^2, water body covered 1232.38 km^2 and rocks occupied the least area of 277.56 km^2. Measurements for the year 2020 indicate that there is a substantial gain in built-up areas as it increased to 2113.54 km^2, while vegetation as a terrestrial cover style experienced significant loss of 1060.59 km^2, bare-surface covered 106.51 km^2, water body covered 364.4 km^2 and rocks occupied the least area of 933.52 km^2.

Change Detection of the study area for the years 2000 and 2020.

Table 4.3
LULC of the study area for 2000 and 2020

Years	**2000**	**2020**
LULC	Area(km^2)	Area(km^2)
Vegetation	1398.44	1060.59
Built-Up	1306.15	2113.54
Bare-Land	364.03	106.51
Water-body	1232.38	364.4
Rocks	277.56	933.52
Total	4578.56	4578.56

Table 4.4
Net alteration in land-use classes involving 2000 and 2020

Category	**Net change between 2000 and 2020**
	(Km^2)
Vegetation	337.85
Built-Up	807.39
Bare-Land	257.52
Water-body	867.98
Rocks	655.96

4.2 Analysis of the spatial pattern of Normalize Differential Vegetation Index (NDVI)

The spatial variant of NDVI is not merely focused on the impact of vegetation quantity, nevertheless landscape, hill, lunar mission obtainable, and further reasons. NDVI is frequently used as a ration of terrestrial apparent greenness grounded on the theory that the NDVI significance is absolutely relative to the sum of green vegetation in an image pixel region. NDVI ethics are signified as a percentage oscillating in rate from – 1 to 1 nevertheless in preparation, great adverse values signify water, values with zero signify bare soil and values near one signify solid green vegetation. The longitudinal dispersal of NDVI over the study area for the period 2000 and 2020 is shown below.

Visual inspection ascertains the variances of each NDVI. The maximum grade of the alteration was perceived in 2020. The ascendancy of adverse NDVI values may be accredited to accumulative expansion leading to new urbanized regions and bare surfaces. The experiential adverse value is for the reflectance assessment in the red band which is advanced than the reflectance value in the near-infrared band. Also, recent decline trendy apparent water employing dehydrated climate was essential to truncated standards of the NDVI in 2020 since the directory declines as vegetation comes under water stress.

NDVI of study Area for the year 2000 and 2020

Figure 4.3 NDVI of Enugu Metropolis 2000

Figure 4.4 NDVI of Enugu Metropolis 2020

4.3 Analysis of land surface temperature (LST)

The land surface temperature over the study area shows that the LST ranged from 28.28^{o}C to 55.26^{o}C in 2000 and 27.93^{o}C to 58.09^{o}C in 2020. In 2000, it is evident that the temperature is extremely subsidiary to the LST of 2020. The metropolitan temperature landmass observed accumulative drift above 20 years era as an effect of cumulative population, anthropogenic activities, and alteration of land cover. It is vibrant that in all the years' 2020 study area exhibits the highest land surface temperature. This is attributed to recent high concentration of buildings and structures, increase in anthropogenic activities, increase in deforestation, lack of adequate drainage facilities for proper channelling of runoff water, increase in concrete pavements along the roads and exploration of minerals might be ascribed to the observed increase of land surface temperature.

Land surface temperature of the area for year 2000 and 2020

Figure 4.5 Land surface temperature of Enugu metropolis 2000

Figure 4.5 Land surface temperature of Enugu metropolis 2020

4.4 Analysis of Temperature heat humidity index

Thermal discomfortability

This index regulates the thermal comfort or discomfort of the three local government area within the study area namely; Enugu East, Enugu North and Enugu South obtained particular heat and virtual moisture in the state, with reverence to the thermal discomfort index (DI). This index was considered from Thom's method which is DI = T - (0.55-0.0055*RH) (T-14.5). The limits of airborne heat and virtual moistness were acquired from records of POWER, NASA (Prediction of Worldwide Energy Resource) for the years 2000 and 2019.

Where **DI = Discomfort index**

T = Temperature

RH = Relative humidity.

The data were acquired during the raining and dry season from January to December 2000 and 2019 for the three local governments of the study area. An annual calculation of temperature and relative humidity was done to get the average mean annual data for our calculation.

Enugu East

The Average Mean Annual data in year 2000 are as follows:

Temperature: 25.08^{o}C

Relative Humidity: 81.24%

And from the equation DI = T - (0.55-0.0055*RH) (T-14.5)

DI = 25.08 - (0.55-0.0055*81.24) (25.08–14.5) = 23.98

From Thom's' classification of DI ranges $21 \leq DI < 24$ shows that under 50% of Population feel discomfort, and our DI for Enugu East in 2000 is 23.98, meaning that under 50% of the population feels discomfort.

While in the year 2019, the Average Mean Annual data in year 2000 are as follows:

Temperature: 26.02^{o}C

Relative Humidity: 81.39%

And from the equation DI = T - (0.55-0.0055*RH) (T-14.5)

DI = 26.02 - (0.55-0.0055* 81.39) (26.02–14.5) = 24.84

From Thom's' classification of DI ranges $24 \leq DI < 27$ shows that over 50% of Population feel discomfort, and our DI for Enugu East in 2019 is 24.84, meaning that over 50% of the population feels discomfort.

Enugu North

The Average Mean Annual data in year 2000 are as follows:

Temperature: 25.08^{o}C

Relative Humidity: 81.24%

And from the equation DI = T - (0.55-0.0055*RH) (T-14.5)

DI = 25.08 - (0.55-0.0055*81.24) (25.08–14.5) = 23.98

From Thom's' classification of DI ranges 21 ≤ DI < 24 shows that under 50% of Population feel discomfort, and our DI for Enugu North in 2000 is 23.98, meaning that under 50% of the population feels discomfort.

While in the year 2019, the Average Mean Annual data in year 2000 are as follows:

Temperature: 26.02^{o}C

Relative Humidity: 81.39%

And from the equation DI = T - (0.55-0.0055*RH) (T-14.5)

DI = 26.02 - (0.55-0.0055* 81.39) (26.02–14.5) = 24.84

From Thom's' classification of DI ranges 24 ≤ DI < 27 shows that over 50% of Population feel discomfort, and our DI for Enugu North in 2019 is 24.84, meaning that over 50% of the population feels discomfort.

Enugu South

The Average Mean Annual data in year 2000 are as follows:

Temperature: 25.08^{o}C

Relative Humidity: 81.24%

And from the equation DI = T - (0.55-0.0055*RH) (T-14.5)

DI = 25.08 - (0.55-0.0055*81.24) (25.08–14.5) = 23.98

From Thom's' classification of DI ranges 21 ≤ DI < 24 shows that under 50% of Population feel discomfort, and our DI for Enugu South in 2000 is 23.98, meaning that under 50% of the population feels discomfort.

While in the year 2019, the Average Mean Annual data in year 2000 are as follows:

Temperature: 26.02^{o}C

Relative Humidity: 81.39%

And from the equation DI = T - (0.55-0.0055*RH) (T-14.5)

DI = 26.02 - (0.55-0.0055* 81.39) (26.02–14.5) = 24.84

From Thom's' classification of DI ranges 24 ≤ DI < 27 shows that over 50% of Population feel discomfort, and our DI for Enugu South in 2019 is 24.84, meaning that over 50% of the population feels discomfort.

4.5 Rainfall Analysis

The three local governments that make up the city center of the State had an increase in its mean annual rainfall in year 2000 and a decrease in year 2019. The rainfall data were measured in mm day-1

Mean Annual Rainfall in Enugu Metropolis		
LGA	Yr2000	Yr2019
Enugu South	8.48	4.15
Enugu North	8.48	4.15
Enugu East	8.48	4.15

Figure 4.7 Statistical analysis of Rainfall of Enugu Metropolis on 2000 and 2019

5.1 Adaptation and Mitigation strategies.

Overheating of urban areas can have serious repercussions for human beings such as a rising in the number of excess deaths for particularly vulnerable group of people, a reduction in the comfort of urban residents with further effects on their productiveness and the urban economy. There is need for adaptive and mitigation measures so as to reduce the impact of heatwave to the population.

These are the adaptive and mitigation ways suggested by which the study area can take to lessen the impacts of heatwave:

Heat Wave Warning System – to inform and alerts inhabitants of Enugu metropolis about current heat wave dangers.

Blue Roofs - water basins on top of buildings to store excess water and thus prevent flooding and, in addition, to use heat exchanger for solar heating and cooling.

Green roofs - Planting the roof of buildings with vegetation to improve the insulation, also planting green rails on new or existing rails with grass.

Afforestation - Planting trees around individual buildings, roads and parking lots to shade urban surfaces and creation of green space such as parks.

Provide community cooling centers, particularly in areas with low-income, elderly, and young populations.

Encourage energy conservation to reduce demand on electricity systems.

Proper regulations needs to be put in the city center to avoid the indiscriminate dumping of waste and blocking of drainage through disposal of waste.

Good urban planning of the city center, and gradual elimination of slumps and cluster environment, as it can leads to the generation of more heats and increase in temperature.

Building of conservative parks and construction of more water fountains in the city center.

5.2 Conclusion And Recommendation

5.2.1 Conclusion

The study has evaluated the outcome of diverse land-use/land-cover types on land surface temperatures over the Enugu metropolis. The maximum grade in NDVI was observed in 2020 with more values below 0, which is attributed to a growth in urbanization. The recent decline in apparent water results from dry weather, therefore we observed the lowest value of NDVI in 2020.1n 2000, the region exhibited positive values. The major results of the research have fulfilled the aim and objectives of this research. Through this analysis, the changing pattern of different land-use scenarios was studied. The most noticeable change was a rising style in built-up vicinity and a declining trend in vegetation cover for the research period (2000–2020). Urban growth has played a dominant role in the thermal arrangement of the Enugu metropolis causing the areas to be heater, and indicating the reality of heatwave in the research area. The surface and air temperature increased over a period of years from January 2000 to January 2020 in the Enugu metropolis which is situated in the city hub. It was revealed that the highest land surface temperature retrieved was associated with the built-up class while the lowest LST was associated with the water body. It was experiential that the vegetation type showed the low radiant temperature in all the time considered while the built-up vicinity exhibited relatively high radiant temperature in all the years.

Thermal comfort ability indicates that in 2000, Enugu East, Enugu North and Enugu South experience that under 50% of Population feel discomfort, according to Thom’s classification. While in 2019, Enugu East, Enugu North and Enugu South which makes up the city center of Enugu state, experience that over 50% of the population feels discomfort, according to Thom’s classification.

In conclusion, the research reveals that there will be possible increase in the temperature every year and making the city uncomfortable for people to dwell of live. But with proper adaptive and mitigation measures outlined, the city will be able to combat the impact of heatwave in the area. Educational and administrative awareness show be made in the aspect of deforestation and indiscriminate cutting down of tress across the city. Finally awareness of the reduction of green gas emission should be made to the inhabitants of Enugu Urban and enlighten them on possible ways to reduce the emission of green gas.

5.2.2 Recommendation

This study reveals the impact of heatwave in the Enugu metropolis and its possible solutions to mitigate it. But some of the causes and effects of heatwave as related to the health of the society are not mentioned. Proper researches should be carried out on this area as to estimate the effect on heatwave to the health of the society. Also proper researches should be carried on the green gas emissions of the state and identify the causes and the gases that heat up and increase the temperature of the state.

Abbreviations

DI
Discomfort index
ETM^+
Enhanced Thematic Mapper
IPCC
Intergovernmental Panel on Climate Change
KM^2
Square Kilometres
LST
Land Surface Temperature
LULC
Land Use / Land Cover
NDVI
Normalized Differential Vegetation Index
OLI
Operational Land Imager
POWER
Prediction of Worldwide Energy Resource
THI
Temperature Humidity Index
RH
Relative humidity
UHI
Urban Heat Island

Declarations

Ethics approval and consent to participate:

Not applicable

Consent for publication:

Not applicable

Availability of data and materials:

Landsat Satellite Imagery was acquired from United State Geological Survey Site (USGS) and air temperature, rainfall and relative humidity were acquired from Prediction of Worldwide Energy Resource (POWER).

Competing interests:

Not applicable

Funding:

Not applicable

Authors' contributions:

Various works involving the analysis and fieldwork were done by the main and co authors in this research.

Acknowledgment

The authors wish to acknowledge two sets of people, the United States geological survey (USGS) and the Prediction of Worldwide Energy Resource (POWER) for providing data used for this study.

References

Agency, U. S. (n.d.). *Climate Change: Basic Information*. Retrieved from https://www3.epa.gov/climatechange/basics/

Alexander L (2015) Introduction to heatwave indices, defining and measuring heat waves. https://www.wmo.int/pages/prog/wcp/ccl/opace/opace4/meetings/documents/ iji2015/D3-5-Alexander_heatwaves.pdf

Aslam AQ, Ahmad SR, Ahmad I, Hussain Y, Hussain MS (2017) Vulnerability and impact assessment of extreme climatic event: a case study of southern Punjab, Pakistan. Sci Total Environ 580:468–48

Balogun R, Samson A, Ajayi V (2016) Investigation of heat wave characteristics over selected stations in Nigeria. *J Geogr Environ Earth Sci Int 4(1):1–22*. https://doi.org/10.9734/JGEES I/2016/18181

Ceccherini G, Russo S, Ameztoy I, Marchese AF, Carmona-Moreno C (2016) Heat waves in Africa 1981–2015, observations and reanalysis. Nat Haz Earth Syst Sci 1 17. https ://doi.org/10.5194/nhess -2016-90

ChengJ, BambrickH, YakobL, DevineG, FrentiuFD, ToanDTT, PhamQ, Zhiwei, and Wenbiao. (2020)Heatwaves and dengue out breaks in Hanoi,Vietnam: New evidence on early warning. PLoSNegl Trop Dis 14(1):e0007997.https://doi.org/10.1371/*journal.pntd.0007997*

Elijah Adesanya & sani Ahmad *et al* (2018). Assessment of heat wave events in a changing climate over Nigeria: *international journals of research management.*

Empirical study of two UK cities, *Global Environmental Change*, 20 (2010), pp. 44–52.

Funk C., Michaelsen J. and Marshall. M. (2012). Mapping recent decadal climate variations in precipitation and temperature across Eastern Africa and the Sahel Remote Sensing of Drought Innovative Monitoring Approaches. Edited by Wardlow B. D. et al (Boca Raton, FL: CRCPress) pp 331–58.

Humer Haider (2019). Climate change in Nigeria: impacts and responses, *independent consultant.*

IPCC (2012) Managing the risks of extreme events and disasters to advance climatechange adaptation. (Press CU, Cambridge U, New York U, NY, (eds).), Intergovernmental Panel on Climate Change. https ://doi.org/10.1596/978-0-8213 8845-7

IPCC (2014) Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri RK, Meyer LA (eds.)]. IPCC, Geneva, 151 pp

Mills D.M. (2009). Climate change, extreme weather events, and US health impacts: J occup *Environ Med*, 51:26-32.

Mitchell D., 2016: Human influences on heat-related health indicators during the 2015 Egyptian heat wave. Bull. Amer. Meteor. Soc.

Nicholson S E *et al* (2013) Temperature variability over Africa during the last 2000 *years Holocene* 23 1085-94.

Nkrumah F, Ama N, Klutse B, Owusu K, Quagraine A, Adukpo DC (2011) Trends in daily extreme precipitation and temperature indices over Ghana from 1980 to 2011

Parker. (2010) urban heat island effects on estimates of observed climate change. Wiley Interdisciplinary Review: *climate change*, 1, 123-133.

Russo S, Dosio A, Graversen RG, Sillmann J, Carrao H, Dunbar MB, Singleton A, Montagna P, Barbosa P, Vogt JV (2014) Magnitude of extreme heat waves in present climate and their projection in a warming world*. J Geophys Res Atmos 119(22):12500–12512.* https ://doi.org/10.1002/2014J D0220 98

Russo S, Sillmann J, Fischer EM (2015) Top ten European heatwaves since 1950 and their occurrence in the future. Environ Res Lett 10(12):124003. https ://doi.org/10.1088/1748-9326/10/12/12400 3

Stott, P. Stone, D. A. and Allen, M. R. (2004) ‘Human contribution to the European heatwave of 2003’, *Nature,* 432, pp. 610–14.

Wolf J., Adger W. N., Lorenzoni I., Abrahamson V. and Raine R. (2010). Social capital, individual responses to heat waves and climate change adaptation: *an empirical study of two UK cities*. *Glob Environ Change*, 20:44-52.

White, B. (2010) climate change impact, adaptation and vulnerability; *Cambridge university press*: London, U.K, pp. 161-162.

Figures

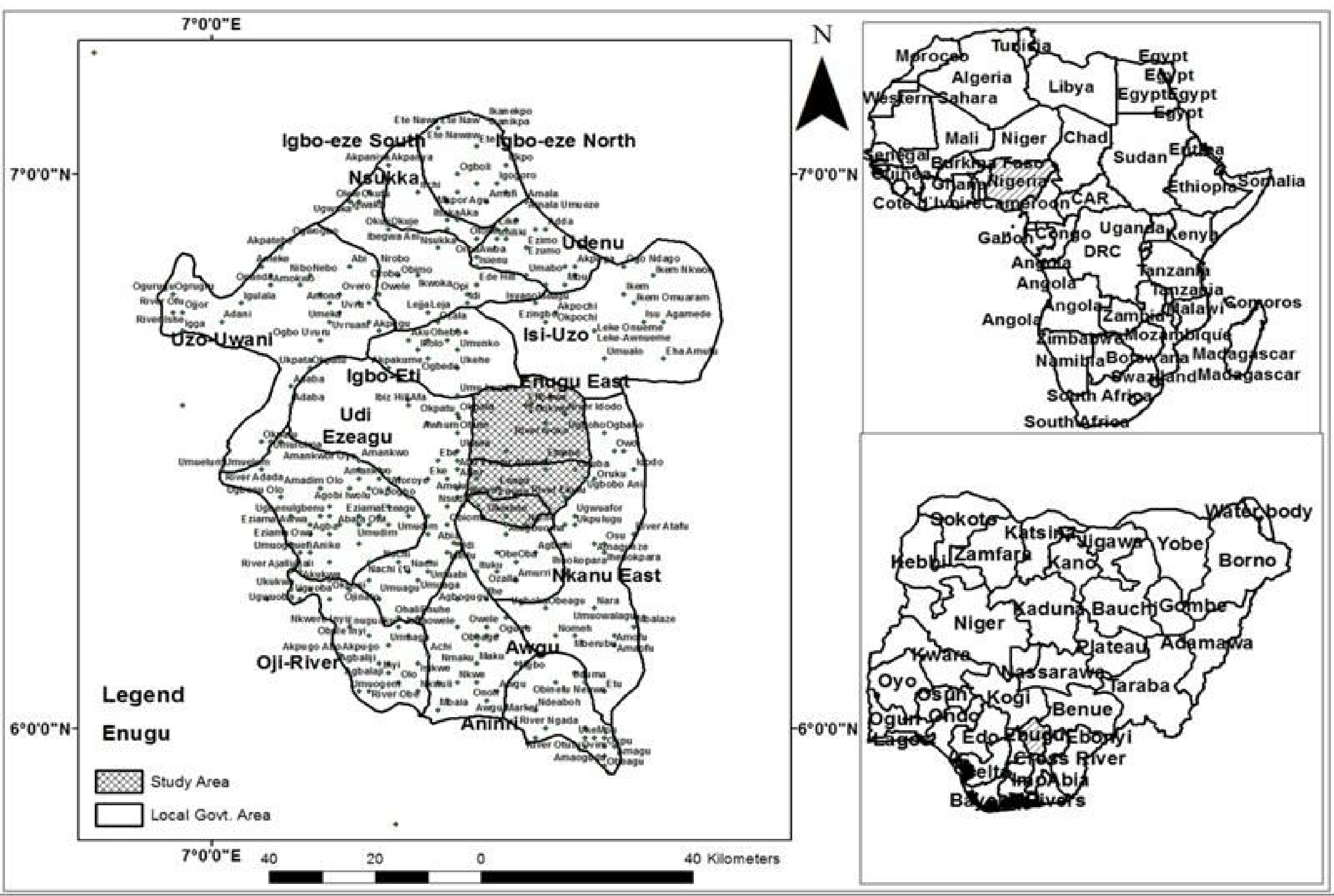

Figure 1

The study area representing the three local governments that makes up the city center of Enugu (Enugu East, Enugu North and Enugu South).

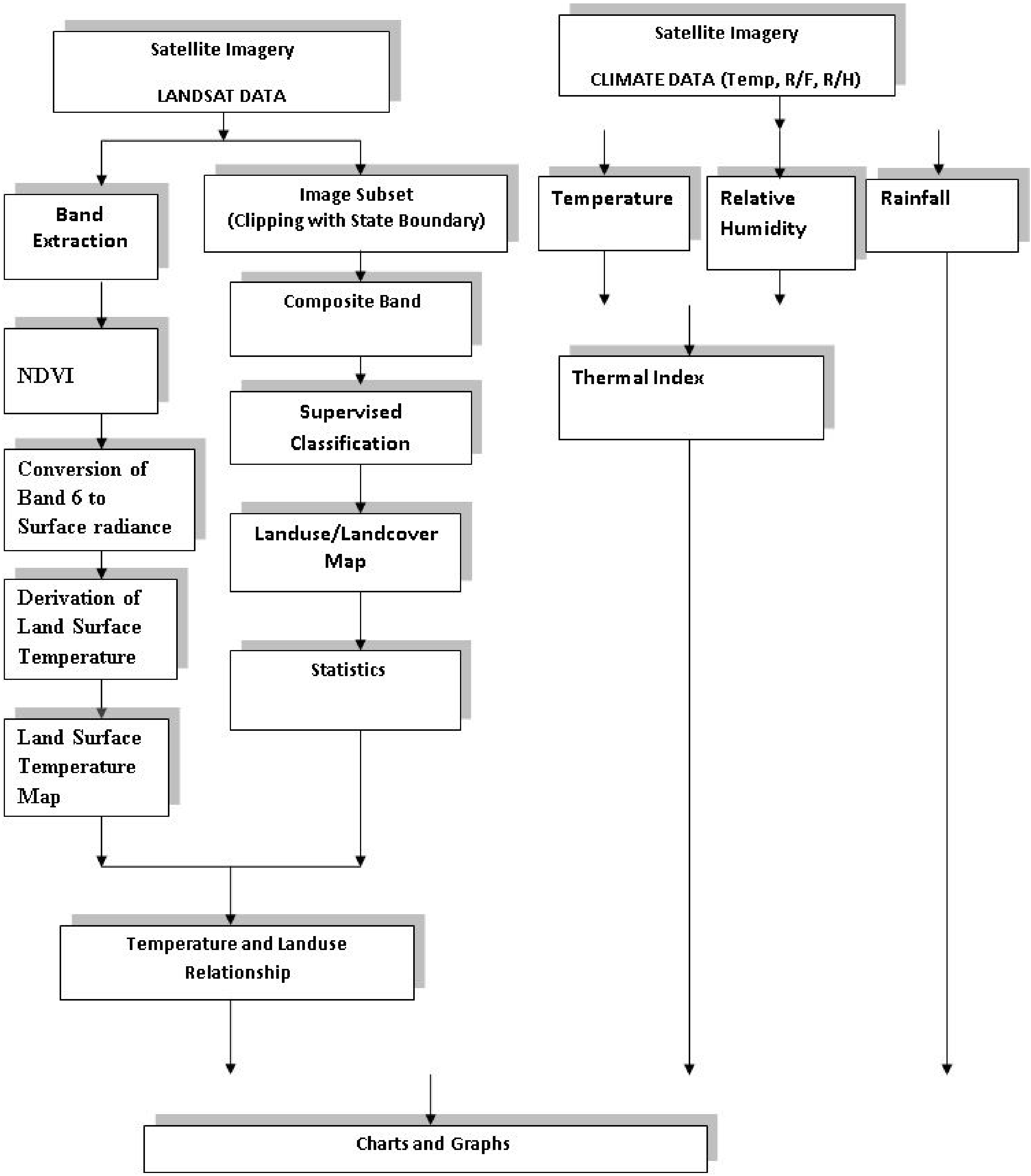

Figure 2

Charts and Graphs

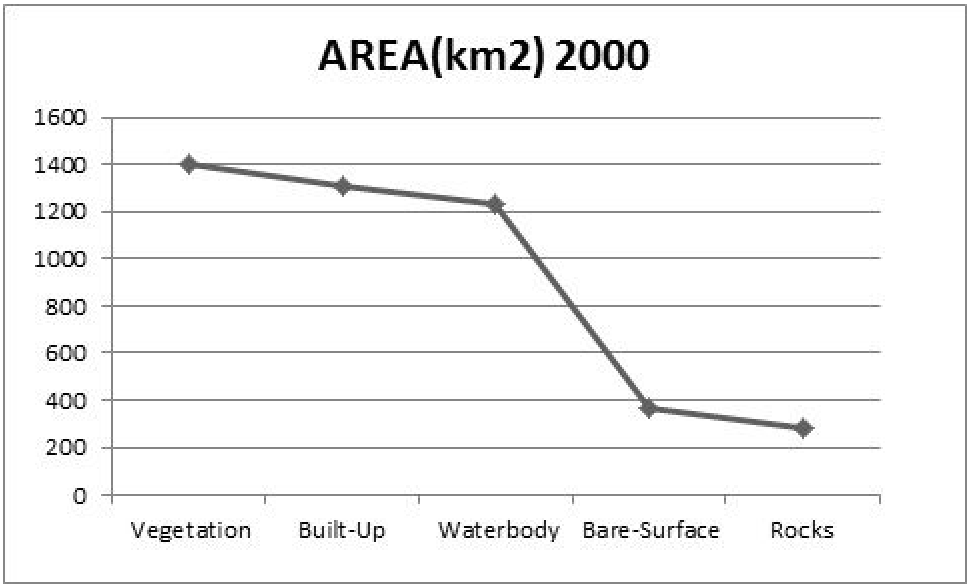

Figure 3

lulc of Enugu Metropolis 2000

Figure 4

lulc of Enugu Metropolis 2000

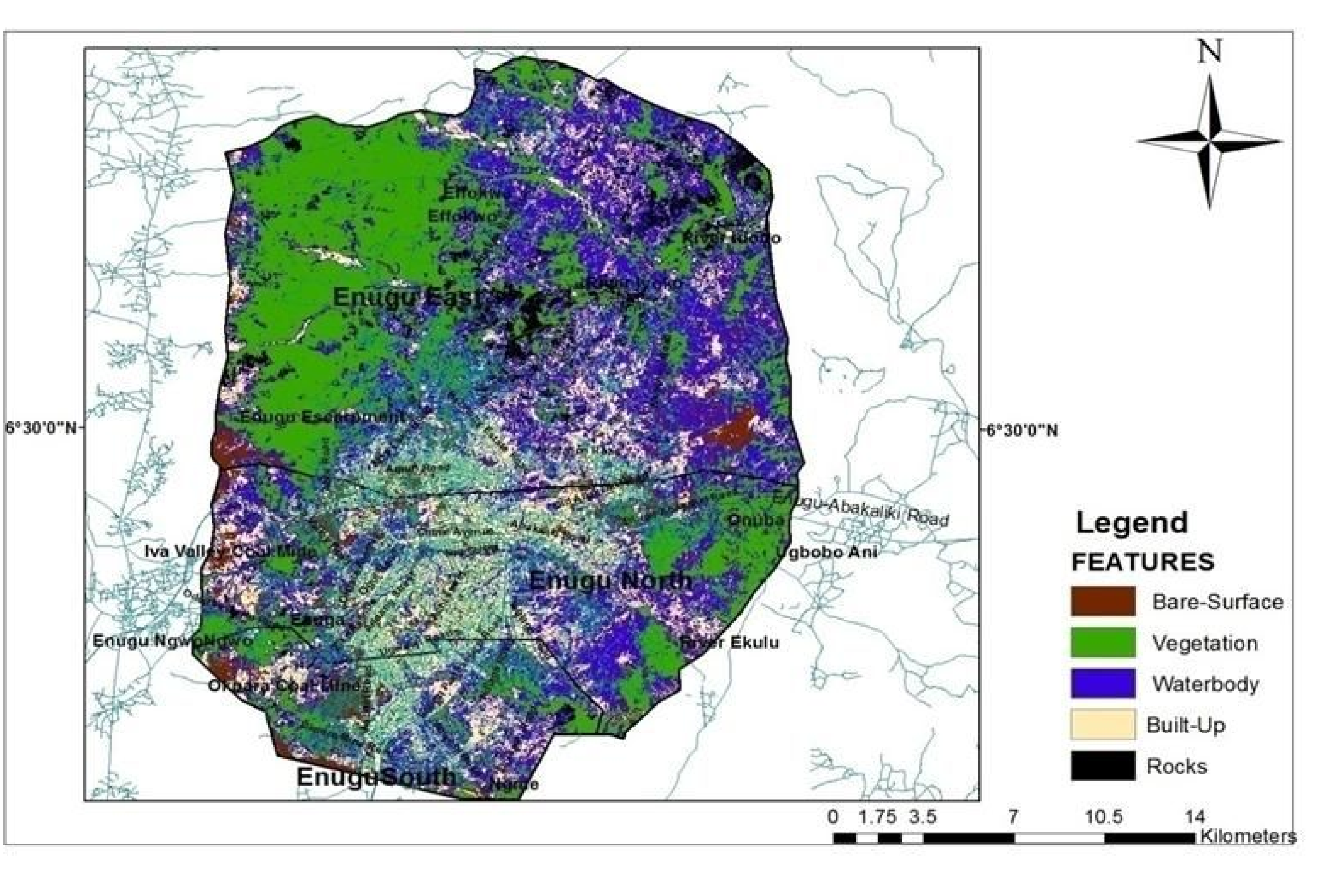

Figure 5

lulc of Enugu Metropolis 2020

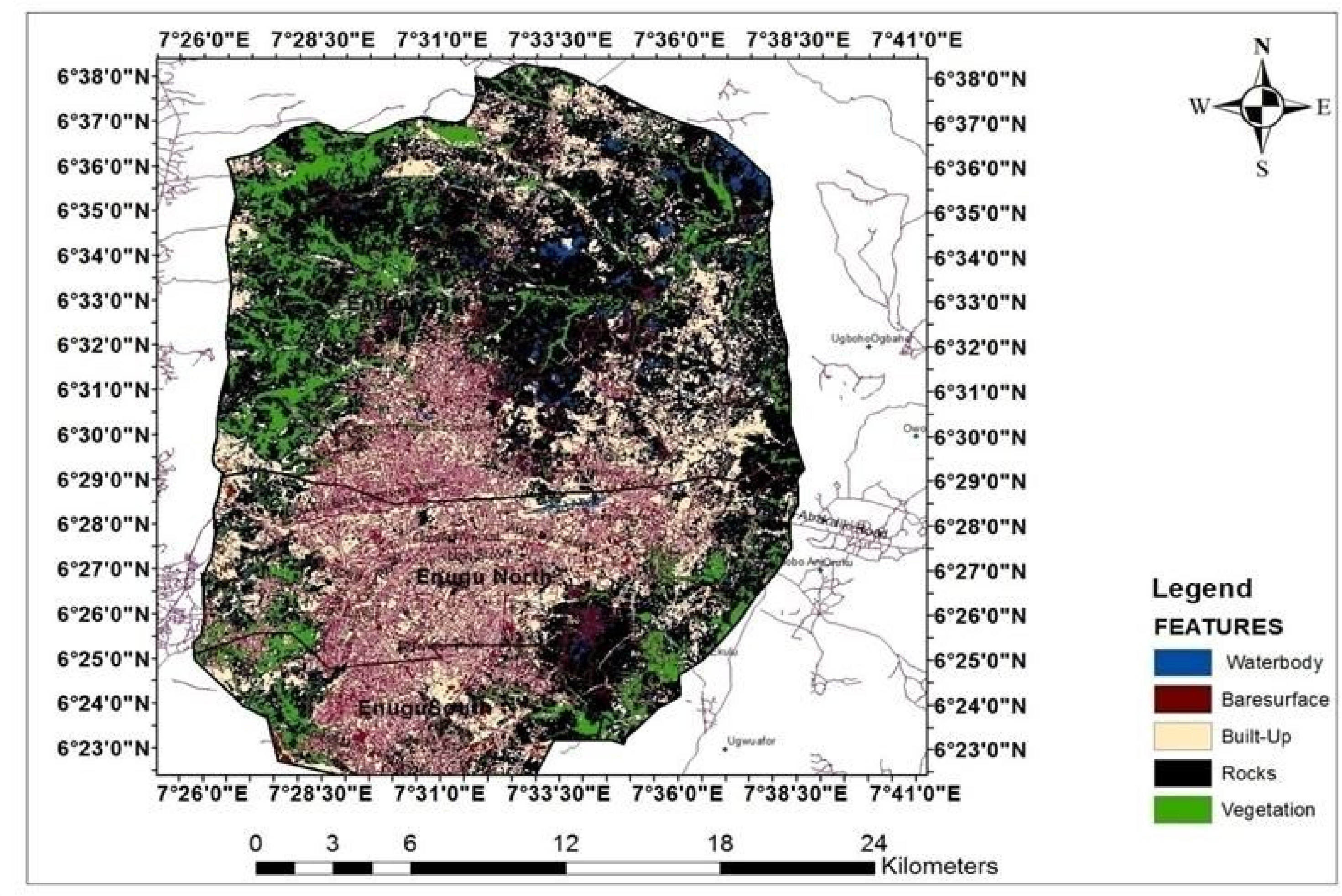

Figure 6

lulc of Enugu Metropolis 2020

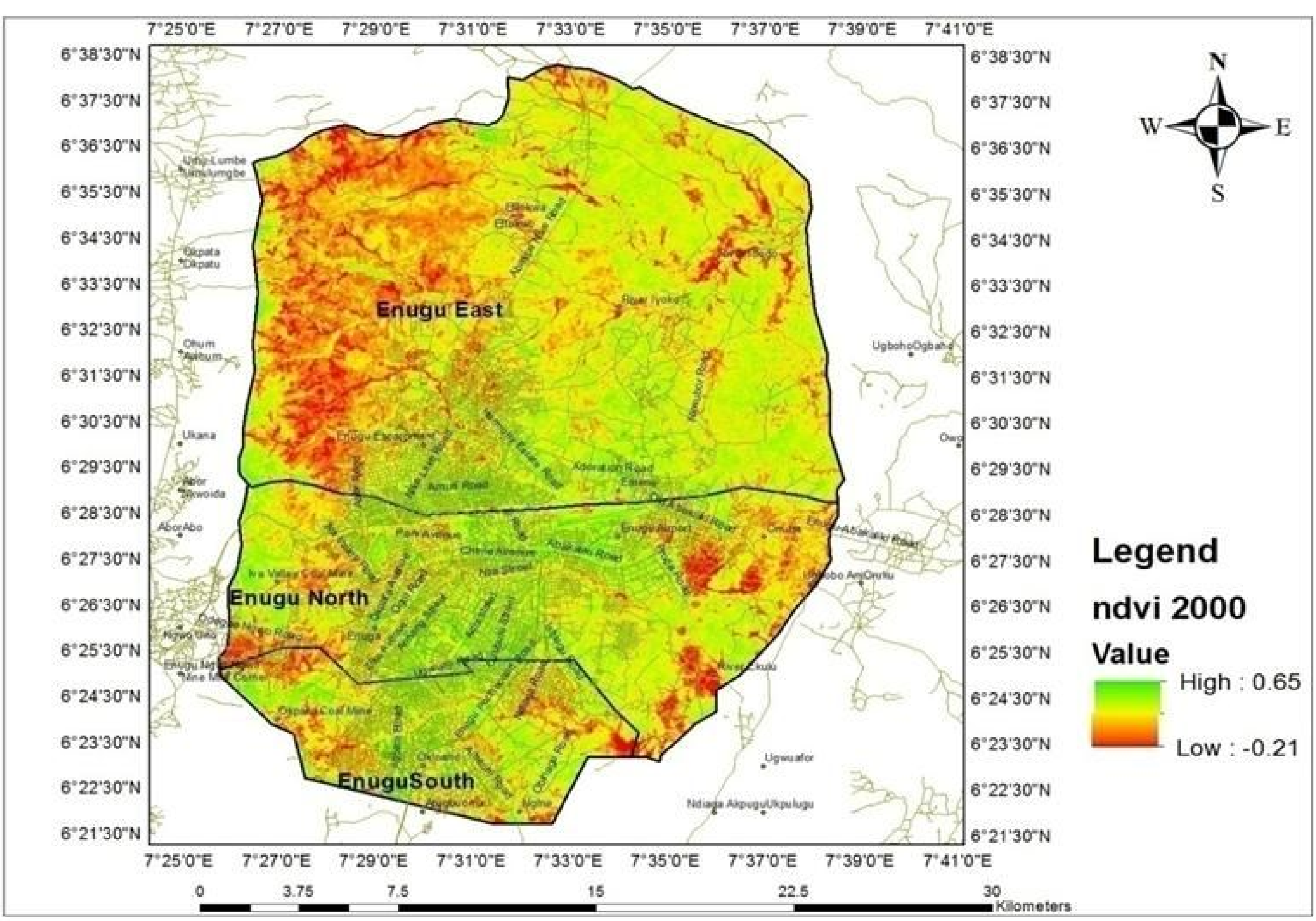

Figure 7

NDVI of Enugu Metropolis 2000

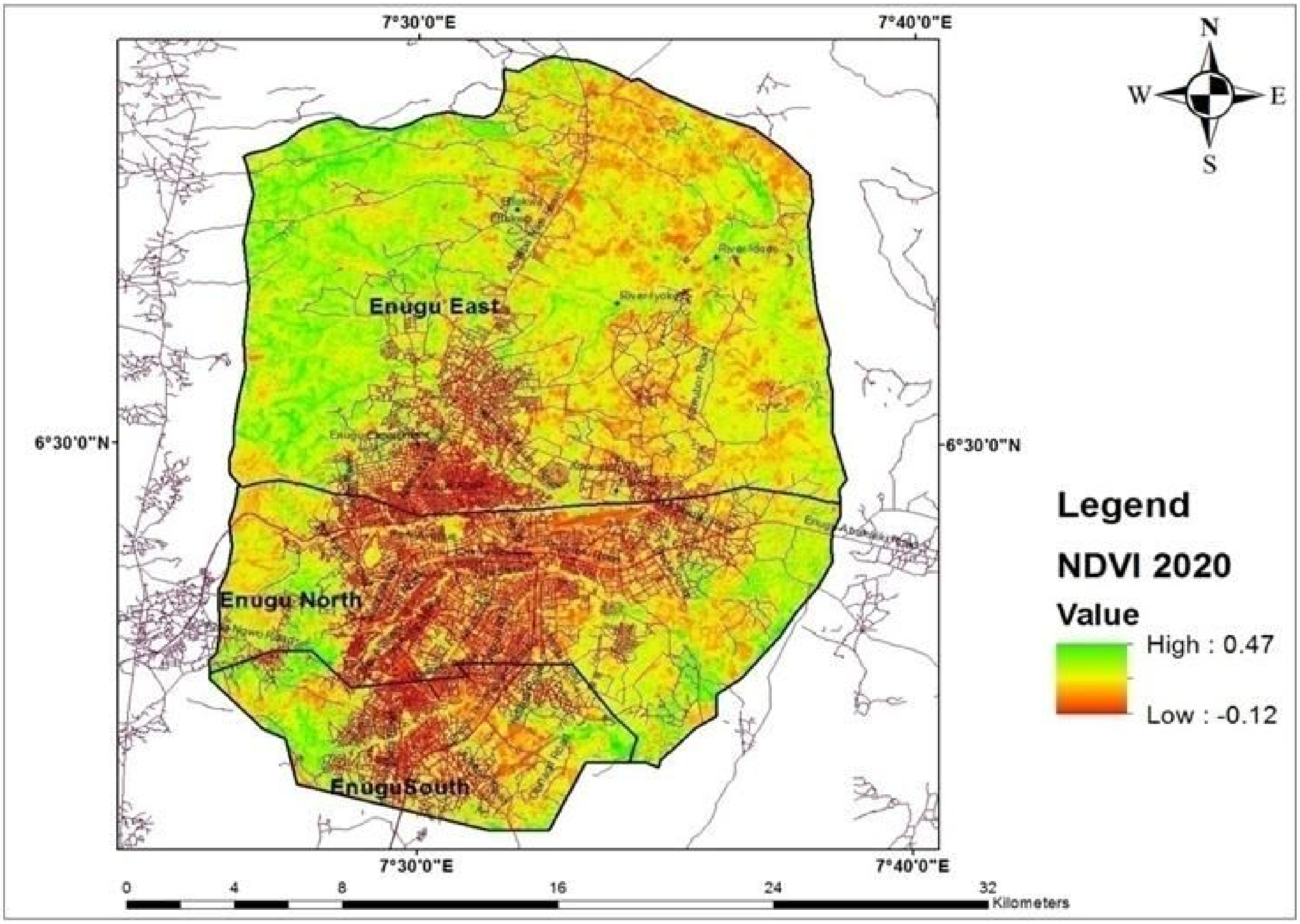

Figure 8

NDVI of Enugu Metropolis 2020

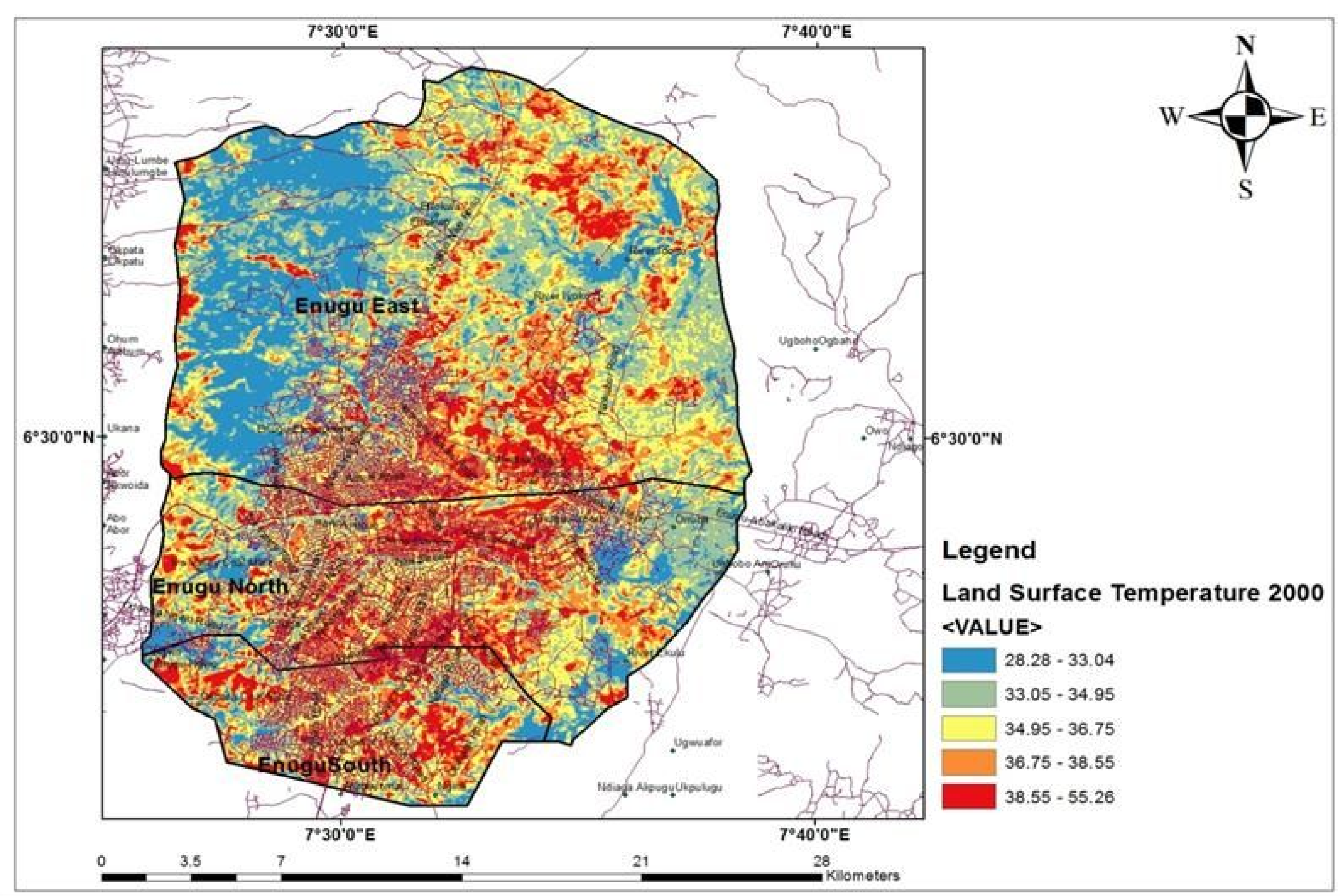

Figure 9

Land surface temperature of Enugu metropolis 2000

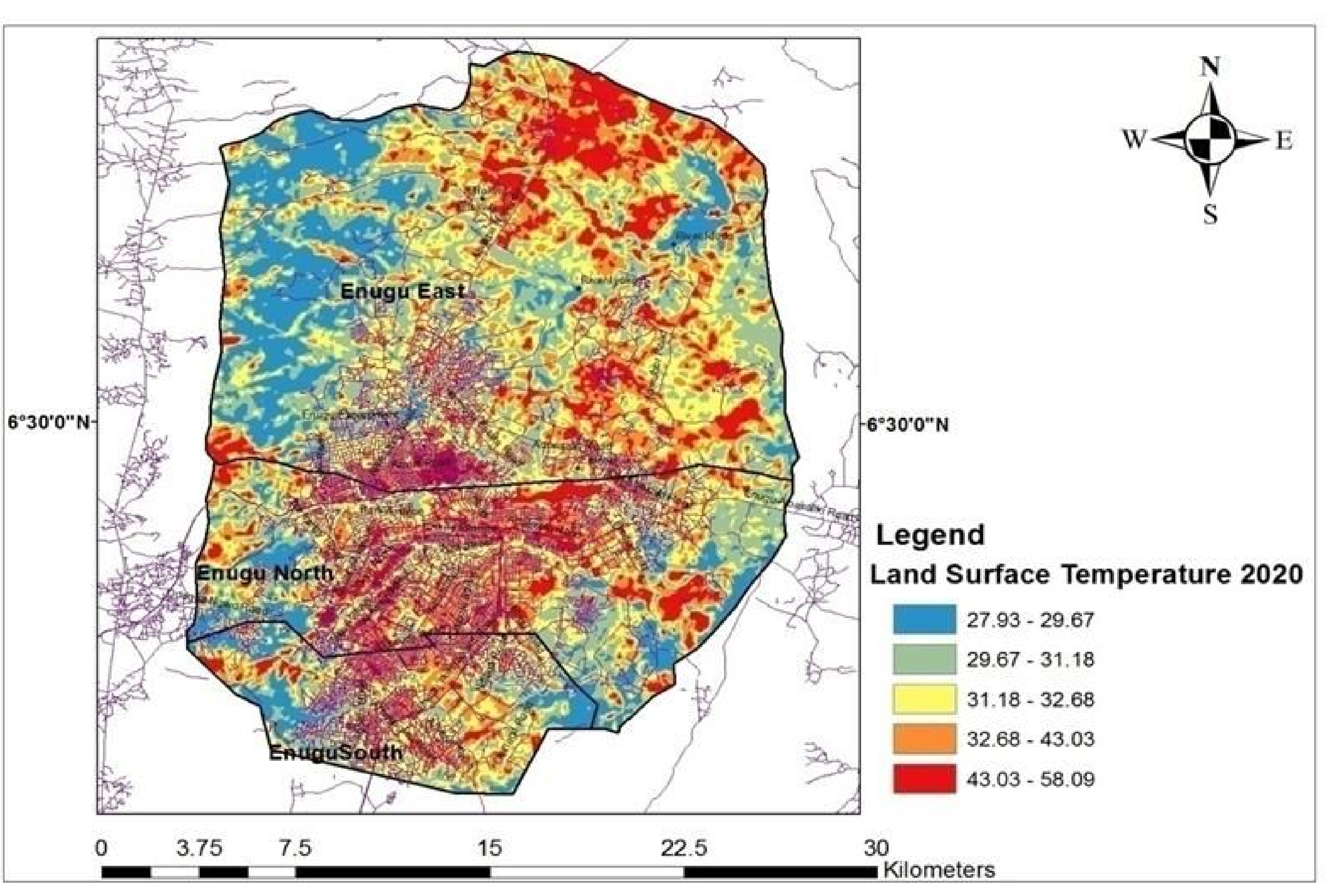

Figure 10

Land surface temperature of Enugu metropolis 2020

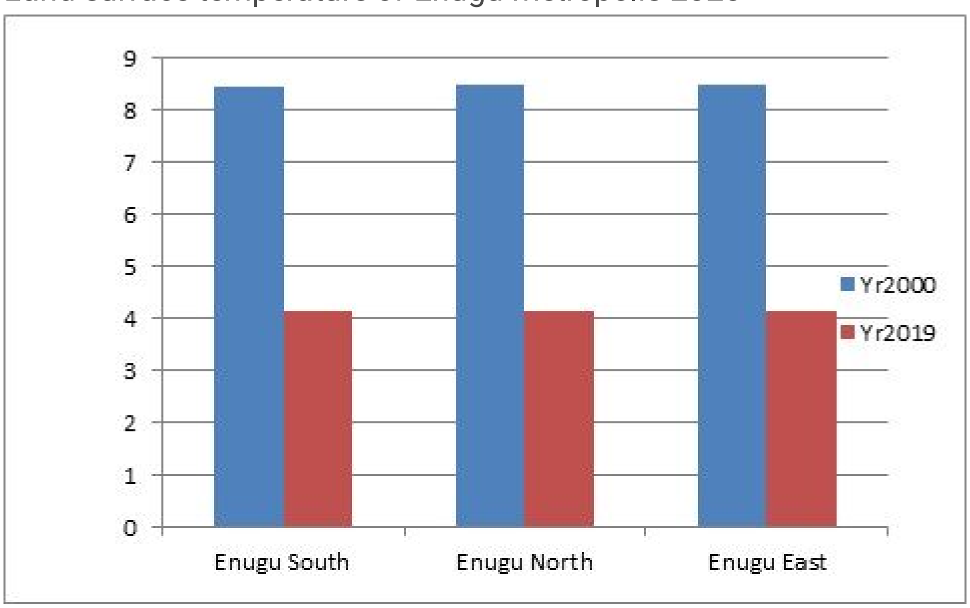

Figure 11