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ORIGINAL RESEARCH ARTICLE

Assessment of Urban Heat Island in the Federal Capital City, Abuja, Nigeria

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ABSTRACT
This study assessed the effects of Urban Heat Island in the Federal Capital City, Abuja, Nigeria. Landsat 7 ETM and 8 OLI_TIS satellite imageries of 1999, 2014, and 2019 were used to ascertain the surface temperatures, while ambient temperatures and Carbon dioxide readings were obtained using a direct field survey. These years were chosen because they align with the availability of reliable and consistent data from sources like Landsat 7 ETM and 8 OLI_TIS. Remote sensing was used for the Land Use/Land cover, Normalized Differential Vegetation Index (NDVI), and Normalized Differential Built-up Index (NDBI) respectively. Crosstab correlation was used to examine the relationship between Land Surface Temperature, Ambient Temperature, and Carbon dioxide. The highest surface temperature was found in bare land, followed by built-up areas. The City center exhibited higher temperature values than its surrounding suburb areas. There are changes in the spatial and temporal pattern of the effect because of urbanization. Findings indicated that urbanization is the leading cause of land cover change that affects surface temperatures in the study area. This is known to cause discomfort to the urban dwellers in the summertime. Alterations of surface area, improper urban planning, and air pollution, amongst others, are causing this increasingly growing phenomenon. It is accountable for human discomfort, human casualties, and global warming. Therefore, urban functions such as glass buildings, paved and impermeable surfaces, dark roofs, and thermal mass because of urbanization are the major causes of the UHI effect in the Federal Capital City (FCC). There is a need for proper urban planning by planting more trees, using high albedo surfaces, initiating policies and sensitization on local climate change for sustainable development.

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INTRODUCTION

In most large cities, the temperature at the city's heart or center is higher than its surroundings or the suburban area. The phenomenon is called the Urban Heat Island (UHI) effect (Adinna *et al*., 2009; Synnefa *et al*., 2008). In other words, cities demonstrate greater temperature in their center than the surrounding rural areas, known as the Urban Heat Island (UHI) effect (Yamamoto, 2006). A temperature difference often develops between cities and their surrounding suburbs (Yamamoto, 2006), which causes discomfort to city dwellers. When a huge amount of natural land is replaced by an artificially built surface that absorbs incoming solar radiation or heat and re-radiates it at night, it develops UHI (Oke, 1982; Quattrochi *et al.,* 2000). The phenomenon exists in almost every big city with numerous factors that are held accountable for this effect, including anthropogenic heat release, surface cover, climatic conditions, and air pollutants. (Yamamoto 2006). According to Oke (1982), UHI may be up to 10-150C under proper conditions. As a consequence of the microclimate created by the UHI, the demand for energy to cool buildings increases (Adinna *et al.* 2009).

Furthermore, to meet the demand, more power is needed, which results in increased greenhouse gas emissions and a decline in climate. One of the vital reasons for the formation of UHI is the large number of built-up surfaces like concrete and asphalt with a high heat capacity (Akbari *et al*., 2001). Low albedo materials are further contributing to worsening the phenomenon. According to Taha (1997), when non-reflective and water-resistant, impervious materials at the surface take the place of natural vegetation, Urban Heat Island is created. It is a process that varies with a metropolitan area's built regions and geographical conditions (Grimmond and Oke, 1991). Another reason to exacerbate the Urban Heat Island effect is the improper planning of cities (Li *et al*., 2013). Taha (1997) reported that air pollutants from industrial processes, power plants, exhaust gases from vehicles, and

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anthropogenic heat may add to the intensity of the UHI effect. According to Akbari *et al.* (2001), the demand for electricity rises from 2-4% for every 1°C rise in temperature. In a typical urban area, surfaces are darker, and vegetation is less than its surroundings. The temperature difference of a typical city with its' surrounding rural areas may be as much as 2.5°C in a warm summer daytime, which may cause for additional 5-10% municipal peak electricity demand (Akbari *et al.,* 2001). However, in the winter, as it is cold in the environment, the UHI effect plays a positive role for city dwellers by providing them with warm air (Voogt, 2003; Mobaraki, 2012). However, it has a negative effect in the summertime on the comfort of human health and energy consumption both day and night. A study in Markurdi, Benue State, examined the surface urban heat island effect, providing insights into the relationship between land use patterns and urban heat islands (Abah, 2012). The interactions of urban surfaces with the atmosphere are governed by surface heat fluxes, the distribution of which is drastically modified by urbanization. Urbanization has changed the city environment greatly, owing to the replacement of vegetation by asphalt and concrete and the increase in population and anthropogenic heat (Zhang and He, 2006). Consequently, estimating surface temperature (ST) and Ambient Temperature are key steps in analyzing urban heat islands, which necessitated the research work. This study focuses on the Federal Capital City, one of the fastest-growing cities in Sub-Saharan Africa. The study area is part of the Federal Capital Territory (FCT), Abuja, which falls within latitude 7° 25' N and 9° 20' North of the Equator and longitude 6° 45'E and 7° 39' East (Figure 1). It covers an area of about 8,000 square kilometers (FCDA, 1998). Abuja, under the classification, features a tropical wet and dry climate. This includes a warm, humid rainy season and a blistering dry season. In between the two seasons, there is a brief period of harmattan occasioned by the northeast trade wind, with the main feature of dust haze, intensified coldness, and dryness (GEO-UNESCO, 2011). About 1469mm and 57.8 inches of precipitation fall annually within the study area (Nimet, 2019). The warmest month is in March, with an average maximum temperature of 37°C, and the coldest month is in December, with an average maximum temperature of 29°C. Mean monthly temperatures range from 25.8oC to 30.2oC (Nimet, 2019), with an average maximum temperature of 290C and mean monthly temperatures from 25.8°C to 30.2°C (Nimet, 2019).

Ayedun *et al.* (2011) reported that the advent of petroleum in the Nigerian economy in the late 60s and early 70s brought advantages. The main benefits were increased government revenue, a noticeable rise in industrial investment in the public and private sectors, a balance of payment surplus, growth in construction industries, rapid urbanization, and ostensible educational, health, and infrastructural development advancement. In fact, by the time the Third National Development Program was launched in 1973, it was said that money was no longer a problem in the economic development of Nigeria but how to manage it. The era of numerous creation of states and local governments in Nigeria has resulted in unprecedented acceleration of urbanization processes in all state capitals nationwide to the extent that it is feared that city dwellers in the country have outnumbered those residing in the rural areas, and yet many more people are still desirous of moving into cities in search of paid employment (Ayedun *et al.,* 2011).

The Federal Capital City, like most urban centers in sub-Sahara Africa, is experiencing high rates of urbanization due to the increasing population densities (consequence of the natural population increases and migration) and the inevitable natural phenomenon of spatial growth with resultant rampant changes in the use of land and buildings. The urbanization process of the FCC provides a unique character of a rural-urban transformation ignited by a political transformation that combined both socio-economic and spatial growth rapidly. As a result, the unbuilt land in/ around is gradually converted into a built-up environment containing buildings and other related physical structures such as roads. As such, the city center has been experiencing higher temperatures than its suburbs, forming an Urban Heat Island.

According to Bhatta (2010) increase in temperature in urban areas is caused by two factors. First, dark surfaces such as roadways and rooftops efficiently absorb heat from sunlight and reradiate it.

In addition to the local climate, which is influenced by various meteorological parameters such as temperature, relative humidity, and wind, a number of anthropogenic causes promote the emergence and intensification of urban heat islands. These causes are greenhouse gas emissions, gradual loss of urban forest cover, the impermeability and low albedo of materials, the thermal properties of materials, urban morphology, cities' size, and anthropogenic heat.

RESEARCH METHODOLOGY

To gather primary data, ambient temperature and land surface temperature readings and CO2 levels were obtained using specialized instruments and direct field surveys. A pSense High Accuracy Portable CO_2 meter (Model AZ-0002-DL) was used to measure air temperature and CO_2.

The secondary data source was obtained through Landsat 7 ETM and 8 OLI_TIS satellite imageries to ascertain the surface temperature of the study area's land use/land cover. Also, annual rainfall data for 1999-2019 were obtained from Nigeria Meteorological Agency (NIMET).

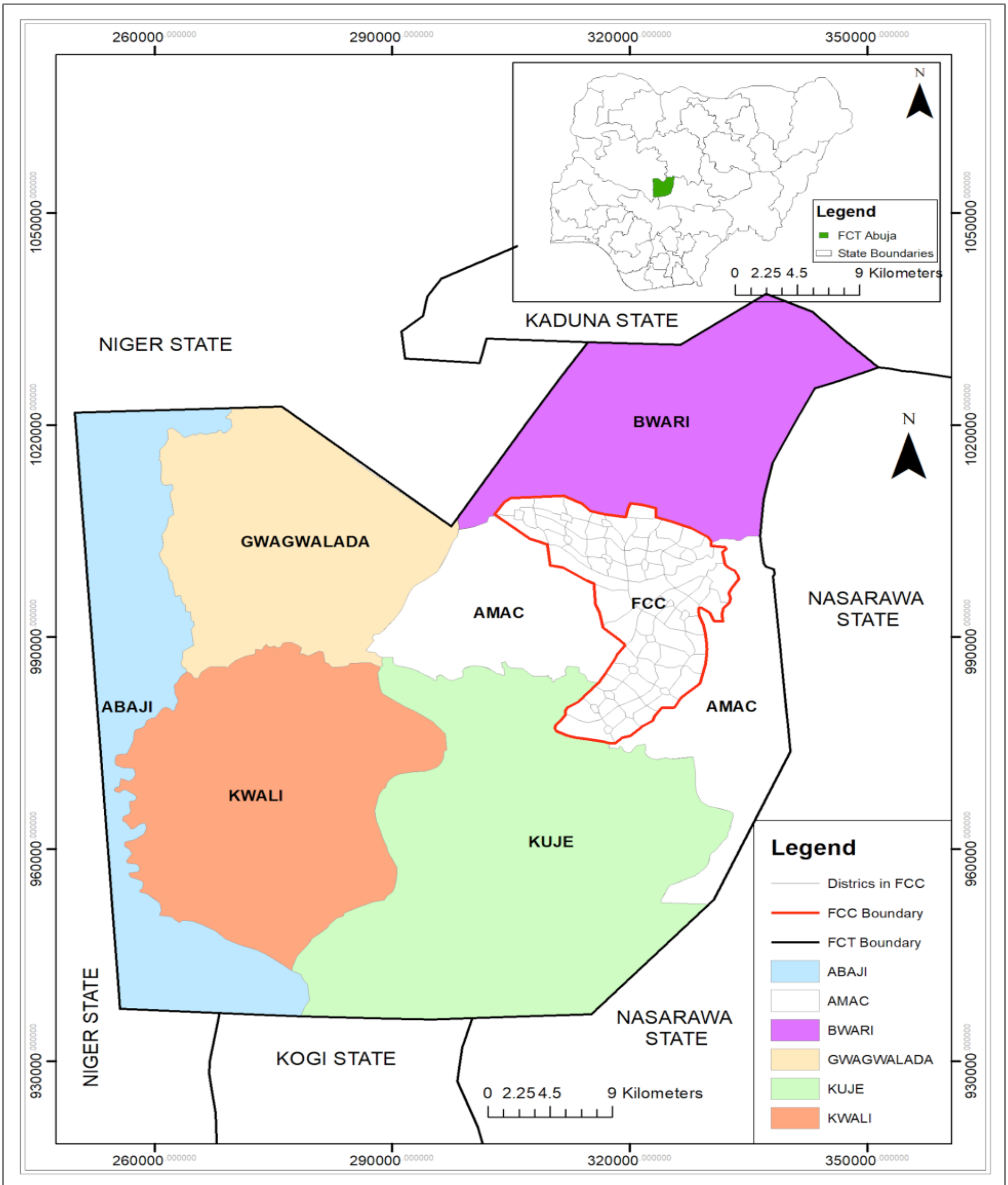

Figure 1: The Study Area

RESULTS AND DISCUSSION.

Table 1 reveals that Guzape (control point) recorded a mean minimum ambient temperature of 24.88°C with a corresponding land surface temperature of 26.98°C and 449.50 for CO_2ppm. Conversely, Jabi exhibited the highest maximum ambient temperature of 36.88°C with a corresponding land surface temperature of 35.64°C and 529.00 ppm for CO_2, respectively. The ambient temperature ranged from 11.925°C and a mean of 30.63°C, whereas the corresponding land surface temperature range is 8.66°C and a mean of 30.64°C. Similarly, CO_2 has a range of 79.5 ppm and a mean of 472.16 ppm.

Notably, Jabi, Gudu, Wuse2 (Banex), and Garki Area 11 displayed elevated temperatures and higher Carbon dioxide levels. This correlation can be attributed to the intense anthropogenic activities within these areas. As a greenhouse gas, Carbon dioxide contributes to increased temperatures.

In contrast, Guzape and Durumi (control points) exhibited relatively lower temperatures and less carbon dioxide. These areas retain more natural vegetation and human induced green spaces characterized by reduced anthropogenic activities.

This study highlights the strong correlation between land surface and ambient temperatures as separate environmental variables that are highly correlated when observed within the exact locations.

Land use/land cover data was extracted from Landsat satellite imageries of the study area for 1999, 2014, and 2019. Supervised classification with maximum likelihood algorithm categorized the areas into four land classes: built-up regions (elements of urban/rural settlements such as buildings), bare land (areas with no dominant vegetation, all other surfaces such as open space with bare soil and rocks), vegetation (trees mixed with grasses) and water body (lakes and other water bodies).

Table 2 summarizes the total land area for each land use land cover class across the study area in hectares and their corresponding percentages.

The findings from Table 2 indicate that the vegetation area occupied 12782.25 ha (73.81%) in 1999, 9177.12 ha (52.99%), and 60.4737 ha (34.92%) in 2014 and 2019. Built-up has 4172.04 ha (24.12%), 6176.79 ha (35.68%), and 85.4703 ha (49.36%) in 1999, 2014, and 2019. The water body has 148.41 ha (0.85%), 121.86 ha (0.7%), and 1.3167 ha (0.76%) in 1999, 2014 and 2019. Bare land occupied 212.94 ha (1.22%), 1839.87 ha (10.63%), and 25.8957 ha (14.96%) in 2014 and 2019, respectively.

There was a decrease in vegetation over the research study period; this can be attributed to rural urban migration as vegetation gradually transitioned into urban/built-up areas. Vegetation features the largest land cover transition into urban/built-up areas from 1999-2019. However, while vegetation was decreasing, built-up was on the increase, this is no surprise as the change in this land cover type can easily be attributed to the influx of people within the city center. Also, past and current urban developments are concentrated within the Federal Capital City, which triggers higher urban functions, hence this increase.

Bare land also increased within the years of this research study; this might be due to the Federal Capital Development Authority's (FCDA) policy of demolishing several built-up areas and leaving some areas bare to fit into the Abuja master plan.

Table 1 Mean Ambient Temperature, Carbon Dioxide, and Land Surface Temperature.

LOCATION	Ambient Temperature (°C)	Carbon dioxide (ppm)	Land Surface Temperature (°C)
GARKI AREA11	30.33	459.50	30.06
WUSE2(BANEX)	33.75	462.75	32.06
DURUMI(CONTROL POINT)	25.35	451.25	27.06
GUDU	32.80	481.00	32.052
JABI	36.68	529.00	35.64
GUZAPE(CONTROL POINT)	24.88	449.50	26.98

Table 2: Land Use Land Cover Statistics for the Years 1999, 2014 and 2019

Class	1999		2014		2019	
Land cover type	(ha)	%	(ha)	%	(ha)	%
Vegetation	12782.25	73.81	9177.12	52.99	60.4737	34.92
Built-Up	4172.04	24.12	6176.79	35.68	85.4703	49.36
Water Body	148.41	0.85	121.86	0.7	1.3167	0.76
Bare Land	212.94	1.22	1839.87	10.63	25.8957	14.96
Total	17315.64	100	17315.64	100	17315.64	100

Table 3 Cross tabulation analysis for the relationship between Ambient Temperature, land Surface Temperature and Carbon dioxide.

	Ambient Temperature	Land Surface Temperature	CO_2
Ambient Temperature	1		
Land Surface Temperature	0.393	1	
CO_2	0.374	0.574	1

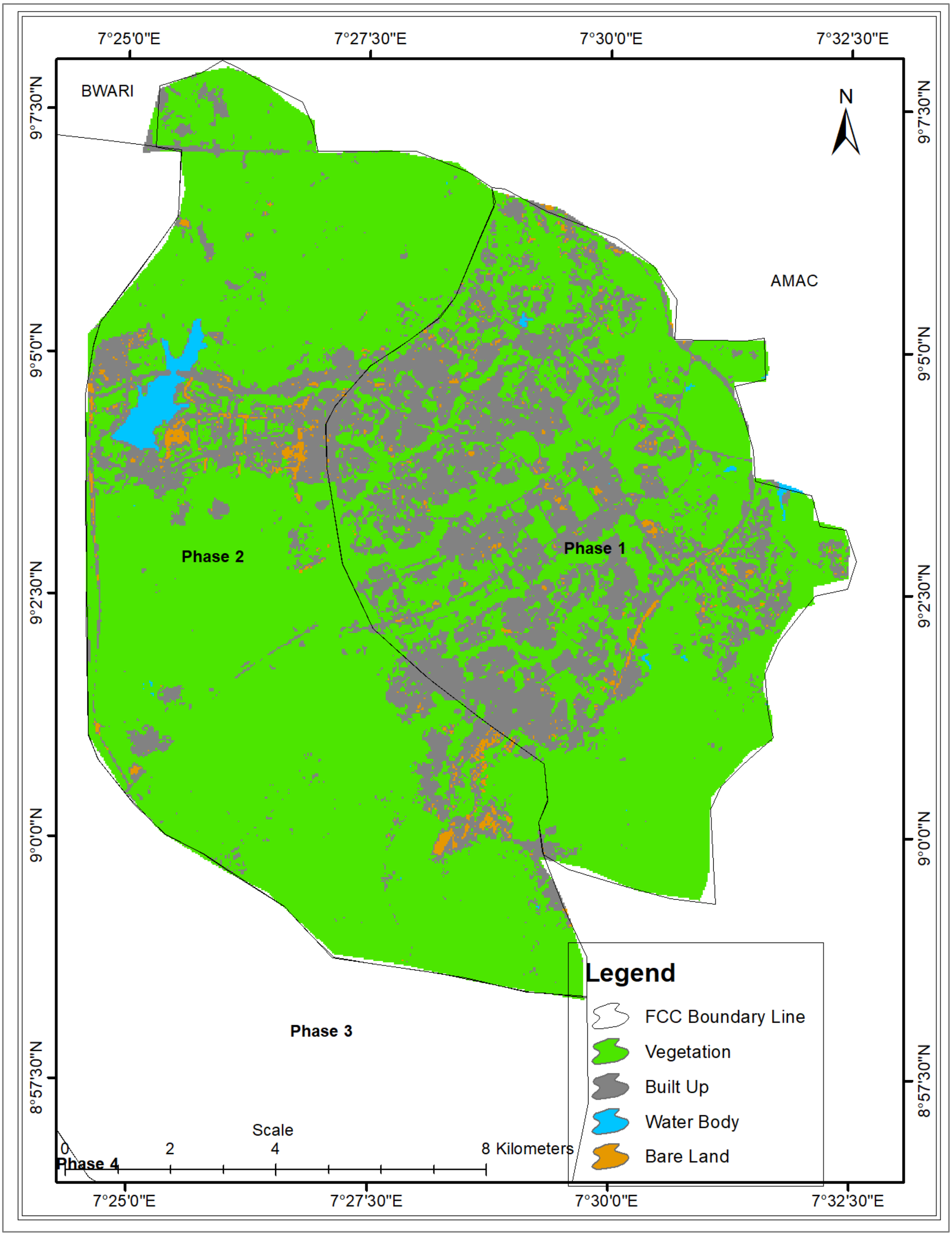

Figure 2: Land Use/Land Cover Map of the Study Area (1999)
Source: Author's Landsat Imagery Analysis, 2020

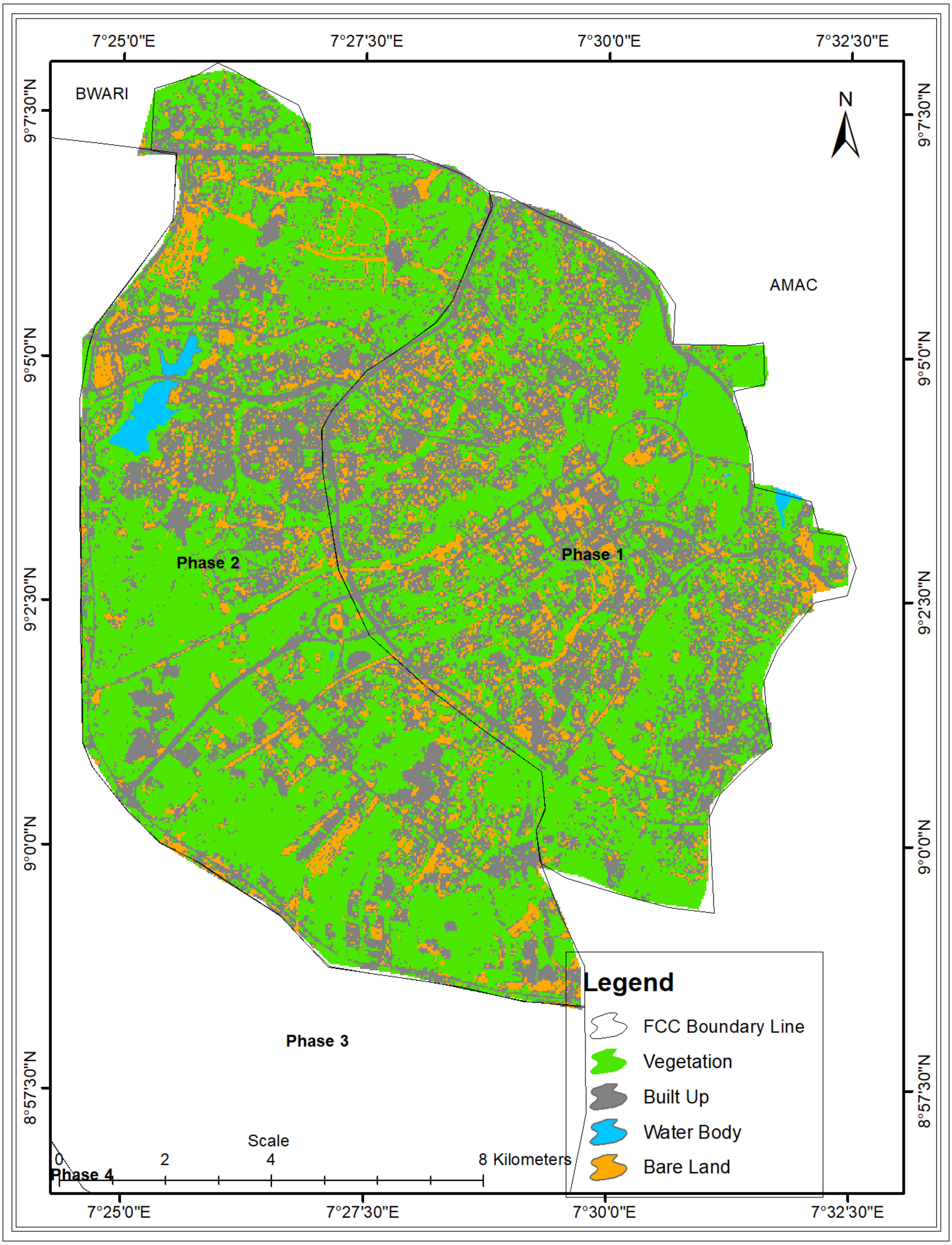

Figure 3: Land Use/Land Cover Map of the Study Area (2014)
Source: Author's Landsat Imagery Analysis, 2020

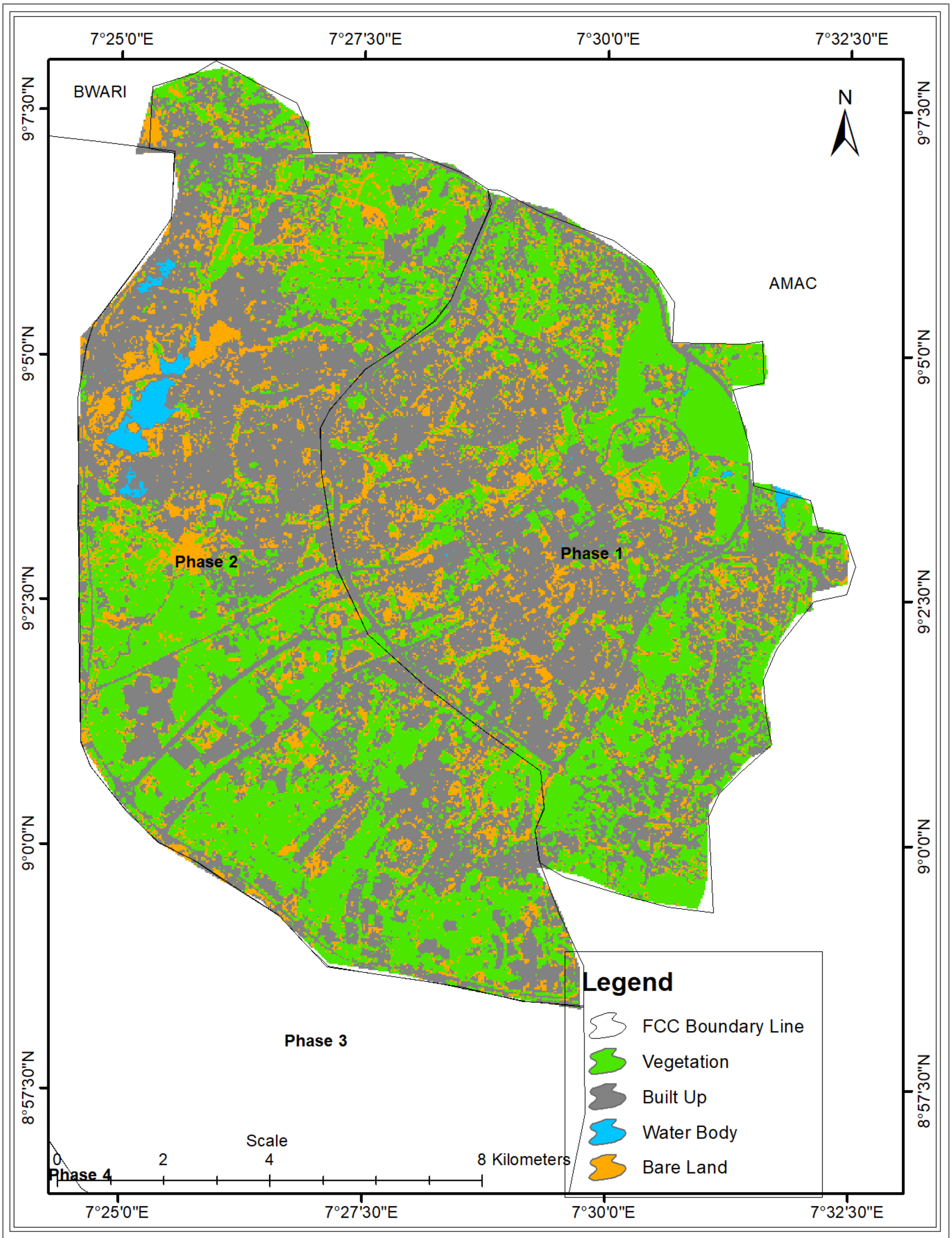

Figure 4: Land Use/Land Cover Map of the Study Area (2019)
Source: Author's Landsat Imagery Analysis, 2020

To examine the relationships between land surface temperature, ambient temperature and carbon dioxide, crosstab correlation was used. The results are as shown in Table 3.

The relationship between ambient temperature and land surface temperature shows a positive relationship with a value of 0.393, while the relationship between ambient temperature and carbon dioxide equally shows a positive relationship with a value of 0.374. The relationship between land surface temperature and carbon dioxide shows a strong positive relationship with a value of 0.574. In this research, classified Landsat 7 ETM and 8 OLI_TIS imageries were used to identify the four land cover types. These are vegetation, bare land, built-up, and water bodies. Vegetation was the major land cover type in 1999, covering about 73.81% of the total land area; water bodies had the minor land cover type in the same year, constituting about 0.85%. Although vegetation coverage declined from 52.99% in 2014 and 34.92% in 2019, it remained the dominant land cover type over the 20 years. This can be attributed to replacing cleared natural vegetation with newly planted ones, such as grasses, flowers, and trees along the roads and in houses. Built-up areas experienced an increase, rising from 24.12% in 1999 to 35.68% in 2014 and 49.36% in 2019, respectively. This change can be attributed to the rural-urban migration within the city center in search of white-collar jobs.

Analysis of 1999 and 2019 images revealed significant land cover changes over time, driven by population growth. Also, vegetation areas were converted to built-up areas, indicating rapid expansion of the study area between 1999-2019.

Some parts of the study area that were initially dominated by vegetation with few buildings changed due to population growth and urbanization. The built-up in the study area includes commercial, administrative, and residential areas. As a result of increased human activities, bare land also risen from 1.22% to 10.63% and 14.96% in 1999, 2014, and 2019 respectively. Areas like Guzape, Durumi and some parts of Gudu that were initially dominated by natural vegetation began to expand and have become residential and commercial areas. Therefore, vegetation areas were lost as a result of urbanization. With the exception of bare land, other land covers decreased because of urban expansion. This shows that the Federal Capital City (FCC) is one of the world cities experiencing high UHI.

The Federal Capital City, like most urban centers in sub-Sahara Africa, is experiencing high rates of urbanization due to the increasing population densities (consequence of the natural population increases and migration) and the inevitable natural phenomenon of spatial growth with resultant rampant changes in the use of land and buildings. The UHI is the resultant impact of these rapid urban growths within the city center. As a result, the unbuilt land in/ around is gradually converted into a built-up environment containing buildings and other related physical structures such as roads. All these distort the natural environment, which leads to UHI.

Statistics show that more than half of the world's population lives in urban areas (United Nations, 2011; Uysal *et al.,* 2015). This result concurs with the findings of Ayedun *et al.* (2011), who conducted a similar study in Nigeria. They found out that the era of numerous creations of states and local governments in Nigeria has resulted in unprecedented acceleration of urbanization processes in all state capitals nationwide to the extent that it is feared that city dwellers in the country have outnumbered those residing in the rural areas and yet many more people are still desirous of moving into cities in search of paid employment which in turn leads to UHI.

CONCLUSION AND RECOMMENDATIONS.

This study assessed the effect of Urban Heat Island within the Federal Capital City (FCC), Nigeria. Results from the images indicated that urbanization is the primary cause of Urban Heat Island. The City Center exhibits higher surface temperature than the surrounding residential areas (control points) forming UHI. The spatiotemporal pattern of LST effects increased due to urbanization or urban growth. This is to say that there is a relationship between urbanization and temperature and there is also a relationship between vegetation and UHI mitigation.

The LST effect was examined in the FCC by extracting the LST from the imageries. It revealed that bare land has the highest temperature, followed by built-up areas. The City Centre exhibited higher amounts of temperature and carbon dioxide than its surrounding suburb areas, showing the UHI effect. There is also an increase in the surface temperature in all land cover classes because of global warming. The relationship between Ambient temperature, land surface temperature and Carbon dioxide was also analyzed using cross-tabulation analysis. The results showed a positive relationship.

Urban Heat Island-related policies such as using high albedo materials, indiscriminate cutting down of trees, and encouraging planting more trees should be implemented. Sensitization on the impacts of human anthropogenic activities on the environment will also help to achieve sustainable urban development. There is a need for proper urban planning to reserve some parts of the metropolis as "green areas." This will provide a cooler microclimate through evapotranspiration. Policies that would reduce the emission of greenhouse gases should be implemented.

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