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Urban Heat Island: Challenges, Adaptation AndMitigation Measures For Sustainability In Ondo State, Nigeria

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Abstract
Despite the increasing knowledge of the consequences of climate change and global warning, urban micro climate is increasing on daily basis. This significant change is brought about by rapid urbanization and increased industrialization over the years. This experience has been aggravated through the depletion of urban green belts, increase in automobile and paved spaces among others. It is in light of this background that this paper focused on alleviating urban heat island through inclusive green economy for urban comfortability. The paper examined urban hike in temperature with a view to ameliorating it through the adoption of green economy towards attaining human betterment in the 21st century. The study adopted measurement and comparative approach in ascertaining disparities in average temperature in the study area over a given period of time after proper delineation of the area. Field surveys were conducted in and around Akure and surface temperature data were gathered using thermometers at a number of predetermined locations with the aid of polygon approach. The study revealed differential in average temperature range across the study area; rapid wear and tear of asset was also observed in the down town compared to urban fringe of the study area, increased cost of maintenance in the urban area was revealed, poor government regulations and inadequate public sensitization on the relevance of green cities. In view of the above findings, the study recommended aggressive tree planting across the city, review of government policy with respect to urban deforestation, public enlightenment campaign and adequate funding of the concerned agencies of government towards enhancing green cities for better livelihood.

Key words*: Environmental quality, Relative humidity, Surface temperature, Energy Consumption, Intensity, Green infrastructure*

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I. Introduction

Urban development has great impact on the global environmental quality, including the quality of land, air, water and atmospheric temperature.With global assessment of urban growth, there are speculations that through rapid urbanization, the population living in urban areas is forecasted to be five billion by 2030 (Zhi, Guangiin, Lixiao & Xinliang, 2014). Meanwhile, the anticipated population forecast will aggravate the series of modifications of land surface as an accumulating number of people migrate into metropolitan areas (Wang, Wang, Wang, Sparrow, Yang & Chen, 2007). These scenarios of landsurface modifications also increase the intensityof the urban climate change. This culminatedinto asignificant phenomenon for urban temperature, that the temperatures of urban land and their surrounding rural areas are different. The sharp differences in the temperature are referred to as urban heat island (UHI)

An urban heat island (UHI) is a climatic phenomenon in which urban areas have higher air temperature than their rural surroundings as a result of anthropogenic modifications of land surfaces, significant energy use and its consequent generation of waste heat (*Solecki et al, 2005)*. The outcome of which has in-advertently leads to excessive energy use for cooling and putting the urban population at great risk of high morbidity and mortality.The majority of cities are sources of heat and pollution and the thermal structure of the atmosphere above them is affected by the “heat island” effect. A heat island is best visualized as a dome of stagnant warm, which has become an issuer over the heavily built-in areas of cities. (Emmanuel, 2015).

Today, the majority of cities are around 2^0C warmer than rural areas and commercial and high density residential areas are hotter by 5^0C to 7^0C (Gordon, Samuel, Levis, Laurent & Keith, 2002).There are some main parameters which influence the temperature increase in cities and thereby play significant role on it. Therefore, urban heat island is caused by different factors that can be divided into two types: viz meteorological factors, such as cloud cover, wind speed and humidity; and city parameters, such as city and population size, anthropogenic heat and urban canyon (Gordon, Samuel, Levis, Laurent & Keith, 2002).

The infusion of anthropogenic heat and pollutants into the urban atmosphere further contributes to the intensity of the urban heat island effect (Taha, 1997). Urban centres tend to have higher energy demands than surrounding areas as a result of their high population density. Though the heat island effect reduces the need for heating in the winter, this is outweighed by the increase demand for air-conditioning during the summer months (Landsberg, 1981)

In recent years, the impact of weather on human health has become an issue of increase significance, especially considering the potential impacts of global warming and an increased urban heat island effect due to urbanization.The offensive weather events therefore have a greater impact on acute mortality and that the highest mortality levels occur when the hottest, but not the most polluted, air mass is present in each city(Karen, Laurence, Scott, Greene & Hengchun, 2000). In addition, Kershaw, Sanderson, Coley & Eames **(2000)** noted thatduring the very hot summer of 2003 nearly 15,000 people died in Paris from heat related illnesses arising in part from a failure of the buildings to adequately moderate internal air temperatures. It is estimated that there were 35,000 additional deaths across the whole of Europe caused by this heat wave (Wright, Young, & Natarajan, 2005). Many of these additional deaths were likely to be caused by an enhanced UHI during the heat wave, where the elevated night-time air temperatures prevented people from being able to cool themselves at night. Approximately 50% of the world's population currently live in an urban environment (IPCC. Climate Change 2007) and this number is set to increase over the 21st century. At this height,the consideration of the urban climate in building design, simulations of building thermal performance, adaptation and mitigation measures is therefore very important for achieving livable human settlement.

Urban regions are among the most rapidly changing environments on earth. As cities grow, they impact local and regional climates, including temperature averages. Urban areas are known to alter mean annual air temperatures by 25^oF per 100 years and up to20^oF at night (Smart, 2002). The changes create a distinct urban boundary layer, or heat dome. This heat dome extends vertically above the city, and in windy conditions can be located downwind as a plume.

In view of the foregoing, the growing influence of the city and its attendant problems must be investigated towards taking proactive steps in reducing the negative manifestations of urban heat Island. This research is therefore determined to unveil the current state of the above phenomena and their implications for urban livability, comfortability and overall sustainable development.

II. Literature Review

More than half of the world's population (3.49 billion people) now lives in built-up areas (United Nations, 2012), a share that is expected to reach nearly 70% by 2050 (UNFPA, 2009; UN-Habitat, 2010). However, within the next decade, it has been projected that there will be nearly 500 cities of more than a million people, including several-- megacities with a population exceeding 20 million globally (Hammer, Rosenzweig & Solecki, 2011). The implication of this global urbanization is that, as the dynamics of this population shift occur, there will be most drastic alteration of the landscape or transformation of natural groundcover into impervious land parcels.

When compared to rural surroundings, urban activities are associated with increased anthropogenic emissions and significant increases in air temperature. According to Oke (1987), the urban areas experience higher temperature than the rural areas as the built fabric stores the absorbed incident solar radiation and anthropogenic heat released from vehicles and equipment, resulting in the formation of heats pockets that are termed urban heat island

The intensity of heat islands depends on the density, population and size of a city and the morphology of cities (Oke, 1982). According to Voogt (2004), urban heat Island (UHI) is the name given to the characteristic warmth of both the atmosphere and the lithosphere in cities. This phenomenon (UHI) has been well documented and found to be universally typical by many researchers (Shashua-Bar and Hoffman, 2000). Consequently, Taha (1997) posited that, for almost 200 years, climatic differences between urban and rural environments have been recognized. Meanwhile, temperature is the most obvious climatic difference identified with the scenario (Unger, Sumeghy, Zusci, Pal, Kadar & Barany, 2001). Accordingly, temperature deferences, usually, is larger at night than the day and it is most apparent when winds are weak. In the same vein, the intense human activities coupled with high consumption pattern and bogus lifestyles especially of the western communities' results to more demand for energy resource, which eventually create a microclimate, as a result of the consequences of the urban heat island. (Adinna, Christian & Okolie, 2009). As a result of this, demand to cool buildings increases, which ultimately translate to meeting the demand for more generation of power and the ultimate increase in amount of greenhouse gases emission and decline of climate (Nuruzzaman, 2015). One of the major reasons for the formation of urban heat island is the large amount of surface like concrete and asphalted roads which have a high heat capacity and that low albedo materials further compound the scenario (Akbari, Pomerantz & Taha, 2001)

Theeuwes (2012) carried out a study on the measurement of the impact of green vegetation and water surfaces in the urban area on urban heat island effect revealed that, 10% of vegetation cover can reduce temperature by 0.6^0 F. This suggest that trees can reduce the UHI effect substantially. The research also showed that, existence of water bodies does not decrease temperature, rather, it increases the effect. Moreover, in a related study, Akbari, Pomerantz & Taha (2001) studied the effect of cool surface and shade trees on the urban heat island effect. They found out that surfaces with high albedo materials and urban trees have a significant contribution to heat island reduction. This conclusion was arrived at on the premises that for every 1^0 C increase in temperature, the electricity demand may rise by 2-4%. On the other hand, 20% of energy used for air conditioning can be saved if mitigation measures are taken in order to reduce the urban heat island effect (Akbari, Pomerantz & Taha, 2001)

However, while observing some mitigation measures towards urban heat island effect, Yamamoto (2006), discovered myriads of mitigation projects in Japan and other countries like Freiburg, Germany, where energy saving buildings, traffic systems, restoring green areas in the built environment and improvement of urban airflow are not only efficient, but effective in ameliorating urban heat island. A study at Szeged, Hungary, established a strong relationship between increased air temperatures and urban land use and built density, indicating an increasing trend of isotherms from suburbs to city core with distinct seasonal variation in UHI intensity (Unger, Sumeghy, Zusci, Pal, Kadar & Barany, 2001).

One of the earliest studies in tropical cities on urban heat island was conducted by Niewolt in Singapore. The study investigated air temperature and relative humidity measurements from nine urban and suburban locations and compared with the data from the airport region representing rural characteristics. The study found that the city was 3.51^0C warmer than the airport area (Niewolt, 1996).

Subsequent UHI study in Singapore found the severity of UHI with 4.01^0C intensity during night time with higher temperatures at Central Business District area, (Wong, 2006). Also the night time UHI study at Singapore found that the commercial and business areas experienced higher ambient temperatures than industrial and airport areas (Jusuf, Wong, Emlyn, Roni & Yan, 2007). Sailor (2006) identified two ways of urban heat island effect mitigation, one is by increasing the albedo of the urban surface and the other is by increasing evapotranspiration. Meanwhile, literature recognizes high albedo roofing materials, high albedo pavements green vegetation, shade trees, water bodies, green roofs, as some of mitigation measures that need to be put in place to ameliorate the menace of urban heat island in urban areas (Nuruzzaman, 2015). Of all these strategies, green growth practice or green economy is the most affordable convenient and effective for developing countries. Cancino (2010) averred that “the only viable solution to this alteration of our environment is to implement better urban planning through inclusive urban green growth. Apart from creating threats to humanities, cities can equally provide the need for modern existence of man (Oduwaye, 2015).

Although, cities are seen as key engine of economic growth, job creation and innovation and also, major contributors to global warming and environmental problems; they are also at the heart of the transaction to global green economy agenda (Hammer, Rosenzweig & Solecki, 2011). If sustainability agenda is going to be achieved, ameliorating the urban heat island effect through inclusive green economy becomes imperative because it is a transformational shift that characterizes efficient and sustainable use of natural resource, low-emission, climate-resilient, increased income opportunities and greater social equity. Similarly, OECD (2010) posited that many countries have included green growth components in their economy recovery and stimulus package, putting in place structures to evaluate policies from an economic efficiency, environmental quality and social equity. UNEP (2011) defines a green economy as one that results in improved human well-being and social equity, which significantly reduces environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive.

STUDY AREA

Akure, a typical traditional city in the south western geo-political zone of Nigeria, is located on latitude 7^0 $17^{''}$ North and longitude 5^0 $14^{''}$ East and at a height of about 370m above the sea level (as shown in figures 1 and 2). The city accommodates a population of 38,852 in 1952, 71,000 in 1961, 109,000 in 1980, and 112,000 in 1981; 114,000 in 1982; 117,000 in 1983; 120,000 in 1984; 123,000 in 1985. This population rose steadily to 239,124 in 1991. In 2014, the city has an estimated population of 375,425.

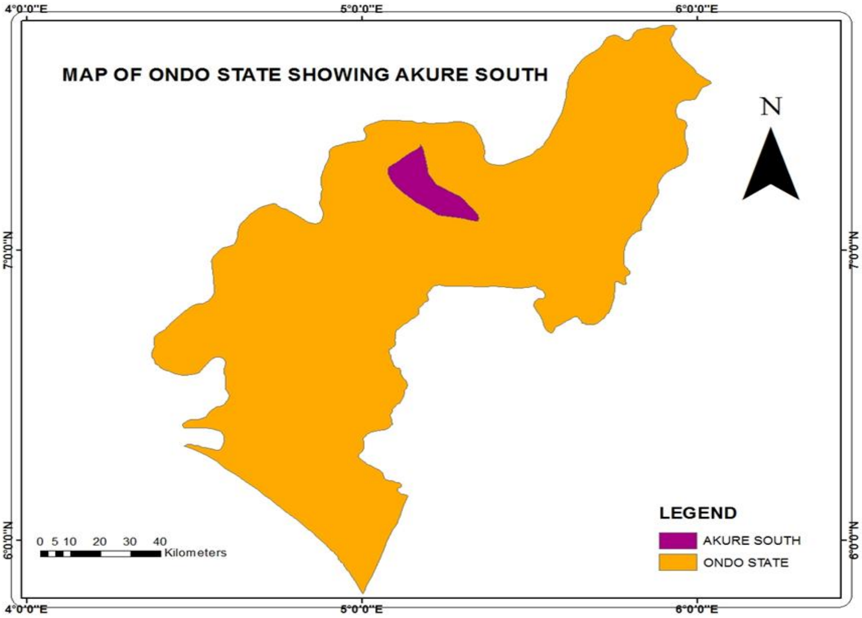
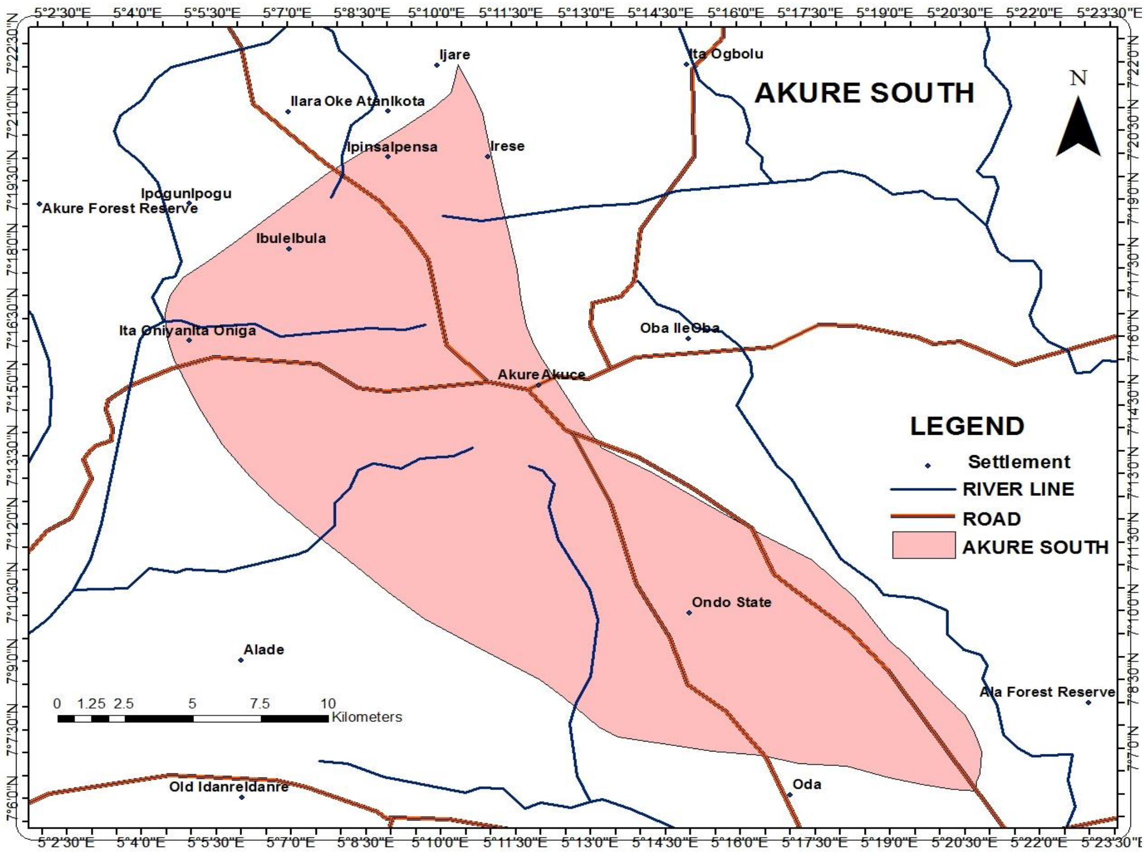


Figure 2: Map of Ondo State

Source: Sogbon, 2014



III. Akure Urban Geometry

Urban geometry refers to the dimensions and spacing of buildings within a city. Urban geometry influences wind flow, energy absorption, and a given surface's ability to emit long-wave radiation back to space. In developed areas, surfaces and structures are often partially obstructed by objects, such as neighboring buildings, and become large thermal masses that cannot release their heat very readily because of these obstructions. At night, the air above urban centers is typically warmer than air over rural areas. Nighttime atmospheric heat islands can have serious health implications for urban residents during heat waves because of the pattern of development that has taken place at densely built up area of the city. This scenario is not different in the case of Akure- the study area. (See figure 3 for activities concentration in the study area).

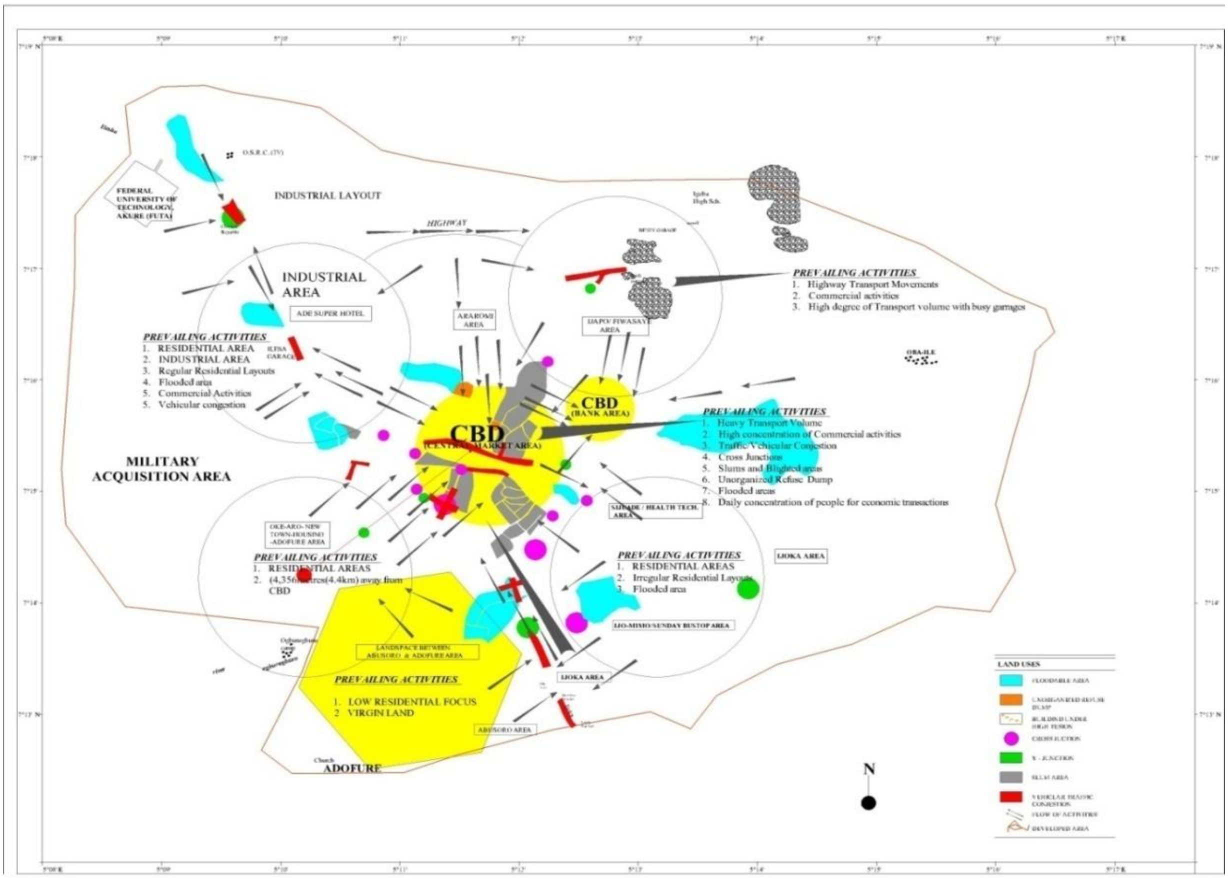
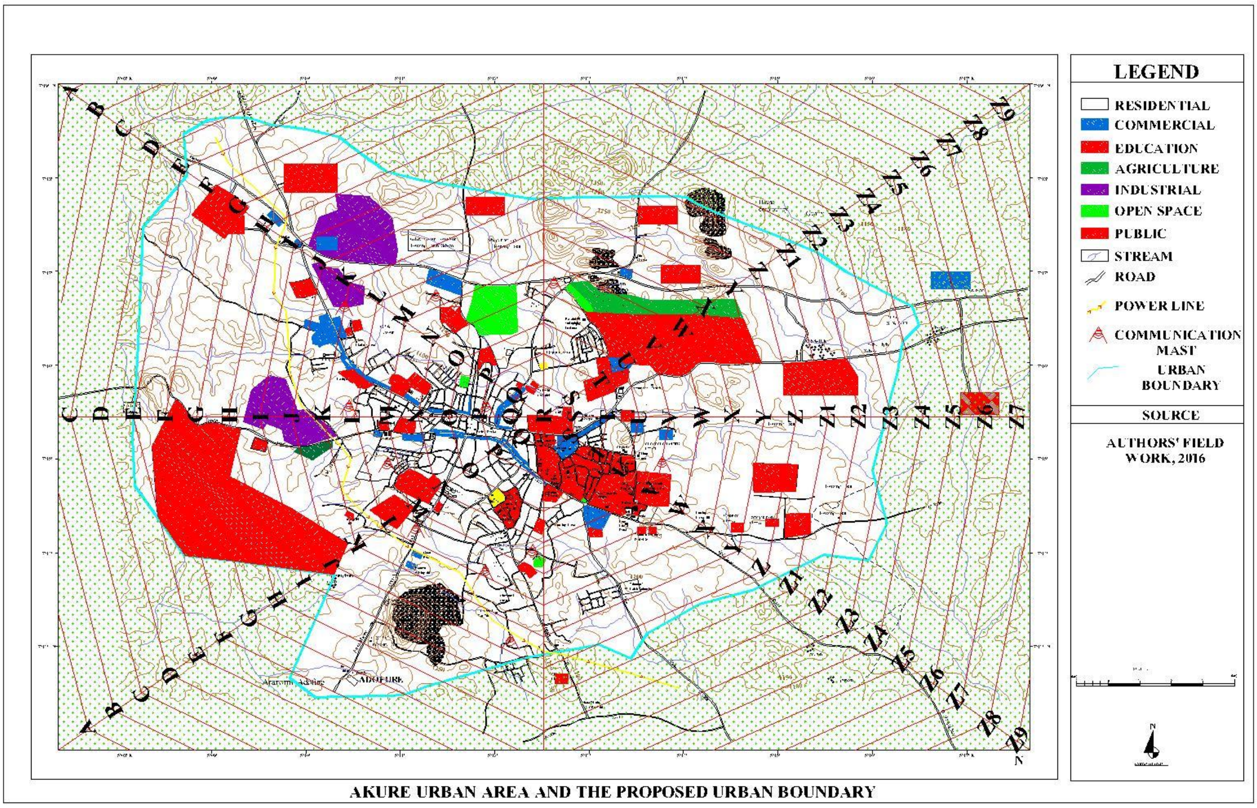


Figure 3: showing the Flow and concentration of activities in Akure metropolis
Source: Authors field work, 2017 - 2019.

IV. Research Methodology

The study was carried out in Akure, the capital city of Ondo State. Surface temperature data were collected using thermometers at a number of predetermined locations using central polygon approach. This approach was adopted and considered more suitable in the sense that; it helps to ascertain the cross-sectional heat of the study area. Meanwhile, thermographs were equally positioned at an average of 1km interval along the cross section line drawn across the city. See figure 4 below. The locations were chosen so as to ensure proper and adequate representation of all parts of the metropolis and the metropolitan area. The observation and reading time was near the least temperature epoch, when the heat Island effects were identified to be prominent or pronounced. Meanwhile, days with cleared skies or less cloudy were picked for survey. Thermographs were equally positioned in the predetermined locations to record temperature range and trend. General temperature rage at the various locations was plotted on map of the metropolitan area and these were consequently interpreted accordingly.



AKURE URBAN AREA AND THE PROPOSED URBAN BOUNDARY

Figure 4: Showing approach adopted for the study

Source: Authors field work, 2017 - 2019.

V. Results and Discussions

The study revealed that urban heat Islands are associated with complex urban cores in relation to their morphology. It was observed that the heat island was prominent over and across densely built-up zones and areas of the metropolis.

A concentration of heat dome was identified to be more evident at the core business district of the study area. Meanwhile, pocket of relatively cool zones was also noticed in and across the metropolis. The temperature of the study area decreases outward toward the fringe of the city. Having observed the general pattern of temperature distribution over the metropolis and having identified the general zones susceptible to the formation of heat island, some of the surveys carried out during the period of study shown that high temperatures were recorded over the metropolis with the exception of some selected clusters

There is a sharp temperature variation between urban inner zone and its periphery. The inner-city tense to be passes more high temperature while the city fringe tense to be low.

In general, the temperature of the urban core was observed to be very high, ranging from 34 c to 42c in the day time. While at the night time the temperature raging from 24c to 28c. On the contrary, the day time surface at the fringe rages 30cto 34c, while the nighttime temperature falls between 18^{0}c to 22^{0}c.

The study revealed a significant correlation between hotter surface temperatures and low vegetation. Regions or district with critically or especially high temperature anomalies, including down town are part of the least vegetated areas and zones. Conversely, neighborhoods and districts of higher vegetation cover, such as Ijapo estate buffer zones, Federal College of Agriculture Ondo State Radiovision Corporation compound, St Lious Primary and Secondary School Compound to mention a few had lower average surface temperatures. These trends occur both during the day and at night.

One discrepancy between day time temperatures and night time temperatures occur along and around natural drainages across the study area, particularly the popular river, Ala. The temperature along these river courses appears relatively cool during the day and warm at night. The temperatures become more cooler at wetlands with densely vegetated area along these corridors. This is because water takes more energy, to heat and cool than land does. In view of this process, water bodies warm up very gradually and slowly during the day and retain stored daytime heat till night. This accounts for cooler daytime temperatures and warmer night time temperatures.

As earlier pointed out by other scholars, the study identified paved areas and asphaltic locations as severe points of heat Island. Some of these locations include popular NEPA area along Arakale road and popular Oja-Oba along Adesida.

The cross-sectional polygon approach revealed clearly the average heat under across the study area. The average surface temperature showed that the temperature of the heart of the city is relatively higher than the surrounding areas as discovered by other scholars in their studies at their various location. The average surface temperature ranges from 22^0c to 49^0c and 26^0c respectively. Aponmu area, which falls along Ondo road has the lowest surface temperature range of 22^0c. While the township area has average temperature range of 49^0c and Igoba axis along Ado road has average surface temperature range of 26^0c. This showed a sharp difference between the city surface temperature and its surrounding areas that are highly vegetated. See figure 5 below.

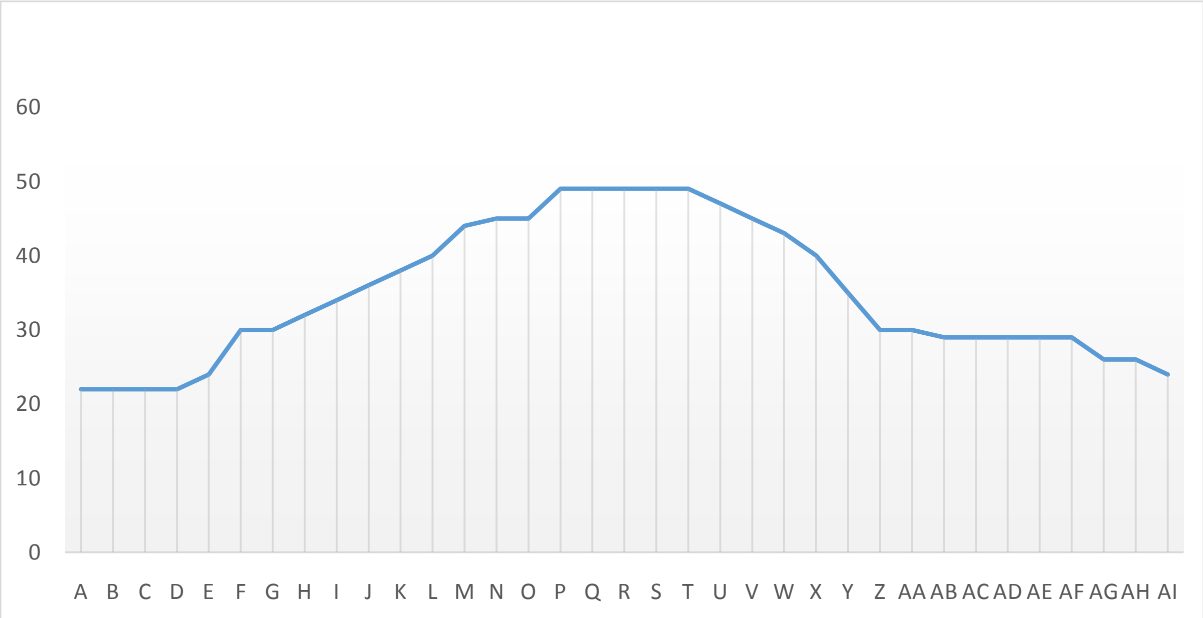


Figure 5: Showing Akure metropolitan heat dome
Source: Authors field work, 2017 - 2019.

VI. Recommendations and Conclusion

Government should pursue tree planting agenda with vigor. Bearing mind that trees provide substantial health, social, economic and environmental benefits to individual and communities.

Government should also embark on immediate and implementable urban design across cities in the state. This will enable government to acquire abandoned sites, uninitialized set- backs, and redevelop-chaotic portions of the cities with a view to enhance city beautification through incorporation of tree planting in urban design.

Residents should be encouraged to increase shade around their buildings by planting tropical trees and other vegetations to lowers surface and air temperatures by providing shade and cooling through evapotranspiration. These trees and vegetations that are directly shading the buildings will certainly decrease the need for air conditioning, making place of residence more comfortable and reducing energy bill cost. Presence of trees will also protect family’s health by improving air quality, providing cooling shade for outdoor activities, and reducing the tendency to be exposed to harmful radiations.

Installation of green roofs should also be introduced and encouraged for easy adaptation for all and sundary. This should form part of government policies and subdivision regulations and bye laws as the case may be.Thisapproach, that is, green roof or rooftop garden include vegetative layer grown on a rooftop. This will provide shades and remove heat from the air through evapotranspiration, thereby reducing temperatures of the roof surface and the surrounding air. Thesegreen roofs will absorb heat and act as insulators for buildings, decreasing energy needed to provide cooling and heating, which consequently lowering energy bill, improving indoor comfortability, and reducing stress associated with heat waves within the vicinity.

Cool roofs code should be incorporated into our national building code as it is being done in California. This code defines cool roof as having a minimum solar reflectance of 70 percent and a minimum thermal emittance of 75 percent, unless it is concrete or clay tile, in which case it can have a minimum solar reflectance of 40 percent. This cool roof provision should be made a mandatory requirement for all new non -residential construction and re-roofing projects that involve more than 2,000 square feet (180m2) or 50 percent replacement. This should form part of our Legislation amendment.

There should be re-introduction of public mass transit that will be commuting people around the city. This will assist in reducing the green- house gases being generated by multiple vehicles.

There should be re-introduction of vehicular registration movement code use by day with automated identification and tracker device with sophisticated and modern data management technology in and around the metropolitan areas.

Government should make policy formulation and implementation on urban heat island a public participatory affair and not government in house agenda. There should be stakeholders' engagement in the implementation of this public urgent demand task.

Public enlightenment campaign should be made mandatory by the appropriate organ of government. The public should well informed and sensitized on the need to imbibe the culture of conserving and protecting their immediate environment.

VII. Conclusion

Climate change and urban heat is not underway but a realistic phenomenal in Akure, as it is in the rest cities of the world. This can be seen in several key features of climate, including warming temperatures in city centres than their surrounding areas, changes in precipitation patterns, shifts in the growing season and other related climate change issues. Several organizations in Nigeria and around the world are working to reduce greenhouse gas emissions and limit global warming so that climate change does not metamorphose to catastrophic situation. However, the increased concentration of greenhouse gases that has already occurred will ensure that the earth will continue to warm for several decades, even if we are able to make concerted and deliberate attempt towards the reductions in emissions in the near future. This warming will continue to change temperatures, rainfall, storm patterns and other important features of our weather and this will inevitably and consequentially impact on our communities, lives, property and ultimately hurt sustainable livability and comfortability. Akure, the study area occupies a prominent position in the State as the capital city of Ondo State. Its unique attributes need to be nurtured and protected from climate change and urban heat effects bearing in mind the administrative capacity it holds, commercial and industrial activities it bears and human resources it develops coupled with population composition it accommodates. Meanwhile, several attempts by organizations and individuals have already begun with a view to increasing the capacity of Akure to adapt but not adequate and not yielding desirable results. Tackling the trend will require concerted efforts to elevate the awareness and engagement of the public and key stakeholders. It will also require more and better-coordinated climate information, a commitment to assessing impacts of climate change adaptation planning throughout the State. It is imperative that resources will have to be mobilized and deployed both for planning and for implementation of adaptation programmes in the study area and Ondo state at large toward combating the inherent attendant problems of urban heat and climate change in general for the attainment of sustainable human settlements in the study area and the State at large.

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