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ASSESSMENT OF URBAN HEAT ISLAND SITUATION IN AWKA.

BY

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DEAPRTMENT OF GEOGRAPHY AND METEOROLOGY

FACULTY OF ENVIRONMENTAL SCIENCES

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CERTIFICATION

It is certified that this is an original work of Obidike Emeka Esae (NAU/2005324191) an undergraduate (B.Sc.) student of the Department of Geography and Meteorology, faculty of Environmental sciences.

This work has not been submitted in part or full for any diploma or degree to this university or any other and references made to other work were properly acknowledged.

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DEDICATION

This research work is dedicated to God Almighty for his love and guidance throughout the duration of my academic pursuit.

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My special appreciation goes to my indefatigable supervisor, Mr. C.I. Enete and also the head of department of Geography and Meteorology, Dr. E.A. Obienusi who took time to go through this work thoroughly.

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Obidike Emeka

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ABSTRACT

Urban Heat Island (UHI) is the name given to the characteristics warmth of both the atmosphere and lithosphere in cities (urban) compared to their rural (non-urbanized) surroundings. This study was directed towards studying urban heat island situation in Awka, Anambra state. During the study transect and fixed temperature of some selected locations were measured to determine spatial extent of UHI in Awka. The study revealed both the positive and negative impacts of UHI in Awka. Results demonstrate that land-use/land-cover correlates with temperature range in Awka capital territory i.e. temperature correlates with the concentration of urban structures, population density and human activities. Temperature gradient are formed at the central business district (CBD) in the downtown areas and progressively lowered to the suburbs. The study suggested the pursue of high-density green over, reflective roofing materials wit h high albedo, building massing (arcades) and lightening of pavements as adaptive/mitigation measures against UHI in Awka urban.

CHAPTER ONE

1.1 BACKGROUND OF THE STUDY

It has been proven by scholars that cities are generally warmer than their surroundings, more rural areas. As urban areas develop, land cover alterations occur in the earth surface and the lithosphere. Buildings, roads, and other infrastructure replace open land and vegetation. Surfaces that were once permeable and moist become impermeable and dry. These changes cause urban regions to become warmer than their rural surroundings forming an "Island" of higher temperatures in the landscape. An urban heat island is the name given to describe the characteristic warmth of both the atmosphere and surfaces in cities (urban areas) compared to their (non-urbanized) surroundings (Voogt, 2004). These urban heat island maybe up to 10-15 ^{o}C under optimum conditions (Oke, 1982). With increasing urban development, heat islands may increase in frequency and magnitude. Los Angeles, California, for example has been 1°F hotter every decade for the past 60 years (Voogt, 2004). On a hot, sunny dry season day, roof and pavement surface temperatures can be 50-90°F (27-50°) hotter than the air, while shaded or moist surfaces- often in more rural surroundings- remain close to air temperature (Sailor, 2002). These surface urban heat islands, particularly during the dry season, have impacts and contribute to atmospheric urban heat islands. Air temperatures in cities, particularly after sunset, can be as much as 22°F (12°C) warmer than the air in neighboring, less developed regions (Sailor, 2002). Though the air temperature urban heat island is generally most apparent at night, urban heat island exhibits significant and somewhat paradoxical diurnal behavior. The air temperature urban heat island is large at night and small during the day, while the opposite is true for the surface temperature urban heat island (Roth et al, 1990). It is well-known that compared to non-urban areas urban heat islands raise night-time temperatures more than daytime temperatures (Int. J. climatology, 1994).

For almost 200 years, climatic differences between urban and rural environments have been recognized (Taha, 1997), of which temperature is the most obvious (Unger et al.., 2001). This phenomenon has been well documented and found to be universally typical by Shashua-Bar and Hoffman (2002). Urban heat islands develop when a large fraction of the natural land-cover in an area are replaced by built surfaces that trap incoming solar radiation during the day and then re-radiate it at night coke, 1982; Quattrochi, et al, 2000).

United Nations (2000) projections indicated that by the end of 2050 half of the world's population will be crowded in urban areas. As population centres grow they tend to modify a greater proportion of urban land, Thus having a corresponding increase in average temperature. Each city's urban heat island varies based on the city's morphology and other meteorological parameters within the city. The microclimate caused by urban heat island

(UHI) has the effect of increasing the demand for cooling energy in commercial and residential buildings. Increased demand for energy can cause consumers and cities, thousands of additional naira in air-conditioning bills in order to maintain comfort level. In addition, increased electricity generation by power plant leads to higher emissions of sulfur dioxide, carbon monoxide, nitrous oxide and suspended particulate as well as CO_2, a green house gas (GHG) known to contribute to global warming and climate change.

In particular, the energy implication of climatic changes induced by urban heat island (UHI) have received very little attention in urban design and planning. This is especially the case in Awka, where urbanization is at its peak. Thus, the main task of this study is to unmask and exploit the impact of urban heat island on living things and the environment.

1.2 STATEMENT OF THE PROBLEM

Urban heat island is the name the characteristic warmth of both the atmosphere and the lithosphere in cities (urban areas) compared to their rural (non-urbanized) surroundings. The micro-climate caused by urban heat island (UHI) has the effect of increasing the demand for cooling energy in commercial and residential buildings. Increased demand for energy can cause consumers thousands of additional naira in air-conditioning bills in order to maintain comfort levels. In addition, increased electricity generation by power plants leads to higher emission of sulfur dioxide, carbon monoxide, nitrous oxide and suspended particulates as well as co2, a green house gas (GHG) known to contribute to global warming and climate change. Warmer days and nights along with higher air pollution levels can contribute to generate discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke and heat related mortality.

Deforestation or the reduction of vegetation, increased urbanization are some of the factors that

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contribute to this problem of UHI. This research is therefore seeking for solutions to the associated UHI problems in Awka.

1.3 RESEARCH QUESTIONS

1) How do we determine points of urban heat island (UHI) in Awka urban?
2) How does urban heat island (UHI) impact man and his environment?
3) How can we solve the problems of urban heat island (UHI) in Awka?

1.4 AIM AND OBJECTIVES

The aim of this study is to assess the urban heat island situation in Awka through the following objectives

1) Determine the spatial extent of urban heat island in Awka
2) Identify the major impacts of urban heat island in Awka

3) Suggest ways of reducing urban heat island in Awka

1.5 RESEARCH HYPOTHESIS

Ho: There is no significant correlation between land-use/land cover and temperature range in Awka capital territory.

1.6 JUSTIFICATION OF THE STUDY

Urban heat island (UHI) have the potential to directly influence the health and welfare of Awka residents. Within the United state alone, an average of 1,000 people die each year due to extreme heat (Changnon et al; 1996). As UHIs are characterized by increased temperature, they can potentially increase the magnitude and duration of heat waves within Awka city. Research has found that mortality rate during a heat wave increases exponentially with the maximum temperature (Buechley et al.; 1972).

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Statistics for Nigeria, shows increased mortality during transition period heat wave (Adefolalu, 1999). Urban heat island give rise to increasing demand for cooling energy which also results to elevated emission of air pollutants

1.7 SIGNIFICANCE OF THE STUDY

The findings of this study will be of great benefit not only to the researcher but also to the entire Awka people and its environs. Furthermore, this study will go a long way in revealing the necessary information needed to minimize the problem of urban heat island to government and other environmental organization. The findings of this research work will educate the public on the impacts of UHI. The findings of the research will be of great value to geography students and other researchers.

1.8 SCOPE OF THE STUDY

The study is focused on the urban heat island situation in Awka. Temperature readings of some selected locations (Udoka estate, UNIZIK temp. site) in Awka will help the researcher determine the spatial extent of UHI in Awka

1.9 THE STUDY AREA

Awka is the capital of Anambra state. It was created on the 27th of august, 1991. The town witnessed rapid growth due to its central location as well as proximity to higher school of learning Nnamdi Azikiwe University. Awka is historically known for its blacksmithing art.

1.9.1 GEOGRAPHICAL LOCATION

Awka is located on latitude $6^{o}25$N and longitude 7 ^{o}E. The city is traversed by the old Enugu road (Ziks avenue). Awka is bounded with Nibo in the south west, Mgbakwu and Okpuno in the north, east with Umuawulu, Isiagu, Ezinato in the south east. As one moves from Onitsha to Enugu, the town stretches over a distance of 26 kilometers.

1.9.2 TOPOGRAPHY AND LANDFORMS

Awka is predominantly a low lying region on the western plain of the Mamu river with all parts at 333 meters above sea level. The region is traversed by some streams like lyiagu, Ofiachi, Olepalayan, Obiabia etc. the major topographic feature in the legion is two celestas (asymmetric ridges) with east facing escarpments each trending southward outside Awka urban to form pert of Awka-Orlu upland. The higher one is the Abagana- Agulu celesta. The section of Agulu where the land rises above 333 meters or (1000ft) above mean sea level outside Awka urban.

1.9.3 CLIMATE, RAINFALL, TEMPERATUYE AND HUMIDITY.

Climate: Awka has a rainforest vegetation with two seasonal climatic conditions. They are the ruing season and the dry season which is characterized with the harmattan. The dryness of the climate tends to be discomforting during the hot period of February to may, while the wet period, between June and September is very cold. The harmattan which falls within December and February is a period of very cold weather when the atmosphere is generally mist.

1.9.4 RAINFALL

Awka is characterized by the annual double maxima of rainfall with a slight drop in either July or August known as dry spell or (August break). The annual total rainfall is above 1,450mm concentrated mainly in eight months of the year with few months of relative drought. Climatologically records since 1978, shows that Awka has a mean annual rainfall of about 1,524mm.

1.9.5 TEMPERATURE AND HUMIDITY

Awka has mean daily temperature of 27^{o}C, with daily minimum temperature of 18^{o}C annual minimum and maximum temperature ranges ace about 22^{o}C and 34^{o}C respectively. It has a relative humidity of 80% at dawn.

1.9.6 GEOLOGY AND SOIL TYPE

The geological formation that underlies Awka urban are Imo shale and Bende Amichi formation. In the riverine and low-lying areas particularly the plain west of Mamu river as far as to the land beyond the permanent site of Nnamdi Azikiwe University, the underlying impervious clayshales cause water logging of the soil during rainy season. The soil sustaining forest vegetation on the low plains farther away from the river maintains a good vegetation cover. The soil are rich and good for root tuber coops like yam, cassava and also maize. The two main types of soil found in the area are farraginous and hydromorphic soils. Farraginous soil is rich in iron and is derived from marine complexes of sandstone, clay and shales. They therefore very from the deep red and brown porous soil derived from the sandstones and shales to deep porous brown soil identified from sandstone and clay.

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1.10 PLAN OF THE STUDY

For effective and easy comprehension, this study is treated under five chapters with each chapter treating a part of the study in details. Chapter one details. Chapter one deals on the introduction/background of the study statement of the problem, aim and objectives, research questions and hypothesis etc. chapter two continues on the review of related literature chapter three is on the research methodology. While chapter four deals with data presentation and analysis as well as the discussion of findings. Chapter five covers the summary, recommendation and conclusion and areas for further research.

CHAPTER TWO

2.1 DEFINITION OF URBAN HEAT ISLAND

Urban heat Island (UHI) is the name given to the characteristics warmth of both the atmosphere and the lithosphere in cities (urban areas) compared to their rural (non urbanized) surroundings (Voogt, 2004). Urban heat Island may be up to 10-15^{0}c under optimum conditions (Oke, 1982). As urban areas develop, changes occur in their landscape. Roads and infrastructure replace open land and vegetation. These changes cause urban regions to become warmer than their rural surrounding forming an "Island" of higher temperatures in the landscape. Urban heat Islands develop when a large fraction of natural land-over in an area are replaced by built surfaces that trap incoming solar radiation during the day and then re-radiate it at night. (Oke, 1982; Quattrochi et al; 2000). Marked differences in air temperature are some of the most important contrasts between urban and rural areas.

2.2 TYPES OF HEAT ISLANDS

According to (Voogt, 2004) there are three types of heat islands.

i. Canopy layer heat Island (CLHI)

ii. Boundary layer heat island (BLHI)

iii. Surface heat island

The first two refer to a warming of the urban atmosphere: the last refers to the relative warmth of urban surfaces. The urban canopy layer (UCL) is the layer of air closet to the surface in cities, extending upwards to approximately the mean building height. Above the urban canopy layer lies the urban boundary layer, which may be one kilometer (km) or more in thickness by day, shrinking to hundreds of meters or less at night. It is the boundary layer heat island (BLHI) that forms a dome of warmer air that extends down-winds of the city (Voogt, 2004). Wind often changes the dome to a plume shape.

Heat islands types vary in their spatial form (shape), temporal (related to time) characteristics, and some of the underlying physical processes that contribute to their development, scientists measure air temperature for canopy layer heart island (CLHI) or boundary layer heat island (BLHI) directly using thermometers, where the surface heat island (SHI) is measured by remote sensors mounted on satellites or aircraft.

- **CANOPY LAYER HEAT ISLAND (CLHI):** The heat island intensity increases with time form sunset to a maximum somewhere between a few hours after sunset to the predawn hours. During the day the canopy layer heat island (CLHI) intensity is typically fairly weak or sometimes negative (a cool island) in some parts of the city where there is extensive shading by tall buildings or other structures and a lag in warming due to storage of heat by building materials.
- **SURFACE HEAT ISLAND (SHI):** This heat island is strongly positive both day and night due to warmer urban surfaces. Day time surface heat island

is usually largest because solar radiation affects surface temperatures.

- **BOUNDARY LAYER HEAT ISLAND (BLHI):** This heat island is generally positive both day and night but much smaller in magnitude than canopy layer heat island or surface heat island.

2.3 DIURNAL BEHAVIOUR

The IPCC states that it is well-known that compared to non-urban areas urban heat islands raise night-time temperatures more than day time temperatures". For example, Moreno Garcia (Int. .J. Climatology, 1994) found that Barcelona was 0.2^{0}c cooler for daily maxima and 2.9^{0}c warmer for minima than a nearby rural station. In fact, a description of the very first report of urban heat island (UHI) by Luke Howard in 1820 says:

Howard was also to discover that the urban center was warmer at night than the surrounding countryside, a condition use now call the urban heat island. Under a table presented in the climate of London (1820) of a nineyear comparison between temperature readings in London and in the country, he commented: "Night is 3,70^0 warmer and day 0.34^0 cooler in the city than in the country". He attributed his difference to the extensive use of fuel in the city.

Though the air temperature UHI is generally moist apparent at night, urban heat islands exhibit significant and somewhat paradoxical diurnal behaviour. The air temperature UHI is large at night and small during the day, while the opposite is true. For the surface temperature UHI. From Roth et al (1990): Nocturnal urban-rural differences in surface temperatures are much smaller than in the day-time. This is the averse of the case for near-surface air temperature.

Throughout the daytime, particularly when the skies are free of clouds, urban surfaces are warmed by the absorption of solar radiation. As described above, the surfaces in the urban areas tend to warm faster than those of the surrounding rural areas. By virtue of their high heat capacities, these urban surfaces act as a giant reservoir of heat energy. (For example, concrete can hold roughly 2000 times as much heat as an equivalent volume of air). As a result, the largely daytime surface temperature UHI is easily seen via thermal remote sensing (e.g. bee, 1993).

However, as in often the case with daytime heating, this warming also ahs the effect of generating convection winds within the urban boundary layer. It is theorized that, due to the atmospheric mixing that results, the air temperature urban heat island is generally minimal or non-existent during the day, though the surface temperatures can reach extremely high levels (Camilloni and Barros, 1997).

At night, however, the situation reverses. The absence of solar heating causes the atmospheric convection to decrease and the urban boundary layer begins to stabilize. If enough stabilization occurs, an inversion layer is formed. This traps the urban air near the surface, and allows it to heat from the still-worm urban surfaces, forming the nighttime air temperature

UHI. The explanation for the night-time maximum is that the principal cause of urban heat island (UHI) is blocking of “sky view” during cooling: surface lose heat at night principally by radiation to the comparatively cold) sky, and this is blocked by the buildings in an urban area. Radiative cooling is more dominant when wind speed is low and the sky is cloudless, and indeed the urban head island is found to be largest at night in these conditions.

2.4 FACTORS THAT CONTRIBUTE TO UHI

Chandler (1965) stated that the formation of a heat island is the result of the interaction of the following factors:-

- the release (and reflection) of heat from industrial and domestic buildings

- the absorption by concrete, brick and of heat during the day, and its release into the lower atmosphere at night.
- the reflection of solar radiation by glass buildings and windows. The central business districts of some urban areas can therefore have quite high albedos rates (proportion of light reflected);
- the emission of hygroscopic pollutants from cars and heavy industry act as condensation nuclei, leading to the formation of cloud and smog, which can trap radiation. In some cases, a pollution dome can also build up;
- resent research on London's heat island has shown that the pollution domes can also filter incoming solar radiation, thereby reducing the build up of heat during the day. At night, the dome may trap some of the heat from the day, so these domes might be reducing the sharp differences between urban and rural areas.

- the relative absence of water in urban areas means that less energy is used for evapotranspiration and more is available to heat the lower atmosphere;
- the absence of strong winds to both disperse the heat and bring in cooler air room rural and suburban areas. Indeed, urban heat islands are often most clearly defined on calm summer evenings, often under blocking anticyclones.

Oke (1982) outlined the several causes of an urban heat island. The principal reason for the night-time warming is (comparatively warm) building the view to the (relatively cold) night sky. Two other reasons are changes in the thermal properties of surface materials and lack of evapotranspiration in urban areas. Materials commonly sued in urban area, such as concrete and asphalt, have significantly different thermal bulk properties (including heat capacity and thermal conductivity) and surface radiative properties (albedo and emissivity) than the surrounding rural areas. This causes a change in the energy balance of the urban area, often leading to higher temperatures than surrounding rural areas. The energy balance is also affected by the lack of vegetation in urban areas, which inhibits cooling by evapotranspiration.

Other causes of an urban heat island are due to geometric effects. The tall building within many urban areas provide multiple surfaces for the reflection and absorption of sunlight, increasing the efficiency with which urban areas are heated. This is called the "canyon effect'. Another effect of buildings is the blocking of wind, which also inhibits cooling by convection. Waste heat from automobiles, air conditioning, industry, and other sources also contributes to the urban areas can also increase the urban heat island many forms of pollution change the radiative properties of the atmosphere.

The Environment Protection Agency (EPA) discusses one of the reasons when it says:

Heat islands form as vegetation is replaced by asphalt and concrete for roads, buildings, and other structures necessary to accommodate growing populations. These surface absorb rather than reflect the sun's heat, causing surface temperatures and overall ambient temperatures to rise.

The lesser-used term heat island refers to any area, populated or not, which is consistently hotter than the surrounding area.

According to (Woolum, 1994) the following factors contribute to the relative warmth of cities

- during the day in rural areas, the solar energy absorbed near the ground evaporates water from the vegetation and soil. Thus, while there is a net solar energy gain; this is compensated to some degree by evaporative cooling. In cities, where there is less vegetation, the buildings, streets and sidewalks absorb the majority of solar energy input.
- Because the city has less water, runoff is greater in the cities because the pavements are largely non-porous (except by the pot holes). Thus, evaporative cooling is less which contributes to the higher air temperatures.

- Waste heat from city buildings, cars and trains is another factor contributing to the warm cities. Heat generated by these objects eventually makes its way into the atmosphere. This heat contribution can be as much as one-third of that received from solar energy.
- The thermal properties of buildings add heat to the air by conduction. Tar, asphalt, brick and concrete are better conductors of heat than the vegetation of the rural area.
- The canyon structure that tall buildings create enhances the warming. During the day, solar energy is trapped by multiple reflections off the building while the infra-red heat losses are reduced by absorptions.
- The urban heat island effects can also be reduced by weather phenomena. The temperature difference between the city and surrounding areas is also a function of the syrioptic scale winds. Strong winds

reduce the temperature contrast by mixing together the city and rural air.

- The urban island may also increase cloudiness and precipitation in the city, as a thermal emulation sets up between the city and surrounding region.

According to (Voogt, 2004), the following factors contribute to the occurrence and intensity of heat islands;

- weather
- geographic location
- time of day and season
- city form
- city functions

WIND AND CLOUDS AFFECT HEAT ISLAND FORMATION

Weather, particularly wind and cloud, influences formation of heat islands. Heat island magnitudes are largest under calm and clear weather conditions. Increasing winds mix the air and reduce the heat island. Increasingly cloud reduces radiative cooling at night and also reduce the heat island. Seasonal variations in weather pattern affect heat island frequency and magnitude.

GEOGRAPHY INFLEUNCES THE CLIMATE

Geographic location influences the climate and topography of the area as well as the characteristics of the rural surroundings of the city. Regional or local weather influences, such as local wind systems, may impact heat islands; for example coastal cities may experience cooling of urban temperatures in the summer when sea surface temperatures are cooler than the land and winds blow onshore. Where cities are surrounded by wet rural surfaces, slower cooling by these surfaces can reduce heat island magnitudes, especially in warm humid climates.

SEASONS CHANGE HEAT ISLANDS

Seasons play a role too. Heat islands of cities located in the mid-latitudes usually are strongest in the summer or winter seasons. In tropical climates, the dry seasons may favour large heat island magnitudes.

CITY FORM

City form comprises the materials used in construction, the surface characteristics of the city such as the building dimensions and spacing, thermal properties, and amount of green-space. Heat island formation is favoured by;

- relatively dense building materials that are slow to warm and store a lot of energy.
- replacement of natural surfaces by impervious or waterproofed surfaces, leading to a drier urban area, where less water is available for evaporation, which offsets heating of the air.
- lower surface reflecting to solar radiation
- dark surfaces such as asphalt roads absorb more sunlight and become much warmer than light-coloured surfaces.

CITY FUNCTIONS

City functions govern the output of pollutants into the urban atmosphere, heat from energy usage and the use of water in irrigation. Anthropogenic heat, or heat generated from human activities, primarily fossil fuel combustion, can be important to heat island formation. Anthropogenic heating usually has the largest impact during the winter season of cold climates in the downtown core of the city. In select cases, very densely developed cities may have significant summertime anthropogenic heating that results from high energy use for building cooling.

In summary, some group of scientists came up with the seven hypothesized causes of the urban heat island listed below:-

1. Increased counter radiation ($L\downarrow$) due to absorption of outgoing long-wave radiation and re-emission by polluted urban atmosphere.
2. Decreased net long wave radiation loss ($L^* = L\downarrow - L\uparrow$) from canyons (tall buildings and narrow sidewalks)

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due to a reduction in their sky view factor by buildings.

3. Greater shortwave radiation absorption ($K^* = K\downarrow - K\uparrow$) due to the effect of canyon geometry on the albedo.
4. Greater daytime heat storage due to the thermal properties of urban materials and its nocturnal release.
5. Anthropogenic heat from building sides.
6. Decreased evaporation due to the removal of vegetation and the surface "waterproofing" of the city.
7. Decreased loss of sensible heat due to the reduction of wind speed in the canopy.

2.5 THE IMPACTS OF URBAN HEAT ISLAND

(Voogt, 2004) listed the following impacts of an urban heat island

- human health
- energy use
- air pollution

- water use

HUMAN HEALTH

Urban heat islands have the potential to directly influence the health and welfare of urban resident. Within the United States alone an average of 1000 people die each year due to extreme heat (Cuangnon et al, 1996). As urban heat islands are characterized by increased temperature, they can potentially increase the magnitude and duration of heat waves within cities. Research has found that the mortality rate during a heat wave increases exponentially with the maximum temperature (Buecgley et al, 1972), an effect that is exacerbated by the urban heat island. The night-time effect of urban heat islands can be particularly harmful during a heat wave, as it deprives urban residents of the cool relief found in rural areas during the night (Clarke, 1972). Statistics for Nigeria show increased mortality during transition period heat waves (Adefolala, 1999).

Increased daytime temperatures, reduced night-time cooling, and higher air pollution levels associate with urban heat islands can affect human health by contributing to general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroker and heat related mortality. The centers for Disease control and prevention estimates that from 1979-2003, excessive heat exposure contributed to more than 8,000 premature deaths in the United States. This figure exceeds the number of mortalities resulting from hurricanes, lighting, tornadoes, floods and earthquakes combined.

ENERGY USE

Elevated summertime/dry-season temperatures in cities increase energy demand for cooling. Research shows that electricity demand for cooling increases 1.5-2.0% fro every 1^0F (0.6^0c) increase in air temperatures, starting from 68^0 to 77^0F (20 to 25^0c), suggesting that 5-10% of community-wide demand for electricity is used to compensate for the heat island effect (Akberi, 2005).

Urban heat island increase overall electricity demand, as well as peak demand, which generally occurs on hot summer weekday afternoons, when offices and homes are running cooling systems, lights and appliances. During extreme heat events, which are exacerbated by urban heat islands, the resulting demand for cooling can overload systems and require a utility to institute controlled, rolling brown-outs or blackouts to avoid power outages (Akberi, 2005).

AIR POLLUTION

Urban heat islands raise demand for electrical energy in summer/day season. Companies that supply electricity typically rely on fossil fuel power plants to meet much of this demand, which in turn leads to an increase in air pollutant and greenhouse gas emissions (Aknari, 2005). The primary pollutants from power plants include sulfur dioxide (SO_2), nitrogen oxides (NO_2), particulate matter (PM), carbon monoxide (CO), and mercury (Hg). These pollutants are harmful to human health and also contribute to complex air quality problems such as the formation of ground-level ozone (Smog), fine particulate matter, and acid rain (Voogt, 2004). Increased use of fossil-fuel-powered plants also increases emissions of greenhouse gases, such as carbon dioxide (CO_2), which contribute to global climate change.

In addition to their impact on energy-related emissions, elevated temperatures can directly increase the rate of ground-level ozone formation. Ground-level ozone is formed when No2 and volatile organic compounds react in presence of sunlight and hot weather. If all other variables are equal, such as the level of precursor emission in the air and wind speed and direction, more ground-level ozone will form as the environment becomes sunnier and hotter (Voogt, 2004).

WATER USE

High pavement and roofing surface temperatures can heat storm water runoff. Tests have shown that pavements that are 100^0F (21^0c) to over 95^0F (35^0c) (James, 2002). This heated storm water generally becomes runoff, which drains into storm sewers and raise water temperatures as it is released into streams, rivers, ponds and lakes.

Water temperature affects all aspects of aquatic life, especially the metabolism and reproduction of many aquatic species. Rapid temperature changes in aquatic ecosystems resulting from warm storm water runoff can be particularly stressful, even fatal to aquatic life.

The literature gap is that no research has been carried out on the Urban Heat Island situation in Awka Urban Center.

CHAPTER THREE

METHODOLOGY

3.1 DATA SOURCES AND COLLECTION

During the study, a network of sensors (KT 300) thermometers were set over Awka urban centre to measure temperature. Data was collected for the months of May and June for the year 2009.

3.2 SITE SELECTION

Quadrant and purposive sampling methods were employed to select the following sites;

[a] High-density, high-rise, non-residential areas with no greenery (DTL).

[b] High-density, high-rise, residential areas with low greenery (HDR).

[c] Medium-density, mixed residential (some residential, some commercial/institutional area with a greenery extent between (a) and (b) above (Nw_2).

[d] Areas with similar land-use, building density and greenery, one having more fully developed vegetation canopy than the other [LVR and LOR].

The following sites were then selected

i) DTI - Downtown location = Zik avenue

ii) HDR - High-density residential site = works road.

iii) NW_2 - Multi-family residential institutional = UNIZIK temporary site.

iv) LVR - Low-density vegetated residential neighborhood = Udoka estate

v) LOR - Low density open-canopy residential neighbourhood = Ahocol estate.

3.3 ESTIMATION OF ATMOSPHERIC STABILITY

Atmospheric stability was estimated using modified Pasquil –Turner (MPT) – index (Karlson, 1986).

MPT = Q*/(U)2…………………………… (equ 3.3)

Where;

Q* = hourly average net radiation

U = hourly average wind speed

The following MPT values were adopted:

MPT > 30 = Unstable

10 < MPT < 30 = Neutral

MPT <-10 = Stable

3.4 METHOD OF DATA COLLECTION AND ANALYSIS

During the study period, transect and fixed point measurements were taken hourly and coveraged over a month. All temperature differences were calculated as site temperature minus reference temperature. Thus, a negative (-) temperature difference indicates that the site was cooler than the reference station; and positive (+) temperature indicates the site was warmer than the reference station. A reference station was established in a rural like setting.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSIONS

4.1 DAY-TIME

Table 4.1 shows temperature variations during stable atmospheric conditions. The following were the average air temperature differences under stable conditions.

Table 4.1 – Temperature variation under stable conditions

Sites	**Temperature difference**
DTL	+ 0.64
LOR	- 0.22
LVR	- 2.31
NW_2	- 2.0
HDR	- 3.3

The downtown location site was the warmest (+0.64) warmer than the residential sites. Places like Dike park, Eke-Awka and parts of Zik's Avenue were warmer than neighbouring sites. The high density urban residential sites (HRD) e.g. works road and (LVR) e.g. Udoka estate, with fully developed vegetation. Canopy were the coolest (-3.3 and -2.31) respectively. The low-density residential sites (LOR) like Ahocol, was only -0.22^{0}c cooler than the reference site. Except for sites (NW_2) where institutions and residential quarters are housed, hour-to-hour variation in air temperature during the day-time was not much. The NW_2 sites witnessed higher temperatures during the day than in the night.

The number of sites that witnessed unstable conditions on multiple days was very few (sites DTL, LVR and NW_2), the patterns were very similar to those produced by stable conditions (see table 3.3).

Table 4.2: Temperature variation under unstable condition

Sites	**Temperature differences**
DTL	+1.52
NW_2	-3.0
LVR	-3.45

Under unstable conditions too, downtown location sites (DTL) were the warmest maximum day-time UHI was about 3.2^{o}c and hour-to-hour difference was about 3.5^{o}c. But unlike stable conditions, difference between LVR and NW_2 under unstable conditions were 0.45 warmer than the reference site.

4.2 NIGHT-TIME

Unlike the day-time temperature differences, nighttime temperature (DTN) showed a clear downtown centered heat island. Table 4.3 clearly depicts this variation.

Table 4.3: Temperature variation during the night

Site	**DTN**
DTL	+1.48
LOR	-0.64
LVR	-0.34
NW_2	-0.39
HOR	-0.52

All residential sites were cooler than the reference site (from 0.34^{o}c to 0.64^{o}c) while the downtown location was up to 1.48^{o}c. This led to a maximum night-time air temperature heat island of about 2.0^{0}c during the study period. The highest nighttime intra-urban air temperature difference was observed during early night period (1800hrs to 2300hrs). Unlike day-time, the hour-to-hour variation in air temperature during the night was very significant, particularly at the residential sites

Heat island at the city-wide scale correlated well with ground level characteristics. The influence of buildings and vegetation maturity were apparent. The magnitude of the temperature differences decreased as background climate become hotter. But hotter conditions led to larger intra-urban thermal comfort differences than the cooler nights.

During the day, a mix of cool and heat island was recorded. The more open residential sites were warmer in the day and coolest at night. Under very hot conditions, the low ground cover at the more open residential sites did not significantly improve daytime cooling.

This suggests that shading was more central to day-time cooling than ground cover. Extensive tree canopy produced some cooling during the day, but the cooling provided by building shade at the high-density sites also did equally well. However, extensive tress canopy cover resulted in warm micro-climate at night. The extra-heat generated due to urbanization necessitates the need to factor in the potential impacts of UHI in urban planning.

4.3 HOW DO HEAT ISLAND IMPACT CITIES

Heat islands have a range of impacts for city dwellers, including;

- Human comfort:- Positive (winter), negative (summer).
- Energy use:- Positive (winter), negative (summer)
- Air pollution:- negative
- Water use:- negative

- Biological activity (e.g. growing season length) positive
- Ice and snow:- positive

Heat islands can increase the demand for energy for air-conditioning, which releases, more heat into the air as well as green house gas emissions, degrading local air quality. Higher urban temperatures in the daytime, boundary layer heat island (BLHI) may increase the formation of urban smog, because both emission of precursor pollutants and the atmospheric photo-chemical reaction rates increases (Oke, 1987).

Heat islands may also directly impacted human health by exacerbating heat stress during heat waves, especially in temperate areas, and by providing conditions suitable for the spread of vector-borne diseases.

CHAPTER FIVE

RECOMMENDATION AND CONCLUSION

5.1 RECOMMENDATION

The study based on these findings proposed some design strategies for the mitigation and adaptation to urban heat island (UHI) in Awka urban center. Most of these strategies are applicable to the downtown location with the warmest temperature. The first is that, there will be substantial green cover increase in the downtown locations, while street level thermal comfort is enhanced by arcades and suitable building massing (Compact designs).

The building massing is such that taller buildings are in the north-east side of the side city blocks while green areas are at the center and to the north-side. Two other design strategies aimed at enhancing the thermal properties of the high density residential areas and multi-family residential areas and multi-family residential neighbourhoods includes: The design strategy for the former proposes a 50% increase in tree cover. Suggestions for the multi-family residential areas include a court-yard built-form with grass-covered inner lawns to allow for building-shade.

Finally, using light-coloured materials for roofing of downtown locations as well as improving the reflectivity of pavements within the urban centers and the adjoining suburbs will reduce UHI in Awka Urban.

5.2 CONCLUSION

The study explained the place of UHI in urban planning. It highlights the potential impacts of UHI which must be factored into urban planning to maintain optimum comfort level. The study have shown how strategically planting shade trees and increasing the reflectivity of building and pavement surfaces can greatly reduce energy use for cooling and prevent the formation of smog and UHI.

The study advocated programs and policies that encourage albedo modifications and shade trees. Such policies include efforts to specify the use of light-coloured materials in downtown areas, strengthen the ability of roads and parks departments to plant new trees and maintain existing ones.

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