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TREE CANOPY COVER VARIATION EFFECTS ON URBAN HEAT ISLAND IN ENUGU CITY, NIGERIA

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ABSTRACT

Urban settings, such as buildings of varying heights, large Ares of paved streets and parking lots generate a unique urban weather environment, such as urban heat Islands. In addition, high temperature and heat waves are becoming more frequent in our cities. Rising temperatures are being blamed on global warming and rapid urbanization. Street trees are highly effective at ameliorating urban warmth at the micro-scale. This study seeks to determine the contributions of street trees in Enugu Urban in ameliorating urban heat Island. Measurements and Monitoring of temperature under street trees in some selected areas were undertaken. Data collection spanned over two seasons (dry and rainy seasons) represented by months of February - March and June- July respectively. A control temperature monitoring data was generated in some selected streets without trees. The resultant data were subjected to further data analysis in order to assess the thermal comfort benefits of street trees using Tzenkova discomfort Index. The result indicated that street trees decreased street temperatures by 8 and 5 degree Celsius during rainy and dry seasons respectively. The result also showed that trees like anacarduim, catalpa Bungei, mangifera Indica and azadirachta indica can reduce ambient air temperature to as low as 12 degrees Celsius. In addition, the result pointed out that where street trees are planted, human thermal comfort (HTC) are usually tolerable. In conclusion the Decreasing temperature using shade trees have other multiplier effects such as lowering evaporative emissions of volatile organic compounds (VOC) from cars, reduction of urban noise, increase property values, decrease stress and aggressive behavior.

Keywords: Urbanization, Street trees canopy cover, urban heat Island, temperature variation

1. Introduction:

The characteristics of urban settings, such as buildings of varying, heights, large areas of paved streets and parking lots generate a unique urban weather environment. Urban heat Island is one of them. And given that three out of five people worldwide are expected to live in an urban environment by 2030 (UN, 2010), accurate information on urban weather becomes increasingly important to protect these densely-populated areas from the impacts of adverse weather that may stem from current rapid urbanization.

Urbanization is a defining phenomenon of this century. Developing countries are at the locus of this transformation, as highlighted in the World Bank's 2009 urban strategy (World Bank, 2009). Urbanization can significantly alter the climate of a landscape. Urban temperatures, although significantly variable, are generally greater than neighboring rural temperatures. The height of buildings, width of roads, presence of water and vegetation and anthropogenic heat source contribute to modified urban temperatures. Increasing building densities with materials of high thermal admittance are likely to increase the temperatures of the surrounding area, especially during the night. This is enhanced by the high run-off rate within urban areas due to presence of impervious surfaces. The cumulative effect of these warming is urban heat Island.

Urban heat Island is the name given to describe the characteristic warmth of both the atmosphere and surface in cities (urban areas) compared to their (non- urbanized) surroundings. Urbanization has been reported to modify local city climate (World Bank, 2010). The city of Enugu has witnessed remarkable growth in its urbanization in recent years and its population during the past few decades has more than tripled. Urban heat Island (UHI) is also referred to as increase of air temperature in the near-surface layer of the atmosphere within cities relative to their surrounding countryside (Voogt, 2002). Heat Islands develop when a large fraction of the natural land cover in an area is replaced by built surfaces that trap incoming solar radiation during the day and then re-radiate it at night (Quattrochi et al, 2000).

Street trees are highly effective at ameliorating urban warmth at the micro-scale (referring to ground to building height). Tree shading reduces the amount of heat stored within urban surfaces. Heat Island reductions of varying extent and magnitude using street trees have been observed in most urbanized areas of the world. For example, a multi-month study measured maximum surface temperature reductions ranging from 11-25^{o}c for walls and roofs at two buildings (Akbari et al, 1997) . Another study examined the effects of vines on wall temperatures and found reductions of up to 20^{o}c (Sandifer et al, 2002). A third study found that tree shading reduces the temperature inside parked cars by about 25^{o}c (Scott et al, 1999).

As a follow up, this study seeks to determine the contributions of street trees in Enugu Urban in ameliorating urban heat Island using the following objectives:

i. Quantify actual temperature benefits of street trees;
ii. Assess the benefit of different tree canopy; and
iii. Quantify thermal comfort benefits of some selected street trees.

2.Study Area

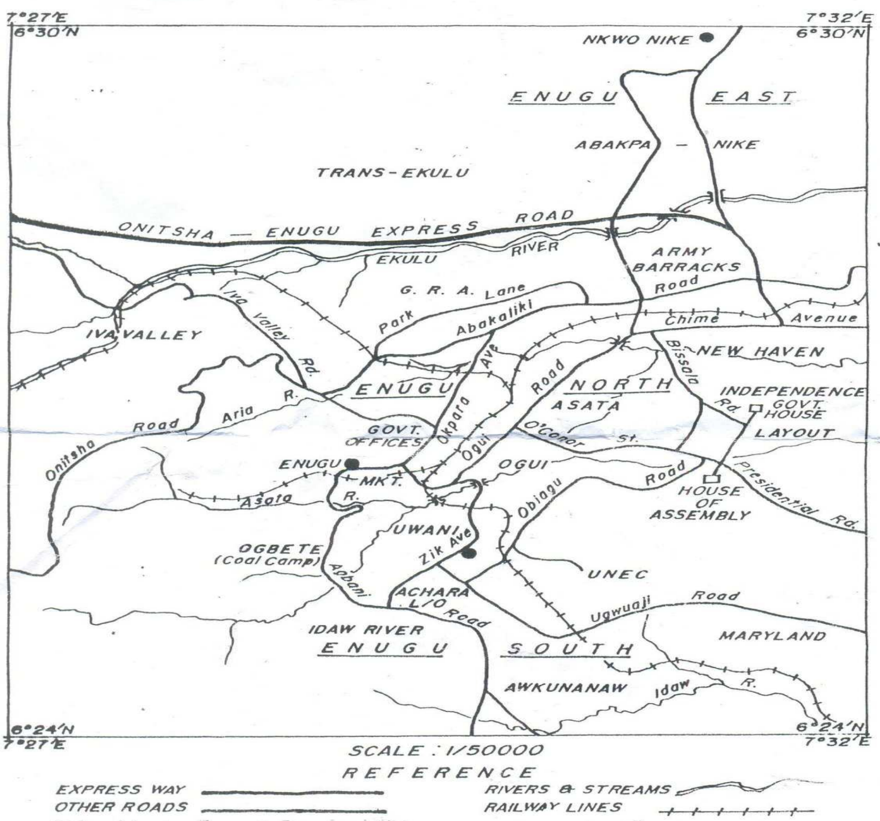

Figure 1.2. Map of Enugu Urban
Source: Ministry of Lands and Survey Enugu

Enugu State is one of the states in southeastern Nigeria. Its capital is Enugu. The state was created in 1991 from the old Anambra State. Enugu state is located within latitude 6^0.00'N and 7^0.00'N and longitude 7^0.00'E and 7^0.45'E. The state is called the Coal City State because of the discovery of coal in a commercial quantity in Enugu Urban in 1909. Enugu was then the capital of East Central State of Nigeria. Some of the important towns in the State are Enugu Urban, Oji, Udi and Nsukka Urban. The state shares borders with Abia State and Imo State to the south, Ebonyi State to the east, Benue State to the northeast, Kogi State to the northwest and Anambra State to the west. Enugu State is made up of 17 local government areas. Enugu Urban which is the study area is made up of Enugu East, Enugu North, and Enugu South (figure 1.2). Enugu Urban is located within latitude 6.24^{0}N and 6.30^{0}N and longitude 7.27^{0}E and 7.32^{0}E. 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, both of which are trading centers in Nigeria. Enugu Urban shares boundary with Igbo Etiti and Isi-Uzo Local Governments in the north, Udi local Governments in the west, Nkanu West Local Government in the south and part of Nkanu East Local Government Area in the east. There are 18 prominent residential areas in the Urban. These are Abakpa, Trans-Ekulu, Nike, GRA, Ogui, Asata, New Heaven, Obiagu, Ogbete, Iva valley, Independence Layout, Achara Layout, Ugwuaji, Maryland, Awkanaw, Uwani, Agbani, and Coal Camp. Enugu Urban is the most developed urban area in Enugu state.

The study area falls within the humid tropical rain forest belt of Southeastern Nigeria. It has two seasons, the raining season and the dry season. The rainy season which is characterized by heavy thunderstorms lasts from April to October with the South Westerly moisture accompanied by air mass moving northwards into the city. The turbulent runoff result in leaching, sheet erosion and eventually gullies (Akabuike, 1990). The mean temperature varies from about 20.30ºC to about 32.16ºC in the dry season and rainy season respectively, (Akabuike, 1990). During the dry season the humidity is lower than in the rainy season. Temperature is most often high during the day and low during the night. This results in high evaporation rate during the day. Harmatten which occurs between the months of November and February is always accompanied by poor visibility mostly at night and early in the morning. The rivers and streams which flow from the Udi hills dissect the study area into several sections. Thus there are rivers such as Ekulu, Idaw, Asata and Nyaba Rivers which separates Enugu South from Nkanu East. These rivers have many tributaries; the study area is generally marked by low land, slopping towards Enugu South Local Government Area and the Southern part of Enugu East Local Government Area. The elevations are between 182.88 meters and 219.45 meters above the sea level. Below is a table showing the population of each local government area that make up the study area. This is based on the figure of National population Census of 2006.

3.Methodology:

The objectives of this study were achieved by monitoring and measuring temperature under some street trees in some selected streets of Enugu Urban. This temperature measurement spanned over two seasons (dry season and rainy season) with months of February- March and June - July representing dry and rainy season months respectively.

These months were selected because they are adjudged to be the peak of dry season and rainy season in Enugu Urban. The mean data were used to determine the contributions of street trees to urban heat Island reduction. Selected trees represented trees of different canopy and different species. A control temperature monitoring data was generated in some selected streets without trees. The resultant data were subjected to further data analysis in order to assess the thermal benefit of street trees within Enugu Urban. The thermal comfort benefit was determined using discomfort Index by Tzenkova et al (2000).

4. Results

In this study, tree canopy cover is defined as the area of ground covered by the extension of plant foliage. The Urban temperature measurements as well as the temperature under tree foliage are reported in table I as a spatial average.

Table 1: Mean Monthly Temperature Measurement

Month	Non-Tree Temperature	Under Tree Temperature
February	31.0^{oC}	23^{oC}
March	32.5^{oC}	27.5^{oC}
June	29.8^{oC}	17.8^{oC}
July	28.2^{oC}	18.2^{oC}
Feb-July	30.3^{oC}	21.6^{oC}

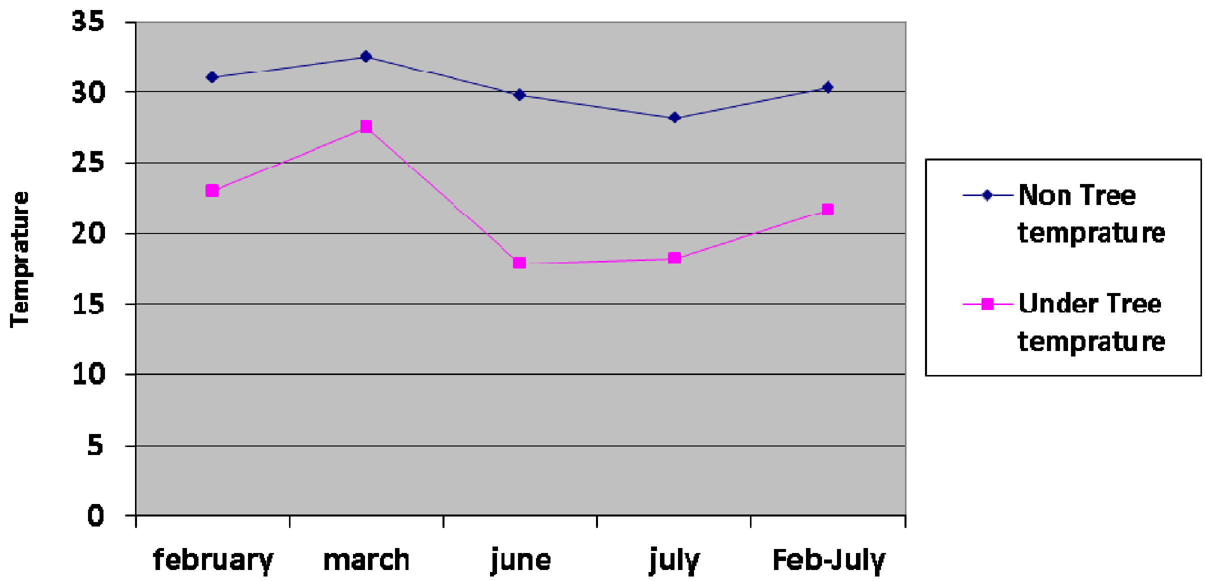

Figure 2 monthly temperature at different points

The mean monthly temperature for dry season months represented by February and March were 31.0^{oC} and 35.5^{oC} respectively; while June and July representing rainy season months had 29.8^{oC} and 28.2^{oC} respectively. Temperature record under the tree during the same period showed that months of February had 23^{oC}, March $27.5^{oC,}$ June 17. 8^{o}c and July 18.2^{o}c. On the average, months of February to July had a total temperature of 30.3^{o}c while total temperature measurements under the foliage were recorded to be 21.6 degree Celsius.(figure 2)

Again Measurements were taken under different trees to determine the contributions of different plants to temperature reduction as shown in table 2.

Table 2: Mean Temperature Under different Trees

Tree/Plant	Mean Temperature
Anacarduim (cashew)	12^oc
Citrus Genus (Citrus Trees)	18^oc
Cocos Nucifera (Coconut)	28^oc
Mangifera Indica (mango)	14^oc
Psiduim Guajava (Guava)	17^oc
Azadirachta Indica (Dongoyaro)	19^oc
Pinus Genus (Pine)	25^oc
Catalpa Bungei	12^oc

All temperature Measurements were reported as monthly average. The highest temperature was recorded on Cocos nucifera (28^{oC}), followed by Pinus Genus (25^{oC}); while lowest temperature was recorded on Catalpa Bungei and Anacarduim (12^{oC}).

Human comfort benefit was also considered on some selected streets and classification of discomfort index(DI) used by Tzenkova etal (2000) was employed in the analysis of level of comfort provided by different street trees. Tzenkova etal (2000) Discomfort index classification is shown in table 3.

Table 3: Classification of Discomfort Index

Thermo- Hydrometric Discomfort Index	D1^{0}c
No discomfort	>21 ^oc
Under 50% of the Population feels discomforted	21-24 ^oc
Over 50% of the population feels discomforted	24-27 ^oc
Most of the population feels discomforted	27-29 ^oc
Everyone feel stressed	80-32^oc
State of medical emergency existed	>32

Source: Tzenkova et al,(2000).

The analysis of temperature of the selected trees in table 2 and discomfort Index in table 3 showed that 75 percent of trees assessed produced shades (reduced temperature) that caused no discomfort. Pinus Genus (25^oc) and Cocos nucifera (28^oc) fell under the category where over 50 percent of the population feels discomforted and where most of the population feels discomforted respectively.

5. Discussions:

Tree shading reduces the amount of heat stored within urban surfaces. Shading has been observed to decrease late afternoon street temperature by 3^oc (Ali-Toudert and Mayer, 2007). Our result showed that shading decreased the temperature of months of February and March by 8 and 5 degrees Celsius respectively. In rainy season months of June and July, shading decreased temperature by 12 and 10 degree Celsius respectively. Virtually no direct sunlight gets through the canopy of a healthy shade tree. A fully shade surface has a soler gain of less than 20BTU per hour per square foot. As a result, complete shading by trees eliminates over 90 percent of the solar energy falling on a surface. Shade trees are wide in relation to their height, so they continue to be effective when the sun is at low elevations.

The cooling potential of street tree is variable and dependent upon the level of canopy coverage, planting density and geometry of the street (Shashua-Bar et al, 2010). Evapotranspiration processes also lessen the levels of atmospheric heating of the surrounding area, acting to mitigate "the heat Island not by cooling the air, but by warming the air less" (Kurn et al, 1994).Trees and vegetation absorb water through their roots and emit it through their leaves. The conversion of water from liquid to a gas also occurs from the soil around vegetation and trees. Together, these processes are referred to as evapotranspiration. Evapotranspiration cools the air by using heat from the air to evaporate water. Huang et al, (1990) and Kurn et al, (1994) have measured peak air temperatures in tree groves that are 5 degrees Celsius cooler than over open terrain, and air temperatures over irrigated agricultural fields that are 3 degrees Celsius cooler than air over bare ground.

Again, the contribution of different trees to temperature reduction was carried out. Result revealed that the level of canopy and density of trees decreased the level of temperature observed. It was also observed that trees with broad leaves and evergreen provide more shade and contribute more to temperature reduction than trees with narrow leaves and deciduous plants. However, one of the major advantages of using deciduous trees for shading is that they do not seriously obstruct solar heat gain during cold weather.

In our assessment, anacarduim, catalpa Bungei, Managifera indica, psidium guajava and azadirachta indica were found to decrease temperature in that order within the streets of Enugu urban. Most of these trees are evergreen and broad leaves. These trees reduce temperature to as low as 12 degrees Celsius. Apart from shading and reduction of solar energy, tree shade can keep parked cars cooler, particularly their gas tanks, which lower evaporative emissions of volatile organic compounds (VOCs). One analysis predicted that vehicle evaporative VOC emission rates could be reduced by 2 percent per day if the community increased the tree canopy over parking lots from 8 to 50 percent (Kurn et al, 1994). And by reducing air pollution, trees and vegetation lower the negative health consequences of poor air quality, heat wave, and reduced direct exposure to ultra violet rays (Heisler and Grant, 2000;Heisler et al, 2002).

Trees and vegetation can provide a range of quality-of-life benefits. Trees can reduce urban noise by 3 to 5 decibels (Nowalk and Dwyer, 2007). Urban trees and vegetation have been linked to reduced crime (Kuo and Sullivan, 2001), increased property values (Laverne and Winson-Geideman, 2003), and other psychological and social benefits that help decrease stress and aggressive behavior (Wolf, 1998; Hansmann et al, 2000).

Finally, the thermal comfort benefits of some of these selected street trees were analyzed. Observations showed that planting trees like Anacarduim, Mangifera indica, Catalpa Bungei and Azadirachta indica will reduce any discomfort caused by temperature. These trees decrease ambient temperature to less than 21 degrees Celsius. The implication of this is that when trees of these natures are planted around Enugu urban streets, temperatures around these streets will cause no discomfort to inhabitants of the city. Only trees like cocos nucifera and pinus genus can cause over 50 percent of Enugu population to feel discomforted. This is because the shade they provide is low.

6.CONCLUSION

Urban heat island is an urban environmental problem. The threat of urban heat islands will be increasing especially as half of the world's population is expected to live in our urban centers by 2030. This study assessed the contributions of street trees to temperature reduction in Enugu urban. The analysis showed that street trees decreased temperature drastically. It was also observed from literature that street trees have other benefits such as: cooling gas tanks on car parks, which lowers evaporative emissions of volatile organic compounds (VOCs); reduction of urban noise; increase property values; decrease stress and aggressive behavior.

Street trees also collect particulates and increase aesthetic environment of our cities. Trees by reducing air pollution lower the negative health consequences of poor air quality, heat wave and direct exposure to ultra violet rays. The overall status of urban heat island in Enugu urban demands that trees such as Anacarduim, mangifera indica, catalpa Bungei and Azodirachta indica be used as shade plants. The major advantages of using these trees for shading are that they are evergreen and provide high level canopy. Too, these trees through the shade they provide regulate ambient air temperature, thus affecting human comfort.

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