Street Tree Canopy Cover Variation Effects on Temperature in Lokoja, Nigeria

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Abstract

Urban settings, such as buildings of varying heights, large Areas 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 Lokoja city centre in modifying the microclimate. 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. 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

1:1 Introduction

The study area have been going through rapid population growth, and increase rate of urbanization which by extension have brought in different dimensions of development in terms of increased built up, road pavements and the introduction of different kinds of trees (both exotic and indigenous)which have collectively provided unique urban microclimatic environment . These have brought in paradigm of urban heat island (UHI), urban heat canyons (UHC).

UHI as the name implies has been described as the characteristic warmth of the both the atmosphere and surfaces in cities (urban area) as compared to the surrounding (non urbanized) surroundings. Voogt (2002) described UHI as the increase air temperature in the near surface layer of the atmosphere within cities relative to their surrounding country side.

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Field studies carried out in 1989, in Sacramento , California on the canopy cover variations, shows that tree canopy cover variations throughout the city and in the park greatly influenced both surface and 1.5m UHI distributions by blocking both incoming solar radiation during daytime hours and outgoing long wave radiation during night time hours (Imura,1992).

Street trees have been found to be highly effective in ameliorating urban warmth at the micro scale (referring to growth and building height) that is the development of urban heat canyon, which is due to the contribution of paved roads to the heating of the air. 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. This is supported by Akbari et al(1997)whose finding shows that a multi-month study measured maximum surface temperature reductions ranging from 11-25^{o}C for walls and roofs at two buildings. This is through the process evapotranspiration. Evapotranspiration process lessens the level of atmospheric heating of an area, acting to mitigate the heat island not by cooling the air, but by warming the air less. Kurn et al (1994) explained that trees are found to absorb water through their roots from the soil and emits it through the leaves thereby cooling the surrounding. He further measured peak air temperatures in tree groves and found that the area is 5 degrees Celsius cooler than the open terrain, and air temperatures over irrigated agricultural fields are 3 degrees Celsius cooler than air over bare ground.

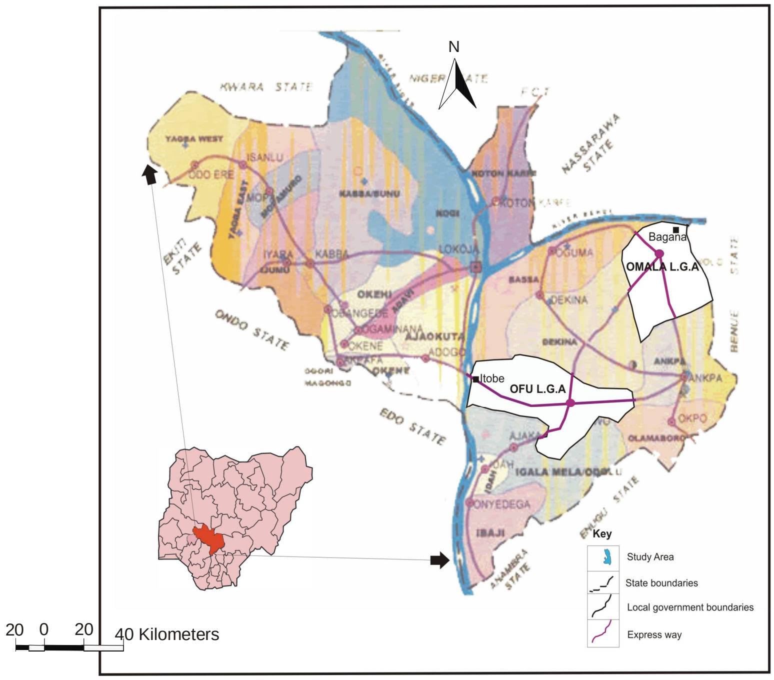
He further attempted to find contribution of different trees to temperature reduction. Result revealed that the level of canopy and density of trees decreased the level of temperature observed. It was also observed that trees with broad leaves and evergreen provide more shade and contribute more to temperature 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. Trees and vegetation have been found to provide range of quality-of-life benefits, by their ability to reduce urban noise by 3 to 5 decibels (Nowalk and Dwyer, 2007). Urban trees and vegetation have also been linked to crime reduction (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 in the cities (Wolf, 1998; Hansmann et al, 2000). Sandifer et al, (2002), examined the effects of various wall temperature and found reductions of up to 20 ^{o}C. The effect of tree canopy cover shading was also carried out by Scott et al, 1999, who found that tree shading reduces the temperature inside parked cars by about 25 ^{o}C.

Considering the environmental benefits of planting trees in ameliorating the increase warming of the city, it has become pertinent to have knowledge of what kind of trees or shrub to be planted in landscaping the streets and our surroundings.

This study therefore seeks to determine the effects of street trees in Lokoja in ameliorating urban heat island. This will be carried out through the following objectives:(i) To quantify temperature benefits of street trees ,(ii) To assess the canopy shade effects of different tree species ,(iii) To quantify thermal benefits of some selected street trees.

1.2 Study area

Lokoja in Kogi State, Nigeria



Source: Adapted from Kogi State map 2009

The study area, Lokoja, lies between latitude $7^{0}45'N$ and longitude $6^{0}45'E$. Lokoja is the administrative headquarters of Kogi State in Nigeria. It is well connected and accessible through state and federal highways. It is also located close to confluence of the River Niger and Benue; the area is sandwiched between a water body and a hill i.e. River Niger and Mount Patti respectively which had streamlined the settlement to a linear one and has a modifying effect on the climate.

The climate is characterized by wet and dry season. AW type of climate as classified by Koppen's and situated in Guinea Savannah Region. The annual rainfall is between 1016mm and 1524mm with the mean annual temperature of 33.2"C (Kogi state website, 2009).

1.3 Methodology

The objectives of this study were achieved by monitoring and measuring temperature under some street trees in some selected streets of Lokoja city centre. 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 the study area. 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 the area. The thermal comfort benefit was determined using discomfort Index by Tzenkova et al (2000).

1.4 Result

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

Table 1: Mean Monthly Temperature Measurement

Month	Non-Tree Temperature	Under Tree Temperature
February	30.48^{oC}	22.48^{oC}
March	29.93	27.5^{oC}
June	27.74^{oC}	17.8^{oC}
July	26.89^{oC}	18.2^{oC}
Feb-July	**30.76^{oC}**	**21.4^{oC}**

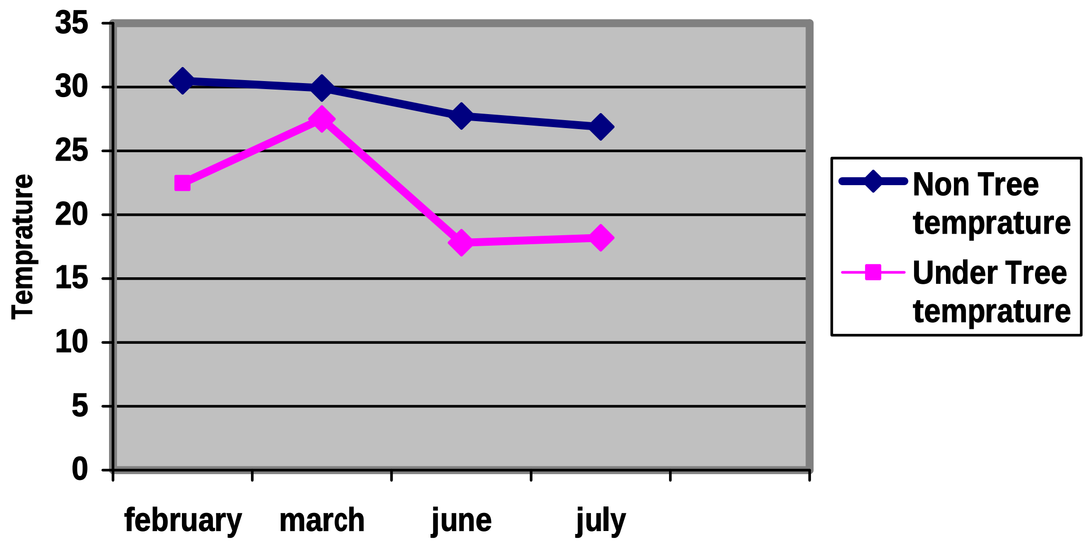


Figure 2: monthly temperatures at different points

The mean monthly temperature for dry season months represented by February and March were 30.48 ^{o}C and 29.93 ^{o}C respectively; while June and July representing rainy season months had 27.74 ^{o}C and 26.89 ^{o}C respectively. Temperature record under the tree during the same period showed that months of February had 23 ^{o}C, March 27.5 ^{o}C June 17.8 ^{o}C and July 18.2 ^{o}C.The drastic variation in temperature can easily be observed in the line graph on figure two, when the under tree temperature is compared to non tree temperature. On the average, months of February to July had a total temperature of 30.76 ^{o}C while total temperature measurements under the foliage were recorded to be 21.4 ^{o}C degree Celsius (figure 2). Measurements were also taken under different trees to determine the contributions of different plants to temperature reduction, the result is shown in table 2.

Table 2: Mean Temperature Under different Trees

Tree/Plant	Mean Temperature
Anacarduim (cashew)	15 ^{o}c
Citrus Genus (Citrus Trees)	20 ^{o}c
Cocos Nucifera (Coconut)	28 ^{o}c
Mangifera Indica (mango)	15.5 ^{o}c
Psiduim Guajava (Guava)	17 ^{o}c
Azadirachta Indica (Neem)	20 ^{o}c
Pinus Genus (Pine)	25 ^{o}c
Catalpa Bungei	13 ^{o}c

All temperature Measurements were reported as monthly average. The highest temperature was recorded on Cocos nucifera (28 ^{o}C), followed by Pinus Genus (25 ^{o}C), while the lowest temperature was recorded on Catalpa Bungei and Anacarduim (13 ^{o}C).

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 ^{o}c
Under 50% of the Population feels discomforted	21-24 ^{o}c
Over 50% of the population feels discomforted	24-27 ^{o}c
Most of the population feels discomforted	27-29 ^{o}c
Everyone feel stressed	80-32^{o}c
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 ^{o}C) and Cocos nucifera (28 ^{o}C) fell under the category where over 50 percent of the population will feel discomforted (Tzenkova et al, 2000).

1.5 Discussion

The foregoing shows that tree shading reduces the amount of heat produced on urban surfaces. These shading has been observed to decrease late afternoon street temperature by 3 ^{o}C (Ali-Toudert and Mayor, 2007). The research carried out by Enete and Alabi et al ,2011, in Enugu Urban show also that shading decreases temperature to as less as 8 ^{o}C from the surrounding temperature in the month of march . Findings in this research shows shading decreases the temperature of months of February and March by 8 and 5 degrees respectively. It also agrees with the earlier findings that a fully shaded surface has a solar gain of less than 20 BTU per hour square foot. Where complete shading by trees eliminates over 90 percent solar radiation falling on a surface where virtually no direct sunlight gets through the canopy of a healthy shade tree. However the cooling potential of street tree varies and depends on the level of canopy coverage or foliage, plant density, and street geometry (Shashua-Bar et al, 2010).

The findings of this research reveals that , anacarduim, catalpa Bungei, Managifera indica, psidium guajava and azadirachta indica were found to decrease temperature in that order within the streets of Lokoja. 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).

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 this nature are planted around streets in Lokoja, temperatures around these streets will remain at the level of no discomfort to inhabitants of the city. However only trees like cocos nucifera and pinus genus indicates the tendency of causing discomfort of high temperature where planted. This is because the shade they provide is low.

1.6 Conclusion

This study assessed the contributions of street trees to temperature reduction in Lokoja city center. The analysis showed certain 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. It is hereby suggested that to ameliorate the effects of urban heat island and to maintain comfortable microclimate in Lokoja, trees such as Anacarduim, mangifera indica, catalpa Bungei and Azodirachta indica be used as shade plants. These trees have major advantages of providing heavy shades, they are evergreen and provide high level canopy. These trees through the shade they provide regulate ambient air temperature, thus affecting human comfort.

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