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EFFECT OF TREE CANOPY ON URBAN HEAT ISLAND IN MAKURDI, BENUE STATE, NORTH-CENTRAL NIGERIA

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ABSTRACT

This study determines the effect of tree canopy on urban heat island in Makurdi, Benue State of North-Central Nigeria. Applying a multi-stage sampling technique, 150 residential houses with tree canopies, and 150 without tree canopies in urban and rural locations in and around Makurdi were sampled for the study. Data were collected by measuring wall temperatures in selected residential houses with tree canopies and those without tree canopies for both dry and rainy seasons. A total of 29 species of trees with 284 individuals representing 15 families were encountered in residential houses within and around Makurdi. There was a significant difference in temperatures of residential houses with tree canopy and those without tree canopy in rural areas (Mean Difference = 0.88 ± 1.55, p = 0.01) and in urban locations (Mean Difference = 3.64 ± 2.86, p = 0.01). There was significant difference in mean temperature variation between urban (27.75 ±3.57a) and rural (24.64 ±2.16b) locations within the study area. Significant difference exists between mean temperature values for rainy and dry seasons within the study area (Mean Difference = 1.42 ± 1.69). Individuals living (50%) in residential houses without tree canopy felt discomfort while those with tree canopy showed no discomfort. There was no discomfort to residents in rural areas of Makurdi. This study has established the existence of urban heat islands within Makurdi and therefore proved the positive effect of trees in contributing to reducing the occurrence of urban heat islands

Key words: heat Island, tree canopies, residential houses, wall temperature variations

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INTRODUCTION

Countries around the World, Nigeria inclusive, are experiencing human congestion, increasing vehicular movements, and production activities with attendant negative impact on the environment and human health. These, according to the United Nations (2018), is due to constant population growth coupled with rural-urban migration in search for better opportunities and living conditions. In fact, cities are good hubs for ideas, commerce, culture, science, productivity, and social development.

According to UN (2014), globally, more people live in urban areas than in rural areas, with 54 percent of the world's population residing in urban areas in 2014. In 1950, 30 percent of the world's population was urban, and it is projected that by 2050, 66 percent of the world's population will be living in urban centers. Continuing population growth and urbanization are projected to add 2.5 billion people to the world's urban population by 2050. It is expected that nearly 90 percent of this increase will be coming from Asia and Africa. Scholars believe that basically, three countries (India, China, and Nigeria) - will be responsible for the increase within the period. These three countries of India, China and Nigeria are expected to account for 37 percent of the projected growth of the world's urban population between 2014 and 2050. India is projected to add 404 million urban dwellers, China 292 million and Nigeria 212 million (Aliyu and Amadu, 2017). The authors maintained that "Urbanization in Nigeria is demographically driven without commensurate socio-economic dividends and benefits to the urban environment".

According to Statista (2018), the total population of Nigeria that lived in urban areas and cities as of 2017 was 49.4 percent. This clearly corroborates the argument of Bloch *et al* (2015) that the urban population in the country has increased rapidly over the years and will continue to grow relatively fast in the coming decades. Bloch *et al* (2015) also submitted that the underlying cause of rapid urban population growth and urban expansion in Nigeria has been driven by declining mortality and persistently high fertility.

"Urbanization is integrally connected to the three pillars of sustainable development: economic development, social development and environmental protection" (UN, 2014). The rapid growth in urban population is seen to create a need for the development of more urban infrastructures. Consequently, natural surfaces such as vegetation are being replaced with non-vegetated surfaces of asphalt and bricks, which can absorb heat and release it later. These changes in land cover seem to increase the urban land surface temperatures (Igun, 2017, Adebayo *et al*, 2017).

The term "urban heat islands-UHI" refers to the observed temperature difference between urban environments and the surrounding rural areas (Adebayo *et al*, 2017, Heaviside *et al*, 2017, Conserve Energy Future, 2018). An important aspect of this UHI phenomenon is its impact on local climate change and variability. In addition, climate change caused by anthropogenic emission of greenhouse gases is intensified by the temporal pattern and spatial extent of the UHI in metropolitan regions. Such activities cause alterations of land surfaces through urban developments, which uses materials that effectively retain heat (Adebayo *et al*, 2017). Urban heat island is recognized as the most evident characteristic of urban climate (Isioye, *et al.*, 2020; Nnah *et al.*, 2021)

Urban environments are a patchwork of diverse forms of impermeable surfaces, such as green and blue infrastructure, streets, and buildings (Sharmin *et al.,* 2023). Up to 50% of urban areas may be covered by these impervious surfaces (concrete, asphalt, and buildings), the percentage varies greatly between cities (Fuller and Gaston, 2009). Additionally, urban areas are different from peri-urban and natural areas in terms of their radiative, thermal, aerodynamic, and moisture characteristics. Thus, they absorb heat and re-radiate longwave radiation within the urban matrix, resulting in higher air and surface temperatures (Manoli *et al.*, 2019).

To change the heat balance in metropolitan environments, a variety of heat mitigation techniques are available. Among these, nature-based solutions are emphasized as lasting, affordable ways to lower urban heat and enhance the livability of cities around the world, example: installing green walls and roofs, planting trees. The potential of trees to lower local air temperatures has been established (Akbari *et al.* 2001; Bowler *et al.,* 2010). Trees are an important part of urban green space. In fact, a modeling analysis of four cities from various temperate zones—Melbourne, Australia; Zurich, Switzerland; Phoenix, USA; and Singapore, Singapore—found that vegetation cover can lower daily maximum air temperatures by 3.1 to 5.8 °C (Meili *et al.,* 2021). Additionally, empirical studies conducted in Campinas, Brazil, showed that tree canopies were responsible for 2.8 °C air temperature reductions (De Abreu-Harbich *et al.*, 2015). Similarly, 1.1 °C was observed in Australia's Greater Sydney (Sharmin, 2022). The amount of air temperature reduction caused by tree tops varies significantly among studies (Meili *et al.*, 2021), with variations presumably caused by the type of nearby built-up region, the amount of vegetation cover, the availability of soil water, the time of day, and the local microclimate (Motazedian, 2020).

This study therefore determined the effect of tree canopy on UHI in Makurdi, North-Central, Nigeria. Specifically, the study determined the: tree species composition in residential houses, temperature variation between residential houses with tree canopy and residential houses without tree canopy, temperature variation between urban and rural locations within

Makurdi, comfort zones for human habitation, building materials used in residential houses, and determine the effects of the building materials on temperature within Makurdi.

MATERIALS AND METHODS

Study Area

Makurdi, which doubles as the Capital city of Benue State and the headquarters of Makurdi Local Government Area, is the largest urban area in the State. It is located between latitudes 7°20' and 8°10' North, and longitudes 8°4' and 9°40' East (Ancha *et al*, 2011). It has a land area of about 800km^2, and the city is traversed by the River Benue, which divides it into two: Makurdi North and South (Ogwuche and Asobo, 2013). It is also surrounded by suburban areas like Adaka, Daudu, Ikpayongo, Apir, Angbaaye, Abua, and Tyo Mu. The town is made up of eleven (11) Council Wards.

The climate of Makurdi town is the tropical wet (rainy) and dry season, the rainy season lasts from April to October, while dry season start from November to March (Abah, 2012). Annual rainfall in Makurdi town is consistently high, with an annual rainfall of 1500-1800 millimeters (Ancha *et al*, 2011, Abah, 2013). Temperature in Makurdi is generally high throughout the year, with February and March as the hottest months (Abah, 2012). The mean annual temperature is about 32°C (Ancha *et al*, 2011). Makurdi is located within the Guinea Savannah vegetation zone (Abah, 2013; Ogwuche and Asobo, 2013). This is a transitional zone separating the forested belt of the South and the true savannah of the North. The vegetation consists mainly of giant grass and a variety of scattered fire-resistant trees and shrubs (Ikyaagba *et al.,* 2020). Some of these tree species includes; *Parkia biglobosa, Prosopis africana, Khaya senegalensis, Daniellia olliveri, Lophira lanceonlata, and Vitex doniana.* Most of the grasses are perennial, namely: *Hyparrhenia inclucruta, Panicum unerimum, Pennisetum purpureum, Andropogon gayanus, and Pennisetum unisetum*. This vegetation type has been adversely affected by human activities leading to the clear-cutting of tree cover in many parts of the town. Due to this, artificial vegetation has replaced natural and secondary vegetation (Abah, 2013). The population of the people as at 2006 was 300,377: of which 154,138 were Males, and 146,239 Females (National Population Commission, 2006).

Data Collection and Analysis

Multistage sampling technique was adopted for the study. The study area was first stratified into urban and rural areas. Then, five (5) locations were randomly selected from both the urban and the rural strata and studied. Eventually, ten (10) locations in all were selected. The five (5) randomly selected urban locations were High Level, Wurukum, Wadata, North Bank and Gyado Villa (Table 1). In each of the selected urban locations, three (3) streets were randomly selected: resulting to 15 streets. Then, on each of the selected streets, ten (10) residential houses were purposively selected; five (5) residents each with tree canopies, and five (5) each without tree canopies. Eventually, one hundred and fifty (150) urban residential houses were sampled and studied.

Similarly, the five (5) randomly selected rural locations or settlements surrounding Makurdi metropolis were: Akile, Angbaaye, Tyo Mu KM13 and KM14, and Abua (Table 1). Since streets were not well-marked within these settlements, three (3) landmark areas such as markets, churches and school areas were used in each of the five settlements to purposively select residential houses with tree canopies and those without tree canopies. Thus, 15 such landmark areas were purposively sampled and ten (10) residential houses: five (5) each with tree canopies, and five (5) without tree canopies selected purposively and studied. A total of one hundred and fifty (150) residential houses were eventually selected from these rural settlements and studied.

Consequently, a total sample size of three hundred (300) residential houses were sampled and studied. In every residential houses visited, measurements were taken twice in each of the representative months of the rainy and dry seasons. All tree species available in residential houses were identified and recorded, and the type of roofing materials used were also identified and recorded.

Data collection on wall temperature measurements were taken at a height of 1.5m above ground level following Amusa and Adebayo (2018). Mercury-in-glass thermometers were used in all the selected residential houses with tree canopies and those without tree canopies. The measurements were taken between 11:30am and 12:30pm when no precipitation was expected. This process spanned over two seasons: the dry and rainy seasons representing respectively September and October, and February and March.

Data were analyzed using a Paired sample t-Test, analysis of variance (ANOVA), Pearson Correlation and Thom's Thermo-Hydrometric Discomfort Index, DI. The Paired samples t-Test tested for significant variation in temperature between residential houses with tree canopies and those without tree canopies in urban and rural areas of the study. The formula for two sample t-Test is stated below.

$$t = (\bar{x}_1 - \bar{x}_2) / \sqrt{[(s^2_1 / n_1) + (s^2_2 / n_2)]} \;\ldots\ldots (1)$$

Where,

- $\bar{x}_1$ = Observed Mean of 1st Sample
- $\bar{x}_2$ = Observed Mean of 2nd Sample
- s_1 = Standard Deviation of 1st Sample
- s_2 = Standard Deviation of 2nd Sample
- n_1 = Size of 1st Sample
- n_2 = Size of 2nd Sample

Analysis of Variance (ANOVA) was used to test significant temperature variation between urban and rural locations within Makurdi.

The formula of ANOVA is

$F = MST/MSE$ ……. (2)

F = ANOVA coefficient

MST = Mean sum of squares

MSE = Mean sum of squares due to error

Pearson Correlation was used to test the effects of different building materials and trees on temperature in residential houses in the study area. The formula for Pearson Correlation's is state below.

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

Where,

r = Pearson Correlation Coefficient

x_i = x variable samples $\quad$ y_i = y variable sample

$\bar{x}$ = mean of values in x variable $\quad$ $\bar{y}$ =mean of values in y variable

Thom's Thermo-Hydrometric Discomfort Index, DI, was used to determine comfort zones for human habitation within the study area. The Formula is as follows:

DI = T – (0.55 – 0.0055RH) (T – 14.5) ….. (4)

Where;

T is Temperature in °C

RH is Relative Humidity of the air.

Table 1: **Sampling Frame and Sample Selection Matrix**

Urban Area							Rural Area						
Location	**Name of the Street**	**Coordinates**		**RWT**	**RWOT**	**Total**	**Location**	**Landmark Used**	**Coordinates**		**RWT**	**RWOT**	**Total**
		Latitude	**Longitude**						**Latitude**	**Longitude**			
High	1. Iorkyaa Ako street	7.7265254	8.5260608	5	5	10	Akile	1. NKST Nur/Pry sch	7.7223830	8.6811420	5	5	10
Level	2. Uke Wende Street	7.7223083	8.5259896	5	5	10		2. Royal Partners Global			5	5	10
	3. David Mark Bye-Pass	7.7265250	8.5259900	5	5	10		Resources	7.7242600	8.6833770	5	5	10
								3. Doobee Nur/Pry Sch	7.7337200	8.6263930			
Gyado	1. Villa Suite road	7.7211160	8.5698780	5	5	10	Angbaaye	1. Christian Reformed Church	7.7496230	8.7431710	5	5	10
Villa	2. Mercy Yilase street	7.7211160	8.5698780	5	5	10		2. Angbaaye Market	7.7358670	8.7048540	5	5	10
	3. Joseph Ayu street	7.7220020	8.5670678	5	5	10		3. Piggery, Masev road,	7.7496280	8.7382620	5	5	10
								Angbaaye					
North	1. Ter Guma street	7.7606020	8.5465430	5	5	10	Tyo-Mu	1. Emmanuel Foundation	7.7080373	8.6348259	5	5	10
Bank	2. Udei street	7.7532202	8.5479020	5	5	10	KM13	Academy II					
	3. Alhaji Jidda street	7.7534595	8.5581958	5	5	10		2. St Donatus Catholic Church,	7.7072587	8.6320456	5	5	10
								Igbaule					
								3. Tyo-Mu KM13 Market	7.773372	8.6213930	5	5	10
Wadata	1. Benue Crescent Road	7.737298	8.508774	5	5	10	Tyo-Mu	1. Redeemed Christian Church of	7.7072580	8.6320456	5	5	10
	2. Ahmadu Commassie	7.7402974	8.5101463	5	5	10	KM14	God					
	Road			5	5	10		2. NKST Church, Ioryina	7.7733720	8.6213930	5	5	10
	3. Zaki-Biam street	7.7310526	8.5015692					3. St Peter's Catholic Church,	7.7146379	8.5994055	5	5	10
								Ibua					
Wurukum	1. Awe street	7.7284609	8.5407234	5	5	10	Abua	1. Living Faith Church, Abua	7.760780	8.578798	5	5	10
	2. Amokachi Lane	7.7255940	8.5389830	5	5	10		2. Abua Market	7.7273940	8.6882700	5	5	10
	3. Iyorchia Ayu Road	7.7261321	8.5418970	5	5	10		3. Paradiso Farms	7.7254040	8.6909620	5	5	10

Note*: RWT = Residential houses with trees, RWOT= Residential houses without trees*

RESULTS

Tree Species Composition in Residential Houses in Makurdi and the Surrounding Rural Communities

A total of 29 species of trees with 284 individuals representing 15 families were encountered in residential houses within the study area (Table 2). The result of the study shows that *Mangifera indica* had the highest frequency of occurrence of 61 and percentage composition of 19.4% and ranked 1st while 6 other tree species: *Anacardium occidentale*, *Caryota urens*, *Leuceana leucocephala*, *Moringa oleifera*, *Psidum guajava* and *Tectona grandis* all have frequency of occurrence of 1 each with 0.3% composition and ranked 14th. Fabaceae was the most represented family with 4 species.

Temperature Variation between Residential Houses with Tree Canopy and those without Tree Canopy in Makurdi

The result of the study as presented in Table 3 revealed that, the mean temperatures of residential houses with tree canopy and those without tree canopy in the rural locations of Makurdi, showed a significant difference (Mean Difference = 0.88 ± 1.55) (t = 31.20; r. value = 0.59; df = 599; p = 0.01). Furthermore, the result on Temperature variations in the urban area (Table 4) showed a significant difference in wall temperatures of residential houses with tree canopy and those without tree canopy (Mean Difference = 3.64 ± 2.86) (t = 31.20; r. value = 0.65; df = 599; p = 0.01). -Also, comparing the mean temperature values of residential houses with tree canopy in rural locations within Makurdi and residential houses with tree canopy in urban locations within the study area, there was a significant difference (Mean ±SD = 0.88 ± 0.44). The same scenario applies for residential houses without tree canopy in rural locations within Makurdi and those in urban locations within the study area (Mean ±SD = 4.6 ± 1.89).

Table 2: Tree species recorded in Makurdi Metropolis and the Surrounding Rural Communities

S/N	Tree Species	Common Name	Family	Frequency occurrence of species	Urban	Rural	%	Ranking
1	*Mangifera indica*	Mango tree	Anacardiaceae	61	x	x	19.4	1
2	*Terminalia mentalis*	Umbrella tree	Combretaceae	25	x	x	8	2
3	*Citrus sinensis*	Orange tree	Rutaceae	25	x	x	8	2
4	*Cocus nucifera*	Coconut tree	Arecaceae	21	x	x	6.7	3
5	*Elaeis guineensis*	Oil Palm tree	Arecaceae	18	x	x	5.7	4
6	*Newbouldia laevis*	Boundary tree	Bignoniaceae	18	x	x	5.7	4
7	*Ficus polita*	Heart-Leaved fig	Moraceae	15	x	x	4.8	5
8	*Ficus thonnigii*	Strangler Fig	Moraceae	15	x	x	4.8	5
9	*Azadirachta indica*	Neem tree	Meliaceae	10	x	x	3.2	6
10	*Delonix regia*	Flamboyant tree	Fabeaceae	9	x	x	2.9	7
11	*Polyalthia longifolia*	Masquerade tree	Annonaceae	8	x	x	2.5	8
12	*Terminalia catapa*	Almond tree	Combretaceae	8	x	x	2.5	8
13	*Gmelina arborea*	Gmelina/White teak	Lamiaceae	8	-	x	2.5	8
14	*Parkia biglobosa*	Locust bean tree	Fabeaceae	6	-	x	1.9	9
15	*Khaya senegalensis*	Mahogany	Meliaceae	6	x	x	1.9	9
16	*Prosopis africana*	African mesquite/Iron tree	Fabaceae	5	x	x	1.6	10
17	*Vitex doniana*	Black plum	Lamiaceae	4	-	x	1.3	11
18	*Eucalyptus mansonia*	Eucalyptus tree/blue gum	Myrtaceae	4	-	x	1.3	11
19	*Hura crepitans*	Sandbox tree	Euphorbiaceae	3	x	x	1	12
20	*Ficus asperifolia*	Sutro	Moraceae	3	-	x	1	12
21	*Spondias mombin*	Mombins/Hog plum	Anacardiaceae	2	x	x	0.6	13
22	*Ceiba pentandra*	Silk cotton tree	Bombacaceae	2	–	x	0.6	13
23	*Syzygium guineense*	Bambara	Myrtaceae	2	-	x	0.6	13
24	*Anacardium occidentale*	Cashew tree	Anacardiaceae	1	x	x	0.3	14
25	*Caryota urens*	Fishtail palm/toddy palm	Arecaceae	1	x	x	0.3	14
26	*Leucaena leucocephala*	Jumbay tree/white leadtree	Fabaceae	1	x	x	0.3	14
27	*Tectona grandis*	Teak	Lamiaceae	1	x	x	0.3	14
28	*Moringa oleifera*	Moringa tree	Moringaceae	1	x	x	0.3	14
29	*Psidum guajava*	Guava	Myrtaceae	1	x	x	0.3	14
	Total			**284**			**100**	-

Key: x=present

Table 3: **Temperature variation of residential houses without tree canopy and those with tree canopy in rural locations in Makurdi, Benue State**

Rural Residential Houses	Mean ±SD	Mean Difference	r. value	t. Test	df	p. value
Houses Without Trees	25.08 ± 1.87	0.88 ± 1.55	0.59	13.82	599	0.01
Houses With Trees	24.20 ± 1.43					

Significant level = 0.05

Table 4: Temperature variation of residential houses without tree canopy and those with tree canopy in urban locations in Makurdi

Urban Residential Houses	Mean ±SD	Mean Difference	r. value	t. Test	df	p. value
Houses without Trees	29.68 ± 3.76	3.64 ± 2.86	0.65	31.20	599	0.01
Houses with Trees	26.04 ± 2.29					

Significant level = 0.05

Temperature variance between urban and rural locations within Makurdi, Benue State

The result of analysis of variance presented in Table 5 showed that the urban location within Makurdi has a mean temperature of 27.75 ±3.57 while the rural location recorded the mean temperature of 24.64 ±2.16. Consequently, this shows a significant variation in the mean temperature difference between urban area and the rural area within Makurdi.

Temperature variation by season in Makurdi, Benue State

The result of the study as presented in Table 6 shows temperature variation in residential houses with tree canopy and those without tree canopy during rainy and dry seasons in the study area. The results showed a significant difference in wall temperatures of residential houses with tree canopy and wall temperatures of residential houses without tree canopy during rainy season (Mean Difference = 1.38 ± 1.95) (t = 10.28; r. value = 0.48; df = 209; *p* = 0.01). The scenario is the same for dry season where the results of paired sample t-test for means comparison showed a significant difference in wall temperatures (Mean Difference 2.80 ± 3.64) (t = 22.69; r. value = 0.46; df = 869; p. value = 0.01). Comparing the mean temperature values for rainy and dry seasons within the study area, the results of paired sample t-test for means comparison also showed a significant difference (Mean Difference = 1.42 ± 1.69).

Table 5: Analysis of variance of wall temperatures between the Urban and rural locations in Makurdi, Benue State

Nature of Area	N	Mean±SD
Urban	1140	27.75 ±3.57^{a}
Rural	1260	24.64 ±2.16^{b}
FStat.	-	582.543
Df	-	1
P.Value	-	0.00

Significant Level = 0.05

Table 6: Temperature Variation by Season in Makurdi

Season	Paired Samples	Mean ±SD	Mean Difference	r. Value	t. Test	Df	p. value
Rainy	Wall temperature of houses without trees	26.55 ± 2.13	1.38 ± 1.95	0.48	10.28	209	0.01
	Wall temperature of houses with trees	25.17 ± 1.58					
Dry	Wall temperature of houses without trees	27.97 ± 4.08	2.80 ± 3.64	0.46	22.69	869	0.01
	Wall temperature of houses with trees	25.17 ± 2.30					

Significant level = 0.05

Determination of comfort and discomfort zones in urban locations in Makurdi

The result of determination of comfort and discomfort zones in urban locations in Makurdi indicates that, residential houses with tree canopy within Wadata recorded highest mean temperature of 28.5°C and Discomfort index (DI) value of 20.8˚C, while residential houses with tree canopy in Gyado Villa recorded lowest mean temperature of 26.7˚C and DI value of 20.1˚C. Besides, residential houses without tree canopy in Wadata recorded highest mean wall temperature of 31.5˚C with a DI value of 22.0˚C while residential houses without tree canopy in Gyado Villa recorded the lowest mean wall temperature of 30ºC with a DI value of 21.6ºC (Table 7)

Determination of comfort and discomfort zones in rural locations in Makurdi

The result of determination of comfort and discomfort zones in the rural locations in Makurdi indicates that, residential houses with tree canopy within Tyo-Mu KM13, Tyo-Mu KM14, Angbaaye and Akile all recorded highest mean temperature of 24.5ºC and DI value of 19.1˚C, while residential houses with tree canopy in Abua recorded lowest mean temperature of 23.5˚C and DI value of 18.6˚C. Also, residential houses without tree canopy in Tyo-Mu KM13, Angbaaye and Abua all recorded highest mean wall temperature of 27.00˚C with a DI value of 20.2˚C while residential houses without tree canopy in Akile recorded the lowest mean wall temperature of 25.5˚C with a DI value of 19.5˚C (Table 8).

Table 7: **Determination of Comfort and Discomfort Zones in Urban Locations in Makurdi**

Houses with Trees in the Urban Area				**Houses without Trees in the Urban Area**			
Locations	**Mean Temp°C**	**DI °C**	**Remark**	**Locations**	**Mean Temp °C**	**DI°C**	**Remark**
Wurukum	27.5	20.4	No discomfort	**Wurukum**	30.5	21.8	Under 50% of the population feels discomfort
Wadata	28.5	20.8	No discomfort	**Wadata**	31	22.0	Under 50% of the population feels discomfort
North Bank	28	20.6	No discomfort	**North Bank**	30.5	21.8	Under 50% of the population feels discomfort
High Level	27	20.2	No discomfort	**High Level**	30.5	21.8	Under 50% of the population feels discomfort
Gyado Villa	26.7	20.1	No discomfort	**Gyado Villa**	30	21.6	Under 50% of the population feels discomfort

Table 8: **Determination of Comfort and Discomfort Zones in Rural Locations in Makurdi**

Houses with Trees in the Rural Area				**Houses without Trees in the Rural Area**			
Locations	**Mean Temp°C**	**DI°C**	**Remarks**	**Locations**	**Mean Temp°C**	**DI°C**	**Remarks**
Tyo Mu 13	24.5	19.1	No discomfort	Tyo Mu 13	27.0	20.2	No discomfort
Tyo Mu 14	24.5	19.1	No discomfort	Tyo Mu 14	26.5	20.0	No discomfort
Angbaaye	24.5	19.1	No discomfort	Angbaaye	27.0	20.2	No discomfort
Abua	23.5	18.6	No discomfort	Abua	27.0	20.2	No discomfort
Akile	24.5	19.1	No discomfort	Akile	25.5	19.5	No discomfort

DISCUSSION

Tree Species Composition in the Study Area

This study recorded rich tree species diversity with a total of 29 tree species. The tree species encountered in this study is therefore higher than the 22 species recorded by Amusa and Adebayo (2018) in their study in Ilorin. Similarly, Oladele *et al*, (2020) in Rivers State recorded only 26 tree species. Out of the 29 tree species encountered in this study, *Mangifera indica* was the predominant tree species. Its dominance could be attributed to its dual-purpose use for food and ecosystem services for shade. Ogunkalu *et al.* (2017) stated that the kind of trees chosen for planting directly affects the diversity, stability, and usefulness of urban forests. These personal aspirations or goals may include, among other things, the production of non-timber forest products of utmost importance, medicinal and fruit production, the supply of shade, and the prevention of erosion (Ogunkalu *et al.*, 2017). This was demonstrated by the work of Agbelade *et al* (2016) in Abuja and Minna, were good number of tree species recorded such as *Anacardium ocidentale, Cocos nucifera, Psidum guajava*and *Mangifera indica* were species that provide edible fruits for the residents and some of the residents use them for commercial purposes. The diversity of urban tree species is an important component of urban ecosystem providing environmental, social, and economic benefits and this has been reported by many authors and includes influences the provision of several environmental and social services that contribute to improving the quality of life for inhabitants (Nowak *et al.,* 2016; Nunez-Florez *et al.,* 2019; Roebuck *et al.,* 2022). Studies in North America have demonstrated that urban trees have the potential to contribute to climate change mitigation, particularly through the sequestration and storage of carbon (Nowak *et al.,* 2014). The role of diversity and species composition of urban tree populations has been shown to be an important factor in achieving urban cooling and microclimatic regulation by Winbourne *et al.* (2020) and Sharmin *et al.* (2023) in their separate studies. Recent studies have demonstrated localized practical benefits increasing tree species diversity, for example: an increase in the urban heat island mitigation capability of urban green spaces that have a tree species diversity, an increase in user's wellbeing following use of plant and tree species rich urban trails (Nghiem *et al.,* 2021).

Temperature Variation between Residential Houses with Tree Canopy and those without Tree Canopy in Makurdi

The study recorded a significant temperature variation between residential houses with tree canopy and those without tree canopy both in rural and urban locations within Makurdi and environs. This has proven the effectiveness of trees in reducing high temperatures, especially in the urban areas, which are characterized by impermeable surfaces, construction of buildings, as well as emission of heat, moisture and pollution related to human activities. This agrees with the submission by Enete and Alabi (2012) that the amount of heat held within urban surface is decreased the tree shading. This they supported it with the findings of their study where the street temperatures were found dropped by 3°C in the late afternoon when shadings were present. In Enugu City, findings by Enete *et al.* (2014) indicated that shading lowered the temperature by 8 and 5 degrees Celsius, respectively, in the months of February and March. June and July are the rainiest months, and shade lowered temperatures by 12 and 10 degrees Celsius, respectively. A robust shade tree's canopy reflects almost no direct sunlight. Similar experiences were recorded by Enete and Ifeanyi (2015) in Enugu as well as the work carried out by Adebayo *et al* (2017) in Ibadan. All found that "green lands or tree canopy play vital role in reducing or weakening the effects of urban heat islands". The observed temperature variation between urban and rural locations within Makurdi can also be attributed to the rapid growth in population in the urban centers

Mean Temperature Variation in Residential Houses with Tree Canopy and Residential Houses without Tree Canopy during Rainy and Dry Seasons in Makurdi

The study shows that urban heat islands occur in Makurdi during dry and rainy seasons. However, the intensity of this phenomenon was more felt during the dry season. This could be attributed to abscission occasioned by reduced rainfall during dry season, which leads to minimal shading effect within Makurdi. The findings from studies carried out by Enete *et al* (2014) in Enugu city, and Amusa and Adebayo (2018) in Ilorin; all showed that shading effect of trees in reducing temperatures was more effectively experienced during the rainy season. Therefore, the variation observed in this study and findings from the studies carried out by

Enete *et al* (2014) and Amusa and Adebayo (2018) could be due to differences in the observed impact of shading effects of tree-and variability in rainfall during dry and rainy seasons, as well as intensity of solar radiation, vapor pressure of ambient air and others (Enete *et al* (2012) during these studies.

Temperature Variation between Urban and Rural Locations within Makurdi

The study recorded a significant variation in temperature between urban and rural locations within the study area. This could be as a result of the nature of the rural and urban locations, where the urban area, as opposed to the rural area, is characterized by high concentration of large number of buildings in a relatively small urban space. This contributes to modifying various urban climatic elements such as the air temperature or wind speed and direction.

Thermal Comfort Conditions within Makurdi

The study recorded thermal discomfort conditions in all urban locations without tree canopy. However, the situation was different in all urban locations with tree canopy, where there was no thermal discomfort. The situation in the rural location was slightly different. There were no thermal discomfort conditions in both locations with tree canopy and those without tree canopy. The established differences could be largely due to rising temperature over built-up areas in the urban areas, marked by the replacement of vegetated cover with non-permeable surfaces. This agrees with the study conducted by Adebyo *et al.* (2017) in Ibadan, which stated that rising temperature over developed areas could have adverse impact and increase living discomfort within city areas. Furthermore, the nature of rural environments, which is characterized by presence of more trees, low built-up areas, and reduced human activities account for low temperature records in the rural locations. This expresses a pronounced influence of the level of urbanization and human activities on the human sensation of thermal comfort conditions. Heat discomfort, such as recorded in residential houses in urban locations in Makurdi may result in disease of different kinds such as skin rashes, meningitis and stroke among others (Olatunde and Kabir, 2019). Other urban discomfort situations are high body temperature, headache, nausea, confusion, losing consciousness, heavy sweating, and muscle cramps among others (CDC, 2017).

CONCLUSION

This study investigated the effects of tree canopy on urban heat islands in Makurdi, Benue State, North-central Nigeria. A total of 29 species of trees with 284 individuals representing 15 families were encountered in residential houses with predominant species and family been *Mangifera indica* and Fabeaceae respectively. There was significant difference in temperature between urban locations and rural locations within Makurdi. This study has provided empirical evidence about the occurrence of urban heat island in Makurdi metropolis, having established that there was a significant temperature difference between the urban area (27.75˚C) and the rural area (24.64˚C) within Makurdi and environs. The paper has shown that significant differences in temperature occurred between residential houses with tree canopy and residential houses without tree canopy in both urban and rural locations within Makurdi. It further established a strong relationship between the absence of trees and increase in temperature. Similarly, discomfort zones exist within Makurdi metropolis, especially in areas without tree canopy (DI of between 21.6ºC – 22˚ C) which implies that under 50% of people living in such locations feel discomfort.

RECOMMENDATIONS

It was recommended that, Government institutions charged with responsibility of implementing various towns' master plans should be effective and efficient in delivering their constitutional mandates. Particularly such plans that encourage the development and maintenance of green environment in cities to slow the trend in urban heat islands so as to ameliorate the negative impact of temperature increase in the urban areas. Also, Forest Officials charged with the responsibility of implementing forestry laws in the state and regulating tree felling must be professional in discharging their responsibilities to curtail indiscriminate cutting down of trees for various purposes. Similarly, promotion of urban tree planting in Makurdi will contribute immensely towards decreasing urban heat island and entrenchment of urban micro-climate that create more comfort zones conducive for human habitation. Further research should be carried out using meteorological weather station data of rural and urban sites or remote sensing.

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