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An Analysis of the Urban Canopy Heat Island (UCHI) of Kano Metropolis during the Warm/Wet Season

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Abstract
Urbanization has had a profound impact on our local, regional and even global climate, through the modification of the natural environment by replacing it with artificial surfaces, canyons and materials. This study seeks to assess the nature of Urban Canopy Heat Island (UCHI) intensities in Kano metropolis during the Wet/Warm season. The study involved the measurement of temperature within the period and determination of the UCHI within Kano metropolis. The study measured the temperature data using an automatic temperature data logger and determined the UCHI from the data collected. The different sample stations were determined using the canyon zoning system known as the Urban Climate Zone (UCZ). Temperature and UCHI variation for the study were also determined for two periods that showed its diurnal distribution. The study area was categorized into 13 stations and all the classes of the UCZ fit into the study area. The UCHI Characteristics shows a generally warm profile during the day time and night time periods, suggesting that most of the stations had high temperatures. This can be attributed to the high amount of clouds found in August, which provides a green house effect for the out going long wave radiation, there by conserving the heat within the UCZ.

1. INTRODUCTION

An urban area is perhaps the most complex of the entire earth surface phenomenon; this is due to the multi-facetious nature of its artificial character as promoted by the various activities taking place in such an area. The highly varying temperature characteristics of the urban structures, the artificial injection of heat into the urban system and the presence of aerosols in the atmosphere have led to a considerable urban temperature field (Montávez*et al*, 2000).Significant and widespread changes in land use/land cover resulting from urbanization cause changes in climatic conditions of a place. The best-known phenomenon resulting from these modifications is the so-called Urban Heat Island (UHI) (Landsberg, 1981 and Montávez*et al*, 2008). Oke (1987) defined UHI as the temperature differences between the urban area and its rural surroundings, always assuming that the records should be similar if there were no urbanization.

Landsberg (1981) stated that an understanding of the urban heat island is important for a variety of reasons; the radiation absorbed warms the ambient air thus increasing the low-level stability and consequently preventing the pollution dispersal, which will result in an increase in pollution concentration. It also helps in setting up of the recirculation of pollutants thus making the pollution problems more serious with increasing emphasis on planning for healthier and comfortable physical environments in cities: Thus, the need to recognise the role of cities increasing and meeting the challenges posed by climate change has become greater. This paper is aimed at presenting the UCHI of Kano metropolis during the Hot/Dry season.

2. STUDY AREA

Kano Metropolis is one of the nerve centers of commercial activities in Nigeria. It is located between latitudes 12^0 25'N and $12^0$40'N and $8^0$35'E and 8^0 45'E. Its boundary keeps on changing with time (Mortimore, 1989). The area is presently made up of six local Government areas namely: Municipal,Gwale, Dala, Tarauni, Nassarawa and Fagge.

Kano metropolis exhibit the characteristics of a typical African city with cleared vegetation, reclaimed ponds, constructed buildings of various sizes and orientation, criss-cross of roads as well as open spaces like parks, institutions; human activities from transportation, homes, small, medium and large scale industries which serve as sources of pollution and heat generation to a high degree. The population of the area in 1991was put at 1,364,300 with a population density well over 450/km^2 (Mortimore, 1989) and the 2006 census revealed that Kano state had over 9 million persons with more than half living in the metropolis.

The present climate of Kano is the Tropical wet and dry type, coded as Aw according to Koppens classification,. Air temperature characteristics in Kano metropolis as a whole are typical of West African savannah climate. Temperature in the region is generally high throughout the year. The season found within the metropolis includes; The dry and cool season (mid – November to February), The dry and hot season (March to about mid – May), The wet and warm season (May to Mid September), and The dry and Warm (September to December).

3. METHODOLOGY

The study area was divided into several climate zones or canyon category as defined by Oke (2006). The categorization of the climate zone was done using Urban Climate Zone (UCZ,) and it was based on aerial, street view and sky-view photographs, height to width ratio were applicable, surface coverage, nature of surface, nature of building materials and other descriptions given to such categories or zones, which include function of such zones. 13 stations were identified, 12 of which were under the urban fields, while 1 was a rural field and served as the control station.

The temperature data was measured using the digital Thermochron from maxim-ic. For details on its durability and reliability see Hubbart et al (2005). The device was mounted about 3 meters above the ground and 10 meters from the nearest obstacle (house/tree), except where the measurement is supposed to depict a direct effect of obstacles, as when measuring urban vegetation. The iButton was programmed to log data at every 15 minutes interval for 15:00hrs (day time) and 20:00hrs (night time). The exposure period was 30 days (1 to 30th April).

The UCHI intensity sought is the multiple heat islands spread across the entire study area and among the various zones of the LULC categorization done for the study. The UCHI intensity is defined for this study as UCHI = $Tu_x - Tr_c$; where:

T represents temperature of a sample station.
u represents urban stations.
r represents rural control site.
x represents the sites from site 1 to 12 which are in the urban area.
c represents the control site outside the area.

4. RESULTS AND DISCUSSION

4.1Temperature Variation

Figure 4.1 Show the results and graphical representation of mean temperature during Wet season at the different UCZ, it revealed an uneven distribution among most of the study stations. TF, SG, BG, and LS have the highest mean temperature values of 30.47^{0}C, 30.30^{0}C, 28.76^{0}C, and 28.25^{0}C respectively while AP, BK, and SH have the lowest mean temperature values of 24.12^{0}C, 24.48^{0}C and 24.89^{0}C respectively.

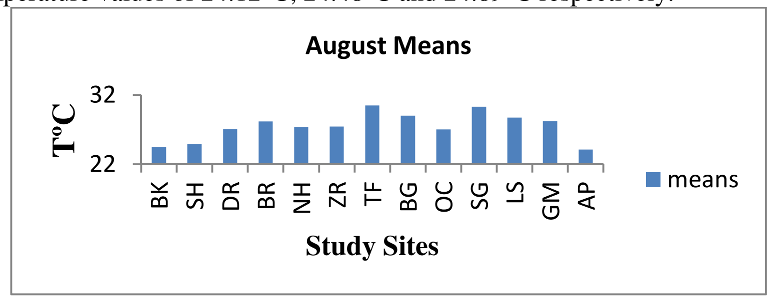

Figure 4.1 Mean temperatures for the study area during Wet period

The difference between the highest and the lowest mean values of the UCZ is 6.0^{0}C the result found in Kano is still higher than that of Ibadan, but same with that of Yola (6^{0}C). This could be attributed to the high amount of clouds found in August, which provides a green house effect for the outgoing long wave radiation, there by conserving the heat within the UCZ. This may be the probable cause of the high temperature range. In order to test for significant variation among the UCZs during the season, a single factor analysis of variance (ANOVA) was used. The results obtained are as presented in Table 1, and shows a very significant variation in temperature between the UCZ at 0.1% significant level.

Table 4.1 ANOVA results for Wet period

	Sum of squares	df	Mean square	F	Sig
Between Groups	393.226	12	32.769		
Within Groups	15210.157	299	50.870	.644	.804
Total	15603.384	311			

Figure 4. 2 show the results and the graphical representation of mean diurnal temperature for the various observation sites during the wet season in August at 15:00 local time (3:00pm). The results reveal that TF, SG, LS and GM have the highest mean temperature values of 43.90^{0}C, 42.22^{0}C, 39.83^{0}C and 38.78^{0}C, while AP and SH have 34.12^{0}C and 35.87^{0}C. It has a mean temperature range of 9.78^{0}C.

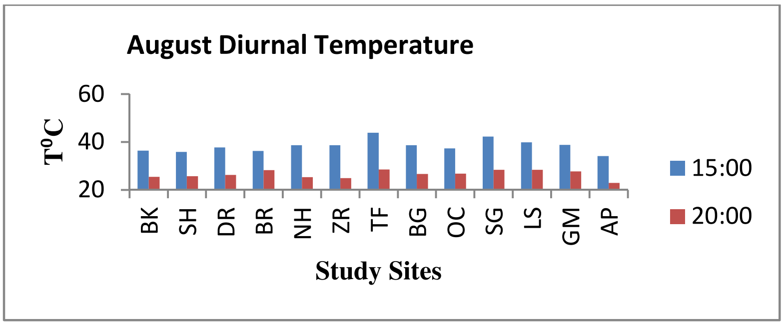

Figure 4.2 showing the Diurnal temperature variation for Wet period

Figure 4.2 show the mean diurnal temperature value at 20:00 local time (8.00pm) representing night time reading in the stations. TF, LS, SG, BR and GM have the highest diurnal mean temperature value of 28.45^{0}C, 28.33^{0}C, 28.31^{0}C, 28.21^{0}C and 27.72^{0}C, while AP and ZR have the least value of 22.96^{0}C and 24.94^{0}C respectively. It also has a mean temperature range of 7.1^{0}C. The difference between the day time intensity and night time is 5.49^{0}C. The differences among the stations are because of the various functions of the streets and the nature of their surfaces. SG, TF and LS are the highest because they have

Very busy streets, thick walls and close-set buildings, and are able to generate a lot of heat.

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	87.26119	12	7.271766	0.645055	0.785043	2.147926
Within Groups	293.1007	26	11.2731			
Total	380.3519	38				

4.2 The day time for August Spatial Pattern

From figure 6.12 representing the wet season's spatial variation, the mean value in the urban climate zones are almost similar to the April readings with the highest stations being TF, SG and BG while AP and BK are the lowest with a temperature range of 6.0^{0}C. This may be attributed to the nature of the impervious surface characteristics, green house effect and cloud cover

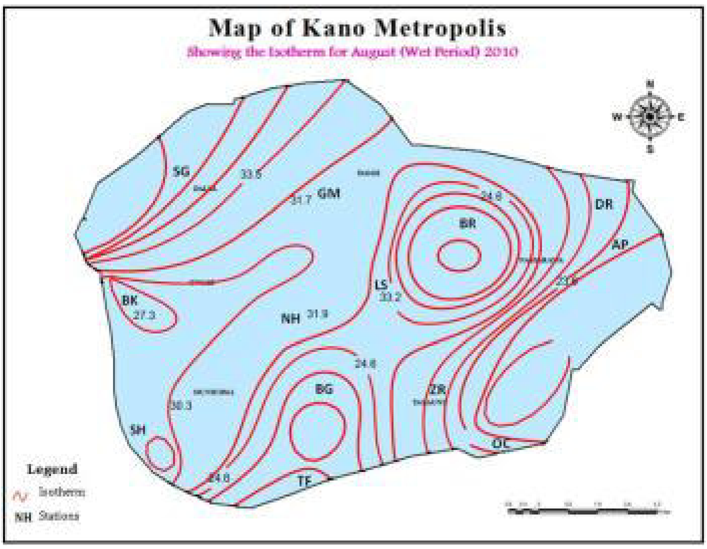

Figure 6.12 Spatial Temperature (°C) Variation during the August (Wet) period

4.2 Daytime UCHI characteristic

Figure 4.3 is characterized as being warm and wet and shows a UCHI intensity profile that suggests a higher UCHI intensity. The highest recorded was for TF with a UCHI intensity of 9.78°C, with other stations such as SG following closely at 8.1°C. These differences could be attributed to the roughness elements there, as well as the level of anthropogenic heat and pollution resulting from the types and level of human activities going on in these areas. The mean UCHI intensity is 4.22°C and has about 58% of the stations above the mean intensity. The lowest UCHI intensity in the period is 1.75°C at SH. This is due to the nature of the surface, especially its ability to retain water after the rains, thereby reducing the amount of ambient heat through evaporative cooling. The range of UCHI intensity during this period is 8.03°C.

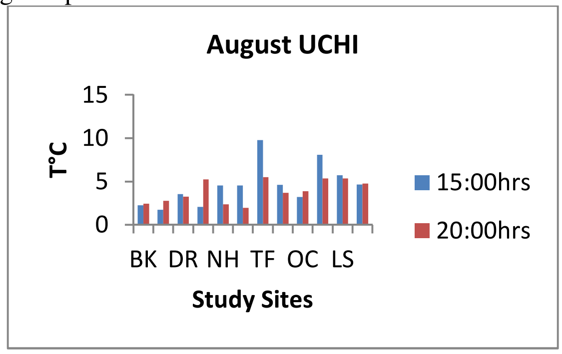

Figure 4.3 Diurnal UCHI Variations for Wet period

4.3 Night time UCHI Characteristics

Figure 4.3 shows the UCHI intensity profile for August representing the wet season. The highest night time UCHI intensity for this period is TF at 5.49°C, followed closely by LS, SG and BR at 5.37°C, 5.35°C and 5.25°C respectively. These stations have quite high surface roughness elements and also high level of human activities (For example high vehicular and human traffic). These places have mostly mixed activities, i.e. more than one form of activity, like serving as both commercial and residential quarters. The mean UCHI intensity for this period is 3.58°C, and the profile shows that 58.33% of the stations show a result that is higher than the mean. The station that had the highest intensity was also the same for the day time measurement; this suggests that a lot of activities must have taken place during the daytime to make it retain that much heat. The lowest record was for ZR at 1.98°C, and this record was followed closely by NH at 2.36°C and BK at 2.43°C. These places have vegetation, and with the exception of ZR, the rest are found in the fringes of the city. The UCHI range for this period is 3.51°C. The result is similar in intensity to studies in the extra-tropical regions (Elias son, 1996; Elias son and Svensson, 2003) and some in tropical regions (Chow and Roth 2006). Low UCHI is caused by low thermal storage resulting from lack of tall skyscrapers that would have restricted thermal radiation, reduced turbulent exchanges, and allowed thermal radiation to be emitted from the vertical building surfaces.

5. CONCLUSION AND RECOMMENDATION

The UCHI Characteristics shows a generally warm profile during the day time, suggesting that most of the stations had high temperatures. The UCHI intensities can be attributed to the nature of the surface materials and characteristics, as well as level of human activities ranging from moderate to high, taking place within the various stations. And the night time UCHI intensities' result suggests a generally warm night. The result suggests that the UCHI intensity during this period, indicating the ability of the various stations to retain heat.

These studies hereby recommend that urban planners should engage in extensive decongestion of the crowded parts of our cities, so as avoid heat stress. The traffic conditions within the city should also be addressed, as the nodal points within the metropolis play an important role in the temperature/UCHI intensity distribution. Re-a forestation should be encouraged rather than deforestation. Trees planted around a building, shades it from direct solar heating. A forestation should be seen as a necessary option for reducing Green House Gases (GHGs), through carbon-dioxide sequestration.

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