

Urban Heat Island Magnitude and Discomfort in Enugu Urban Area, Nigeria.

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Abstract
The aim of this study is to assess the urban heat island magnitude and associated discomfort in Enugu Urban Area, Nigeria. The Study Design used was Survey Study. The study area was Enugu urban between months of February, March, June and July of 2010 and 2011. Different sites were selected as experimental sites in Enugu urban area and a reference station created in a rural like environment. Also, the cooling degree days for Enugu was calculated for two years (January – December) 2010 and 2011. The result showed a significant difference between the urban and rural temperature. The observed UHI reaches its peak intensity in the late evening and early night. The air temperature difference between the urban and rural reaches maximum at 2100 hours and goes down gradually until reaching a minimum at 1400 hours. The range of temperature across the study area is 2.0^{0C}. The CDD analysis showed that Enugu urban has no month that is not discomforting. The level of discomfort experienced by the people of Enugu from UHI shows that they are always in discomfort from weather conditions. This is usually in the form of heat stress, heatstroke, heat cramps, fatigue, exhaustion and even death. These impacts also have multiplier effects on labour and productivity as well as socio-economic development of the people.
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1. Introduction

It has long been recognized that urban areas have their own climates (Howard, 1818; Oke, 1982 and Arnfield, 2003), and are generally warmer than surrounding rural areas. The urban environment has the capacity to store heat during the day, which originates from both absorption of solar radiation and human activity. This absorbed heat is then released at night. Because of this heat release, night-time air temperatures in urban areas are higher than surrounding rural areas. The temperature difference between the urban and rural area is referred to as the "Urban Heat Island" (UHI). The result of this change can have significant effects on local weather and climate (Landsberg, 1981).

According to (UNFPA, 2007; World Bank, 2009; UN, 2010) more than half of the world's population currently lives in cities and this number is anticipated to reach 60% (or 4.9 billion) by the year 2030. These urban populations are therefore exposed to both urban-induced climate modification and larger-scale climate change resulting from increasing greenhouse gas concentrations. This rapid population growth will largely drive the extent and rate of global environmental changes and many of these changes are related to the climate and atmospheric composition of cities, including the canopy layer UHI – the observed warmth of the urban core compared to its rural surroundings, heat stress, and various forms of air pollution (Landsberg, 1981; Oke,1982) UHI exacerbate climate change, which will impact living and working environments negatively and create health threats for millions of people (IPCC, 2007; Costello et al., 2009).

Urban centers are drivers of heat islands because they concentrate industries, transportation, households and many emitters of greenhouse gases (GHG) and they are affected by climate change (Lankao and Gnatz, 2008). Climate deterioration of overcrowded and urbanized zones is also due to the scarcity of parklands; grass been replaced by vast concrete surfaces where chains of buildings are built (Makhelouf, 2009).All this cause 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(Oke, 1982). Other causes of UHI include geometric effects, the tall building within many urban areas provide multiple surfaces for reflection and absorption of sunlight, increasing the efficiency with which urban areas are heated and this is called the "canyon effect". However, Fuchs (2005) observed that the main cause of UHI is the modification of the land surface by urban development and waste heat generated by energy usage.

The average global temperature is increasing and it is estimated that it will go up a further $1.8 – 4.0^0C$ (estimated average 3.0^0C) by the year 2100 (IPCC, 2007). Increasing local ambient temperatures implies higher human exposure to heat and this can create very severe heat stress and health risks for the populace. The heat stress may create impacts both on workers' health, productivity and socio-economic development (Kjellstorm, 2000; Kjellstorm, 2009).An understanding of current and possible future changes in the magnitude of the UHI is therefore necessary for planning, developing and classifying Enugu urban comfort zones. This, therefore, is the objective of this study. This study becomes necessary since UHI awareness in Enugu city is at its lowest ebb.Thus, the study is expected to stir awareness and interest.

2. Study Area.

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.

Enugu Urban which is the study area is made up of Enugu East, Enugu North, and Enugu South (figure 1.). Enugu Urban is also 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. 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.

TABLE 1 Enugu Urban Local Government Areas Population

LOCAL GOVERNMENT AREA	MALES	FEMALES	TOTAL
Enugu East	131, 214	145, 905	277, 119
Enugu North	118, 895	123, 245	242, 050
Enugu South	93, 758	104, 274	198, 032
Total	343, 867	373, 424	717, 201

Source: National Population Commission (2006).

Enugu Urban is the educational, commercial, industrial and administrative base of Enugu State. The biggest market within the Urban is located within Enugu North Local Government Area; Ogbete Main Market. There are some other prominent markets such as Kenyeta market in Enugu South, Abakpa Market in Enugu East including New Market situated also in Enugu North. As the administrative center of the State, a reasonable percentage of the inhabitants are civil servants. They work in various Government establishments and offices.

3. Methodology.

3.1 Site selection

Two land use classes (residential and commercial) and two land- cover types (paved and green surfaces) were considered for this study. The permeability of land surfaces to water, role of industry (including automobile) in the land-use category and the potential for evaoptranspiration were the characteristics of distinction used in the selection of the study sites.

3.2 Sampling
Purposive sampling was employed based on location, presence or absence of these variables and the degree of vegetation shade available. Consequently, 20 sites were selected.

3.3 Atmospheric Stability Estimation
The magnitude of microclimate variations in urban areas depend on the atmospheric conditions at the macro-level. Although many methods of estimating atmospheric stability near the ground exist, the Pasquil – Turner Index modified by Karlson (Karlson, 1986) is the most relevant for the study since it utilizes solar radiation and wind speed data only. Karlson's MPT is given as:

$MPT= Q^*/U^2$

Where Q^* =hourly average net radiation at 1.5m above ground (Wm^{-2}). U = hourly average wind speed at 7.4m above ground (Ms^{-1}). The following MPT values were selected as cut-off points for the three atmospheric stability conditions examined in the present study:

$MPT > 30$ Unstable
$-10 < MPT < 30$ Neutral
$MPT < -10$ Stable

Data from Akanu Ibiam Airport was used to determine the MPT values during the study period. Fine sunny days with little wind usually lead to unstable surface atmospheric conditions. Stable atmospheric conditions are generally associated with clear, calm nights while cloudy and windy days tend to produce neutral atmospheric conditions (Oke, 1987).

3.4 Measurement Techniques.
Air temperature was measured at each experimental site and a reference station set up for the study at an open area (Western side) of Akanu Ibiam Airport. In close proximity to a full-featured weather station maintained by Nigeria Meteorological Agency (NIMET) at the Airport. Akanu Ibiam airport is one of the international airports in Nigeria located in Enugu state and 10kms away from Enugu urban area.

The Enugu urban site (1) and the rural reference site (2) are classified as Built Climate Zone (BCZ5) and Agricultural Climate Zone (ACZ3) respectively (Stewart and Oke, 2009). The sites were selected for fixed point observations and data were obtained from shielded portable lascar EL-USB-2 temperature/humidity data loggers, sampled at 5-minutes intervals that were mounted on a lamp post above head height (3m) in the city urban centre and on a mast at the same height in the reference station (near the airport). Position of the sensor at the urban site was carefully selected to prevent elevated heat sources such as rooftops. Afternoon air temperatures at 3m above roof level are about 2 degrees higher than 2m above street level (Sakaida and Suzuki, 1994)

The difference in temperatures between the city and the reference station, Tu –Tr, is the most commonly used index of the intensity of the UHI. The quality of this difference is accepted as a measure of the city's influence on thermal conditions (Balogun et al., 2009).Cooling degree days are values compiled daily to assess how much energy may be needed to cool buildings and create comfort. In determining the cooling degree days (CDD), average temperature value is calculated for a given day. If it is greater than the standard base, the standard base value is subtracted from calculated average temperature to yield the CDD. This is compiled for daily and totaled for entire month. The CDD is calculated using the following formula; CDD=E (ti –T). Where ti is the daily mean temperature and T is the required room air temperature (25 ^{o} C). The rationale behind this technique is that wherever average temperature exceeds the comfort range, some cooling will be required, the requirement for cooling increases with increasing temperature.

4. Results
The average daily temperature and the daily temperature range for each of the sites were compiled using the hourly temperature measurements. These averages were used to determine the site specific average dry season and rainy season temperatures defined by the months of February/March and June/July as shown in table 2.

Table 2: Monthly mean temperature for Reference station (Tr) and urban sites (Tu) reported as a spatial average (Tm u – r).

Month	Urban sites (u)	Reference site (r)	Tm u-r
February	31.0^{0C}	28.5^{0C}	2.5^{0C}
March	32.5^{0C}	30.8^{0C}	1.7^{0C}
June	29.8^{0C}	27.8^{0C}	2.0^{0C}
July	28.2^{0C}	26.4^{0C}	1.8^{0C}
Feb – July	30.3^{0C}	28.3^{0C}	2.0^{0C}

Also, the results of the calculated CDD results for two years (2010 – 2011) are shown in table 3.

Table 3: The Results of the Calculated CDD

Month/ Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2010	5.2	6.4	6.2	5.9	5.2	4.0	2.6	2.5	3.4	4.2	5.2	4.7
2011	4.3	6.6	6.3	6.3	5.1	4.5	3.1	3.5	4.2	4.2	5.4	5.5

5. Discussion

Urban heat island generally increased with increasing air temperature. On a daily basis, the UHI reaches its peak intensity in the late evening and early night. The air temperature difference between the urban and rural reaches maximum at 2100 hours, and goes down gradually until reaching a minimum at 1400 hours. This observation is in conformity with the studies of Yang et al., (1984). The range of temperature across the study area (spatial range) was 2.0^{0C} with maximum heating in the urban core and generally busy areas where human activities are concentrated. Observed factors that encourage UHI within Enugu urban include: poor building design, poor orientation of buildings, insufficient green cover, absence of green roofing and increased pavements.

The mean annual CDD results in degrees Celsius from 2010 to 2011 for Enugu was calculated (see table 3). It was observed that the range of its variation per month for the two year data from January to December was within the range of 2.5 to 6.6, which indicates that they are all within a close range. The high CDD values indicate that there are no comfortable or cold situations in Enugu as no month was below 25^{0C} (see table 2). .

According to Oguntoyinbo (1986), the months proceeding the rainy season (February, March and April) had the most discomfort. And observation has shown too that the months of July August and September tend to be less discomforting. In Enugu, even months of October, November and December also have high discomfort values despite the presence of harmattan. Harmattan is West Africa weather phenomenon which is dry by day and clod by night. It carries dry air from Sahara with cold intrusion from the Mediterrian. The level of discomfort experienced by the people of Enugu based on this study, shows that they are always in discomfort from weather conditions. This is usually in the form of heat stress, heat stroke, heat cramps, fatigue, exhaustion, headache, fainting and even death. And this will ultimately impact both on workers' health, productivity, and socio-economic development of Enugu urban as more of the energy will be geared towards making the area comfortable. These ugly situations will be exacerbated following the recent urbanization processes and the resultant UHI effects.

6. Implications of Uhi and Discomfort on Human Health in Enugu Urban

Extreme heat is more than an issue of discomfort. It forces the body into overdrive as it tries to stay cool through perspiration and evaporation. People in urban areas are at greater risk because the stagnant atmospheric conditions trap pollutants in the air, which, when taken, can trigger respiratory problems for many people. The effect of extreme heat can undermine physical well being so slowly and subtly that the dangers are not apparent until it is too late. Heat can affect anyone; but it is more likely to affect young children, elderly people, and people with health problems.

In regions of low humidity, the most common human response to extreme heat is dehydration. Exposed to direct sunlight and temperature in excess of 32.2^{0C}, man loss as much as half a gallon of water every ten minutes, and this dehydration can seriously interfere with one's internal thermostat. Concerning malaria, the spread of this disease is limited by conditions that favor the disease vector (the malaria bearing mosquito anopheles) and the parasite (plasmodium). Mosquito is most comfortable with temperatures of approximately 20^{0C} to 30^{0C} and at a humidity of at least 60 percent. Also, the malaria parasite develops more rapidly inside the mosquito as the temperature rises, and the development ceases entirely below approximately 15^{0C}. Increased temperature and increase surface water, expected to result from UHI (as hot air rising draws low pressure airs) will produce more breeding grounds for mosquito. Malaria currently kills 2 million people each year (Pim, 2005).

The growing "heat islands" tend to aggravate the risk of more frequent heat waves, as well as their impacts. Research indicates that variability in dry season nighttime minimum temperature (temperature above 32^{0C} at night) – combined with lack of acclimatization, high humidity, and poorly ventilated and insulated housing stock – may be the most important factor in urban heat deaths (Chestnut et al, 1998). Because climate change is expected to raise nighttime minimum temperatures more than daytime highs, urban heat islands would be a significant health concern in the city. Conversely, during the rainy season, the heat island enhances the intensity and frequency of rain showers (Changnon, 1992), leading to higher risk of street flooding or mudslides where the urban poor live. Moreover, warmer and drier climates may aggravate air pollution seasonally because of wind erosion in bare soil areas in cities. Blowing dust and high temperature are likely to increase the incidence of heat stroke, respiratory illness, and transmission of disease by deposition of airborne bacteria in lungs and on food.

7. Mitigation Strategies

The study, based on these findings, proposed some design strategies for the mitigation of Enugu urban heat island. Employing these strategies will result in substantial green cover increase in the city while street level thermal comfort is enhanced by arcades and suitable building massing (compact designs).The building massing is such that tall buildings are on the eastern side of the city blocks while green area is in the center and to the northeastern side of the city. In most of the sampled areas, street tree planting offers the greatest cooling potential per unit area, followed by light surfaces. However, light surfaces offer the greatest absolute temperature reductions, because 23.02% of Enugu urban surface area could be lightened, whereas only 9.45% of the city's surface area could be planted with new street trees.

Planting street trees has greater cooling potential than planting open-surface/plantation trees, because the temperature differential between trees and impervious surfaces is greater than that between trees and grass (Emmanuel, 1993). Also, the cooling effect of open-space trees tends to be localized. For example, surface cooling around judiciary quarters (Okpara square) tends to be limited to 61 meters from the square's borders (Adinna, 2009). Again, mitigation strategies should be chosen to reflect neighborhood conditions. For example, in most case-study areas, curbside planting is the individual strategy with the greatest cooling potential. However, in Achara Layout, Abakpa and New Heaven, with the greatest available rooftop, space, living roofs could have a greater impact. Finally, using light-colored materials for the roofing of downtown locations as well as improving the reflectivity of pavements within the urban centers and the adjoining suburbs could minimize the impact of urban heat islands in Enugu urban.

8. Conclusion

Urban heat island is an environmental threat that is adversely affecting human by causing various health impacts. This study has assessed the UHI magnitude and discomfort associated with it by calculating the comfort index for Enugu urban. The analysis showed that Enugu City has urban heat island magnitude of 2.0^{0C} (spatial range) with minimum and maximum heating at 1400 hours and 2100 hours respectively. The UHI observed, on daily basis, reaches its peak intensity in the late evening and early night. The THI analysis showed that Enugu urban falls within two classifications: one in which most people suffer discomfort and one where everyone feels stressed. The high THI values indicate that there are no comfortable or cold situations in Enugu as no month was below 21^{0C}.

The existence of UHI (magnitude 2.0^{0C}) and high THI value in Enugu urban has a multiplier effect. This is usually in the form of heat stress, heat stroke, heat cramps, etc. They impact on people's health, productivity, and socio-economic development. A range of mitigation strategies were also x-rayed; ranging from building design and orientation, compact designs, green cover increase in the downtown locations, green roofing and increased pavement reflectivity

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