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EFFECT OF GREEN SPACES ON URBAN HEAT DISTRIBUTION IN BWARI AND ABUJA MUNICIPAL AREA COUNCILS OF THE FEDERAL CAPITAL TERRITORY OF NIGERIA

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ABSTRACT

Urban Heat Distribution (UHD) is considered as one of the major problems in the 21st century posed to human beings as a result of industrialization and urbanization, though they tend to improve our material lives and comfort in some ways. Urbanization has resulted in alterations in spatial patterns of urban land use/land cover change; leading to decreases in green spaces. It is necessary to assess the role of green spaces on heat distribution in fast growing cities like Abuja. Developed countries have invested huge resources in developing green spaces as part of the best practices in mitigating urban heat, purifying the air, among others. This study analyzed the effects of green spaces in urban heat distribution (UHD) in FCT, Abuja, Nigeria. The urban temperature was estimated from Landsat Operational Land Imager (OLI) 2015 imagery and *in situ* data. ArcGIS 10.3 was used to generate Normalized Difference Vegetation Index (NDVI) and thermal maps of the study area. Results from the analysis of the thermal band of the satellite images and the *in situ* data revealed that differences in vegetation distribution caused differences in temperature variation. The ratio of temperature between urban heat area and green space areas increased rapidly with increasing distances from the green space boundaries. A comparison of temperature of some selected green areas and non-green areas showed marked differences. The three arms zone, a non-green area had a temperature4.2°C higher than National Arboretum, a green area. Louga Road (non-green area) had a temperature 4.47°C higher than Lobito Crescent Park. Thus green areas had relatively lower temperatures than built up areas and bare sources.This shows the important role played by green spaces in mitigating urban heat in urban central areas. The study also utilized Effective Temperature (ET) in calculating the Human Thermal Comfort Index in the study area to further buttress the mitigating effects of green spaces on urban heat distribution.

Keywords: Green Spaces, Urban Heat Distribution, Effect, Effective Temperature

1.0 Introduction

Increased replacement of the natural green area with urbanised areas has led to significant changes in the local weather conditions. Due to the economic demands, urban populations are constantly growing in size and complexity because more people are migrating from the rural areas to the urban centres. Earlier studies by Akbari (2011), Elsayed (2009), Giannaros and Melas (2012), Senanayake*et al.* (2004) have revealed that the temperature distribution in the urban areas is notably higher than its neighbouring suburban areas. The human induced heat released from vehicles, power plants, air conditioners and other heat sources, dramatic removal of the vegetation cover and increasing of impervious surfaces are major contributors to the formation of Urban Heat Distribution (UHD) (Memon*et al.*, 2008 and Senanayake*et al.*, 2013).

The concept of including green spaces in urban planning is an important feature in the history of urban planning (MacHarg, 1971). Proper understanding of urban heat distribution is important for a variety of reasons. The radiation absorbed warms the ambient air; increasing the low level stability and consequently preventing the pollution dispersal which results in an increase in pollution concentration. The urban heat distribution adds to the development and self-sustenance of a ‘dust-dome’ and a ‘haze hood’ of contaminating particles. It also results in setting up the recirculation of pollutants thus making the pollution problems more serious. With the increasing emphasis on planning for healthier and comfortable physical environments in cities, the need to recognise the role of cities in contributing to and meeting the challenges posed by climate change has become greater. The very presence of a city affects the local climate and as the city changes, so does, its climate. The modified climate adds to the city residents’ discomfort and even ill-health (Devi, 2003).

Studies on adequate environmental preferences specifically this kind on the green space interaction with heat distribution are largely conducted in developed countries, but rarely in developing countries. Thus, the main goal of this paper is to understand the effect of urban green spaces on urban heat distribution in developing Nigeria, taking the city of Abuja as a case study. In a capital city, like Abuja, vegetation is crucial for reducing heat islands and creating shade. The benefits are more obvious when trees are abundant and when their canopies are large. It is believed that in Abuja, the temperature on the environment will not be so high if there are patches of trees that are abundant and large. Also, it has been noted that connected and complex shapes of tree canopy are usually perceived as natural landscapes (Lee *et al.*, 2008). These structures are often favoured because they create the feeling of being close to nature and away from the built environment, and thus bring a restorative experience. The study focuses on determining the effect of green spaces on urban heat distribution in the city of Abuja, Nigeria, taking into cognisance the importance of green spaces, and the effect of urban heat distribution on life and environment. The study purpose include to(1) compare heat distribution effect from Green spaces and non-green from satellite images (2)compare heat distribution effect from Green spaces and non-green from Field survey (3) examine the effects of the heat generated the likely comfort of the area.

1.1 Study Area

Abuja is the capital city of Nigeria; it is located in the centre of Nigeria, within the Federal Capital Territory (FCT). The study area covers 275 sq miles (713KM^2), with a population density of 1,235,880 and lies on latitude 8^0 25’N & 9^0 25’N and longitude 6^0 45’E & 7^0 45’E(Figure 1). Abuja is a planned city, and was built mainly in the 1980s. It officially became Nigeria's capital on 12 December 1991, replacing Lagos, though Lagos remains the country's most populous city. Abuja's geography is defined by Aso Rock, a 400-metre monolith left by water erosion. The Presidential Complex, National Assembly, Supreme Court and much of the city extend to the south of the rock. Zuma Rock, a 792-metre monolith, lies just north of the city on the road to Kaduna State.

Abuja, under Köppen climate classification features a tropical wet and dry climate. The FCT experiences three weather conditions annually. This includes a warm, humid rainy season and a blistering dry season. In between the two, there is a brief interlude of harmattan occasioned by the northeast trade wind, with the main feature of dust haze and dryness. The rainy season begins from April and ends in October, when daytime temperatures reach 28 °C (82.4 °F) to 30 °C (86.0 °F) and nighttimes low hover around 22°C (71.6 °F) to 23 °C (73.4 °F). In the dry season, daytime temperatures can soar as high as 40 °C (104.0 °F) and night-time temperatures can dip to 12 °C (53.6 °F). Even the chilliest nights can be followed by daytime temperatures well above 30 °C (86.0 °F). The high altitudes and undulating terrain of the FCT act as a moderating influence on the weather of the territory. Rainfall in the FCT reflects the territory's location on the windward side of the Jos Plateau and the zone of rising air masses with the city receiving frequent rainfall during the rainy season from March to November every year.

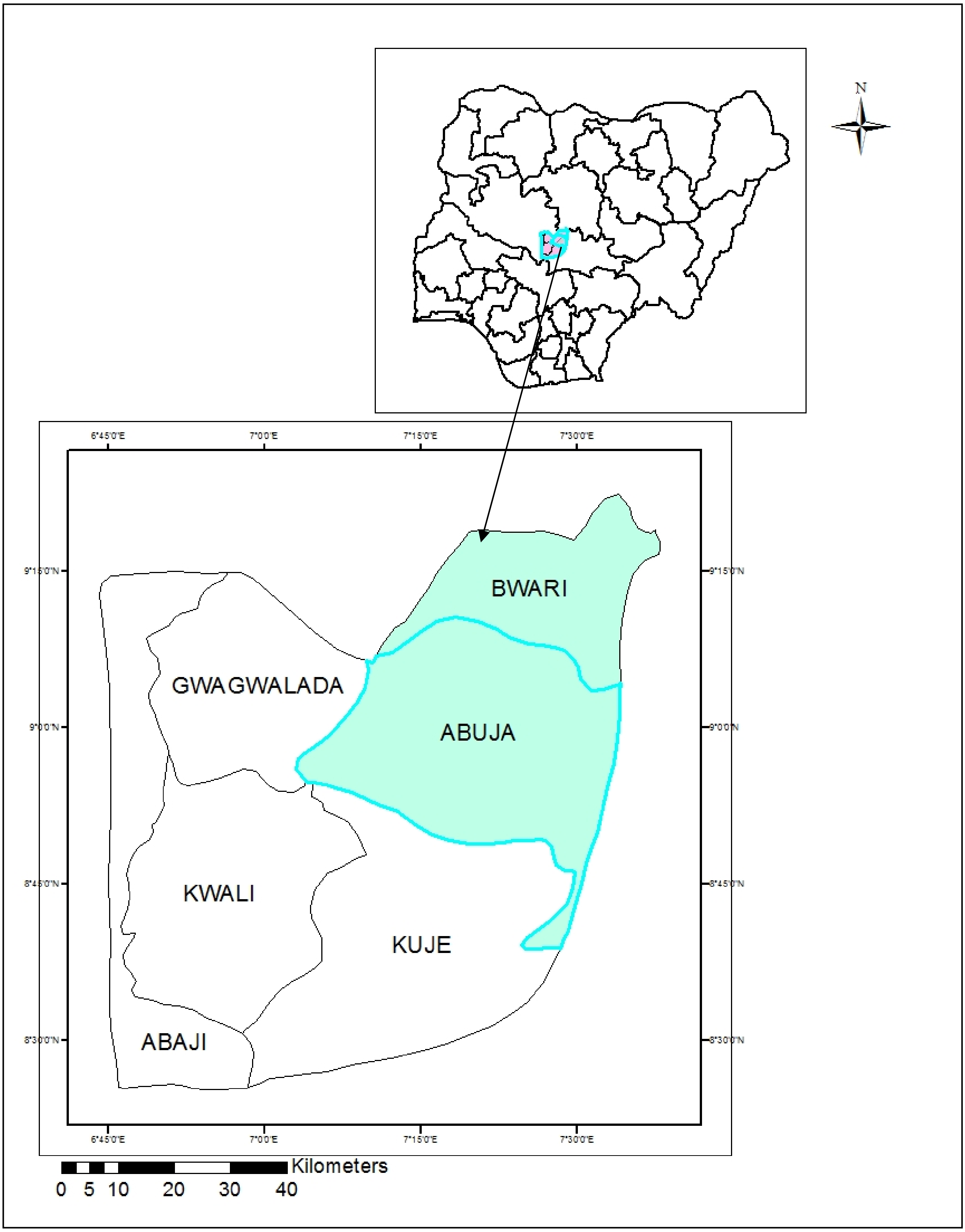

Figure1 Nigeria showing the Study Area Source: Author's Compilation (2017)

2.0 Literature Review

2.1 Urban Heat Distribution

Adinna*et al*. (2009) evaluated the impact of urban heat island effect in the Enugu city of Nigeria and suggested adaptive measures to keep the UHD under control in the city. The study concluded that the use of high dense green vegetation, low absorptive roofing materials and lightening of pavement materials can reduce the effect in Enugu urban settlement. Akbari*et al*. (2001) studied the effect of cool surfaces and trees shades on the UHD. The findings revealed that surfaces with great albedo and urban trees can significantly reverse the heat islands. Tthe cost reduction due to the mitigating measures of UHD was also calculated in the studies. According to Akbari*et al.* (2001), for every 1^0C increase in temperature, the electricity demand may rise by 2-4%. On the other hand, 20% energy used for air conditioning can be saved if mitigation measures are put in place in order to reduce the UHD. Yamamoto (2006) described several mitigation measures for UHD and also gave a description about some mitigation projects in Japan and other countries including the wind paths in Freiburg in Germany and recommended some key mitigation measures such as energy saving buildings and traffic systems, restoring green areas in urban areas and improvement of urban airflow.

2.2 Urban Green Space

Urban forests and trees contribute to a better quality of living environment in cities, for example by improving air quality and consequently the health of urban residents. Using a cross-sectional study design, De Vries*et al.* (2003) tested the hypothesis that people in green areas are healthier than people living in less green areas. The work combined Dutch data on the self-reported health of 17,000 people with land use data on the amount of green space in their living environments. The statistical examination controlled for confounding factors such as age, sex, and socio-economic status. The authors concluded that those living in a greener environment were positively related to all three available health indicators and the association was stronger for housewives and older people. The three health indicators considered by De Vries (2000).were: number of health problems experienced in the previous 14 days; perceived general health measured on a five point scale; and the score on the Dutch version on the General Health Questionnaire.

Currently, vegetal cover removal is one of the most alarming global development challenges. Specifically, it is the most serious long-term environmental issue affecting the world and Nigeria is not left out. Historically, the critical long term development challenge at the attainment of independence in 1960 was how to grow rapidly from a predominantly primary production based economy to an industrialized one with strong inter-sectorial links. The high hopes regarding the possibility of an appreciable progress towards getting self-sustained and rapidly industrialized within a generation or two was heightened by the emergence of the unprecedented large foreign exchange earnings from crude oil and gas exports. But after over four decades, this dream has remained largely unfulfilled in spite of all the development initiatives.

3.0 MATERIALS AND METHODS

3.1 Data

Moderate resolution multispectral and multi-temporal Enhanced Thematic Mapper Plus (ETM+) imageries of Landsatfor the year 2015 covering Abuja was obtainedfrom path 189 and row 54 were downloaded from Global Visualization site. It was used to identify the Green Spaces and Heat Distribution in Abuja and its environs. The image was used as a guide to identify the sampling points. Twenty-two (22) points were picked within the study area as sampled location for micro temperature data of all the points which form the primary data source used. Their respective locations, relative humidity, wind speed and temperature data were gathered using GPS, hand held thermometer, wind meter and humidity meter.The points were divided into two (2), eleven (11) of which are areas with green spaces and the other eleven(11) are areas without green spaces.Google earth image of the study area was also acquired.

3.2 Methods of Data Analysis

3.2.1 Micro Temperature Data Analysis (from Field work)

A portion was extracted from study area map for more detail study. From the extracted portion, figure 5 represents the NDVI map of the area while figure 6 represents the thermal map of the same area. Samples of different points were taken from both extracted maps based on two criteria as follows:

i. Built-up areas and bare ground (represented by alphabets a-k)
ii. Vegetated (green) spaces (represented by numbers 1-11)

The green spaces are represented by numbers 1-11 on the satellite images and shown on table 4.1 together with their absolute locations, relative humidity, wind speed and temperature; while the built-up/ bare ground areas indicated with alphabets (a-k). The details can be found on tables 4.1 and 4.2. This was necessary to compare the effect of vegetation/green spaces on heat distribution in the study area from field work as the same time estimate the thermal comfort of the area (Blazejczyk*et al.*, 2012)

After collecting the micro temperature data of the twenty two (22) locations, the data collected was tabulated and comparisons were made; some analogies were inferred and used in analysing the tabulated data. The result of the analysis was presented through simple line graphs and histograms with analysing comments. Also the micro temperature data from the locations were used to calculate the Human thermal comfort index of which the value accepted as a suitable comfort index for maximum comfort is (-0.5 to 0.5).

3.2.2 Creation of NDVI Map

Normalised Difference Vegetation Index (NDVI) is an index describing vegetation by showing the difference between near-infrared, which is strongly reflected by vegetation and red light which is absorbed by vegetation. The NDVI map was created in ArcGIS 10.2 environment using the Landsat ETM+ Imageries. Healthy vegetation (chlorophyll) reflects more near-infrared (NIR) and green light compared to other wavelengths and it absorbs more red and blue light. This was why NDVI map was chosen for this study because it uses NIR and Red channels to measure healthy vegetation and identify the locations of green spaces in Abuja and its environs.

The formula for calculating NDVI is:

NDVI = $\frac{NIR - red}{\quad}$ ……………………………………………………..(i)

3.2.3 Creation of Thermal Map

Heat map also referred to as thermal map of Abuja was created using ArcGIS 10.3. Thermal map is necessary for identifying the heat distribution in Abuja and its environs. The thermal map was generated using the thermal bands of Landsat Operational Land Imager (OLI) and the NDVI of the study area was calculated. The first step taken was to convert the Digital Numbers (DN) on the imageries to Radiance values using the formula

$$L_\lambda = M_L Q_{cal} + A_L \quad \text{……………………………………………(ii)}$$

where

L_λ = TOA Spectral Radiance (Watts/(m2 * srad *))

M_L = Band-specific multiplicative recalling factors from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)

A_L = Band-specific additive recalling factors from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)

Q_{cal} = Quantized and calibrated standard product pixelvalues (DN)

The Radiance calculated above was then used to generate the Satellite Brightness Temperature with the following formula

$$T = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)} \quad \text{………..…………………………………(iii)}$$

T = At-Satellite brightness temperature (K)

L_λ = TOA spectral radiance (Watts/(m2 * srad * µm))

K_1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the band number, 10)

K_2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the band number, 10)

But this gives the temperature on the satellite whereas land surface temperature was needed which lead to step the third step calculated using the following formula:

Land Surface Temperature = BT/1 + w * (BT/p) * in(e))

Where

BT = At Satellite Temperature

w = wavelength of emitted radiance (11.5µm)

p = h * c/s (1.438 * 10^-2 m K)

h = Planck's constant (6.626 * 10^-34 Js)

s = Boltzmann constant (1.38 * 10^-23 J/K)

c = Velocity of light (2.998 * 10^8 m/s

With these processes, the thermal map for Abuja City and its environs was generated so as to know the Heat Distributions in the area.

3.2.4 Thermal Comfort Index

To assess the thermal exposure of the human body, the integral effects of all thermal parameters must be taken into account. To this end, sophisticated bio meteorological indices are available to assess thermal comfort. Examples include the predicted mean vote (PMV), the physiologically equivalent temperature (PET), and the universal thermal comfort index (UTCI), which are based upon models for the human heat budget. Such models use all relevant meteorological parameters as well as physiological factors as input (Fiala*et al*., 2012) More so, Blazejczyk*et al*. (2012) compared several of the thermal comfort estimates from the simple empirical indices with the UTCI. This index has been proposed for use as the standard model to assess human thermal comfort, and is one of the indices based on a fairly complete description of the human energy balance. It was found that the so-called ET can be regarded as a reasonable proxy for the much more sophisticated UTCI. ET is computed from air temperature, water vapour pressure and wind speed, and these are generally available from meteorological observations. The findings of Blazejczyk*et al.* (2012) were confirmed in an independent analysis based on data from the Dutch city of Rotterdam (Stewart *et al.*, 2012).

Based on the results from the Field survey, ET was used as a thermal comfort index that was considered an alternative exposure indicator. ET was estimated as follows according to (Blazejczyk*et al.*, 2012):

$$ET = 37 - \frac{37 - T_{air}}{0.68 - 0.014RH + \frac{1}{1.76 + 1.4w_{v}^{0.75}}} - 0.29T_{air}(1 - 0.01RH) \quad \text{.........................(iv)}$$

Where:

T_{air} = air temperature (°C)

RH = the relative humidity of the air (%)

W = the average wind speed (m/s).

The ET threshold used to count occurrences of thermal discomfort is shown in Table 1. This table has been used to relate thermal comfort to ET in West Africa (Blazejczyk*et al.*, 2012). The situation where value ET ranges between 31-37 °C, conditions are generally perceived as ‘warm’, which corresponds to strong heat stress in other indices. Hence the number of zones where the maximum ET exceeds 31°C was counted. The perception of heat has typically been derived for daytime conditions.

Table 1: Effective Temperature Rating Table

ET RANGE (°C)	THERMAL COMFORT CLASS
>37	Hot
31-37	Warm
27-31	Comfortable
21-27	Fresh
17-21	Cool
11-17	Cold
1-11	Very cold

Note: ET values are different form air temperature values Source: Blazejczyk*et al.*, 2012

4.0 Results and Discussion

4.1 Green spaces and heat distribution effect from satellite image comparison

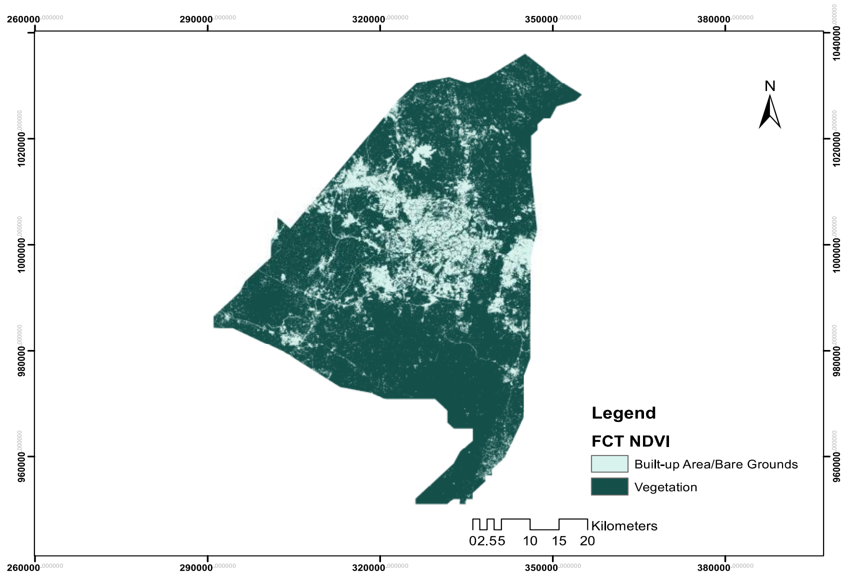

Figure 2: NDVI of the Area (FCT) in 2015 distinguishing Vegetation from built-up/bare ground

Source: Author (2016)

The major vegetation distribution of study area (FCT) Nigeria is shown on figure 2, the image showcases the various green spaces and built up area/bare ground available in the area from which the twenty-two sampled locations were picked and mapped. The dark green represent the green spaces in the area while the white bluish colour is the built up/ bare ground surface of the study area. It was seen that the dark green colour area are more that the built up/bare ground. They are equally found to be more dormant around the built up/bare ground of the study area. (Figure 2)

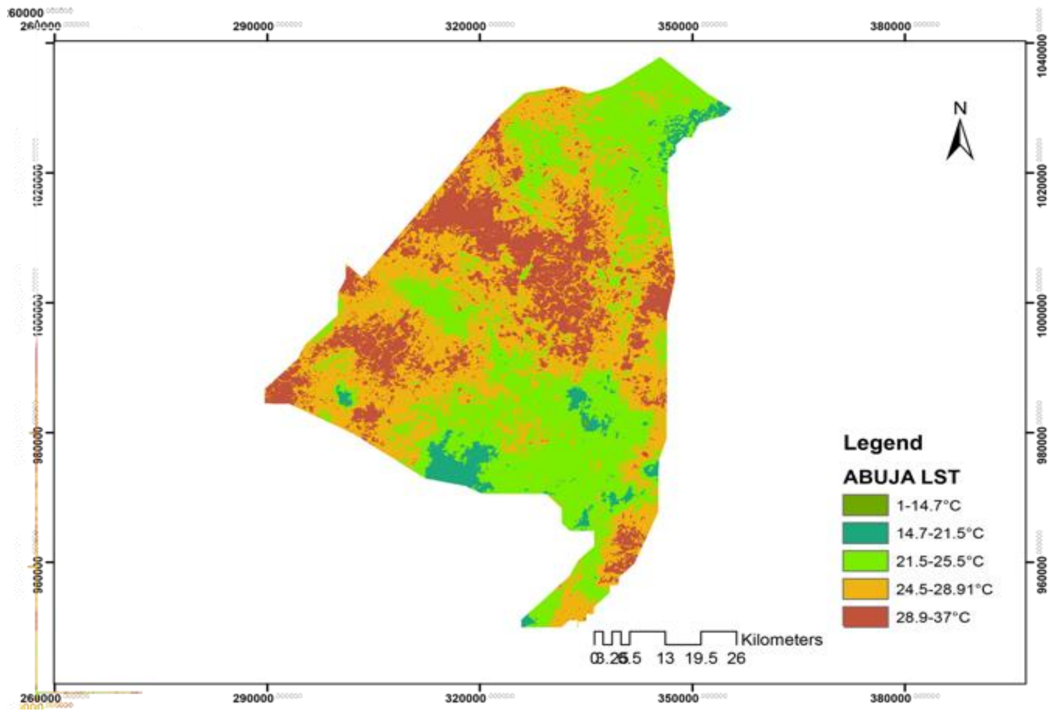

Figure 3: Temperature distribution of the area in 2015 Source: Author (2016)

The major heat distribution of the area is shown on Figure 3, the image showcases the various heat distribution of the study area which correlates with the sampled areas visited during the field survey. From Figure 3, Five (5) different ranges of heat were identified. The lowest temperature range was between 1^0c to 14.7 ^{0}C, which was not too pronounced in the map of heat distribution. This less visibility of this temperate range implies there are no low temperature distributions over the area. The second and third temperature ranges are between 14.7^{0}C to 21.5^{0}C and 21.50C and 25.5^{0}C respectively. These temperature classes are visible at areas at location far away from the centre of the city they represent suburban areas. The moderate temperature ranges these classes connotes that places further away from the city centre have lesser temperature compared with the main city. Temperature ranges, 25.5^{0}C and 28.9^{0}C and 28.9^{0}C and 37.5^{0}C respectively are more dormant at the point representing built up and bare ground surface in Figure 2 which represent the centre of the city the densely urbanized part of the study area. The Google earth image of the area (figure 4) depicts a portion of the built-up/bare ground and vegetation distribution of the area in 2016. Supporting the various effects of green spaces on heat distribution from satellite image comparison.

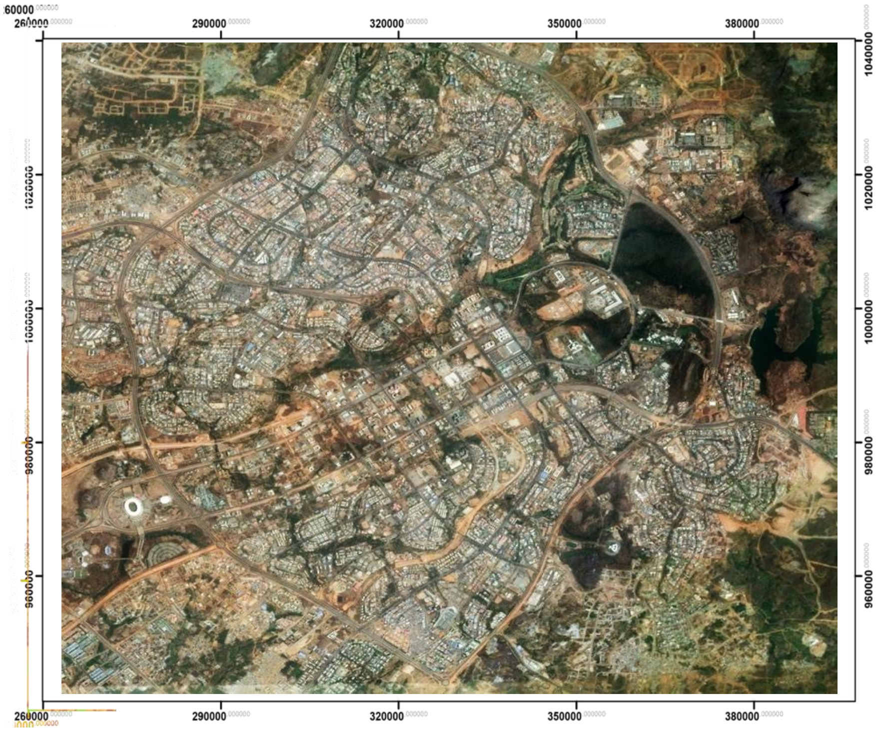

Figure 4: QuickBird image of FCT in 2016 Source: Google Earth 2016

4.2 Green spaces and heat distribution effect from micro field work comparison

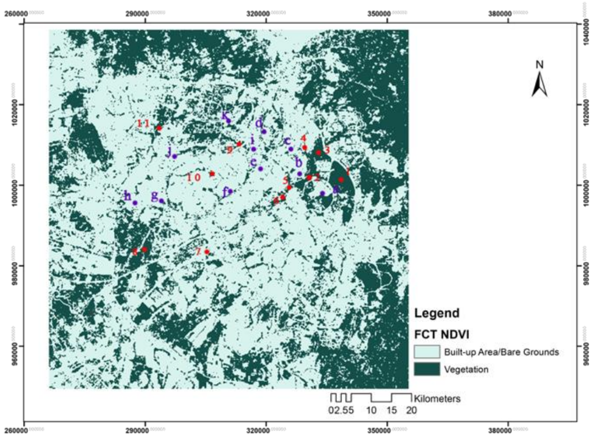

Figure 5: NDVI of an extracted area from Study Area

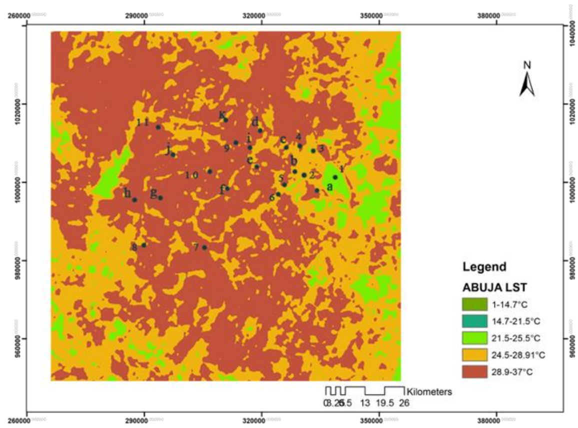

Figure 6: Temperature Distribution of an extracted area from Study Area

Source: Author's field work, 2016

As shown Figures 5 and 6; Tables 2 and 3, it was clear that the sampled green spaces have lower temperature reading than non-green space found in the study area. Comparing points (a) and (1) it was discovered that the temperature readings of point (a) 23.13^{o}C (non-green space, Three arms zone) is 4.2^{o}C higher than that of point (1) at 18.93^{o}C(green space, National Arboretum) . In the same vein, point (e) at 26.67^{o}C (non-green space, Louga road) is 4.47^{o}C higher than point (5) at 22.20^{o}C (green space, Lobito crescent park). Point (k) 24.12^{o}C (non-green space,Tapeta Street) is 2.14^{o}C higher than that of point (11) at 21.9^{o}C(green space,City Park). Details of other the temperature readings comparison between greens pace and non-green are shown see (Tables 2 and Table 3). On a general note, one can conclude that non green spaces mainly which comprises of built up and bare ground generate more heat than green spaces.

S/N	Green Areas	Coordinates		Rel. Humidity (%)	Wind Speed	Temp (^{o}C)
		Latitude	Longitude			
1	National Arboretum	9.087778	7.517747	89	3.4	18.93
2	Millennium park	9.070692	7.498844	82	3.5	19.23

3	IBB Golf Club	9.085819	7.506431	80	3.1	21.89
4	Maitamaneighbourhood park	9.085492	7.500022	79	2.9	22.10
5	Lobito crescent park	9.070408	7.4948	81	3.1	22.20
6	Durban street neighbourhood park	9.063008	7.438036	81	3.0	19.67
7	Abuja national stadium area	9.029297	7.452111	86	2.8	18.62
8	Nigeria army cemetery	9.026472	7.464519	80	3.2	21.45
9	Wuse rock park	9.069172	7.463728	78	2.8	22.12
10	Julius Berger neighbourhood park	9.068192	7.453742	79	2.5	22.06
11	City Park	9.077469	7.475753	79	2.6	21.98

Table 2 Green Areas with the relative temperatures and coordinates

Source: Author (2016)

Table 3 Built-UpAreas/Bare Ground with the relative temperatures and coordinates

	Non green areas	**Coordinates**		**Rel. Humidity (%)**	**Wind speed**	**Temp (ºC)**
		Latitude	Longitudes			
a	Three arms zone	9.066882	7.509857	75	2.5	23.13
b	Usuma street	9.074694	7.497720	76	2.4	22.89
c	Gana street	9.082284	7.498510	74	2.8	24.67
d	Pope John Paul II street	9.084111	7.494939	77	2.3	25.88
e	Louga road	9.073974	7.488556	73	2.2	26.67
f	4u supermarket	9.072122	7.484564	75	2.7	24.12
g	IdrisGidado street	9.048381	7.445309	76	2.4	24.55

h	Wuye	9.043536	7.440944	73	2.1	27.2
i	Madiana close	9.074827	7.470066	75	2.4	25.98
j	Yaounde street	9.074695	7.456771	73	2.5	26.8
k	Tapeta Street	9.077160	7.482543	74	2.2	24.12

Source: Author's field work, 2016

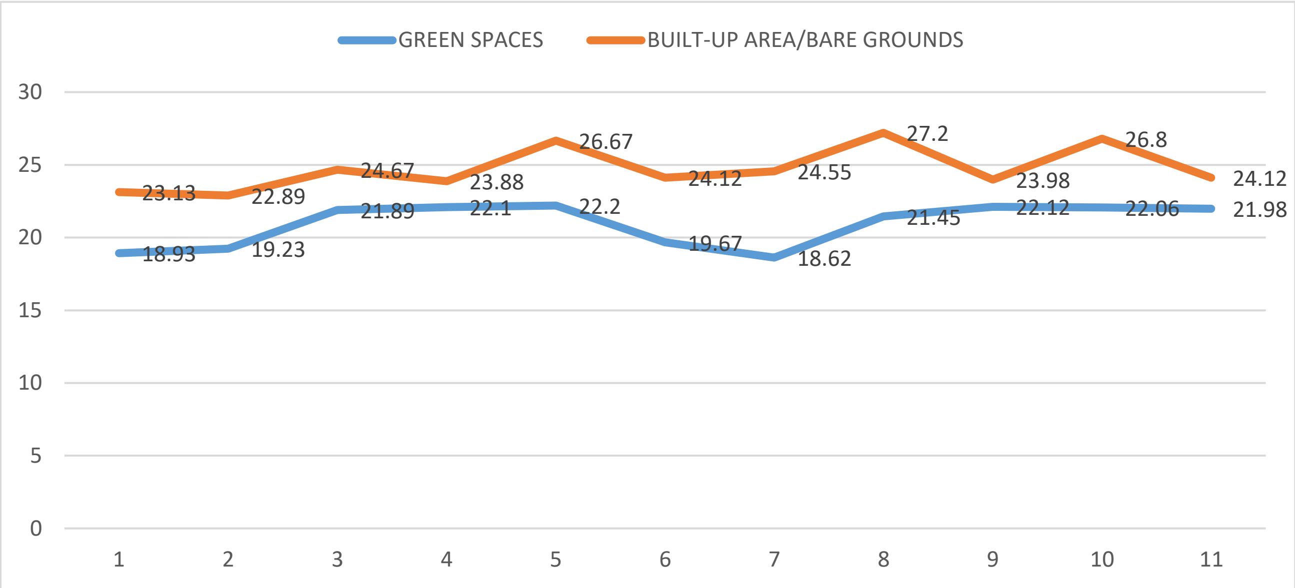

Figure 7 Temperature Graph showing readings from green spaces and Built-up Areas/Bare Grounds (Non green Spaces). Source: Author (2016)

Figure 7 show a clear indication of lower temperature from the line graph in green spaces as compared to Non Green spaces such as the built-up/bare ground areas. The gap between the lines is an indicator of the temperature difference between them. The wider the gap, the more the temperature difference, and the smaller the gap, the less the temperature difference between these points. Figure 7 depicting the temperature gap, proves that non green spaces have effect on temperature /heat distribution.

4.3 Thermal Comfort Index

Table 4 Thermal Comfort results for the selected green spaces.

Location	Efficient temperature (ET)	Thermal comfort index
National Arboretum	31.39	0.39
Millennium park	31.38	0.38
IBB Golf Club	31.59	0.59
Maitama neighbourhood park	31.46	0.46
Lobito crescent park	31.71	0.71
Durban street neighbourhood park	31.08	0.08
Abuja national stadium area	30.83	-0.16
Nigeria army cemetery	31.56	0.56
Wuse rock park	31.35	0.35
Julius Berger neighbourhood park	31.15	0.15
City Park	31.2	0.21

Source: Authors (2016)

The Thermal comfort Indices of the selected green spaces are shown on tables 4. The highest comfort is experience at Lobito Crescent Park with 0.71index value. IBB Golf Club, Nigeria army cemetery and Maitama Neighbourhood Park also have fairly high thermal comfort index of 0.59, 0.56 and 0.46 respectively while National Arboretum and Millennium parks also have thermal indices of 0.39 and 0.38 values. These identified areas have a thermal comfort class between warm and hot because of their high ET and thermal index. Other areas like Julius Berger neighbourhood park, City Park and Durban street neighbourhood park as well as Abuja national stadium area have extremely low 0.21,0.15, 0.08, -0.16 respectively. These areas have a thermal comfort class between cool and cold because of their low ET and thermal index.

Table 5 Thermal Comfort results for the selected non green spaces (Built-up Areas/Bare Grounds).

Location	**Efficient temperature (et)**	**Thermal comfort index**
Three arms zone	31.22	0.21
Usuma street	31.13	0.13
Gana street	31.68	0.68
Pope john paul ii street	31.83	0.83
Louga road	31.71	0.70
4u supermarket	31.57	0.56
IdrisGidado street	31.52	0.52
Wuye	31.77	0.77
Madiana close	31.79	0.79
Yaounde street	31.91	0.90
Tapeta Street	31.51	0.51

Source: Authors (2016)

The Thermal comfort Indices for non-green space (Built-up/Bare ground areas)is shown table5.The highest comfort is experience by virtually all the selected areas with the exception of three arms zone and UsumaStreet having low thermal comfort index of 0.21 and 0.31 respectively. The areas with high values is expected to have a thermal comfort class between warm and hot because of their high ET and thermal index while areas with low values will have a thermal comfort class between cool and cold. The summary of the

Table 6 Thermal Comfort indices for both Green Spaces and non-green spaces (Built-up Area/Bare Grounds)

Thermal Comfort Indices (Green Spaces)	**Thermal Comfort Indices Diff (Built-up/Bare Ground)**
0.39	**0.21**
0.38	**0.13**
0.59	**0.68**
0.46	**0.83**
0.71	**0.70**
0.08	**0.56**
-0.16	**0.52**
0.56	**0.77**
0.35	**0.79**
0.15	**0.90**
0.21	**0.51**

Source: Authors (2016)

KEY

Within Acceptable Range Manageable

Ideal Out of acceptable range

Table 6 shows the results obtained from the calculated thermal comfort indices based on the formula earlier mentioned under methodology. The table was colour coded to show the points that comply with the ET (Efficient Temperature) value needed and the ones that do not comply divided into four ranges starting with places within acceptable range, ideal, manageable and places termed as out of acceptable range.

For Green Spaces(Table 6)**,**National Arboretum, Millennium park and Wuse rock park have within the acceptable thermal comfort indices, while Maitamaneighbourhood park,Durban street neighbourhood park, Abuja national stadium area and Julius Berger neighbourhood park as well as City Park recorded an ideal thermal comfort index. While IBB Golf Club and Lobito Crescent Park have manageable thermal comfort index range but Lobito Crescent Park has a thermal index outside the acceptable index. For non-Green spaces(Table 6)**,**,three arms zone,andUsumaStreet have an ideal thermal comfort index;4u supermarket, IdrisGidado street and Tapeta Street have a manageable thermal comfort index; while other areas have thermal index exceeding the acceptable range.

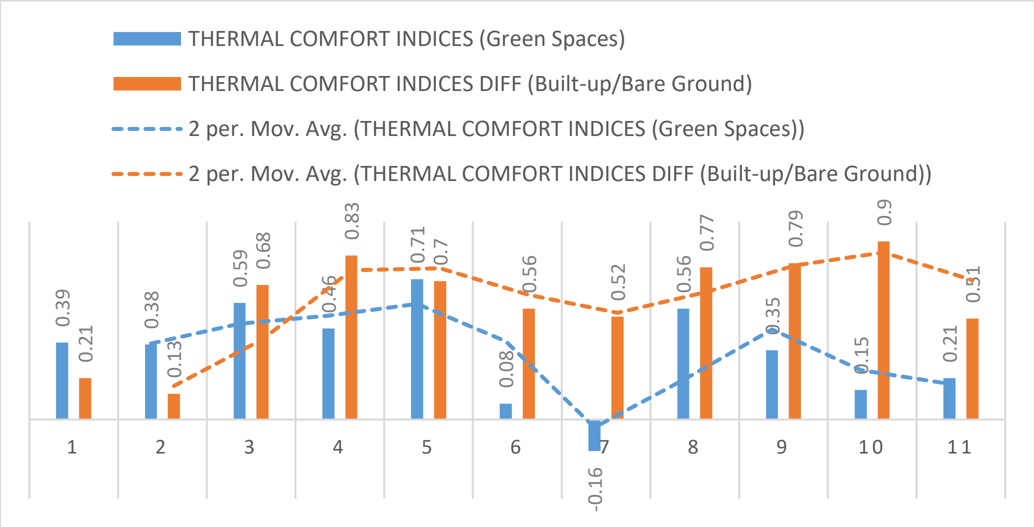

Figure 8: Thermal Comfort Index chat showing results from green spaces and Built-up Areas/Bare Grounds (Non green Spaces). Source: Author (2016)

Figure 8 gives a graphical view of the results displayed in table 4.4; the chart also featured trend lines (Moving Averages) that shows how each variable rise and fall from one zone to another.

4.5 Discussion of Results

The NDVI Map of Study Area (FCT) is indicated with figure 2 from Landsat Operational Land Imager (OLI) ETM+ imagery of Abuja. The image shows the major vegetation distribution of the area and the built-up areas/bare grounds. Figure 3 is the thermal Map of Study Area (FCT) in 2015. The image shows the different heat distributions in Federal Capital Territory (FCT). In contrast to the method used by Qiu*et al.* (2001), who used mono-window algorithm to generate the LST (Land Surface Temperature) map. The mono-window algorithm requires three parameters; emissivity, transmittance and effective mean atmospheric temperature (Sobrino*et al.*, 2004). The atmospheric water vapour content and the near surface air temperature were used to calculate the air transmittance and effective mean atmospheric temperature (Liu and Zhang, 2011). The third parameter is emissivity was calculated from NDVI. This study used DN (Digital Number) to calculate the band radiance, also the radiance generated was in-turn used to generate the temperature at the satellite level followed by the generation of the land surface emissivity which also made use of the already generated NDVI (Normalised Difference Vegetation Index) followed by the land surface temperature (LST).

Figures5 and 6show the comparison of the extracted NDVI map of Study Area and the Thermal Map of the same area. The figures reveal that there is an inverse relationship between temperature and vegetation from the maps (NDVI and Thermal maps).This is evident from the 22 points that were surveyed (11 points with green spaces and 11 points with built-up area/bare grounds). The analysis also shows that areas with more vegetation cover have lower air temperature compared to areas with no vegetation (built-up areas). figure 7 clearly indicates this and also shows the graphical representation of the air temperature readings derived from the different points, it was discovered from the line graph that the areas with vegetation cover tend to have a lower temperature with an average of 3-4^{o}C compared to build-up area/bare grounds.

On the other hand Table 6 shows the Thermal Comfort Indices of both Green Spaces and Built-up Area/Bare Grounds, the table was colour coded to show the areas that comply with the ET (Efficient Temperature) rating of the thermal comfort index and areas that does not comply, Green represents ideal results, Blue represents areas within acceptable range, Orange represents areas with manageable results while red indicates areas that are not within acceptable range, it was noticed from the results obtained that out of the (11) areas selected in the green zone; three (3) zones did not fall within acceptable value, the three zones have values 0.59, 0.71 and 0.56 which falls short of the ±0.5 acceptable value. This is as a result of the green spaces in the zone not being more than one hectare (1ha) and it consists of mostly lawn and shrubs, it is known that areas that tend to have an appreciable effect on human thermal comfort are areas with dense population of trees, because the canopies help mitigate the effect of urban heat distribution among other things. Also, for the Buil-up areas, it was noticed that Nine (9) out of Eleven (11) locations fall short of the acceptable values, while Two (2) of the points fall within the acceptable regions with values; 0.21 and 0.13 respectively, this difference is due to the fact that the two locations with the acceptable values are in close proximity to major green areas in the study area.

The above results further confirmed the effect of Green Spaces on Heat Distribution, it is more evident now that green spaces helps reduce heat, therefore an inverse relationship exists between green spaces and heat distribution, i.e. the more the green space the lower the temperature distribution of a particular area.

5. Conclusion

Through the NDVI and thermal satellite imageries of FCT Abuja, 2015, it was noted that there is a strong relationship between the vegetation distribution and Heat distribution in FCT, 22 points were picked based on two criterion, (i) Areas with Vegetation, (ii) Built-up areas/Bare Grounds. Comparing the results obtained from FCT NDVI map and Thermal Map, it was noted that the 11 points with high NDVI value (vegetation cover) are relatively cooler (lower in temperature) on the thermal map while the 11 points that represents Built-up area/Bare Grounds (non vegetated area) i.e. Low NDVI values are hotter (have a high temperature).

Also, the micro temperature data taken from the 22 points during the ground survey wasfound to correlate with the result from the satellite imagery, temperature readings taken from those locations shows a significant temperature difference between the 11 areas with vegetation cover and the 11 areas with built-up area/Bare grounds, it was noted that the areas with vegetation is significantly lower in temperature than the built-up areas by an average of 4^{o}C. The result of the 22 points that was investigated was used to calculate the Human thermal comfort in FCT Abuja Using the Effective Temperature (ET) Profile and discovered that the areas with low vegetation cover has a significantly low thermal comfort index compared to the non-vegetated areas.

This research has come up with the following recommendations:

1. Selective planting of trees: Mature trees promote cooling through their evapotranspiration capacity and the area of shade they provide. Therefore, tree planting should be encouraged to reduce the effect of urban heat island and help reduce the heat distribution in the area.
2. Vegetation around buildings: Walls of building are one of the main causes of temperature increase in the urban areas; therefore having vegetation around buildings can go a long way in reducing the temperature of the area, reducing the rate at which the walls get heated up. Various plant species provide heat and pollution-mitigating capacities, and compact multi-layering of diverse plant species can help improve overall resilience to drought, heat and pollution. Among plant types, trees have an

exceptional ability to capture and filter multiple air pollutants, including ground-level ozone, sulphur dioxide, nitrogen oxides and particulate matter. Trees are also significantly associated with improved thermal comfort and relief from heat stress at the street level and neighbourhood scale, particularly during hot seasons and times of day.

3. Green roofs: Green roofs is one of the best ways to reduce the heat of an area because, a green roof has a higher albedo compared to dark roofs, and the higher the albedo the higher the spectral reflectance of the object and the higher the reflectance, the lower the heat accumulation, therefore the use of green roofs should be encouraged to help reduce the heat. Implementing these measures will not only help to reduce the energy demand but will also provide healthy environmental benefits such as reduced mortality due to heat stroke, less CO_2 emission, increased thermal comfort, reduced air pollution and hence less lung diseases.

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