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Assessment of Urban Heat Island in Zaria Urban Area

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Abstract
The Urban Heat Island effect is linked to the built environment and threatens human health during extreme heat events. This study aimed to examine the spatial pattern of heat islands in Zaria urban area. Satellite imagery, Landsat imagery Base map and Metrological data were used. Reconnaissance survey was used for data collection with other sources. ArcGIS and Google earth software were used to collect data and analyzed using remote sensing, simple descriptive statistical techniques method. The results show the correlation between the maximum temperature and the years of analysis as 0.8433 with 84.33% linear relationship. The coefficient of determination R^2 is 0.7112 which reveals 71.12% change in maximum temperature caused by variation of time. To attain a balance heat change in Zaria Urban area it is recommended to: Restore loss of vegetation, Consideration for landscaping in plan approval, strategic management on congested city and traffic problems, Consideration for building material and orientation, Creation of shelter belt and stabilizing river embankment, Encouraging the use of permeable surface, Use of contemporary techniques, Partnership towards sustainable environment and Improving the competency of environmentalists.
Keywords: urban heat island, land use; spatial analysis, remote sensing, strategies

Introduction
Global warming has obtained more attention because the global mean surface temperature has increased since 19th century. Urbanization has occurred at unprecedented rates in the last 100 years. The United Nations estimated that in 2010 more than half of the world's population lived in cities, predicting an increase to more than 70% by 2050 (United Nations, 2012). It is argued that the world urban population will increase from 3.5 billion in 2010 to 6.2 billion and by 2050 almost all of which will be focused on developing countries. Growing at about 5% per annum, Nigeria's urban population estimated at 46.2% in 2005 would rise to 58% by 2050 (UN-Habitat, 2008). Given the expected urban expansion, cities are likely to triple their developed land intake a situation that would have untold negative environmental and economic consequences. The implications of negative externalities of climatic change, increased vehicular congestion, alterations in natural drainage systems, and reduced water supply which is generally change in the land use cover are already associated with rapid urbanization.

The term, urban heat Island (UHI) was coined by Gordon Manley in 1958. UHI phenomenon is known for centuries, but the semi-scientific awareness of the urban climate anomaly is traced back to mid-18th century. In the 1750s, Ezra Stiles noted that the air of towns was warmer than the country side (Meyer, 1991). Urban heat island (UHI) can be defined as an urban area which is significantly warmer than its surrounding rural area. It is a measurable increase in urban air temperatures resulting primarily from the replacement of vegetation with buildings, roads, and other heat-absorbing infrastructure (United States Environmental Protection Agency [EPA] (2008).

The urban heat island (UHI) effect is linked to the built environment and threatens human health during extreme heat events. This study analyzed the weather characteristics of land uses within an urban area associated with higher surface temperatures, and whether concentrations of hot land uses exacerbate this relationship. Higher concentrations of these land uses are usually associated with more extreme surface temperatures. Municipal planners and decision-makers formulate policies and regulations that are specific to the problematic land uses in order to mitigate extreme heat. Temperatures are gradually increasing globally due to changing climate. The built environment in urban center is categorized into different land uses for local and regional planning. General meteorological conditions also affect the magnitude of the UHI effect. The UHI is maximized under conditions of minimal cloud cover (increased solar input), low wind speeds (reduced mixing of air) and high vertical stability (thermal inversions) (Oke, 1987). The horizontal and vertical motions of air reduce the rural-urban microclimate contrast. Cloud-cover at night absorbs and re-radiates long-wave radiation emanating from the surface back to the ground so that surface cooling everywhere is diminished and tends to reduce the UHI effect (Oke, 1987; Stull, 1988).

Statement of Research Problem

Extreme temperatures have serious impacts on human health, including but not limited to heat rash, sunburn, fainting, and heat exhaustion. Continuous rising temperatures in urban areas create an uncomfortable environment for residents which results in increasing demand for energy to use air conditioners during extreme heat events, decrease in surface albedo that increase the amount of energy at the surface. Therefore, the understanding of urban heat island concept and strategies will help planners to make physical planning recommendation for sustainable urban development.

Aim and Objectives

The aim of this study is to examine the spatial pattern of heat islands in relation to land use pattern in Zaria urban area.

The following are the specific objectives

1. To review the concept and analytical technique of urban heat island.
2. To examine the physical development characteristics of Zaria urban area.
3. To assess the implications of urban heat island pattern in Zaria urban area.

Description of the study area

Zaria Urban area is located between latitude10˚57’36’’N and 11˚15’32’’N and 7˚39’00’’E and 7˚53’02’’E. the urban area is made up of Sabon Gari and Zaria local government areas and some parts of Giwa Local government area like Shika about from Ahmadu Bello University main campus, Samaru. Zaria Urban Area is bounded by Kudan to the North, Igabi to the South, Soba to the East and Giwa to the West. Zaria is about 26 km from Kudan, 50 km from Igabi, 40 km from Soba and 29 km from Giwa.

Conceptual Advances in Urban Heat Island

The understanding of urban energy balance and search for causes that facilitate it is greatly enhanced by Oke’s (1976) conception of the urban atmosphere as a system composed of two distinct layers: the urban canopy layer (UCL) and the urban boundary layer (UBL). The UBL is the overall atmospheric system that extends for many kilometers above cities, whose characteristics are determined by the form and pattern of cities. And the UCL is that layer of the atmosphere where most life occurs; from ground up to the mean height of roofs (Oke,1982). Montavez *et al.* (2000) shows that in fine weather, the city size and population play important roles in the intensification of UHI. This could be due to increase in anthropogenic heat release, air pollution, surface roughness and structures that absorb, store and transmit more heat. Smith and Levermore (2008) concluded that the bigger or denser the city the bigger also the UHI intensity.

Research have revealed that a wide range of urban factors are responsible for higher temperatures in urban areas compared to those of rural areas (UHI) and they include; urban geometry, anthropogenic heat, thermal characteristics of urban surfaces, obstruction to wind flow by buildings and lack of vegetation. From the works of Landsberg (1981), Oke (1973, 1978, 1982, 1988), Roth et al (1989) and Santamoouris (2002), the most important factors influencing the UHI effect are summarized as follows; Canyon Geometry, Building Materials, Greenhouse Effect, Anthropogenic Heat Source, Evaporative Cooling and Wind Pattern

Materials and Methods

In this study remote sensing, Google earth and GIS data from different sources were used. Three medium resolution Landsat Thematic map (TM), Enhanced thematic map (ETM) and Enhanced thematic map plus (ETM+) of the study years, using path and row, 189 and 52 respectively which were used to detect the heat island pattern of the study area. These images were obtaining from the United States Geological Survey (USGS) website as standard products. Also in order to avoid the impact of seasonal variation, all images were selected from the same season in such a way that the cloud cover will not exceed 10%. The images are also of 60m spatial resolution which makes it convenient for comparison of changes and pattern. The Google earth imagery of Zaria urban area were obtained for Google Earth 4.2 software, using Zaria, Kaduna as point of reference to be searched.

Results and Discussion

The data were analyzed using classification, overlay analysis and descriptive statistical method. The statistical method used: mean and graphs to illustrate trends of heat island pattern over time. The pattern is made up various land use of residential, commercial, industrial, public and semi- public, open spaces, Roads and streets. Even though the heat island pattern is dynamic in respect to economic development and social progress, it does not come without costs, as such there is potential implications of the heat island change in Zaria urban area over time. The potential implications of heat island can be considered as environmental. In trying to establish the environmental implications heat island pattern in Zaria urban area some climatic parameters were considered to define the climatic condition of the study area which are precipitation and temperature. Land use change have been said to affect climatic condition and at the same time the climatic condition of a place do affect land use, as such it can be said that an indirect relationship exist between the two. In trying to understand such relationship for this study, there is a need to understand the variation of temperature of the study area over time. The dynamic heat island distributions for each study year as derived from the maps below;

Heat Island Pattern 1980

The heat island pattern in the study area in 1980 can be visually seen from the map below which depict the highest magnitude as 32.22 ^{0}c, medium, 30.52 ^{0}c and lowest as 28.96 ^{0}c. The difference between the highest and the lowest temperature range is 3.24 ^{0}

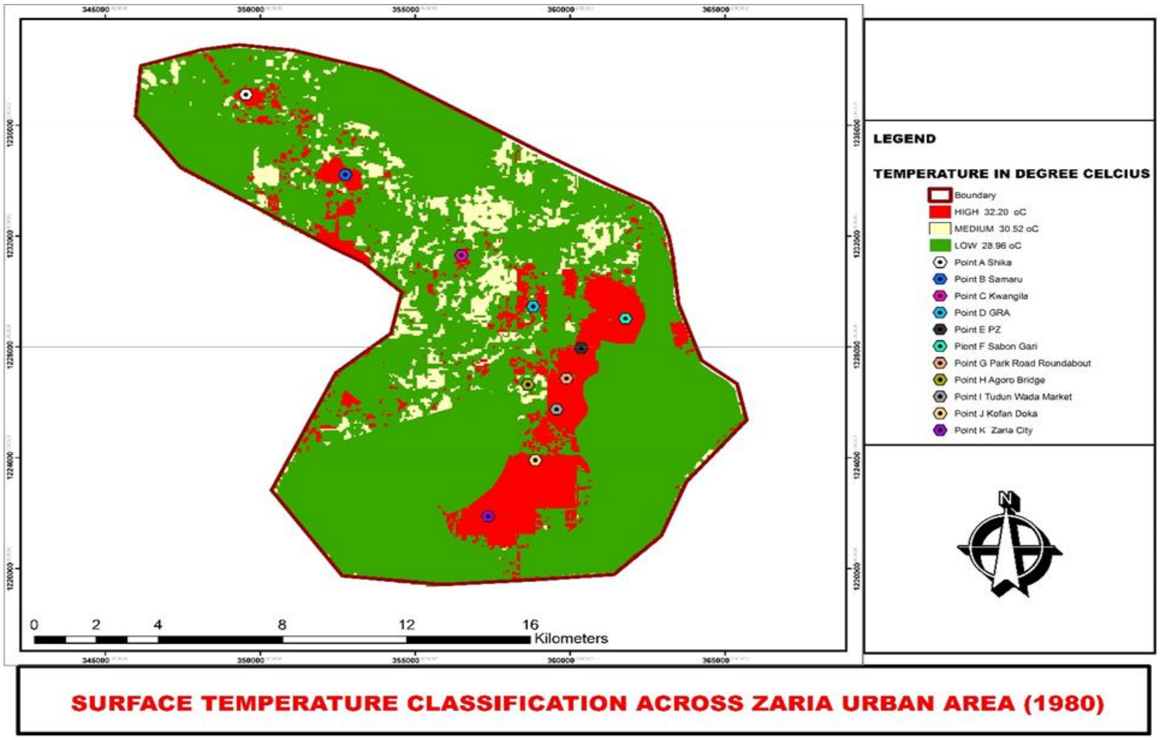

Fig. 1: surface temperature classification across Zaria urban area
Source: Landsat image, 1980

Figure 1, above revealed that there was an urban heat island effect within the study in 1980 the red colour depicts the highest magnitude, yellow colour medium and green colour depict the lowest heat island intensity. Comparing the urban heat island intensities, it can be seen that the patterns shows a typical temperature profile for an urban heat island. The temperature gradient from the rural area to the suburban area form the basis of heat island extend in Zaria urban area within the residential and commercial land use, Zaria city wall expand with residential land use, Tudun Wada residential and commercial land use, Sabon Gari commercial, industrial and mixed land use, Samaru residential, commercial and educational land use. The rest of the sub-urban area has a relatively gentle temperature gradient forming the plateau The thermal center ("Peak") of an urban heat island is usually located in the central urban center.

Heat Island Pattern 2015

The heat island pattern in the study area in 20115 can be visually seen from the map below which depict the highest magnitude as 39.50 ^{0}c, medium, 37.75 ^{0}c and lowest as 36.03 ^{0}c. The difference between the highest and the lowest temperature range is 3.47 ^{0}c.

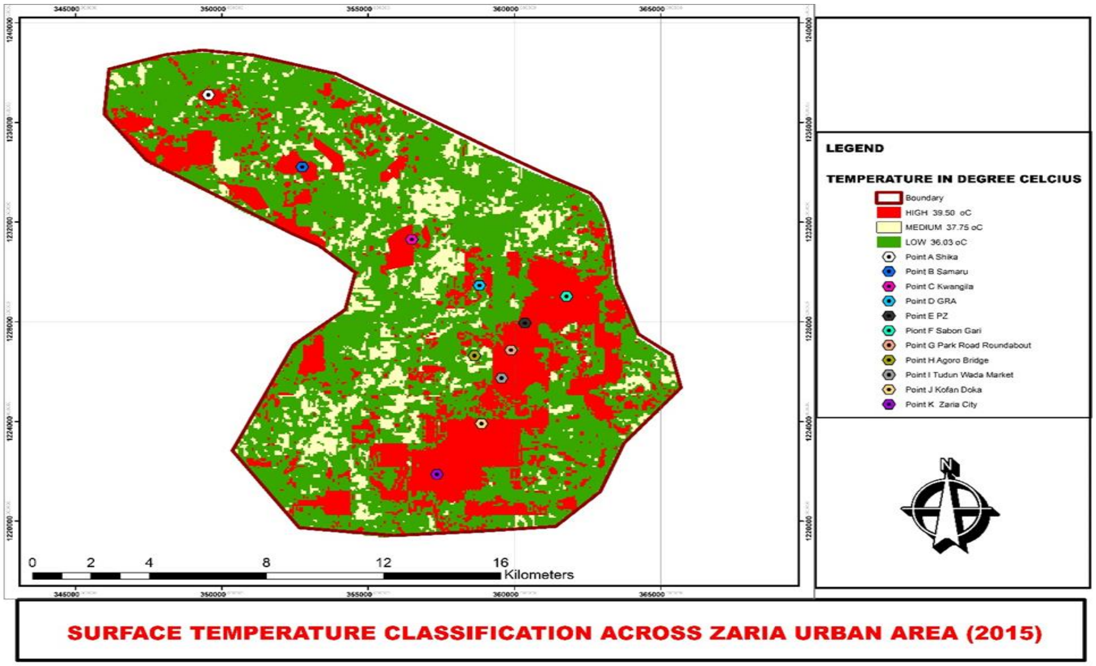

Fig. 2: surface temperature classification across Zaria urban area
Source: Landsat image, 2015

Figure 2, revealed that there was an urban heat island effect within the study in 2015 the red colour depicts the highest magnitude, yellow colour medium and green colour depict the lowest heat island intensity. The temperature gradient from the rural area to the suburban area form the basis of heat island extend in Zaria city, Tudun Wada and Samaru signifies an increase in residential, commercial and educational land use, Sabon Gari and PZ witness an increase in commercial, industrial and educational land use. The rest of the sub-urban area has a relatively gentle temperature gradient forming the plateau The thermal center ("Peak") of an urban heat island is usually located in the central urban center. More over congestion of residential unit, traffic, emission of harmful gases from industries, automobile and the use of firewood and generator as source of cooking and lighting due to urbanization. It is clear that the relationship between land use and surface temperature revealed and confirms that urban heat island effect is usually observed between urban and rural land uses Surface temperature tends to increase with the size of commercial and industrial land use polygons and decreases with the size of parks, recreation and water body polygons.

Rate of Heat Island Change in the Study Area (1980-2015)

The rate of heat change analysis base on the implication of land use change over time, Tables 1 shows the detail of mean maximum and minimum temperature within the study area.

Table 1: Mean maximum and minimum temperature (°C) for Zaria urban area

Year	Max	Min	Mean
1980	35.2	11.57	27.80
1985	36.0	12.67	27.91
1990	37.53	12.58	28.00
1995	35.43	12.65	28.71
2000	37.7	9.935	28.90
2005	37.133	12.58	28.70
2010	38.5	12.42	29.40
2015	39.29	16.19	29.90

Source IAR ABU, Zaria

Table 1: Shows trend of temperature change within the period from 1980-2015.

Regression Analysis of Mean Maximum and Minimum Temperature for Zaria Urban Area

Analysis of Maximum Temperature

Table 2 analysis reveals the correlation between the maximum temperature and the years as 0.8433 (84.33%) indicating linear relationship between the maximum temperature and the years of analysis. The coefficient of determination R^2 is 0.7112 indicating that 71.12% of change in maximum temperature is caused by time change. This is due to change on surface characteristics and morphology over time which include thick walls, concretes surface and tarred roads, high anthropogenic activities such as; high population density, busy streets and high traffic volume accounting for the anthropogenic heat release.

The analysis reveals the least square (regression) model that would be used to predict the maximum temperature pattern in Zaria is $y = 0.100*t - 163.646$. where y is the maximum temperature and t is the time (years). The p-value of the slope of the model (0.009) is less than 0.05 we therefore conclude that the there is a significant increase in maximum temperature over the years of analysis as shown above.

Table 2: Regression Summary for Maximum Temperature

Regression Statistics	
Multiple R	0.84333
R Square	0.711206
Adjusted R Square	0.663074
Standard Error	0.847171
Observations	8

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-163.646	52.22403	-3.13354	0.020233
Year	0.100498	0.026144	3.843964	0.00852

y-0.100*t-163.646

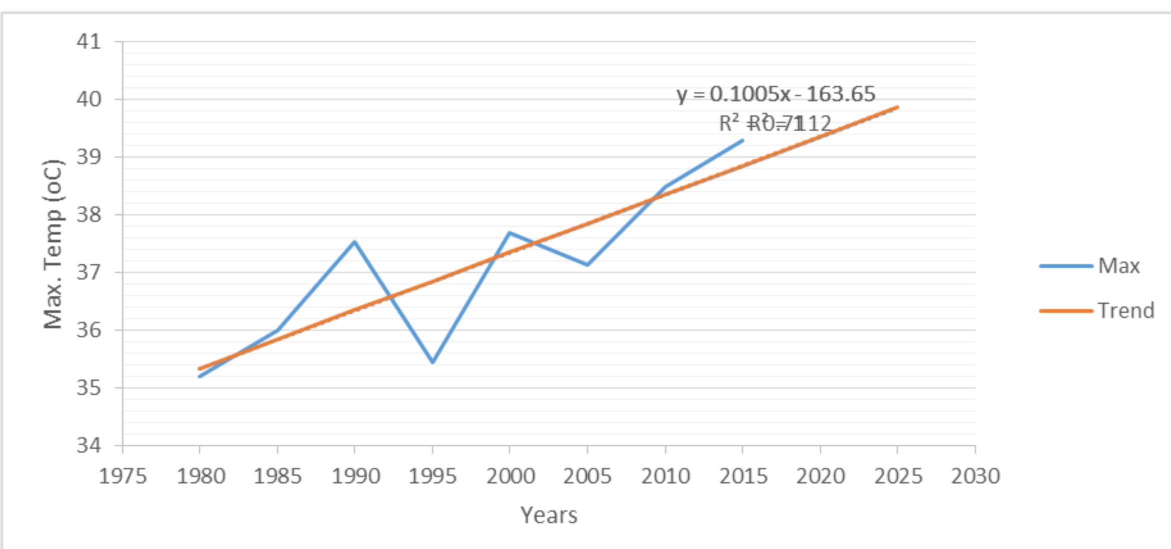

Fig. 3: Max. Temperature pattern with its estimated trend

The graph reveals the least square (regression) model that predict the maximum temperature pattern in Zaria, the blue line represents maximum temperature gradients while the red line represents the trend over years' y ***= 0.100*t – 163.646***. where y is the maximum temperature and t is the time (years). And the coefficient of determination R^2 ***is 0.7112*** indicating that change in maximum temperature is caused by time, which signifies increase in maximum temperature over the years of analysis as shown above. with a projected predicted values at five years' interval to 2025.

Predicted values

Year	Max. Temp (^{0}C)
2020	*39.36*
2025	*39.8625*

The table above reveals the maximum temperature pattern and estimated trend with predicted values at five years' interval to 2025. Which signifies that there will be an increase in maximum temperature in years to come if proper measures are not put in place to mitigate the occurrence.

Analysis of Minimum Temperature

Table 3: Regression Summary for Minimum Temperature

Regression Statistics	
Multiple R	0.476736
R Square	0.227278
Adjusted R Square	0.09849
Standard Error	1.647931
Observations	8

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-122.376	101.5871	-1.20464	0.273699
Year	0.06756	0.050856	1.32844	0.232324

y-0.068*t-122376

Table 3 reveals the correlation between the minimum temperature and the years of analysis as 0.4767, indicating 47.67% linear relationship between the minimum temperature and the years of analysis. The coefficient of determination R^2 is 0.2273 indicating that 22.73% of change in minimum temperature is caused by time change. This is due to surface characteristics and morphology over time which include thick walls, concretes surface and tarred roads, and high anthropogenic activities, such as high population density, busy streets and high traffic volume accounting for the anthropogenic heat release. while area with lower temperatures have lower anthropogenic activities.

The above analysis reveals the least square (regression) model that would be used to predict the minimum temperature pattern in Zaria is ***y = 0.068*t – 122.378***. where y is the minimum temperature and t is the time (years). The p-value of the slope of the model (0.232) is greater than 0.05 we therefore conclude that the there is no significant increase in minimum temperature over the years of analysis as shown above

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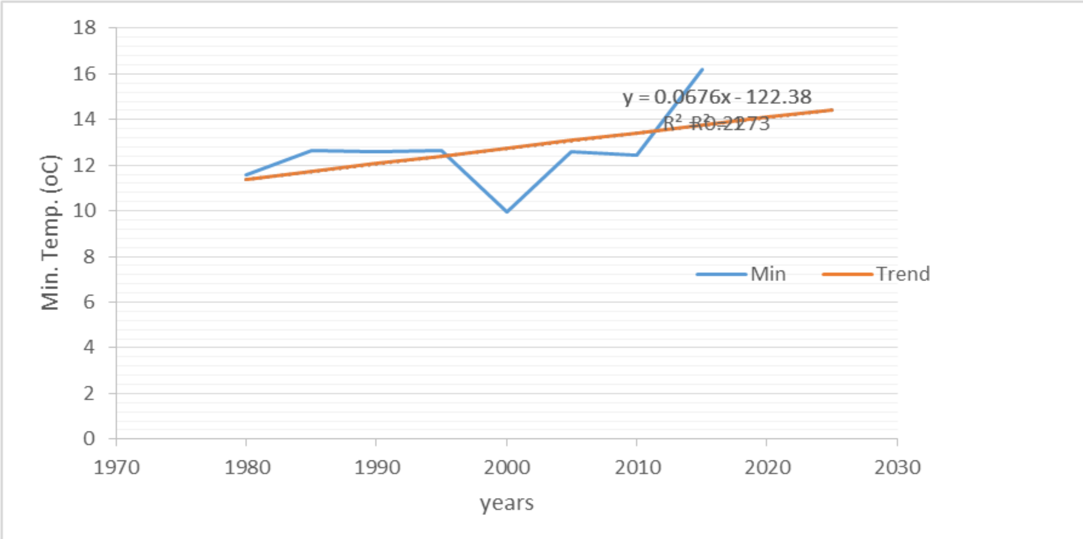

Fig. 4: Min. Temperature pattern with its estimated trend

The graph reveals the least square (regression) model that predict the minimum temperature pattern in Zaria, the blue line represents minimum temperature gradients while the red line represents the trend over years' y = ***0.068*t – 122.378***. where y is the minimum temperature and t is the time (years). And the coefficient of determination R^2 ***is 0.2273*** indicating that change in minimum temperature is caused by time, which signifies a moderate shift in minimum temperature over the years of analysis as shown above. with a projected predicted values at five years' interval to 2025.

Predicted values

Year	Min. Temp (^{0}C)
2020	*14.0932*
2025	*14.431*

The table above reveals the minimum temperature pattern and estimated trend with predicted values at five years' interval to 2025. Which signifies that there will be an increase in minimum temperature in years to come if proper measures are not put in place to mitigate the occurrence.

Temperature Records in Different Days of the Survey (From 14, 15 and 16 July 2016)

Table 4 reveals the temperature record of day one at 8:00am, 2:00 pm and 5:00pm with maximum UHI intensity occurred by 2:00pm at 37 ^{0}c. The minimum UHI intensity occurred in the morning by 8:00am with at 18 ^{0}c. In the evening by 5:00pm at 19 ^{0}c. It can be concluded that the UHI intensity is relatively higher during the daytime.

Table 4: Result Day One Temperature (^{O}c)

Name Of Site	8:00 Am	2:00 Pm	5:30 Pm
Shika	18	25	19
Samaru	20	26	21
Kwangila	22	30	22
GRA	20	24	19
PZ	23	33	24
Sabon Gari	24	35	25
Park Road	25	37	25
Round About			
Agoro Bridge	18	25	19
Tudun Wada Market	20	28	20
Kofan Doka	22	27	22
Zaria City	24	28	23

Diurnal temperature variation for day one

The result reveals the highest diurnal temperature for day one is 37 ^{0}c at 2:00 pm with a mean temperature of 28.9 ^{0}c, this is due to surface characteristics and morphology which include thick walls, concretes surface and tarred roads, and high anthropogenic activities, these area is known as commercial centers with high population density, busy streets and high traffic volume accounting for the anthropogenic heat release.

The graph reveals the temperature record of day one at 8:00am, 2:00 pm and 5:00pm respectively with maximum UHI intensity occurred at 2:00pm with a value of 37 ^{0}c. The minimum UHI intensity occurred during early morning about 8:00am with a value of 18 ^{0}c. And late evening about 5:00pm with the value of 19 ^{0}c. it can be concluded that the UHI intensity is relatively higher during the daytime.

The table reveals the temperature record of day two at 8:00am, 2:00 pm and 5:00pm respectively with maximum UHI intensity occurred at 2:00pm with a value of 35 ^{0}c difference of 2 ^{0}c compare to the day. The minimum UHI intensity occurred during early morning about 8:00am with a value of 17 ^{0}c and late evening about 5:00pm with the value of 18 ^{0}c. With a difference of 2 ^{0}c compare to day one. it can be concluded that the UHI intensity is relatively higher during the daytime.

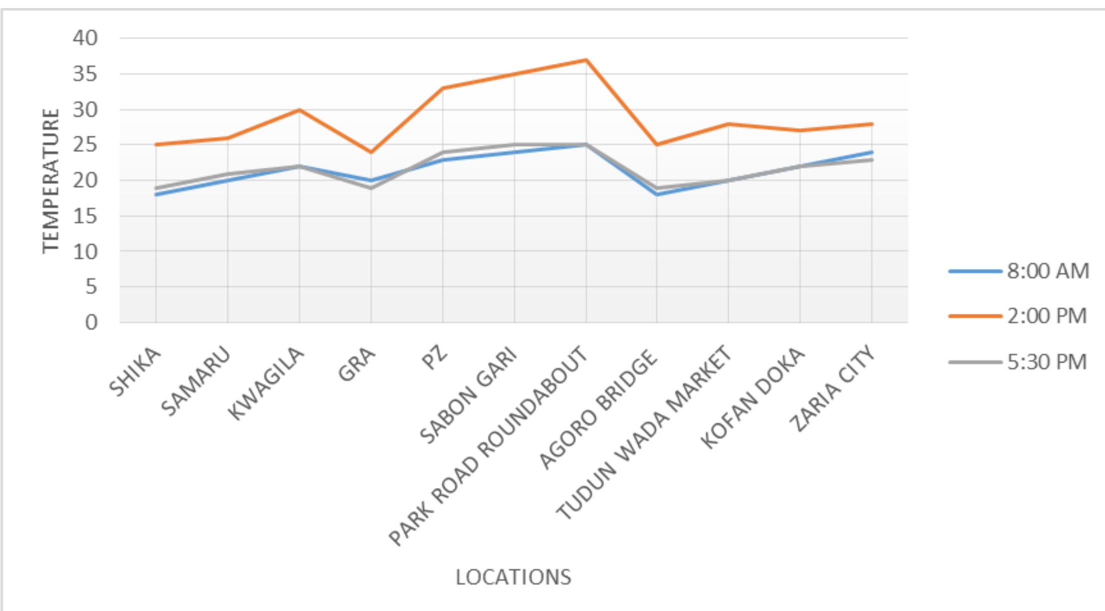

Fig. 5: Result of Day One Temperature

Table 5: Result Day Two Temperature (^{O}C)

Name Of Site	8:00 Am	2:00 Pm	5:30 Pm
Shika	17	25	18
Samaru	20	27	21
Kwagila	22	31	23
Gra	20	26	21
Pz	24	30	25
Sabon Gari	26	32	24
Park Road Round About	26	35	25
Agoro Bridge	18	26	19
Tudun Wada Market	20	32	21
Kofan Doka	22	30	22
Zaria City	25	32	24

Diurnal temperature variation for day two

The result reveals that the highest diurnal temperature for day two is 35 ^{0}c at 2:00 pm and it has a mean temperature value 0f 29.6 ^{0}c, this is due to surface characteristics and morphology which include thick walls, concretes surface and tarred roads, and high anthropogenic activities, these area is known as commercial centers with high population density, busy streets and high traffic volume accounting for the anthropogenic heat release.

The graph reveals the temperature record of day two at 8:00am, 2:00 pm and 5:00pm respectively with maximum UHI intensity occurred at 2:00pm with a value of 35 ^{0}c difference of 2 ^{0}c compare to the day. The minimum UHI intensity occurred during early morning about 8:00am with a value of 17 ^{0}c. And late evening about 5:00pm with the value of 18 ^{0}c. With a difference of 2 ^{0}c compare to day one. it can be concluded that the UHI intensity is relatively higher during the daytime.

The table reveals temperature record of day three at 8:00am, 2:00 pm and 5:00pm respectively with maximum UHI intensity occurred at 2:00pm with a value of 33 ^{0}c difference of 2 ^{0}c compare to the two. The minimum UHI intensity occurred during early morning about 8:00am with a value of 19 ^{0}c. And late evening about 5:00pm with the value of 20 ^{0}c. With a difference of 2 ^{0}c compare to day two. it can be concluded that the UHI intensity is relatively higher during the daytime.

Table 6: Result Day Three Temperature (^{O}C)

Name Of Site	8:00 Am	2:00 Pm	5:30 Pm
Shika	19	26	20
Samaru	20	27	21
Kwagila	23	29	24
Gra	20	25	20
Pz	24	30	25
Sabon Gari	25	31	25
Park Road Round About	25	33	24
Agoro Bridge	21	26	20
Tudun Wada Market	23	28	22
Kofan Doka	22	29	22
Zaria City	25	30	23

anthropogenic factor, while area with lower

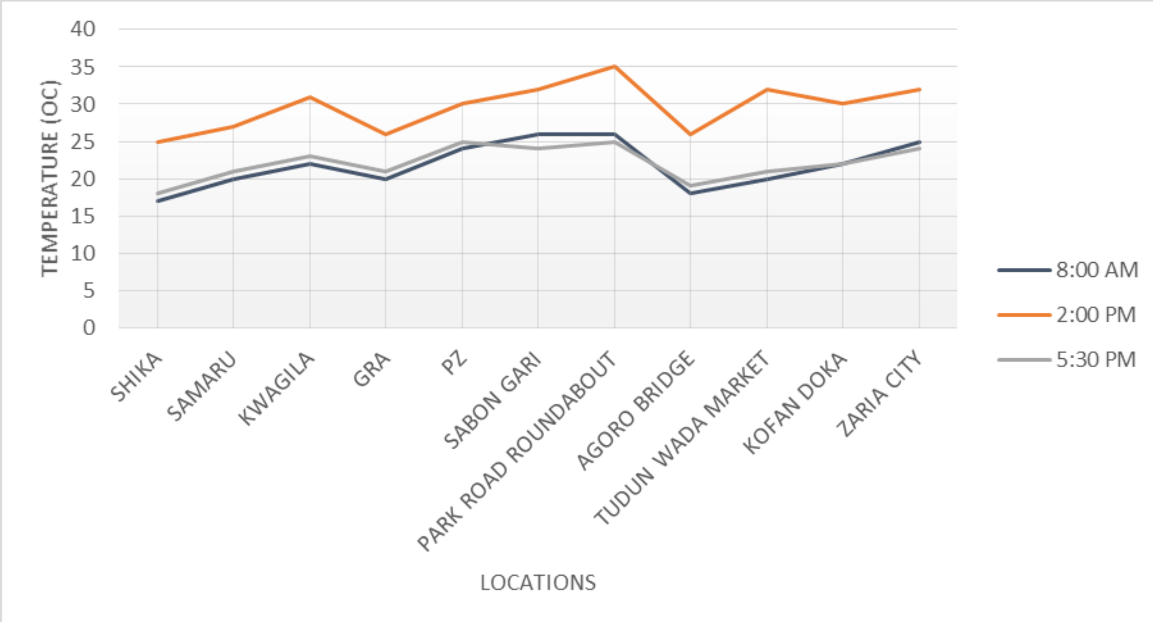

Fig. 6: Result of Day Two Temperature

temperatures have lower anthropogenic activities. Chow and Roth (2006), Balogun and Olaleye (2000), and Okpara (2002) all agree that station with highest temperatures were always at the commercial areas and the high level of traffic and nature of the surface morphology, and this also true for this study.

Diurnal temperature variation for day three

The result reveals that the highest diurnal temperature for day three is 33 ^{0}c at 2:00 pm and it has a mean temperature value 0f 28.5 ^{0}c, this is due to surface characteristics and morphology which include thick walls, concretes surface and tarred roads, and high anthropogenic activities, these area is known as commercial centers with high population density, busy streets and high traffic volume accounting for the anthropogenic heat release.

The graph reveals the temperature record of day three at 8:00am, 2:00 pm and 5:00pm respectively with maximum UHI intensity occurred at 2:00pm with a value of 33 ^{0}c difference of 2 ^{0}c compare to the two. The minimum UHI intensity occurred during early morning about 8:00am with a value of 19 ^{0}c. And late evening about 5:00pm with the value of 20 ^{0}c. With a difference of 2 ^{0}c compare to day two. it can be concluded that the UHI intensity is relatively higher during the daytime.

Cumulative diurnal temperature variation

It is being observed that day one has the highest diurnal temperature of 37 ^{0}c while day two has the highest diurnal mean temperature value of 29.6 ^{0}c in respect to day one and three with 28 ^{0}c, the cumulative diurnal mean temperature is 29 ^{0}c which shows and appreciable variation in the mean diurnal temperature variation, all the station areas of high temperature is due to the

From the analysis carried out, it reveals that Kwagila, PZ, Sabon Gari, park road roundabout Tudun Wada, Kofan Doka and Zaria city wall has the highest pick of heat island compare to Shika, Samaru, GRA and Agoro bridge.

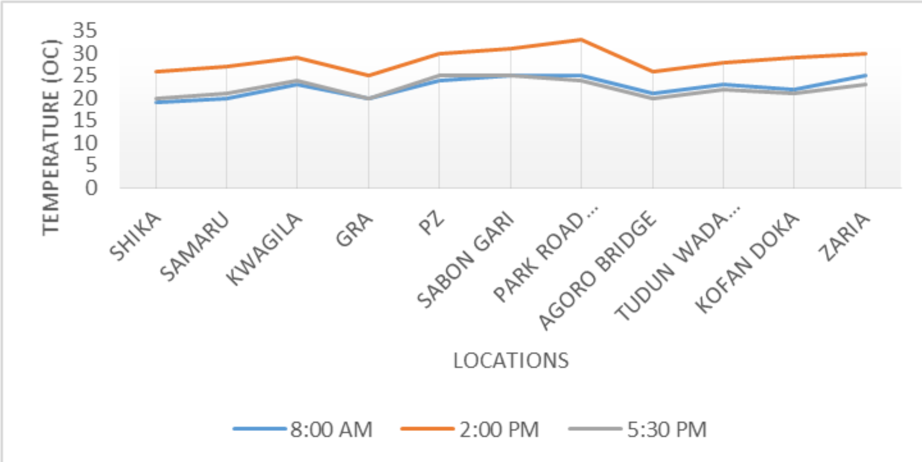

Fig. 7: Result of Day Three Temperature

Conclusion

From the results of this study, it can be concluded that Zaria urban area adequately represent the nature of surface cover and morphology, temperature variables are responsible for significant variation within the study area. The seasonal climatic conditions of the region were also noted to have significant effect on the annual urban heat island variation. The study has shown that Urban heat island studies using satellite-based remote sensing data have also come into prominence. Because apart from providing a large array of information with a wide spectrum of possible applications, the data also have the advantage of availability for areas that may not be physically accessible due to physical dangers or socio-political restrictions.

Planning Recommendations

Having examine the pattern of heat island change in the study area which shows that built-up is increasing with decreasing vegetation cover which is likely to continue into the future. If proper measure is not put in place may likely heighten the vulnerability of the town to the effect of floods, extreme temperature and other heat change related implications as mentioned in the implications above. As such, in order to attain a balance heat change in Zaria urban area, the following are recommended for sustainable urban development, restoration of lost vegetation, tree planting campaign ,consideration for landscaping in plan approval, strategic management of congested part of the city and traffic problems, consideration for building material and orientation ,creation of shelter belt and stabilizing river embankment ,encouraging the use of permeable surface ,use of contemporary techniques, partnership towards sustainable environment, improving the competency of environmentalist.

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