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Evaluation of temperature and urban heat island variability in days of the week and weekends

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ABSTRACT

BACKGROUND AND OBJECTIVES: This study evaluated temperature and urban heat island variability in days of the week and weekends of Port Harcourt city, due to the continuous heat stress and resultant health disaster common in tropical countries such as Nigeria.
METHODS: The data were generated from field observation and Satellite Remote Sensing using Google Earth Engine of Landsat 5, 7, and 8 thermal infrared sensors. Temperature data from the field were captured with LCD Digital Multi-Thermometer Loggers located at different land-use types of 35 sample points in wet and dry seasons. Analysis of Variance was used to establish the temperature difference between days of the week and weekend.
FINDINGS: The rural site during days of the week had temperature of 29.30C and the weekend had 29.50C indicating a concentration of human activities at the rural fringes during the weekend. The temperature of Saturday and Sunday varied between 33.20C and 27.60C (5.60C) with an urban heat island difference of 1.90C. Saturday was the coolest day having 3.70C. During days of the week, Monday had the highest UHI of 70C with the least UHI of 4.20C recorded on Friday showing the coolest day. The temperature difference between days of the week and weekend was 0.20C and UHI variation of 0.40C indicating that days of the week were warmer. The result showed that temperature in days of the week and the weekend differed significantly.
CONCLUSION: It was established that days of the week contributed 52% of the temperature condition of Port Harcourt city and weekend donated 48% showing that 3,095,342 occupants of the city experienced lesser thermal stress during the weekend. Thus, the study concluded that the temperature of urban areas decreased from the city center to the rural fringes. The land surface temperature indicated that the north-eastern part of the city was the warmest. The study recommends proactive city planning and management framework with effective urban greening implementation for a healthy city living.

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INTRODUCTION

Today, the world population has increased to 7.7 billion people with over 4.2 billion living in the cities (UNDESA, 2018; UNDESA, 2019). It is estimated that 60% of the world population will live in the city by 2030 and in 2050 the population of cities will attain 70% (WHO, n.d.). Thus, rise in city population will cause the modification of the natural environment resulting to rise in city temperature and Urban Heat Island (UHI) phenomenon. However, UHI is the cumulated temperature in the city that is greater than the temperature of the outskirts and fringes caused by anthropogenic activities and modification of the natural city surface (Maria *et al.,* 2013; Tan *et al.,* 2015) as in Fig.1 and adapted from (William et al., 2004). In other words, temperature of the city tends to increase from the rural outskirts to the city center modified by urban fabrics and other human activities. These modifiers are in the form of urban geometry and morphology, loss of urban tree cover, rise in urban fabrics and pavement materials, emission of greenhouse gases, low material albedo, size of city and material thermal properties (Kotani *et al*., 2005; Qian *et al.* 2006; Hart *et al.,* 2008). Other factors that could cause rise in temperature are vehicular and industrial emissions as well as the emissions from cooling systems (Memon *et al.,* 2008; Papanastasiou *et al.,* 2012). Brain (2001) concludes that UHI will rise up to the rate of 0.25-2ºF in each decade and will double in high metropolitan cities in the next 50 years. Rise in temperature and heat waves of cities have been associated with heat stress especially during the night. Temperature increment creates enabling environment for the spread of vector diseases which could be harmful to humans and animal species (Samuels, 2004; Ifeoluwa *et al.,* 2012). During hot weather, city dwellers will increase their consumption of electricity and other energy sources (Nuruzzaman, 2015). It is very obvious that rise in ambient air temperature will bring about discomfort in the city with associated poor economic activity, heat cramp, heat stroke, respiratory attack and death (Stephen *et al.* 2016; Ojeh *et al.,* 2016). Thus, every 0.6^0C rise in temperature will trigger 2% consumption of energy in a city and will cost 10% of energy budget at a worldwide scale (James, 2002). Increase in temperature has the capacity to cause death of flora and fauna species in an urban environment (Dejene, 2018). However, due to the psychological and physiological effects of high temperature and UHI, city dwellers will loss economic hours of labour and productivity (ILO, 2019). Increased temperature and UHI have been studied in several cities of the world. Enete *et al.,* (2013) examined the temperature and UHI of Enugu city using remote sensing technique. The findings showed that the city center had temperature above 37^0C and 4^oC to 6^oC warmer than the rural fringes. Alenka *et al.,* (2017) studied the temperature performance of two residential neighborhoods in Ljubljana, Slovenia using thermal satellite images. The study showed that summer period had higher temperature variation and areas with higher concentration of urban pavement materials displayed more urban temperature. Elsayed (2012) studied the urban heat island and temperature variability of Kuala Lumpur, Malaysia. The results showed that Sunday recorded the highest temperature and weekly urban heat island variation of 3.9^0C to 5.5^0C respectively. Reuben (2012) studied the spatio-temporal dynamics of UHI in Singapore using ground observation. The findings showed that UHI was highest in the night. Thus, weekday and weekend UHI at maximum levels were significantly different. These studies showed the use of remote sensing and ground observation to measure temperature and UHI variability across the cities. Efe *et al.,* (2014) carried out a study on the effects of urbanization in Benin City temperature using weather station data and mobile transverse approaches for a one-year period. Findings showed that temperature varied with 0.50C from rural fringes to city center which was 2% warmer than the rural fringes. The study concentrated on ground observation and secondary data from Nigerian Meteorological Agency and did not consider the spatial spread of temperature across different land use types in the city as well as weekday and weekend heat variation of the city. Quah *et al.,* (2012) studied the diurnal and weekly variations of human generated heat on three land use types in the city of Singapore using both top-down and bottom-up modelling techniques for ascertaining energy intensity. Findings indicated that buildings contributed the highest urban energy with 49-82% energy released in the weekdays and 46-81% during the weekends. The study did not consider the rural and urban area heat variation as well as the application of satellite remote sensing in the analysis of the city thermal environment. Kim *et al.,* (2004) studied the daily maximum urban heat island severity

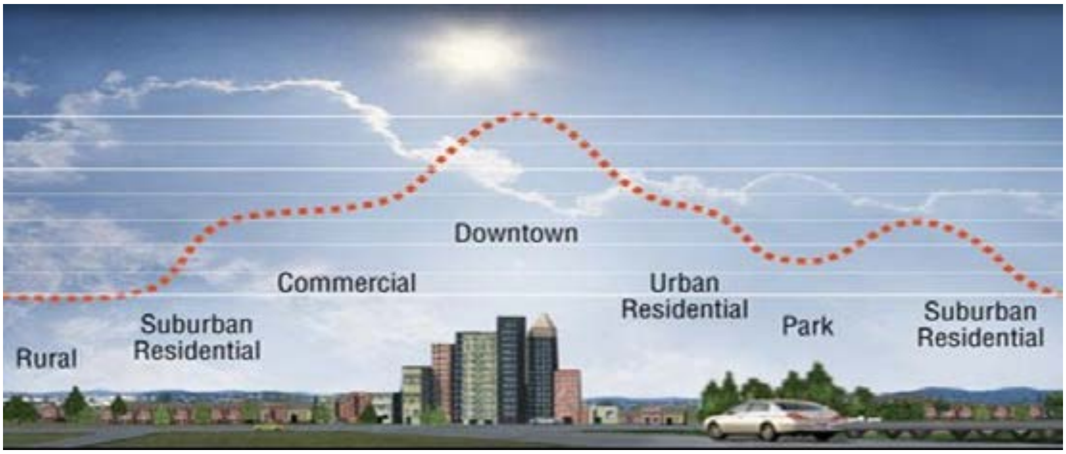

Fig. 1: The Distribution of Temperature and UHI across Urban Area

of South Korean cities of Seoul, Incheon, Daejeon, Daegu, Gwangju, and Busan (1973–2001) using spectral and multidimensional scaling analyses. The findings showed that the daily maximum urban heat island per year in the cities rose over time, decreased according to size of cities and availability of water bodies to the cities. Thus, the cities located at coastal areas such as Incheon and Busan had low urban heat island than cities inland such as Daejeon, Daegu and Gwangju respectively. However, this study did not consider weekday and weekend urban heat island differences across the various cities. However, satellite remote sensing was not used in the methodology for assessing the urban heat island of the various cities. Vincent *et al.,* (2016) studied the differences in temperatures between Lagos city center and the rural fringes using a one-year meteorological field observation located at both rural (Okoafo) and city centers (City Hall). It was found that the urban heat island of Lagos city could exceed 70C which can be influenced by seasonal variation. The study did not consider urban heat island phenomenon in multiple land use types and satellite remote sensing technique was not adopted in the investigation. Furthermore, the study did not consider the weekdays and weekend urban heat island variability of Lagos city. The study of urban heat island is an evolving one that has attracted limited attention but facilitated by the current global warming. From the preceding literature, it is notable that the study of urban heat island using ground observation for a full year and satellite remote sensing in Port Harcourt coastal city of Nigeria does not exist in the public domain. Furthermore, investigation of weekdays and weekend urban heat island of cities has not been given adequate attention and urban heat island literature is highly limited especially for Port Harcourt city in Rivers State, Nigeria. However, with the influx of population and urbanization processes in Port Harcourt city, increased temperature and UHI phenomena have become a critical problem that needed to be investigated. The modification of streets and roads of Port Harcourt Diobu area, Trans-Amadi, Port Harcourt Township, Rumuokoro, Ada-George, Port Harcourt NPA; industrial and daily vehicular traffics as well as general economic activities in the city are capable of triggering the temperature rise and UHI performance of the tropical city. Therefore, this study will serve as part of the urban management framework for those in charge of the planning and management of Port Harcourt city in order to make the city a comfortable place free from thermal stress and death. In this vein, this study investigates the temperature and UHI dynamics in days of the week and weekends across different land use types of Port Harcourt tropical city of Nigeria. The study was carried out from 2017 to 2019.

MTEHRIALS AND METHODS

As a tropical city located at the coast of the Atlantic Ocean, Port Harcourt is approximately founded within the longitude $7^{0'}$E and $7^{0'}$5 E and latitude 4^{0}45'N and 4^{0}50 N. The metropolitan city is occupied by two main Local Government Areas (LGAs) of Obio/ Akpor and Port Harcourt City. The city extends to the fringes of Okiri, Bakana, Oyibo, Ozuoba and Ogbogoro respectively (Fig. 2). Thus, Port Harcourt city and environs has projected population size of 3,229,384 persons (NPC, 2006) as in Fig. 3, Port Harcourt has annual monthly average temperature of 31.3°C and monthly minimum average temperature of 21.8°C as well as average maximum temperature of 31°C. The city has average monthly solar radiation capacity of 10.55mJm^{-2}/day and average annual radiation of 9.25mJm^{-2}/day. It has 80% annual average relative humidity, average annual evaporation of 97.3mm and average annual rainfall of 2000mm to 2500mm

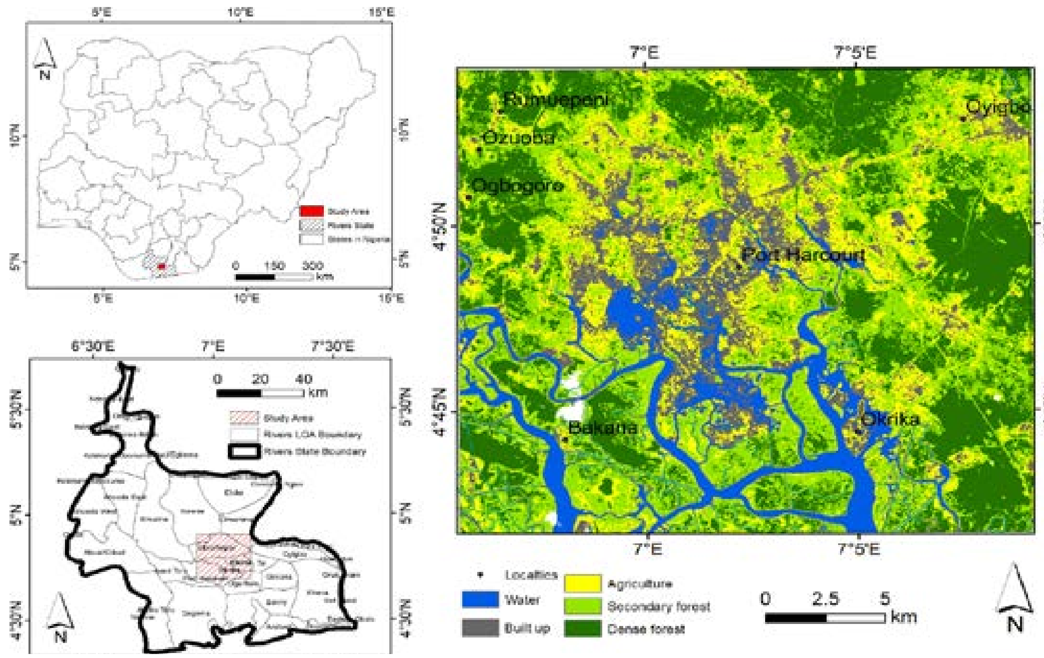

Fig. 2: Location Characteristics of Port Harcourt City

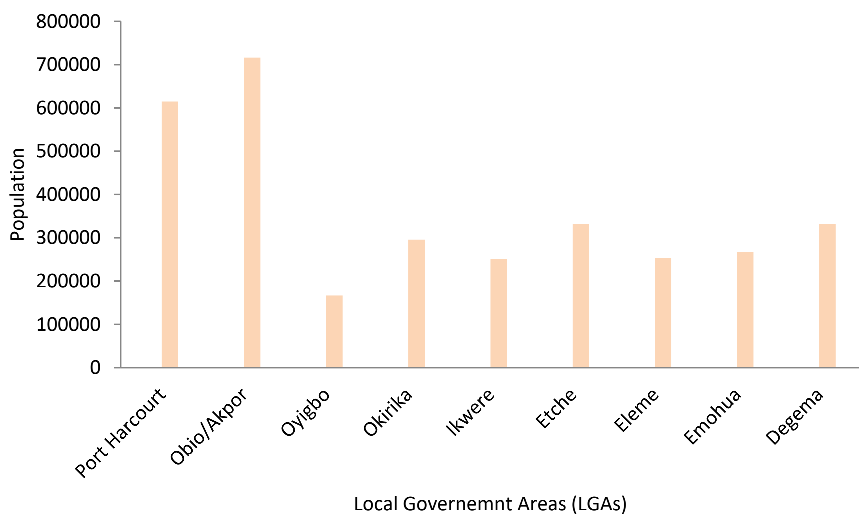

Fig. 3: Population of LGAs in Port Harcourt Metropolitan City

respectively. The city climate is influenced by the sea-land breezes resulting from the close proximity to the Atlantic Ocean and located in the mangrove and rain forests of the Niger Delta Area of Nigeria (Olofintoye *et al*., 2010; Ike *et al.,* 2012; Odu *et al*., 2013) The first dataset was gathered from the field using the digital thermometer in 35 locations conducted in dry and rainy seasons. The second dataset was retrieved from the Satellite remote origin using the thermal infra band (Fig. 4 and Table 1). The data capturing was carried out simultaneously with the help of field assistants from private homes, business areas and offices. The air temperature measurements were carried out for 12 months of April, May and June (AMJ, early wet season), July, August and September (JAS, late wet season), October, November, and December (OND, Early Dry Season) and January, February and March (JFM, late dry season) in 2017/2018. The measurement took place at 0006 (Morning), 1200 (Afternoon) and 1800 (Evening) hours respectively. Thus, change in temperature readings (ΔT) were converted and analyzed on daily

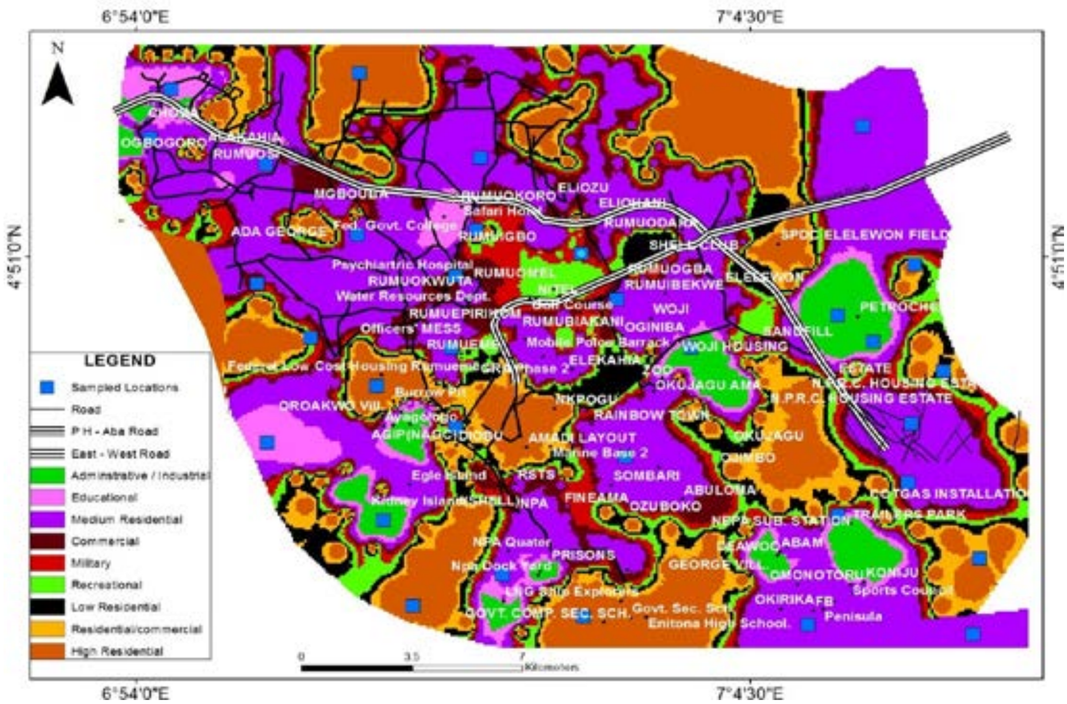

Fig. 4: Sample Locations across Different Observation Sites

Table 1: Land Use Types of Sample Locations

Land use Types	Location
Low Residential	Eleme, GRA, Intel zone, Total Estate, Oyibo, Shell estate, Bolokiri, Igwuruta, Etche, Iwofe, Jetty, Choba, Elelenwo, Okirika, Rumosi, Elekahia, Mgbuoba, Eagle Island.
High Residential	Diobu, D-Line, Enitona School Area
Medium Residential	Ada-George, Abloma, Rumuigbo, Port Harcourt Township, Rumuola, Choba, Mgbuoba, Woji, Okirika, Rumuodara
Educational	University of Port Harcourt, University of Science and Technology, Port Harcourt Poly Technique, Ignatious Ajuru University
Commercial	Mile One market, Rumuokoro Market, Mile 3 Market, Slaughter, Ikoku market, Oil Mill Market
Military	Navy barracks, Bori Camp, Airforce
Recreational	Boro Park, Port Harcourt Tourist, Rainbow Zoo, Port Harcourt Pleasure Park, Woji Housing
Residential/Commercial	Orazi, Rumuokwurusi, Rumuaghorlu, Rumuibekwe, Rumuodomaya, Ogbunabali, Rukpoku, Rumuokwuta
Admin/Industrial	Eleme Petrochemical area, Marine Base, BMH, UPTH, Transamadi, Agip, NPA, Rivers State Secretariat.
Rural	Elibrada, Aleto, Dankiri, Obeta, Omagwa (control sites)

Table 2: Details of Google Engine Satellite Remote Sensing for LST

Dates of Retrieval	Satellite/Sensor	Reference System/Path/Row
01/01/16 - 30/01/16	GEE/Landsat 5/7/8	AoI
01/01/02 – 30/01/02	GEE/Landsat 5/7/8	AoI
01/01/86 – 30/01/86	GEE/Landsat 5/7/8	AoI

average values of urban (u) and rural (r) differences (ΔT (u-r) from the datasets and organized into days of the week and weekends for a year. The temperature devices were Handheld Digital Thermometer ST9269 model with St-9283B/St-9269B, factory-made by MEXTECH. The thermometers resolution were 0.1^{0}C (0.2^{0}F) having measuring range between -50^{0}C and 300^{0}C (-58^{0}F to 572^{0}F) at St-9283B and -50^{0}C and 200^{0}C (-58^{0}F to 372^{0}F) at St-9269B respectively. The thermometers accuracy constant was ±1^{0}C, ranging between -50^{0}C to 150^{0}C (±2^{0}F in the range of -22^{0}F to 302^{0}F). The interpolation technique was used to complete few missing data (Ayoada, 2008; Schneider, 2001). However, the rural sites were characterized with plots of deciduous plants, low plants and grasses as the thermometers were mounted on an average wooden pole or handheld. The rural sites that served as the control were Omagwa, Aleto, Elibrada, Obeta and Dankiri. The sites were purposively sampled based on the homogeneity and shared characteristics of sample sets of delineated land categories. (Acero *et al.,* 2013; Papanastasiou *et al.,* 2012; Giannaros *et al*., 2009; Hawkins *et al.,* 2012). However, for the urban area temperature data were drawn from sites characterized by urban pavements as stones, tiles, bricks, concretes, general construction materials, built-up and treeless portions approximately at height of a head (1.5 meter) above the ground level of the canopy layer (Annamaria *et al.,* 2017; Ifeoluwa *et al.,* 2012; Fortuniak *et al*., 2006; Ram *et al.,* 2015; Salah *et al.,* 2010; Jacob, 2015; Gianmarco *et al.,* 2012; Brian *et al*., 2013). However, for satellite data retrieval and analysis on the Land Surface Temperature (LST) of Port Harcourt city, the algorithm for extracting LST from Landsat 5, 7 and 8 thermal infrared sensors, using different surface emissivity sources from the Google Earth Engine (GEE) was adopted. The LST from satellite remote sensing imageries were used for the analysis as in the directory of Table 2. Finally, the Analysis of Variance (ANOVA) was employed to understand the statistically significant difference between days of the week and weekend temperatures. Thus, in order to manage urban heat island in days of the week and weekend, the study adopted a framework that would evaluate temperature and urban heat island variability by analyzing the existing conditions of temperature and urban heat island as well as recommend mitigation strategies. However, temperature and urban heat island were evaluated by carrying out temperature observations across the different land use types and satellite remote sensing in both urban and rural settings. The data were captured in the field and analyses were carried out using Statistical Package for Social Science (SPSS) and Geographic Information System (GIS). The results of temperature and urban heat island variability as well as satellite imageries were established for use. Finally, urban greening and tree planting were recommended as development planning and management for decision making in intervening for heat disaster in days of the week and weekend in Port Harcourt city, Nigeria.

RESULTS AND DISCUSSION

Temperature of the ambient air and the resultant UHI are displayed in Table 3. The difference between the rural site and other urban sites yielded the urban heat island (UHI = ΔT_{u-r}) which was the quantity of heat added by man's activities and urban fabrics across the days of the week and weekend. During days of the week, rural site had mean temperature of 29.3^{0}C and urban site had highest mean temperature of 33.3^{0}C at residential/commercial land use types with UHI difference of 5.1^{0}C. In the days of the week, temperature was highest on Friday in residential/ commercial site (33.6^{0}C) and lowest in the rural site having temperature of 29^{0}C on Tuesday with a range of 4.6^{0}C. During days of the week, Monday had the highest UHI of 7^{0}C with least UHI of 4.2^{0}C recorded on Friday showing the coolest in the days of the week (Figs. 5 and 6). During the weekend, highest temperature was recorded on Sunday in residential/commercial site having temperature of

Table 3: Temperature and UHI Variability in Days of the Week and Weekend

	Day/Land Use	Rural	Military	Admn /Indust.	High Res.	Res/ Comer.	Med Res.	Commer.	Low Res.	Educt.	Recreat.	Mean Temp.	UHI = (ΔTu-r)
Days of the Week	Mon	29.1	29.3	30.6	29.4	34	30.6	30.1	30	28	27	29.8	7
	Tue	29	31.5	31.6	31.3	33.5	31	31	29	30.4	27.9	30.6	5.6
	Wed	29.1	28.7	31.8	31	33	30.2	30.4	29.2	30.7	29.2	30.3	4.3
	Thurs	30	30.2	28.3	30	32.4	29.5	28.9	29	29	27.8	29.7	4.6
	Fri	29.4	31.9	31.9	30.8	33.6	31.4	31.6	30	30.4	29.9	28.5	4.2
	Mean	29.3	30.3	30.8	30.5	33.3	30.5	30.4	29.4	29.6	28.4	29.9	5.1
Weekend	Sat	29.5	28.5	29.7	30.2	32.1	28.4	31.2	29.2	30.8	28.8	29.8	3.7
	Sun	29.4	29.1	28.8	30.5	33.2	31	29.1	28.6	27.9	27.6	29.5	5.6
	Mean	29.5	28.8	29.3	30.4	32.7	29.7	30.2	29	29.4	28.2	29.7	4.7

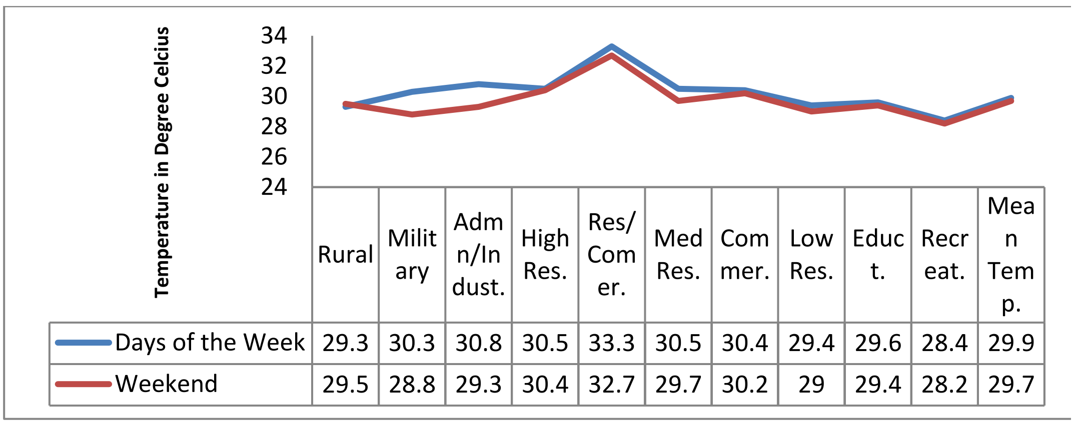

Fig. 5: Temperature Variability in Days of the Week and Weekend across different Land use Types

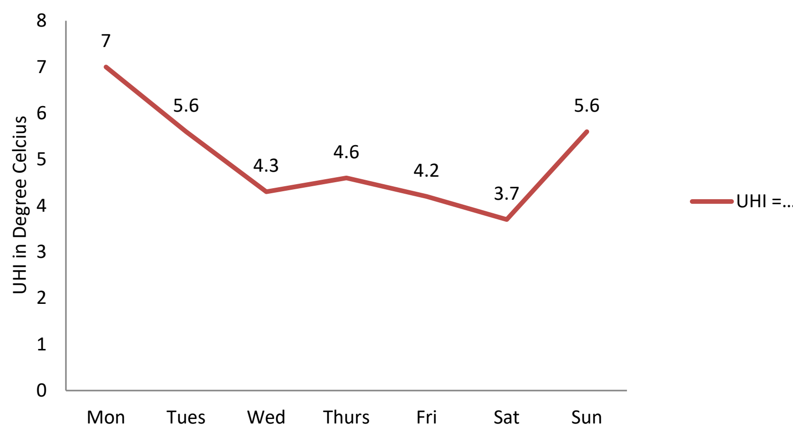

Fig. 6: Daily UHI Variation

33.2⁰C and UHI value of 4.7⁰C. Temperature in the weekend varied between 33.2⁰C and 27.6⁰C (5.6⁰C) with UHI difference of 1.9⁰C having Saturday as the coolest day at 3.7⁰C (Figs. 5 and 6). Comparison of the two categories in the week showed some degree of interaction and characteristics across the various

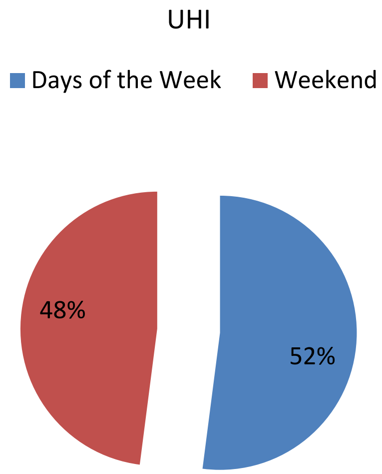

Fig. 7: The Distribution of UHI in Days of the Week and Weekend

land use types (Fig. 5). In the rural site, days of the week had temperature of 29.3⁰C and 29.5⁰C during the weekend indicating that rural sites were warmer during the weekend. This could be as a result of movement of vehicles and human activities at the rural fringes during the weekend. Port Harcourt city people are known for their recreational activities in the rural villages during weekend. The mean temperature difference between days of the week and weekend was 0.2⁰C and UHI variation of 0.4⁰C indicating that days of the week were warmer than the weekend. The residential/commercial land use recorded the highest temperature in days of the week and weekend with 33.5⁰C and 32.7⁰C respectively. This was followed by residential and high residential land use types which were made up of Orazi, Rumuaghorlu, Rumuibekwe, Rumuodomanya, Ogbunabali, Rukpokwu, Rumuokwuta and others which were warmer than other land use types. Other places of warmer temperatures were Diobu, D-Line, Enitonia High School area, Ada-George, Abloma, Rumuigbo, Port Harcourt Township, Rumuola, Choba, Mgbuoba, Woji, Okirika, Rumuodara (Tables 2 and 1). Days of the week contributed 52% of the total city UHI and weekend UHI contributed 48% with a difference of 6% UHI (Fig. 7). The urban pavement materials and the general anthropogenic functions of Port Harcourt city had modified the entire land use types (Fig. 8). The northern part of Oyibo had the highest thermal radiation at 35.1⁰C of surface temperature. The southern part (Bakana and Okirika) had warmness lower than the other parts of the city due to the influence of mangrove, rain forests and the Atlantic Ocean characteristics which usually caused the sea to land breezes from the southern part of the city. The eastern part of the city was warmer than the western segment due to the differences in urban pavement materials and general human activities. Land surface temperature in Port Harcourt city had variation of 13.7⁰C from the lowest areas to the highest sites. The land surface temperature and UHI characteristics had the capacity to influence weekend and days of the week thermal performance. The hypothesis (H_o) stated that there is no statistically significant difference in days of the week and weekend temperatures. The Analysis of Variance (ANOVA) test was applied (Table 4). The results showed that P-value of 0.017802245 and 9.84451E-05 were greater than 0.05 Significant Level (SL). This shows that temperature in days of the week and the weekend varied significantly. This is in tandem with the earlier view that days of the week had different mean temperature of 29.9⁰C and weekend mean temperature of 29.7⁰C; days of the week military temperature had 30.3⁰C and weekend military temperature recorded 28.8⁰C supporting the hypothesis results. The results and findings of this study are in line with the view of Ifeoluwa *et al,*. (2012) who observed temperature difference between the

Table 4: ANOVA Test Explaining the difference in Days of the Week and the Weekend

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F-crit*
Rows	1.4045	1	1.4045	8.368421053	0.017802245	5.117355029
Columns	27.2905	9	3.032277778	18.06719629	9.84451E-05	3.178893104
Error	1.5105	9	0.167833333			
Total	30.2055	19				

SS* Sum of Square, df** degree of freedom, MS*** Mean Square, F**** F-statistics

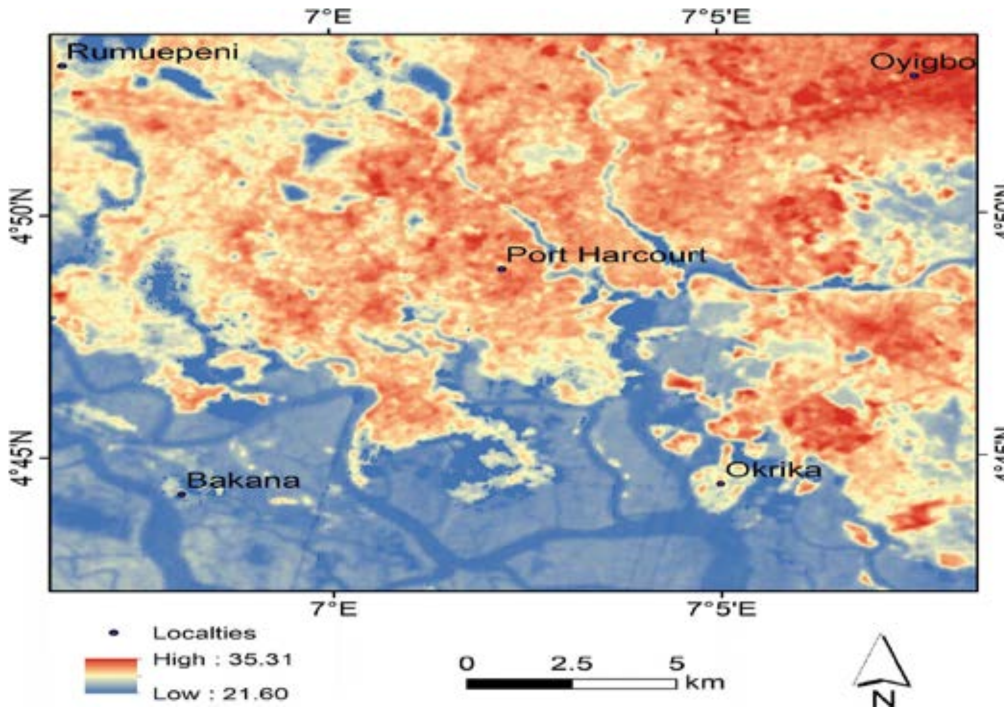

Fig. 8: Land Surface Temperature (LST) of Port Harcourt City

rural fringes and the city center at 4°C in nocturnal period and 2°C in the afternoon. Temperature varied across measurement days, weeks, months and seasons in the city of Akure, Nigeria. Elsayed *et al.,* (2012) who studied temperature and UHI in the City of Kuala Lumpur, Malaysia established temperature difference from weekday to weekend during the study period which the working days were warmer than weekend and UHI was not the same across the city area having its peak at Puduraya part of the city. Reuben (2012) in a study in Singapore noticed variation in the city temperatures across sample points, time of the day and weekdays. Quah *et al.,* (2012) in a study using satellite remote sensing on Zhujiang Delta showed that temperature (LST) in the urban site was 4.56°C higher than the rural fringes due to the pattern of urban development. Baumer *et al.*, (2007) affirmed that during days of the week, people travel, take children to school and engage in other human activities which contribute to thermal variation across the weekdays. Earl *et al.* (2016) observed that the city center is known to generate intense heat from the dense pavements, population and economic activities in a weekly cycle. All of these are in tandem with this study having LST difference of 13.7°C from the lowest rural outskirt to the city center, UHI of 4.1°C weekend and 5.1°C days of the week. These studies recorded variations of temperature at different locations, time, weekdays and seasons. The management of urban temperature is a compendium of various temperature monitoring at different locations and time, weekdays as well as seasons.

CONCLUSION

Urbanization has modified the natural biophysical components of Port Harcourt city surface resulting to variation in the temperature and UHI characteristics across different land use types, days of the week and weekend. The study has employed the combination of temperature field observation and remote sensing of satellite origin from Landsat images and thermal infrared characteristics. Temperature raw data were produced from the field using LCD Digital Multi-Thermometer Loggers located at different land use types of 35 sample points of wet and dry seasons Thus, Port Harcourt city dwellers receive their thermal discomfort based on the land use type they find themselves, days of the week and weekend. This study has shown that days of the week (Monday to Friday) have higher temperature and UHI regime than the weekend (Saturday and Sunday). However, days of the week has contributed 52% of the temperature performance of Port Harcourt city and weekend has 48% indicating that the Port Harcourt city dwellers are more comfortable with less thermal stress during the weekend having population of 3,095,342 occupants. Elsayed *et al.* (2012) has similar view for the City of Kuala Lumpur which reveals that temperature in working days are warmer than weekend with the city of Puduraya having the highest temperature. It is therefore conclusive, that some cities such as Port Harcourt and Puduraya have temperature rise and heat stress during days of the week than the weekend. Furthermore, in Port Harcourt, at the rural fringes, days of the week cumulates temperature of 29.3^{0}C and the weekend has 29.5^{0}C showing that rural fringes are warmer during the weekend due to more concentration of people and economic activities at the outskirts during the weekend. Temperature in the weekend varies between 33.2^{0}C and 27.6^{0}C (5.6^{0}C) with UHI difference of 1.9^{0}C having Saturday as the coolest day at 3.7^{0}C. During days of the week, Monday has the highest UHI of 7^{0}C with least UHI of 4.2^{0}C on Friday showing the coolest in the days of the week. The study shows that temperature in days of the week and the weekend differs significantly. The rural land use remains the coolest and commercial/ residential sites maintains the highest thermal discomfort in Port Harcourt city. This difference between urban and rural segments of the city is similar to the study of Ifeoluwa *et al.,* (2012) who establishes that the city center is warmer than the rural sites in Akura, Nigeria. Also, that temperature varies in weeks, months and seasons in Akure city. Similarly, Quah *et al.,* (2012) establishes that urban area of the city of Zhujiang is higher than the rural fringes. It is conclusive, therefore, that some cities across the world have their city centers warmer than their rural fringes during the days of the week. Although, in this study, the rural sites are warmer than the city centers during the weekend but cooler than the city center during days of the week. The northern and eastern parts of Port Harcourt city are the warmest segments of the city while the southern and western parts remain relatively cooler. In this same vein, Reuben (2012) establishes that temperature varies across different sample points in Singapore depending on the characteristics of the area and weekdays. Thus, rise in urban fabrics and expansion of human activities will continue to trigger the thermal condition as temperature of the city decreases from the city center to the rural fringes. This is similar to the observations of Baumer *et al.*, (2007) and Earl *et al.,* (2016) who affirm that human activities, population and urban pavement variations of different city sites will result to variability of temperature and urban heat island effects. Therefore, it has become very pertinent for development authorities to engage the residents of Port Harcourt city to practice serious urban greening and tree planting as part of the environmental heat management strategies for inhabitable tropical city free from heat disaster.

AUTHOR CONTRIBUTIONS

P. Nwaerema Peace retrieved, analyzed and interpreted the data, prepared the manuscript, wrote the texts and edited the manuscript. S.N. Jiya compiled data, wrote the literature review, and reviewed the entire manuscript.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

ABBRAVIATION

df	degree of freedom
F	F-statistics
F-critic	F-critical value of distribution

ILO	International Labour Organization
LST	Land Surface Temperature
MS	Mean Square
NPC	National Population Commission
P-value	Probability value of distribution
SS	Sum of Square
UHI	Urban Heat Island
UNDESA	United Nations Department of Economic and Social Affairs
WHO	World Health Organization

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