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ORIGINAL RESEARCH PAPER

Impact of urban land cover change on land surface temperature

E. Igun[1,]*, M. Williams[2]

[1]*Department of Environmental Management and Toxicology, College of Natural and Applied Sciences, Western Delta University, Oghara, Delta State, Nigeria*

[2]*Centre for Landscape Ecology and GIS University of Greenwich, Faculty of Engineering and Science, Central Avenue Chatham Maritime, Kent, UK*

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ABSTRACT: The rapid growth in urban population is seen to create a need for the development of more urban infrastructures. In order to meet this need, natural surfaces such as vegetation are been replaced with non-vegetated surfaces such as asphalt and bricks which has the ability to absorb heat and release it later. This change in land cover is seen to increase the land surface temperature. Previous studies have tried to explain the impact of land cover changes on the land surface temperature. However, there is a growing need to spatially quantify the extent to which temperature has increased so as to identify areas where immediate mitigation measures can be introduced. In view of this, this study has incorporated remotely sensed Landsat data with remote sensing techniques in order to effectively quantify the spatial extent of urban growth and its impact on the land surface temperature in Lagos, Nigeria. The result shows that there have been changes in the land cover which has increased the land surface temperature between 2002 and 2013. Overall, there was an increase in the highly dense areas, moderately dense areas and less dense areas by 3.35% (2200.77 ha), 27.87% (13681.35 ha), 6.20% (3284.01 ha) and a corresponding increase in the mean land surface temperature of these urban areas by 3.8 ^{o}C, 4.2 ^{o}C and 2.2 ^{o}C. Hence, it was recommended that in order to reduce the land surface temperature of urban areas, sustainable urban planning strategies that include increasing the vegetated areas and embracing other green initiatives such as urban forestry should be adopted.

KEYWORDS: *Enhanced thematic mapper; Land surface temperature; Linear mixture model. Urban heat island; Urban growth.*

INTRODUCTION

It has been projected by the United Nations that by 2050, over 70% of the human population will live in urban areas due to the current growth rate of urbanisation (United Nations, 2007). This need to develop more urban infrastructure to meet the needs of a growing urban population has been putting pressure on urban areas, such that natural surfaces (such as vegetation, water and soil) are been replaced with manmade surfaces (such as buildings, road and tarmac) (Gill *et al.,* 2007; Fortuniak, 2009). This alteration in urban land cover in replacing natural surfaces with manmade surface is one of the factors that increase the land surface temperature (LST) of the urban environment because manmade surfaces store and release heat hence, contributing to the formation of a phenomenon known as the urban heat island (UHI) (Gill *et al.,* 2007). The difference in surface temperature between an urban environment and rural area such that the urban environment is warmer is referred to as the UHI (Voogt and Oke 2003). The

*Corresponding Author Email: *igun.eghosa@gmail.com*
Tel.: +23480 8226 8827 Fax: +23480 8226 8827

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UHI has been attributed to having negative impact on ecosystem functioning and human health (Imhoff *et al.,* 2010; Tan *et al.,* 2010). Developing countries are expected to experience severe consequences of UHI in the aspect of thermal discomfort and changes in microclimate, considering that that are located within the tropics (Burkart *et al.,* 2011). Hence, there is a growing need to properly examine the impact of urban land cover changes on the overall increase in the LST. Because various land cover surfaces or types vary in the way they emit and absorb energy radiation, they have been studies in order to estimate LST. Low albedo surfaces such as impervious surfaces were seen to have the ability of absorbing large amount of incoming solar radiation and reradiate it in the form of heat seen as thermal infrared at night. Also, estimating the cross sectional relationship that exist between LST and land cover types has helped researchers in investigating the impact of land cover changes on LST for different period of time (Liu and Zhang, 2011). Various studies have been carried out in cities in order to properly examine the variability of the LST due to changing urban land cover types. For example, Hu and Jia (2010), discovered that a decadal fall in vegetation due to change in urban land cover in Guangzhou from 1990 – 2007 led to an overall increase of the LST by 2.48 ˚C. A study carried out by Kimura and Takahashi (2013) revealed that during the day in the Ootemachi, Tokyo, roof areas had the highest temperature (37°C) followed by pavement (36°C), bare soil (34°C), grass (33°C) and water (32°C). Also, a comparative study carried out in Mumbai and Delhi revealed that the intensity of the UHI was more in Mumbai than in Delhi due to the alteration of vegetation cover cause by urban development (Grover and Singh, 2015). In the city of Surat, and normalized difference vegetation index (NDVI), LST and biophysical parameters were used to study the spatiotemporal increase in urbanization. It was discovered that urban growth accounted for 2.6 °C LST increase (Sharma *et al.,* 2013). As noted in Amiri *et al.,* (2009), there is a change in surface temperature values when transiting from a densely vegetated area to a sparsely vegetated area. Tree cover or vegetation has been largely seen to be inversely proportional to the LST in most urban areas (Lambin and Ehrlich 1996; Weng *et al.,* 2004; Weng and Lu, 2008; Raynolds *et al.,* 2008). Hence, in assessing the intensity of cooling or heating in urban areas, LST has been used as a tool (Rosenzweig *et al.,* 2009; Stathopoulou and Cartalis, 2007; Cao *et al.,* 2010; Bowler *et al.,* 2010). Though, vegetation has always been seen to play a vital role in helping to reduce the impact of urban heating in urban areas as shown in various studies such as Ali-Toudert and Mayer (2007), Onishi *et al.* (2010), Li *et al.* (2011); Farina, (2011), Chen *et al.,* 2013 and Zhibin *et al.,* (2015). However, the challenge has been in the aspect of accurately identifying hot spot areas within existing urban areas and also the integration of vegetated areas into existing built-up areas (Rotem-Mindali *et al.,* 2015). Previous study carried out by Nwilo *et al.* (2012) in Lagos, Nigeria estimated the overall increase in the LST using NDVI. However, this index only shows results for only two land surface features hence neglecting others. In view of this, this study adopted the linear mixture model (LMM) which recognises all land surface features hence making it possible to be able to identify hotspot areas and also estimate the role that different land cover classes play on the variations in urban surface temperatures. Lagos, Nigeria was chosen as the study area because it is located in a hot climatic zone (NIMET, 2012). Also, the electrical demands for cooling buildings with air conditioning are already high and have led to shortages in electrical supply (NERC, 2014). Hence it is imperative to examine the true nature of the LST in the study area in order to develop strategies that would help improve the liveability index of the City. Hence, this research has three objectives including: First, to estimate the changes in the land cover that has occurred in the study area; Second, to analyse the extent to which these changes affects the intensity of the UHI; Third, to identify hotspot areas in need of immediate mitigation strategies. The result of this study would not only help urban planners in identifying areas considered as hotspots and point to them what they need to do to improve the overall living conditions of urban areas but also, this study would be beneficiary to other cities having similar climate and experiencing similar living conditions. This study has been carried out in in Lagos, Nigeria in 2014.

MATERIALS AND METHODS

Study area

The study area (Lagos State) is located in the south western region of Nigeria which is on the coastal flood plain of the Bight of Benin (Fig. 1) (Lagos State, 2014). The area lies approximately between longitude 03^0 24' E to 03^0 37' E and latitude 06^0 25' N to 03^0 52' N (Lagos State, 2014). Although it is the smallest State in terms

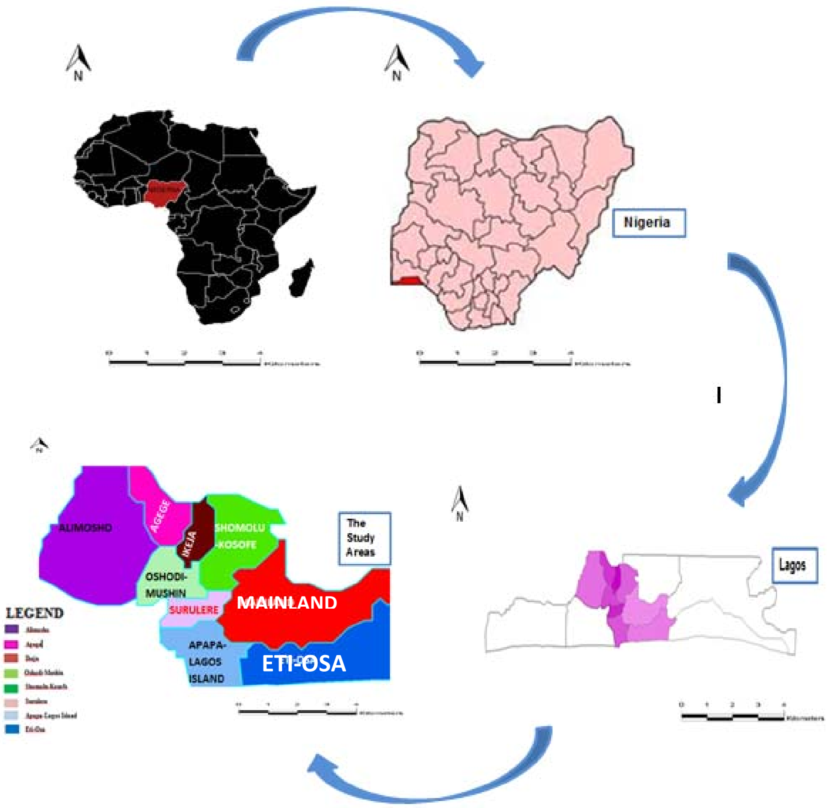

Fig. 1: The study area

of landmass (3,577 square kilometres), it has one of the highest population of people in Nigeria (17.5 million) (Lagos State, 2014). It is bounded by Ogun State in the north and east, by the Benin Republic in the west and the Atlantic Ocean in the south. Lagos is one of the smallest states in Nigeria in terms of landmass, but it has the largest population (Lagos State, 2014). Its official population rose from 20,000 in 1850 to 13.4 million in 2000 with a projected increase to 20 million in 2015 (Lagos State MEPB, 2004). This increase has led to a rapid growth in urbanization as seen in its varying land cover such as built-up area, farmlands and pavements (Lagos State, 2014).

Relief and climate of Lagos

Lagos, the seventh fastest growing city in the world, is located in a vegetated tropical zone consisting of the rain forest, mangrove swamp and fresh water swamp (Lagos State, 2014). It is a coastal area which consists of estuaries, low lying tidal flats, sandy barriers, islands and wetlands. It is characterised by two seasons; the wet (April to October) and the dry (November to March) (NIMET, 2012). The wet season is characterised by a double peak of rainfall in June and October due to the prevailing south-westerly wind, accompanied by the northward and southward movement of the ITCZ (Inter-tropical Convergence Zone). The ITCZ is a convergence zone that encourages the development of weather systems which lead to rainfall (WMO, 2014). In the dry season there is a prevailing north-easterly wind that brings with it the dry dust from the Sahara desert. The mean air temperatures of the wet and dry seasons are 24 ^oC and 34 ^oC respectively (NIMET, 2012). The rainy season in Benin begins in March/April and ends in October/November. Rainfalls are of high intensity and usually double maxima with a dry little spell in August usually referred to as 'August Break'. Rainfall, temperature, wind and relative humidity are the most significant climatic elements in Benin City. Some cases of temperature extremes between 30^0C and 35^0C have been recorded in the city metropolis in November and December.

Meteorological data

The Meteorological data collected from Ikeja Meteorological station covered the period from 1 January, 1980 until 31 May, 2013. However, they were analysed to cover the period under investigation (2002 to 2013) using Microsoft Excel spreadsheet in order to understand the actual trend in the mean annual temperature for Ikeja.

Satellite data

Some remote sensing techniques were used in this study for quantifying the land cover changes and its influence on the LST, namely, land surface temperature estimation, surface emissivity estimation and land cover classification. The spatial resolution of the thermal band used for estimating the LST in this study is 30 metres.

Land surface temperature estimation

The emissivity corrected land surface temperature method which requires the input of emissivity values from different surfaces was used in this study. Firstly, this method entails the conversion of brightness temperature to spectral radiance using Eq. 1.

$$L_{\lambda} = M_L Q_{cal} + A_L \qquad (1)$$

Where, L_{λ} is the spectral radiance (W/m^2); M_L is the 'gain' which is 0.067 for Landsat 7 and 0.00033420 for Landsat 8, QCAL is thermal image with units in DN and A_L *is the 'offset' which is -0.06709 for Landsat 7 and 0.1 for Landsat 8 (*NASA, 2007). Thereafter, the spectral radiance was converted to LST using the Artis and Carnahan (1982) equation represented as Eq. 2.

$$T = K_2 / \ln (K_1 / L_{\lambda} + 1) \qquad (2)$$

Where, T is the brightness temperature of the satellite (K), L_{λ} is the spectral radiance in W/m^2 as calculated in Eq 1, K_1 and K_2 are the thermal band conversion constant which are 666.09 and 1282.71 respectively for band 6 and 774.89 and 1321.08 respectively for band 10.

The temperature values estimated using Eq. 2 were converted from Kelvin (K) to Celsius (°C) (a standard unit of measuring temperature) by subtracting 273 as shown in Eq. 3.

$$T_2 = T_1 - 273 \qquad (3)$$

Where, T_2 is the converted temperature in °C and T_1 is temperature in Kelvin.

Artis and Carnahan's (1982) equation requires the input of the surface emissivity values of different earth's surface features. Hence, the next section explains the method used in obtaining these surface emissivity values.

Surface emissivity

The surface emissivity of different earth's surface features can be estimated using two methods; i) the NDVI which considers that a pixel in an urban area is made up of either vegetated or soil surface; ii) the linear mixture model which considers that a pixel in urban area is made up of more than one earth surface features The LMM was chosen and used in this study because an urban area is made up various surfaces, which increase the likelihood of a pixel having more than one earth's surface features (such as water, vegetation and soil). In order to use the LMM in estimating the surface emissivity, endmembers were selected to represent the earth's surface features in the satellite image from pure pixels. These earth's surface features can be categorised into manmade and non-manmade features (Song, 2005). The manmade features from the satellite image were made up of surfaces with high spectral reflectance such as asphalt and tarmac having emissivity values 0.95 and surfaces with low spectral reflectance such as concrete and brick having emissivity value of 0.93. The non-manmade feature on the other hand was made up of vegetation, soil and water with emissivity values of 0.97, 0.96, and 0.98 respectively. Hence, the LMM (Eq. 4) used the following endmembers for this study include i) high spectral emissivity features ii) low spectral emissivity feature iii) water iv) vegetation and v) soil.

$$E = \left(\sum_{i=1}^{n} P_i \, E_i\right) \qquad (4)$$

Where E is the surface emissivity, P_i is the proportion of the earth's surface features defined by the various endmembers and E_i is the corresponding emissivity of these earth's surface features. The result derived from this surface emissivity estimation was used in correcting the LST result estimated from Eq. 3, in order to assign the various land cover type to their temperature values based as shown in Eq. 5, where CLST is the corrected land surface temperature (°C),

T_2 is the temperature converted from degree Kelvin to degree Celsius and E is the surface emissivity.

$$CLST = T_2 \; x \; E \quad (5)$$

Land cover classification

There are various method used in carrying out supervised land cover such as the box classifier (parallelepiped), the Minimum Distance to Mean (MDM) and the Maximum likelihood method. However, the maximum likelihood method was chosen because a weighting which helps to minimise errors that may arise due to misclassification can be applied during the classification process. A total of nine land cover types were identified namely; highly dense urban areas, moderately dense urban area, less dense urban area, farmland, densely vegetated area, less dense vegetated area, deep water body and shallow water body. Sample areas known as training sites were then defined in the image in order to represent the various land cover types by various classes.

Change detection

In order to observe the rate of increase or decrease in the LST over smaller areas, change detection analysis was also carried out by comparing the LST map for 2002 with that of 2013.

Relationship between land surface temperature and the different land cover types

In order to show the relationship between the LST and the different land cover types, a statistical approach was used to carry out a correlation and regression analysis. This was done using the percentage proportion of the land cover types and their mean LST for 2002 and 2013 respectively. The percentage proportions of land cover types were classified into vegetated and non-vegetated areas. This is because studies such as Walawender *et al.* (2013) and Connors *et al.* (2013) have shown that classifying the land cover types into vegetated and non-vegetated areas helps in estimating the relationship that exist between the LST and the various land cover types.

RESULTS AND DISCUSSION

Land cover change

Results from the maximum likelihood classification for both the 2002 and 2013 land cover images are presented in order to estimate the land cover changes in the study areas as shown in Figs. 2 and 3.

The results from the land cover classification presented in Tables 1 and 2 reveals that there was a general increase in the highly dense urban areas, moderately dense urban areas and less dense urban areas by 3.35% (2200.77 ha), 27.87% (13681.35 ha)

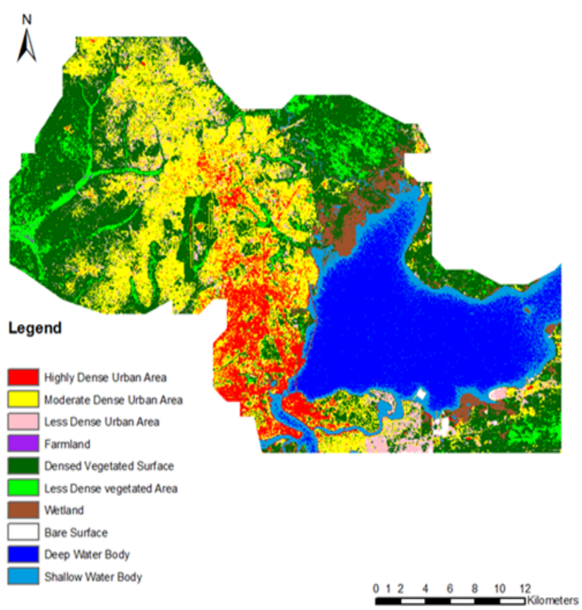

Fig. 2: Land cover classification for the nine local government areas (2002)

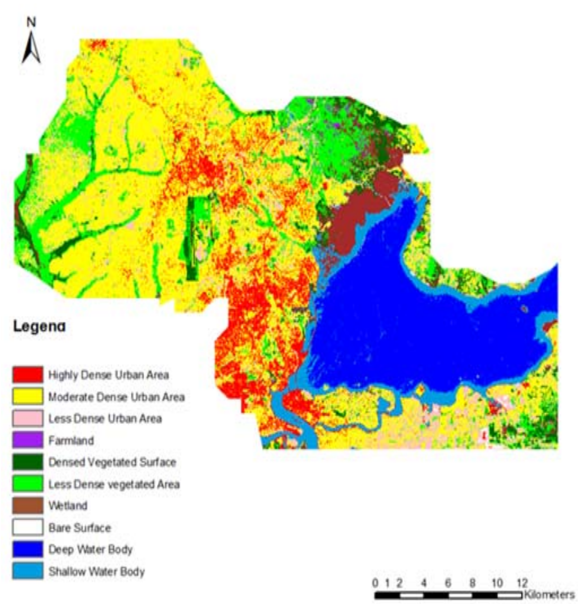

Fig. 3: Land cover classification for the nine local government areas (2013)

and 6.20% (3284.01 ha) respectively across the nine local government areas between 2002 and 2013. This general increase in the urban areas brought about a corresponding decrease in the densely vegetated areas by 48.38% (23778.09 ha), farmlands by 0.28% (212.31 ha), deep water body by 0.63% (1208.25 ha), bare surface by 0.15% (76.86 ha) and shallow water by 1.06% (1290.42 ha). There was also an increase in the less dense vegetated area by 10.57% (5203.35 ha). However, there were some notable local government areas which had the highest increase in their highly dense urban areas (Agege), moderately dense urban areas (Alimosho) and less dense urban areas (Eti-Osa) by 22.58% (611.01 ha), 35.96% (8428.86 ha) and 13.74% (910.98 ha) respectively between 2002 and 2013. Also, there was an increase in the wetland

Table 1: Change detection for the various land cover types for all local government areas between 2002 and 2013 (ha)

Land cover types	Agege	Alimosho	Apapa-Lagos Island	Eti-Osa	Ikeja	Mainland	Surulere	Oshodi-Mushin	Shomolu-Kosefe	Total land cover change for all the local government areas (ha)
Highly dense urban area	611.01	534.60	275.58	62.64	235.62	17.91	159.21	71.64	232.56	2200.77
Moderately dense urban area	548.82	8428.86	456.93	2155.5	313.02	597.96	423.27	101.88	655.11	13681.35
Less dense urban area	114.21	401.49	429.39	910.98	251.91	340.74	330.75	175.32	329.22	3284.01
Farmland	0.72	32.58	Nil	2.7	0.99	0.18	Nil	0.18	174.96	212.31
Densely vegetated area	1238.76	11710.08	665.46	2692.35	1165.14	1219.23	1233.27	349.65	3504.15	23778.09
Less dense vegetated area	192.06	2155.77	108.81	263.79	366.12	388.08	323.55	94.23	1310.94	5203.35
Wetland	0.09	173.34	7.92	402.21	9.27	21.69	5.13	14.49	996.03	1630.17
Bare surface	0.90	0.00	0.09	48.42	0.54	26.46	0.27	0.18	0.2	76.86
Deep water body	Nil	0.00	503.73	189.9	Nil	447.39	Nil	50.94	16.29	1208.25
Shallow water body	1.35	1.53	356.49	73.08	3.33	557.28	1.53	29.43	266.4	1290.42
Total increase (ha)	2707.92	23438.25	2804.4	6801.57	2345.94	3616.92	2476.98	887.94	7485.66	52565.58

Note: 'Nil' indicates that the land cover type is not in that local government area.

Table 2: Change detection for the various land cover types between 2002 and 2013 (in %)

Land cover types	Agege	Alimosho	Apapa-Lagos Island	Eti-Osa	Ikeja	Mainland	Surulere	Oshodi-Mushin	Shomolu-Kosefe	Average land cover change for all the local government areas (%)
Highly dense urban area	22.56% increase	2.28% increase	9.83% increase	0.92% increase	10.04% increase	0.50% increase	8.07% increase	6.43% increase	3.11% increase	3.35% increase
Moderately dense urban area	20.27% increase	35.96% increase	16.29% increase	31.69% increase	13.34% increase	16.53% increase	11.47% increase	17.09% increase	8.75% increase	27.87% increase
Less dense urban area	4.22% increase	1.71% increase	15.31% increase	13.39% increase	10.74% increase	9.42% increase	19.74% increase	13.35% increase	4.40% increase	6.20 % increase
Farmland	0.03% decrease	0.14% % decrease	Nil	0.04% decrease	0.04% decrease	0.2% decrease	0.02% decrease	Nil	0.34% decrease	0.28% decrease
Densely vegetated area	45.75% decrease	49.96% decrease	23.73% decrease	39.58% decrease	49.67% decrease	33.71% decrease	39.38% decrease	49.79% decrease	46.81% decrease	48.38% decrease
Less dense vegetated area	7.09% increase	9.20% increase	3.88% increase	3.88% increase	15.61% increase	10.73% increase	10.61% increase	13.06% increase	17.51% increase	10.57% increase
Wetland	0.01% increase	0.74% increase	0.28% decrease	5.91% decrease	0.40% decrease	0.60% Decrease	1.63% increase	0.21% decrease	13.31% increase	1.50% increase
Bare surface	0.03% decrease	0.01% decrease	0.01% decrease	0.71% decrease	0.02% decrease	0.73% decrease	0.02% decrease	0.01% decrease	0.01% decrease	0.15% decrease
Deep water body	Nil	Nil	17.96% decrease	2.79% decrease	Nil	12.37% increase	5.74% decrease	Nil	0.22% decrease	0.63% decrease
Shallow water body	0.05 % decrease	0.01% decrease	12.71% decrease	1.07% decrease	0.14% decrease	15.41% decrease	3.31% decrease	0.06% decrease	3.56% decrease	1.06% decrease
Total change (%)	100	100	100	100	100	100	100	100	100	100

Note: 'Nil' indicates that the land cover type is not in that local government area.

areas in some local government areas such as Agege, Alimosho, Surulere and Shomolu-Kosefe by 0.01% (0.09 ha), 0.74% (173.34 ha), 1.63% (5.13 ha) and 13.31% (996.03 ha) respectively and a decrease in others such as Apapa-Lagos Island, Eti-Osa, Ikeja, Mainland, and Oshodin-Mushin by 0.28% (7.92 ha), 5.91% (402.21 ha), 0.40% (9.27 ha), 0.60% (21.69 ha) and 1.21% (14.49 ha) respectively.

Land surface temperature

This section presents the results of the LST carried out to evaluate the changes in the surface temperature in the study area between 2002 and 2013. The result of the LST are presented in Fig. 4 and Fig 5. Also, Table 3 shows the result of the maximum and minimum LST, while Table 4 shows the mean LST for all local government areas.

The results presented in Table 3 indicate that the maximum and minimum LST increased across all nine local government areas between 2002 and 2013. The highest increase in the maximum LST (6 °C) was seen in Shomolu-Kosefe, while the highest increase in the minimum LST (6 °C) was noticed in Agege. Also, result in Table 4 shows that the highest mean temperature of 26.64 °C and 32.30 °C with standard deviation of 1.39 and 1.59 were observed for 2002 and 2013 respectively in Agege. The lowest mean LST was observed in mainland having 21.35 °C and 24.78 °C with standard deviation of 1.16 and 1.32, respectively.

Change detection for the land surface temperature

The result of the change detection carried out in order to understand for the change in LST between 2002 and 2013 is shown in Fig. 6.

Table 3: The maximum and minimum land surface temperature for each local government area (2002 and 2013)

Local government areas	2002 maximum LST (°C)	2013 maximum LST (°C)	Difference (°C)	2002 Minimum LST (°C)	2013 Minimum LST (°C)	Difference (°C)
Agege	31	36	5	19	25	6
Alimosho	34	35	1	20	24	4
Apapa-Lagos Island	31	36	5	19	24	5
Eti-Osa	29	33	4	19	23	4
Ikeja	33	35	2	20	25	5
Mainland	28	33	5	19	23	4
Oshodi-Mushin	30	35	5	20	25	5
Shomolu-Kosofe	29	35	6	19	24	5
Surulere	31	35	4	19	24	5

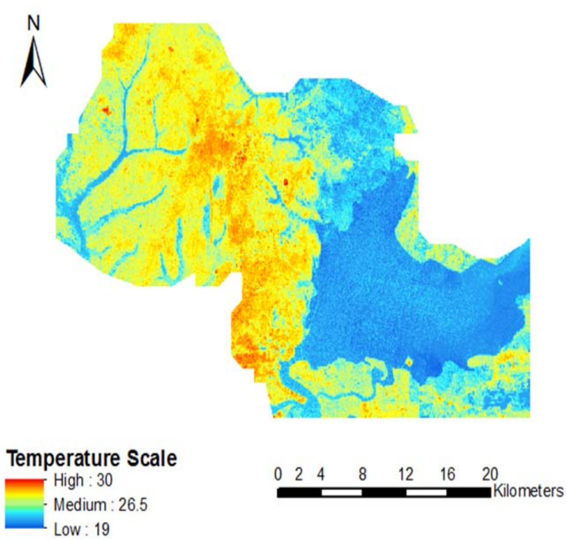

Fig. 4: Land surface temperature map for all local government areas (2002)

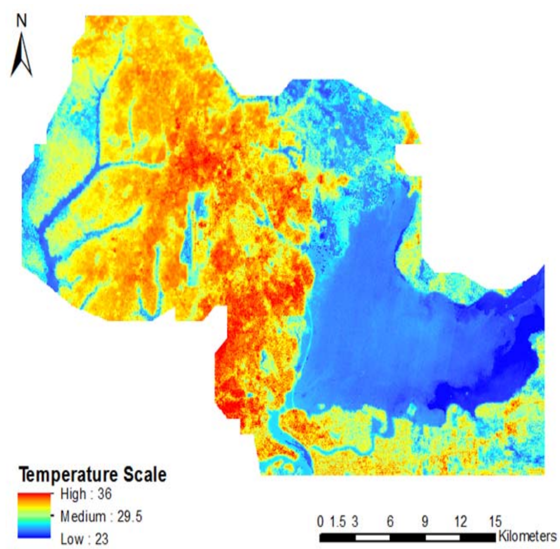

Fig. 5: Land surface temperature map for all local government areas (2013)

Table 4: The mean LST for each of the local government areas (2002 and 2013)

Local government areas	2002 mean LST (°C)	Standard deviation	2013 mean LST (°C)	Standard deviation
Agege	26.65	1.39	32.30	1.54
Alimosho	25.39	1.72	30.87	2.30
Apapa-Lagos Island	24.82	2.51	29.67	3.09
Eti-Osa	23.55	1.95	28.29	2.04
Ikeja	25.13	1.99	30.78	2.37
Mainland	21.35	1.16	24.78	1.32
Oshodi-Mushin	26.56	1.50	32.01	1.77
Shomolu-Kosofe	22.48	1.78	27.29	2.46
Surulere	25.78	2.63	31.12	3.37

The LST map presented in Fig. 6 reveals that one-third of the study area has remained unchanged (*i.e.* areas that have similar temperature both in 2002 and 2013). Also, one third of the area has experience an increase of 2 °C in the LST from 2002 to 2013, while the remaining one-third shows areas where the LST has either decrease by 2 °C of increase by 4 °C and 6 °C respectively. An assessment of these areas was done using ground validation technique in order to get a better understanding of these changes. It was discovered that the area where LST has decrease by 2 °C is a state owned reserved vegetated area in Alimosho. The areas where LST has remained unchanged or has increase by 2 °C are areas that are either occupied by water bodies or still vegetated. Also, the areas with 4 °C and 6 °C increase in the LST were vegetated in 2002 but have had their surfaces changed. For instance, it was discovered that in Alimosho, there was a newly built estate area, while in Apapa-Victoria Island there was a newly established industrial area, in Ikeja airport a new constructed tarmac and in Eti-Osa a densely urban area has emerged. This increase in temperature is a pointer to the change in the spatial pattern of the LST in Lagos.

Relationship between the land surface temperature and the land cover type

In order to understand the relationship that exist between the land cover types and the LST, the mean value of the LST for 2002 and 2013 and the corresponding percentage proportion of vegetation and non-vegetated areas were correlated. The results show that there is a strong negative correlation between the mean LST and the percentage proportion of the vegetated areas of all the nine Local Government areas. This means that as the proportion of vegetated surfaces increases, the mean LST decreases. These results were found to be highly significant at $P < 0.0001$. In contrast, other results revealed a strong positive correlation between the mean LST and percentage proportion of non-vegetated areas such that as the percentage proportion of non-vegetated areas increases, the mean LST increases. The results were also highly significant at $P < 0.0001$.

Mean maximum and minimum temperature

In order to know if there has been an this increase in the LST the study area, an analysis of the trend in the mean annual maximum and minimum temperature of a meteorological station (Ikeja Station) was carried out as shown in Figs. 7 and 8.

The results in Figs. 5 and 6 show that there has been an increase in the trend of the mean annual maximum

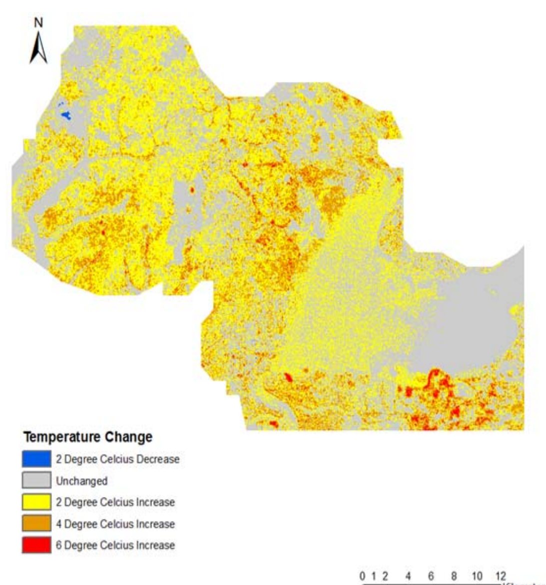

Fig. 6: Change in LST between 2002 and 2013

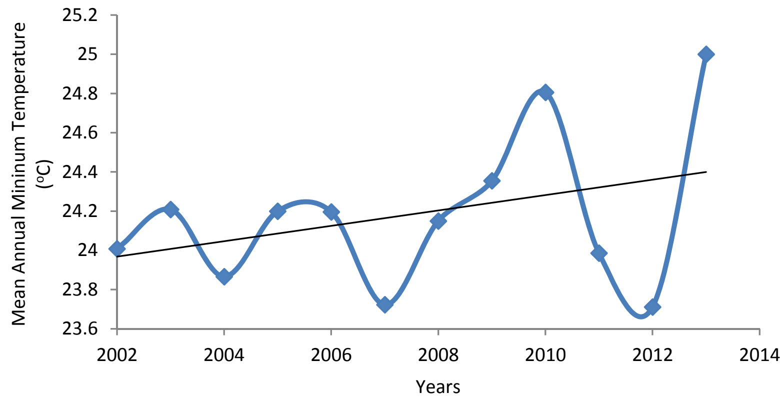

Fig. 7: The trend of the mean annual minimum temperature from 2002 until 2013 for Ikeja, Lagos

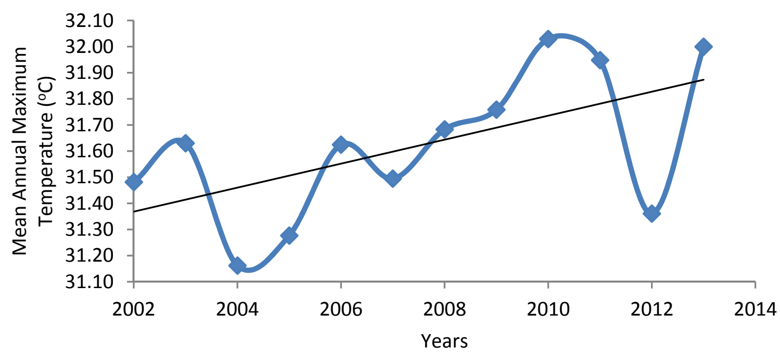

Fig. 8: The trend of the mean annual maximum temperature from 2002 until 2013 for Ikeja, Lagos

and minimum temperature from 2002 to 2013 in Ikeja. Also the mean annual minimum temperature is seen to be increasing by 0.04 ºC per year, while the mean annual maximum temperature was observed to be increasing by 0.05 ºC per year. However, there were variations in the minimum and maximum temperature of some years which according to a study carried out by Akinsanola and Ogunjobi (2014) was due to prolonged dry or wet seasons likely caused by climate change. From the findings of this study, the following can be inferred. Firstly, the Linear mixture model was seen to be suitable in helping to quantify the true nature of the LST as shown in Section and also noted in other studies such as Tan *et al.* (2010) and Nichol and Wong (2013). Secondly, it is evident that most of the densely vegetated areas present in 2002 have been cleared in order to give way for more urban structures (such as buildings and roads) between 2002 and 2013. Also, the decrease in the shallow and deep water bodies indicates that the urban areas are also spreading towards the lagoon in the Mainland local government area. Thirdly, it is apparent that the increase in LST is as a result of the increase in various manmade features (such as bricks and asphalt) that can absorb heat and release it later to warm their surrounding environment. Also, this increase in temperature has modified the urban climate such that the spatial profile between 2002 and 2013 differs. Fourthly, the results of the correlation and regression show that the non-vegetated areas have a positive influence on the increasing temperatures in urban areas. These observations are consistent with Zhao *et al.* (2011) and Connors *et al.* (2013) who observed that non-vegetated areas have an impact in increasing the LST of urban areas. Fifthly, the areas identified and classified as hotspots having temperatures between 4 ºC and 6 ºC, were seen to be newly developed areas. Hence, there is a need for the government and the local planers in Lagos to incorporate the idea of environmental sustainability into their urban planning strategies.

CONCLUSION

Urban development has a major impact on urban climate particularly in the increase of the land surface temperature which in turn contributes to the development of urban heat island. This is true because, changes in urban land cover tend to alter the spectral signature and emissivity of the land surface as observed using remote sensing techniques. The current study was aimed at evaluating the nature of urban growth in Lagos, Nigeria and how this growth has impacted on the overall increase in the LST. The results from the analysis showed that there have been changes in the land cover types due to urban growth. This growth has contributed to the overall increase in the LST such that most areas within the study area experienced upsurge in surface temperature. Also, it was observed that areas with sparse vegetation had high LST compared to areas with dense vegetation which had low LST. The result of this study, reiterate that need for city planners to integrate green spaces and tree covers with urban development activities. Also, in order to help regulate urban temperatures, the right trees should be planted in the right place which could be areas where high temperatures are expected or recorded. Other urban sustainability practices like green walls and green roofs which are currently being used to reduce urban temperatures in cities around the world could also be adopted by city planners. This would help in improving the liveability index as well as achieve environmental sustainability.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

ABBREVIATIONS

%	Per cent
^oC	Degree Celsius
A_L	The ‘offset’ which is -0.06709 for Landsat 7 and 0.1 for Landsat 8
CLST	Corrected land surface temperature
E	Surface emissivity
E_i	Corresponding emissivity of these earth’s surface features
Eq	Equation
Fig.	Figure
Ha	Hectares
ITCZ	Inter-tropical convergence zone
K	Kelvin
K_1	Thermal band conversion constant which is 666.09 for band 6 and 774.89 for band 7
K_2	Thermal band conversion constant which is 1282.71 for band 6 and 1321.08 for band 7
L_λ	Spectral radiance in W/m^2
LMM	The linear mixture model
LST	Land surface temperature
M_L	The ‘gain’ which is 0.067 for Landsat 7 and 0.00033420 for Landsat 8
MDM	Minimum distance to mean
N	Number
NDVI	Normalised differential vegetation index
P_i	Proportion of the earth’s surface features defined by the various end-members
QCAL	Thermal image with units in DN
T	Brightness temperature of the satellite
T_1	Temperature in Kelvin
T_2	Temperature converted from Kelvin to Celsius
UHI	Urban heat island

REFERENCES

Ali-Toudert, F.; Mayer, H., (2007). Effects of asymmetry, galleries, overhanging facades and vegetation on thermal comfort in urban street canyons. Sol. Energy, 81: 742-754 (**13 pages**).

Amiri, R.; Weng, Q.; Alimohammadi, A.; Alavipanah, S.K., (2009). Spatial–temporal dynamics of land surface temperature in relation to fractional vegetation cover and land use/cover in the Tabriz urban area, Iran. Remote Sens. Environ., 113: 2606-2617 (**11 pages**).

Akinsanola, A.A.; Ogunjobi, K.O., (2014). Analysis of rainfall and temperature variability over Nigeria. Global J. Human Soc. Sci.,14: 3–5 (**3 pages**).

Artis, D.A.; Carnahan, W.H., (1982). Survey of emissivity variability in thermography of urban areas. Remote Sensing Environ. 12: 313-329 (**17 pages**).

Bowler, D.E.; Buyung-Ali, L.; Knight, T. M.; Pullin, A.S., (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landscape Urban Plann., 97: 147-155 (**9 pages**).

Burkart, K.; Schneider, A.; Breitner, S.; Khan, M.H.; Krämer, A.; Endlicher, W., (2011). The effect of atmospheric thermal conditions and urban thermal pollution on all cause and cardiovascular mortality in Bangladesh. Environ. Pollut., 159: 2035-2043 (**9 pages**).

Cao, X.; Onishi, A.; Chen, J.; Imura, H., (2010). Quantifying the cool island intensity of urban parks using ASTER and IKONOS data. Landscape Urban Plann., 96: 224-231 (**8 pages**).

Chen, D.; Wang, X.; Khoo, Y.B.; Thatcher, M.; Lin, B.B.; Ren, Z.; Barnett, G., (2013). Assessment of urban heat island and mitigation by urban green coverage. In Mitigating climate change (Springer Berlin Heidelberg) pp. 247-257. (**11 pages**).

Connors, J.P.; Christopher S.G.; Winston, T.L.C., (2013). Landscape configuration and urban heat island effects: assessing the relationship between landscape characteristics and land surface temperature in Phoenix, Arizona. Landscape Ecology, 28: 271–283 (**13 pages**).

Farina, A., (2011). Exploring the relationship between land surface temperature and vegetation abundance for urban heat island mitigation in Seville, Spain. LUMA-GIS Thesis, (**48 pages**).

Fortuniak, K. (2009). Global environmental change and urban climate in Central European cities. International Conference on Climate Change. The environmental and socio-economic response in the southern Baltic region, University of Szczecin, Poland, 25-28 May 2009. Conference Proceedings. Wyd. International BALTEX Secretariat, Publication, 42: 65-66 (**2 pages**).

Gill, S.E.; Handley, J.F.; Ennos, A.R.; Pauleit, S., (2007). Adapting cities for climate change: the role of the green infrastructure. Built Environ., 33: 113-115 (**3 pages**).

Grover, A.; Singh, R.B., (2015). Analysis of urban heat island (UHI) in relation to normalized difference vegetation index (NDVI): A comparative study of Delhi and Mumbai. Environ., 2: 125-138 (**14 pages**).

Hu, Y.; Jia, G., (2010). Influence of land use change on urban heat island derived from multi-sensor data. Int. J. Climato., 30: 1382-1395 (**14 pages**).

Imhoff, M.L.; Zhang, P.; Wolfe, R.E.; Bounoua, L., (2010). Remote sensing of the urban heat island effect across biomes in the continental USA. Remote Sens. Environ., 114: 504-513 (**10 pages**).

Kimura, F.; Takahashi, S. (2013). The effects of land use and anthropogenic heating on the surface temperature in the Tokyo metropolitan. Atm. Environ., 25: 155-164 (**9 pages).**

Lambin, E.F.; Ehrlich, D., (1996). The surface temperature vegetation index space for land cover and land-cover change analysis. Int. J. Remote Sens., 17: 463-487 (**25 pages**).

Lagos State (2014). Lagos state government environmental report.

Lagos State MEPB (2014). A report by the Lagos state ministry of economic planning and budget in collaboration with the Lagos State Ministry of physical planning and urban development.

Li, J.; Song, C.; Cao, L.; Zhu, F.; Meng, X.; Wu, J., (2011). Impacts of landscape structure on surface urban heat islands: a case study of Shanghai, China. Remote Sens. Environ., 12: 3249-3263 (**15 pages**).

Liu, L.; Zhang, Y. (2011) Urban heat island analysis using the Landsat TM data and ASTER data: A case study in Hong Kong. Remote Sens., 3: 1535–1552 (**17 pages**).

NASA, (2007). Landsat science data users handbook. National Aeronautics and Space Administration.

NERC (2014). Nigerian Electricity Regulatory Commission.

Nichol, J.E.; Wong, M.S., (2013). Spatial variability of frontal area index and its relationship with urban heat island intensity. Int. J. Remote Sens., 34: 885–896 (**12 pages**).

NIMET, (2012). Nigeria 2012 climate review bulletin.

Nwilo, P.C.; Olayinka, D.N.; Obiefuna, J.; Atagbaza, A.O.; Adzandeh, A.E.,(2012). Determination of Land Surface Temperature (LST) and Potential Urban Heat Island Effect in Parts of Lagos State using Satellite Imageries. Futy J. Environ., 7(1): 1- 4 (**4 pages**).

Onishi, A.; Cao, X.; Ito, T.; Shi, F.; Imura, H., (2010). Evaluating the potential for urban heat-island mitigation by greening parking lots. Urban For. Urban Greening, 9: 323-332 (**10 pages**).

Raynolds, M.K.; Comiso, J.C.; Walker, D.A.; Verbyla, D., (2008). Relationship between satellite-derived land surface temperatures, arctic vegetation types, and NDVI. Remote Sens. Environ., 112: 1884-1894 (**11 pages**).

Rosenzweig, C.; Solecki, W.D.; Cox, J.; Hodges, S.; Parshall, L.; Lynn, B.; Watson, M., (2009). Mitigating New York City's heat island: Integrating stakeholder perspectives and scientific evaluation. Bull. Am. Meteorol. Soc., 90: 1297-1312 (**16 pages**).

Rotem-Mindali, O.; Michael, Y.; Helman, D.; Lensky, I. M., (2015). The role of local land-use on the urban heat island effect of Tel Aviv as assessed from satellite remote sensing. Appl. Geogr., 56: 145-153 (**9 pages**).

Sharma, R.; Ghosh, A.; Joshi, P.K., (2013). Spatio-temporal footprints of urbanisation in Surat, the Diamond City of India (1990–2009). Environ. Monit. Assess., 185: 3313-3325 (**13 pages**).

Song, C.H., (2005). Spectral mixture analysis for sub pixel fractions in the urban environment: how to incorporate endmembers variability. Remote Sens. Environ., 95: 248-263 (**16 pages**).

Stathopoulou, M.; Cartalis, C., (2007). Daytime urban heat islands from Landsat ETM+ and Corine land cover data: An application to major cities in Greece. Sol. Energy, 81: 358-368 (**11 pages**).

Tan, K.C.; Lim H.S.; MatJafri, M.Z.; Abdullah, K., (2010). Landsat data to evaluate urban expansion and determine land cover changes in Penang Island, Malaysia. Environ. Earth Sci., 60: 7-9 (**3 pages**).

United Nations, (2007). World urbanization prospects.

Voogt, J.A.; Oke, T.R., (2003). Thermal remote sensing of urban climates. Remote Sens. Environ., 86: 370-384 (**15 pages**).

Walawender, J.P.; Mariusz, S.; Monika, J.H.; Anita, B., (2014). Land surface temperature patterns in the urban agglomeration of Krakow, Poland derived from Landsat-7/ETM+ data. Pure Appl. Geophysics, 171: 913-940 (**28 pages**).

Weng, Q.; Lu, D.; Schubring, J., (2004). Estimation of land surface temperature–vegetation abundance relationship for urban heat island studies. Remote Sens. Environ., 89: 467-483 (**17 pages**).

Weng, Q.; Lu, D., (2008). A sub-pixel analysis of urbanization effect on land surface temperature and its interplay with impervious surface and vegetation coverage in Indianapolis, United States. Int. J. Appl. Earth Obs. Geoinf., 10: 68-83 (**16 pages**).

WMO, (2014). Significant natural climate fluctuations. World Health Organization.

Zhao, C.; Fu, G.; Liu, X.; Fu, F., (2011). Urban planning indicators, morphology and climate indicators: a case study for a north–south transect of Beijing, China. Bul. Environ., 46: 1174–1183 (**10 pages**).

Zhibin, R.; Haifeng, Z.; Xingyuan, H.; Dan, Z.; Xingyang, Y., (2015). Estimation of the relationship between urban vegetation configuration and land surface temperature with remote sensing. J. Indian Soc. Remote Sens., 43: 89-100 (**12 pages).**

AUTHOR (S) BIOSKETCHES

Igun, E., Ph.D. Candidate, Department of Environmental Management and Toxicology, College of Natural and Applied Sciences, Western Delta University, Oghara, Delta State, Nigeria. Email: *igun.eghosa@gmail.com*

Williams, M., Ph.D., Associate Professor, Centre for Landscape Ecology and GIS University of Greenwich, Faculty of Engineering and Science, Central Avenue Chatham Maritime, Kent, UK. Email: *m.williams@gre.ac.uk*

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