Mapping Urban Heat Island Areas in Ibadan

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Abstract

Today, across the world many urban areas are experiencing higher temperatures compared to their surrounding rural areas; this difference in temperature is known as Urban Heat Island (UHI). UHI has created temperature hotspots in our urban centers which are known as UHI areas. This study maps Urban Heat Island areas in Ibadan using remotely sensed data for 1984, 2000 and 2011. Land Surface Temperature (LST) and land use land cover characteristics of Ibadan urban were examined. Normalized Difference Vegetation Index (NDVI) was computed for the study area. Correlation analysis was performed, and the results reveals that a negative relationship exist between LST and NDVI. Urban Heat Island (UHI) areas were defined using the land use land cover and LST for 1984, 2000 and 2011. The result further reveals that to map UHI areas, maximum LST and LULC conventionally regarded as UHI areas should be used, such as: high density residential areas, commercial/industrial area, and public/educational institution. The result presents an objective approach adopted to give us a detailed view of places that fall under UHI areas and account for their change through the study years. Based on findings, possible mitigation measures as means of controlling the menace of UHI were highlighted for the study area.

Keywords

Urban Heat Island, Land Surface Temperature, Land Use Land Cover, Normalized Difference Vegetation Index, Ibadan

1. Introduction

Man's development and construction of large cities has had a profound influence on the local climate [1]. Urbanization, the conversion of other types of land to uses associated with growth of populations and economy, is the most important type of land use and land cover change in human history [2]. Urban growth has had an increasingly significant socioeconomic and environmental impact at local, regional and global scales. In-turn, the level of pollution that is air, water and land has increased because of lack of poor environmental management. Data, given by the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, reported that Nigeria's urban population was almost 3.5 million in 1950, this rose to about 78.8 million in 2010, and is expected to increase to about 217 million in 2050[3]. The estimate implies that by the year 2050, about seventy-five percent of Nigerian population will reside in urban areas [4]. The most

staggering evidence of this projection can be seen in the continuous population growth of Ibadan urban. This explosive increase in the exponential form of ''population growth'' has caused havoc for the human life in the city environment. Doubling and tripling of urban population practically in all major cities and towns, and the consequent strain on the existing system manifest in environmental chaos [5]. In Ibadan urban, the rapid expansion of urban centres and their peripheries has led, in many cases, to a series of complex problems related to flooding, loss of agricultural land and natural vegetation, uncontrolled urban sprawl, increased traffic congestion and degradation of air and water quality could be seen to increase due to increase in high density and industrials areas. This in-turn has produced Urban Heat Island effects. Ojo [6] defines Urban Heat Island (UHI) as a metropolitan area within a city which is relatively warmer than its immediate environment.

Over the past few decades (from 1980 to date) Urban Heat Island (UHI) has been a nightmare to government, planners, citizens and other stake holders [7]. Such that planners, government, architects, scientist, environmentalist and geographers have adhered to the mantra that urban sprawl increases pollution and housing costs, more driving time to work and shopping, stress, and the escalating consumption of scarce farmland and open space. Irrefutable evidence, however, have shown that urban planning and zoning areas creates the very nightmares which it is supposed to eliminate [7]. Christopherson [8] states that the physical characteristics of urbanized regions produce Urban Heat Island that has on the average both maximum and minimum temperature higher than nearby rural settings. Jensen [9] also states that it is well known that Urban Heat Island exists over most urban areas compared to the relatively cooler non-urban surrounding countryside. According to Cao et al. [2] this alteration will inevitably result in the redistribution of incoming solar radiation and induce the urban-rural contrasts in surface radiance and air temperatures. Lockwood [10], states that the changes in the surface conditions will usually modify the local radiation and water balance and therefore change the local climate. The extent of the built environment, population size and density, anthropogenic activity, and socio-economic aspects of a city play a critical role in determining the effect of urbanization on temperature variation [11], [12]. Urban Heat Island (UHI), an anthropogenically generated phenomenon, is a distinct surface signature of human habitation. Urban Heat Island occurs when an urban center is warmer than its surrounding environment. This effect may be up to 10^oC warmer, although there is considerable variation due to different local environments and atmospheric conditions [13]. Heat Islands of varying extent and magnitude have been observed in most urbanized areas in the world [14]. Furthermore, Ojo [6] stressed that within a city you can have more than one heat island. While change in the energy balance of the urban area often leads to higher temperatures than surrounding rural areas [15], this contributes to the development of Urban Heat Island. In other words, heat Islands develop when a large fraction of the natural land cover in an (urban) area is replaced by built surfaces that trap incoming solar radiation during the day then re-radiate it at night [15],[16].

Due to variations in UHI effect and its lower magnitude during the day, very limited research is available to study daily variations of urban heat in cities when the UHI effect threatens usability of outdoor public spaces [17], [18], [19]. In response to substantial excess heat in cities, people increasingly move into air-conditioned buildings to benefit from indoor thermal comfort. Meanwhile, resultant anthropogenic heat generated from indoor air-conditioning causes an ever-increasing outdoor temperature. There are several impacts associated with UHI, and the most recurrent are: 1. Influence on local microclimate (contributing to an increase in surface temperature, reduced relative humidity (RH) and latent heat, and intensified sensible heat); 2. Changes in the displacement of air masses, precipitation, hydrological behavior (such as displacement of water bodies) [20], [21]; 3. Thermal discomfort [22]; 4. Socio-environmental and public health impacts [15], [23]; 5. Increase in mortalities when combined with natural phenomena such as Heat Waves (HWs) [24].

In this research, remote sensing technique is adopted as an indirect measurement to study and predict (Surface) Urban Heat Island areas in Ibadan urban. Also, this method is a quantitative remote sensing study of temperature changes, a promising application, currently still limited. This approach is not subjective as early believed and adopted but objective. It gives us

a detailed view and places that fall under UHIs areas [7], [25]. This approach also shows us areas that may not qualify for UHI when subjective method was used but could be included in this objective approach. This approach has explained the fact that remote sensing is an objective method and technically quantifies UHI while transverse method is a subjective approach in studying the phenomena. Also, UHI has created temperature hotspots in our urban centers which are known as UHI areas. Remote sensing approach forms a suitable means to give us detailed view of areas that fall under UHI conventionally using the LULC to assess such changes. The objectives of this research include: (1) To examine land use land cover changes in Ibadan from 1984 to 2011; (2) To derive and study changes in Land surface temperature (LST) in Ibadan for 1984, 2000 and 2011; and (3) To map Heat Island areas in Ibadan for 1984, 2000 and 2011. For proper comprehension, this study is divided into four sub titles, namely: (a) assessing changes in the land use land cover; (b) assessing changes in the land surface temperature; (c) assessing changes in vegetation density; and finally, (d) mapping Urban Heat Island areas in Ibadan between 1984 and 2011 using GIS techniques.

2. Study Area

Ibadan is located in Southwestern Nigeria, 128 km inland Northeast of Lagos and 345 km Southwest of Abuja, the federal capital and is a prominent transit point between the coastal region and the areas to the North [26]. Ibadan is located between Longitude 591714.71 meters Easting to 605334.71 meters Easting (3°50' to 3°58' East) and Latitude 822840.25 meters Northing to 808260.11 meters Northing (7° 26' to 7° 19'North). Figure 1 shows the location of Ibadan urban indicating Oyo state and Nigeria.
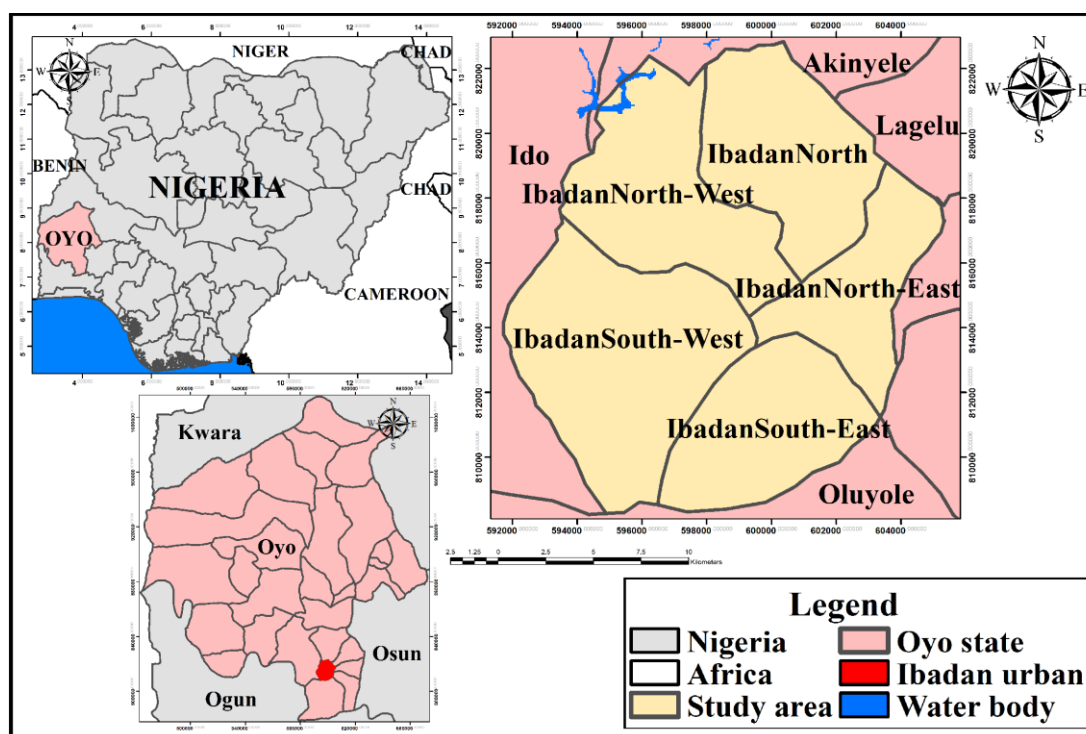

Figure 1.   Geographical location of Ibadan urban.

It borders Olouyole and Ona Ara Local Government Areas to the South, Akinyele Local Government Area to the North, Ido Local Government Area to the East, and Egbeda and Lagelu Local Government Areas to the West. The population of Ibadan is 1,338,659 people according to census results for 2006 [27]. Ibadan covers an area of 128 km². Ibadan has a population density of about 2,144.50sq. mi (828km^2) [26]. Ibadan (also known as *Ibadan urban*) is divided into five Local Government Areas (LGAs) [26] and it includes: Ibadan North, Ibadan Northeast, Ibadan Northwest, Ibadan Southwest, and Ibadan Southeast.

3. Methodology

The methodology adopted for this research includes:

3.1 Data collection

The data collected for this study can be classified into primary and secondary data. Primary data includes: Field survey (GPS reading and ground trotting) conducted to help understand and get first-hand information about the land use and Urban Heat Island areas throughout the study area which is useful to assess the dynamics of change. Secondary data used for this research includes: (a) Landsat Thematic Mapper (TM) 5 and Enhanced Thematic Mapper Plus (ETM+) 7 Imagery. This was acquired from USGS-Earth Explorer for 1984, 2000 and 2011 with a path/row of 191/55. The image and spectral characteristics are presented in Tables 1; (b) Administrative map of Ibadan and Nigeria (vector GIS shapefile format). This was acquired from the Department of Geography, University of Lagos, Akoka, Nigeria; (c) Mean temperature data for Ibadan. This was obtained from NIMET (Nigerian Meteorological Agency) station in Oshodi, Lagos (Nigeria) for 1984, 2000 and 2011; (d) Population of Ibadan; this was obtained from National Population Commission (NPC) [27]; and (e) Review of existing literatures.

Table 1.   Landsat 5 TM and 7 ETM + imagery acquired and characteristics.

Satellite	Sensor	Spectral Range(μm)	Band	Scene Size(Km^2)	Pixel Resolution(meters)
L 5	TM multi-spectral	0.45 - 2.35	1, 2, 3, 4, 5, 7	185 x 185	30
L 5	TM TIRS *	10.40 - 12.50	6		120
L 7	ETM+ multi-spectral	0.450 - 2.35	1, 2, 3, 4, 5, 7		30
L 7	ETM+ TIRS *	10.40 – 12.50	6.1, 6.2		60
L 7	Panchromatic	0.52-0.90	8		15

L- Landsat; * TIRS -Thermal Infrared Sensor

3.2 Method adopted for Land Use Land Cover (LULC) classification

Landsat TM 5 and ETM+ 7 imagery for 1984, 2000 and 2011 were used to create a land use land cover (LULC) by selecting band 4, 5 and 7 (Table 1). Image mosaicing was not performed because one image scene was used (path/row-191/55). While enhancement and creation of a composite for training sites were carried out. The images were already rectified to a common UTM coordinate system (31N). Land use land cover (LULC) was classified using supervised classification method, the following steps were adopted which includes: definition of training sites, extraction of signatures and classification of the remotely sensed imagery using maximum likelihood classification procedure into ten classes, namely: *High- and low-density residential*

area, bare ground/open space, agricultural land, other built-up area, public/educational institution, commercial/Industrial service, forest land, wetland and water body. The procedure was implemented in Idrisi Andes software.

3.3 Method of deriving Land Surface Temperature (LST)

Landsat TM 5 and ETM+ 7 thermal imagery (band 6 and 6.2) (Table 1) for 1984, 2000 and 2011 was processed to extract Land Surface Temperature (LST). Digital number (*DN*) values of Landsat ETM+ 7 was converted to spectral radiance value using published post-launch gains, which was calculated in Idrisi Andes using the following equation:

$$L_\lambda = \frac{(L\min - L\max)}{255} \times DN + L\min \tag{1}$$

For Landsat TM 5, radiance was computed through the following equation:

$$L_\lambda = offset + gain \times DN \tag{2}$$

Where, *offset*, *gain*, K_1 and K_2 = User defined parameters, L_λ = Cell value as radiance (W/m^{-2}sr^{-1}μm^{-1}), *DN* = Digital number of the thermal imagery, *Lmax* and *Lmin* = Derived temperature depending on gain status. In the next step, the spectral radiance is converted to brightness temperature at satellite sensor (T_B) using the following equation:

$$T_B = \frac{K_2}{\ln\left[(K_1 / L_\lambda) + 1\right]} \tag{3}$$

Where: K_1 and K_2 = Calibration constants (W/m^{-2}sr^{-1}μm^{-1}), L_λ= Spectral radiance (W/m^{-2}sr^{-1}μm^{-1}) and T_B=Brightness temperature (K). Land surface temperature was derived based on the brightness temperature. The conversion was carried out through the following equation:

$$T_{LST}(K) = \frac{T_B}{1 + \lambda \times T_B / \rho \times \ln \varepsilon} \tag{4}$$

Where, T_{LST} *(K)* = Land Surface Temperature (Degree Kelvin); λ= Wave length of emitted radiance (11.5μm); *ρ=hc/σ* = 1.438×10^{-2} (m K); σ = Stefan Boltzman constant = 1.38×10^{-23} J/K; C= Light velocity = 2.998×10^{-8} ms^{-1}; *h*= Planck's constant = 6.626×10^{-34}Js; and *ε* = Emissivity in the range between 0 and 1.Emissivity (ε) was computed using NDVI[28] as:

$$\varepsilon = \int_v \varepsilon_v + (1 - \int_v) \varepsilon_s \tag{5}$$

Where, ε= Composite emissivity, ε_v = Vegetation emissivity, ε_s= Soil emissivity, and $\int_v$= Fractional vegetation cover. Fractional vegetation cover was computed using the following equation [29] expressed as:

$$f_v = 1 - \left(\frac{NDVI - NDVI_{Min}}{NDVI_{Max} - NDVI_{Min}} \right)^\alpha \tag{6}$$

Where, $NDVI_{Max}$ = NDVI for complete vegetation cover and $NDVI_{Min}$ = NDVI for bare soil. $NDVI_{Max}$ and $NDVI_{Min}$ were assigned NDVI values derived from TM 5 and ETM+ 7. The coefficient α is a function of leaf orientation distribution within the canopy, where erectophile to planophile canopies have values between 0.6 and 1.25. A value of 0.6 was used in this current investigation. The fractional vegetation cover was compared with limited ground observations and the results were consistent. Emissivity was estimated using the derived fractional vegetation cover and specified emissivity of soil and vegetation. Using equation 7, LST was converted from degree Kelvin to degree Celsius using the following equation as:

$$T_{LST}(°\text{C}) = T_{LST}(K) - 273.16 \tag{7}$$

Where, T_{LST} (^{0}C) = Land Surface Temperature in degree Celsius (°C) and T_{LST} (K) = Land Surface Temperature in degree Kelvin (K).

3.4 Method of deriving Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) is a simple numerical indicator that can be used to analyze remote sensing measurements, typically but not necessarily from a space platform, and assess whether the target being observed contains live green vegetation or not [30]. NDVI for 1984, 2000 and 2011 is calculated using Idrisi Andes software as follows:

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}} \tag{8}$$

Where, $\rho_{nir:}$ = Spectral reflectance measurements acquired in the near-infrared regions, and ρ_{red}= Spectral reflectance measurements acquired in the red regions, respectively. NDVI value is transformed from -1 to 1 into an 8 bit value image. The scale value was used in statistical analysis using correlation model. NDVI value was scaled to remove negative value for easy computation using SPSS 17 software [7]. Scaled NDVI [7] was computed using Idrisi Andes software as follows:

$$\text{Scaled NDVI} = (\text{NDVI - 1}) \times 100 \tag{9}$$

3.5 Statistical Model adopted

3.5.1 Pearson Correlation Coefficient Statistics

Pearson Correlation Coefficient statistics was used to determine relationship between Land Surface Temperature and NDVI in Ibadan for 1984, 2000 and 2011. Correlation statistics is expressed as:

$$r = \frac{N\sum XY - \left(\sum X\right)\left(\sum Y\right)}{\sqrt{N\sum X^2 - \left(\sum X\right)^2 N\sum Y^2 \left(\sum Y\right)^2}} \tag{10}$$

Where, r = Correlation coefficient, N = Total number of sample or parameters, X = Independent variable, Y = Dependent variable, and Σ= Summation function. The model was computed using SPSS 17 software.

3.5.2 Root Mean Square Error (RMSE)

Root Mean Square Error (RMSE) method was used to validate temperature derived from Landsat TM 5 and ETM+ 7 for 1984, 2000 and 2011. The validation consists of comparing LST to observed temperature, with respect to their mean, and RMSE. RMSE is expressed as:

$$RMSE = \sqrt{\sum_{i=1}^{N} \frac{a_i - b_i}{N}} \qquad (11)$$

Where, a = Temperature derived (from LST) and b =Temperature observed (from NIMET station) and N= Total number of sampled points (stations). T-test statistics was used to determine whether the two datasets are significantly different from one another or not for 1984, 2000 and 2011. The above procedure was implemented in Microsoft Excel 2010 software.

3.6 Mapping Urban Heat Island areas

Land use land cover (LULC) was used as a criteria to define areas conventionally regarded as Urban Heat Island (UHI) areas, namely as: *High density residential areas, commercial/industrial areas, and public/educational institution* sometimes *low density residential areas* depending on the level of the density. Areas conventionally not regarded as UHI areas are *forest, wetland, water body, and agricultural land* [7], [25]. Using the LULC and LST (maximum) as criteria, UHI areas for Ibadan were defined for 1984, 2000 and 2011. The above procedure was implemented in ArcGIS 10 software.

4. Results and Discussion

For proper comprehension, the results is divided into the following areas which include: (i) assessing changes in the land use land cover; (ii) assessing changes in the land surface temperature; (iii) assessing changes in the vegetation density; and finally, (iv) mapping Urban Heat Island areas in Ibadan between 1984 and 2011.

4.1 Assessing changes in the Land Use Land Cover of Ibadan between 1984 and 2011

Land use land cover (LULC) for 1984, 2000 and 2011 is shown in Figures 2 for Ibadan derived from Landsat TM 5 and ETM+ 7 imagery. Table 2 show the distribution and changes in land use land cover (LULC) in Ibadan for 1984, 2000 and 2011. The land use pattern in Ibadan shows that agricultural land increased from 1.79Km^2 in 1984 to 5.10Km^2 in 2000 and then, decreased to 4.05Km^2 in 2011. While, commercial/industrial services decreased from 15.59 to 7.88Km^2 from 1984 to 2000, then increased to 8.19Km^2 in 2011. Forest land reduced from 1.29 to 0.01Km^2 from 1984 to 2000 and increased to 0.11Km^2 in 2011. Low density residential areas increased from 46.42 to 39.58Km^2 and then decrease to 23.80Km^2 for 1984, 2000 and 2011. High density residential areas increased from 7.34 to 21.57Km^2 and then to 27.23Km^2 in 1984, 2000 and 2011. Bare ground/open spaces increased from 1.26 to 1.28Km^2 and then to 3.29Km^2 for 1984, 2000 and 2011. Public/educational institution increased from 28.65 to 34.44 Km^2 and then to 40.27Km^2 in 1984, 2000 and 2011. These changes as shown in Figure 2 imply that built-up area has increased at the expense of forest land, agricultural land and water body in 2000 and 2011. From the above result in Figure 2 in compliment to other studies reveals that continued growth in Ibadan population has resulted in drastic changes in the LULC pattern of the area over the past few decades [31], [32], [33]. This change enhances the incident

radiation absorptivity, heat retention capacity and heat conductivity of the region [34], which in-turns increase the radiating surface temperature of the area [35].
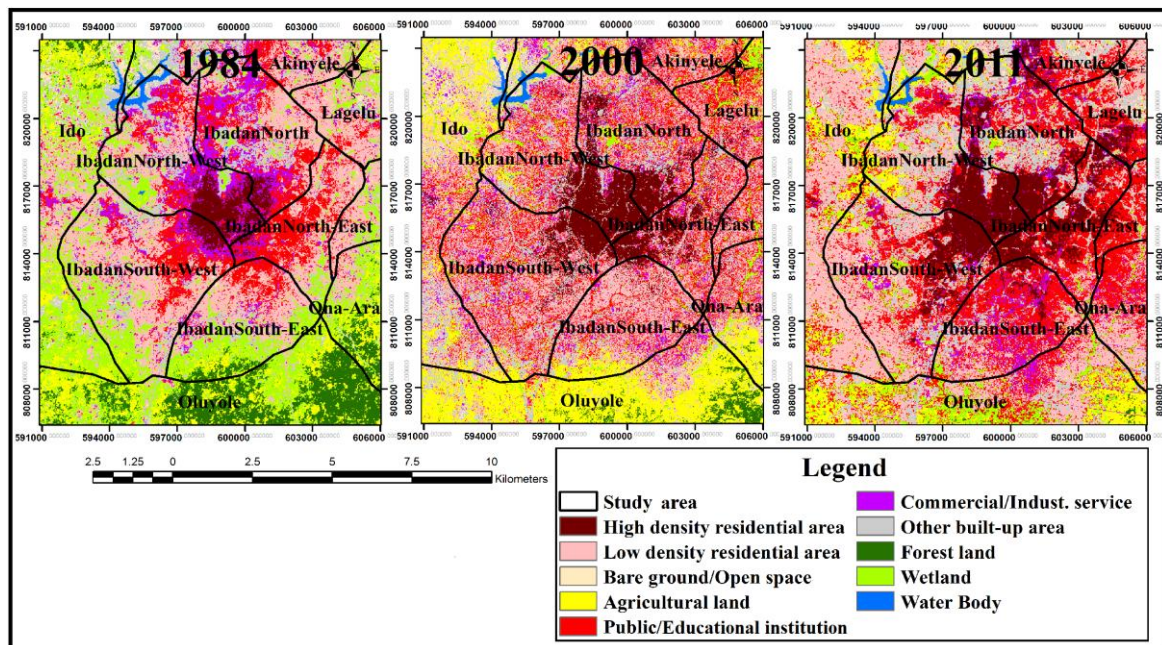

Figure 2. Land use land cover (LULC) of Ibadan for 1984, 2000 and 2011.

Table 2. Land use land cover distribution and changes (in Km^2) of Ibadan for 1984, 2000 and 2011.

Land Use Land Cover(LULC)	1984	2000	2011	Land Use Land Cover(LULC)	1984	2000	2011
High density residential area	7.34	21.57	27.23	Commercial/Industrial service	15.60	7.88	8.19
Low density residential area	46.41	39.58	23.80	Other built-up area	13.77	22.07	24.45
Bare ground/Open space	1.26	1.28	3.29	Forest land	1.30	0.01	0.11
Agricultural land	1.80	5.10	4.05	Wetland	19.03	3.43	4.14
Public/Educational institution	28.65	34.44	40.27	Water body	0.80	0.61	0.43

4.2 Assessing changes in the Land Surface Temperature (LST) of Ibadan between 1984 and 2011

Land Surface Temperature (LST) was computed using thermal band derived from the Landsat TM 5 and ETM+ 7 for 1984, 2000 and 2011. Land Surface Temperature (LST) for Ibadan is shown in Figure 3. Land Surface Temperature (LST) for the Local Government Areas (LGAs) is tabulated in Table 3. Ibadan Northeast, Northwest, North, and Southeast in 1984 have mean temperature values between 25.88°C to 26.12°C and Ibadan Southeast have low mean temperature of 24.75°C. For 2000, Ibadan Northeast, Northwest, and Southwest have high mean temperature values between 27.91°C to 28.22°C and Ibadan North and Southeast have high mean temperature value of 28.23°C and 27.99°C. In 2011, Ibadan Northeast, Northwest and North have high mean temperature values between 28.73°C to 28.07°C and Ibadan Southeast and Southwest have high mean temperature value of 26.87°C to 26.69°C.
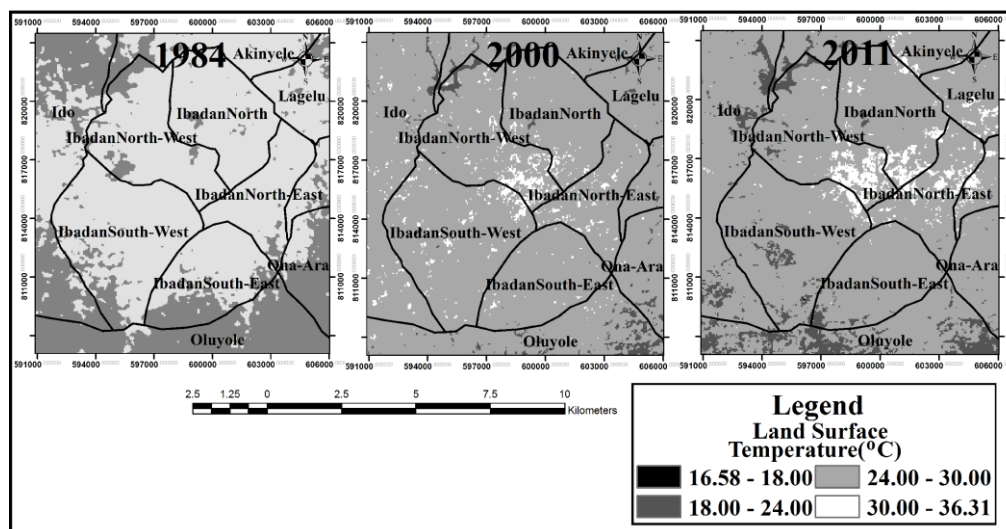
Figure 3. Land Surface Temperature (LST) of Ibadan for 1984, 2000 and 2011.

Table 4 show the spatial distribution of land surface temperature (LST) for the land use land cover (LULC) of Ibadan for 1984, 2000 and 2011. High density residential area have a minimum LST of 21.9°C, 27.37°C maximum and mean of 25.42°C for 1984, and for 2000, 24.94°C minimum, 32.71°C maximum with a mean of 29.26°C and for 2011, 24.91°C minimum, 31.66°C maximum and 29.36°C mean. Low density residential area LST have 18.06°C minimum, 30.87°C maximum with a mean of 26.49°C for 1984, while for 2000, 16.59°C minimum, 32.45°C maximum with a mean of 27.88°C and for 2011, 22.40°C minimum, 28.90°C maximum with a mean of 25.47°C. Bare ground/open space LST have 15.39°C minimum, 32.18°C maximum with a mean of 26.60°C for 1984, while for 2000, 21.82°C minimum, 32.45°C maximum with a mean of 27.69°C and for 2011, 21.60°C minimum, 28.90°C maximum with a mean of 24.42°C. Commercial/industrial service LST have 13.57°C minimum, 37.57°C maximum with a mean of 27.66°C for 1984 and for 2000, 17.47°C minimum, 32.71°C maximum with a mean of 28.34°C, while in 2011, 22.90°C minimum, 28.90°C maximum with a mean of 26.41°C. Agricultural land LST have 32.60°C minimum, 26.4°C maximum with a mean of 22.91°C for 1984 and for 2000, 21.25°C minimum, 31.13°C maximum with a mean of 25.83°C, while in 2011, 21.53°C minimum, 28.46°C maximum with a mean of 25.38°C. Public/educational institution LST have 23.30°C minimum, 29.30°C maximum with a mean of 26.63°C for 1984 and for 2000, 21.10°C minimum, 32.44°C maximum with a mean of 27.77°C and for 2011, 18.94°C minimum, 31.40°C maximum and 27.60°C mean. Other built-up areas LST have 22.39°C minimum, 30.87°C maximum with a mean of 26.66°C for 1984, while for 2000, 21.82°C minimum, 32.45°C maximum with a mean of 27.75°C and for 2011, 22.00°C minimum, 28.00°C maximum with a mean of 24.75°C. Forest land LST have 21.82°C minimum, 25.46°C maximum with a mean of 23.16°C for 1984, while for 2000, 22.10°C minimum, 28.19°C maximum with a mean of 23.95°C and for 2011, 21.60°C minimum, 26.30°C maximum with a mean of 22.31°C. Wetland LST have 20.39°C minimum, 29.27°C maximum with a mean of 24.41°C for 1984, while for 2000, 21.25°C minimum, 30.87°C maximum with a mean of 25.94°C and for 2011, 22.00°C minimum, 26.80°C maximum with a mean of 23.90°C. Water body LST have 19.30°C minimum, 20.61°C maximum with a mean of 19.86°C for 1984 and for 2000, 21.25°C minimum, 27.92°C maximum with a mean of 22.73°C, and for 2011, 21.10°C minimum, 24.63°C maximum and 22.84°C mean.

It is evident from Figure 3 that the land surface temperature (LST) varies from one place to another within the metropolitan area, and some areas reflect high temperatures. The rising temperatures of some regions are mainly caused by the thermal property of building materials, dark surfaces with low albedo and urban geometry [36], anthropogenic heat production [37], and finally, the geographic location of the urbanized area [38]. The dip and spike in surface temperatures over water

bodies show how water can maintains a fairly constant temperature, due to its high heat capacity [39]. While forest land have the lowest LST followed by agricultural land because of its high albedo. The highest LST is observed in high density residential area, commercial/Industrial service and public/educational institutions because its surface property is impervious with low albedo which store and emit more heat. The above result in consensus with the growing body of literature have revealed that LULC is directly associated with increase in (urban) LST and is a significant indicator and factor of UHI formation [37, 40, 41, 42]. Finally, model validation was performed using the Root Mean Square Error (RMSE) method. This test is based on the observed temperature compared with derived LST. The computed value of RMSE is 6.89 (6 degree of freedom at α=0.05) which implies that the result is acceptable and statistically significant. The RMSE model quantitatively assess the capabilities of LST models in predicting different changes in temperature, and also show a statistically significant difference at α = 0.05 when compared with the temperature observed (from NIMET station in Oshodi) for 1984, 2000 and 2011.

Table 3. Land Surface Temperature (°C) of the Local Government Areas in Ibadan for 1984, 2000 and 2011

Local Government Area(LGA)	1984			2000			2011		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Ibadan Northeast	22.00	28.90	25.88	21.82	36.31	27.91	21.53	32.18	28.07
Ibadan Northwest	22.00	29.30	26.12	22.67	32.44	28.53	23.52	31.66	28.73
Ibadan North	22.00	28.90	25.77	21.24	32.18	28.23	22.10	31.66	27.53
Ibadan Southeast	21.60	28.00	24.75	23.79	31.40	27.99	22.10	30.60	26.87
Ibadan southwest	22.00	28.90	25.41	16.58	32.71	28.22	13.39	31.40	26.69

Table 4. Land Surface Temperature (°C) of the land use land cover for 1984, 2000 and 2011 in Ibadan.

Land Use Land Cover(LULC)	1984			2000			2011		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
High density residential area	25.10	28.90	27.85	24.91	36.31	29.26	24.91	31.66	29.36
Low density residential area	22.40	28.90	25.47	16.58	32.44	27.88	18.06	30.87	26.50
Bare ground/Open space	21.60	28.90	24.42	21.82	32.44	27.69	15.39	32.18	26.60
Agricultural land	21.60	26.30	22.91	21.54	31.13	25.84	21.54	28.46	24.38
Public/Educational institution	23.30	29.30	26.63	22.10	32.44	27.77	18.94	31.40	27.50
Commercial/ Industrial service	22.90	28.90	26.41	17.47	32.71	28.34	13.57	37.57	27.66
Other built-up area	22.00	28.00	24.75	21.82	32.44	27.75	22.39	30.87	26.66
Forest land	21.60	26.30	22.31	22.10	28.19	23.95	21.82	25.46	23.16
Wetland	22.00	26.80	23.90	21.25	30.87	25.94	20.39	29.27	24.41
Water body	22.00	25.50	22.46	21.25	30.60	23.38	22.10	24.63	22.84

4.3 Assessing changes in the Vegetation Density of Ibadan between 1984 and 2011

Vegetation density was computed using Normalized Difference Vegetation Index (NDVI) derived using near-infrared and red bands from Landsat TM 5 and ETM+ 7 for 1984, 2000 and 2011. The NDVI value ranges between 1 to -1, the value of 1(high) represents pixels covered by substantial proportion of healthy vegetation while the value of -1 (low) represents pixels cov-

ered by non-vegetated surface including water, man-made features, and bare soil, dead or stressed vegetation. Normalized Difference Vegetation Index (NDVI) for Ibadan is shown in Figure 4.
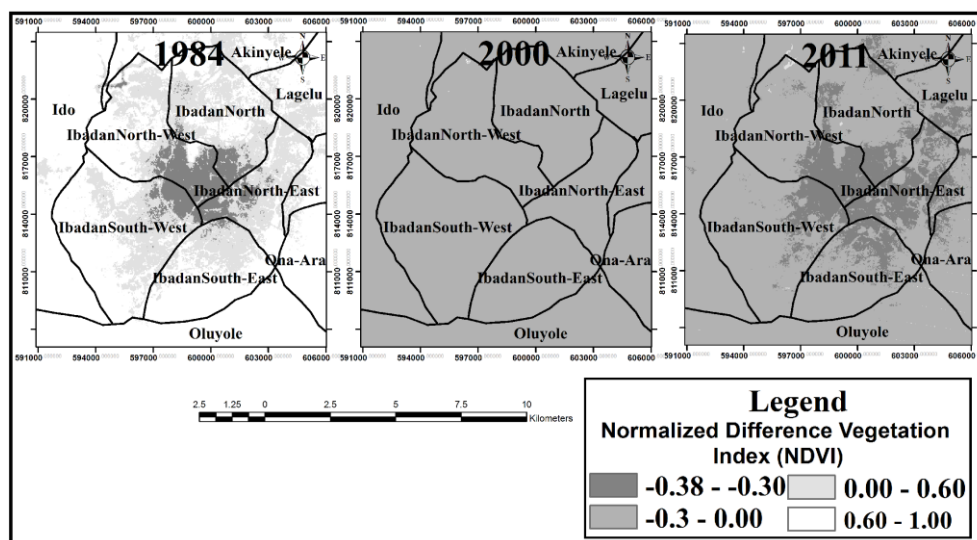

Figure 4. Normalized Difference Vegetation Index (NDVI) of Ibadan for 1984, 2000 and 2011.

Table 5 shows the spatial distribution of Normalized Difference Vegetation Index (NDVI) for the land use land cover (LULC) of Ibadan for 1984, 2000 and 2011. As presented in Table 5, forest lands have the highest NDVI while commercial/industrial services have the lowest. High and low density residential areas have low NDVI due to urban development which has converted the natural vegetation into impervious surface which is non-evaporating and non-transpiring such as metal, asphalt and concrete. In 1984, NDVI range (-0.06-0.34) indicates the presence of non-vegetation to a not very green area with the presence of very few healthy vegetation. NDVI in 2000 and 2011 (-0.22-0.04) is characterised by a drastic reduction in healthy vegetation which is replaced by non-vegetated surface including water, man-made features, bare soil, and dead or stressed vegetation.

Table 5.Normalized Difference Vegetation Index (NDVI) of the land use land covers between 1984 and 2011 for Ibadan.

Land Use Land Cover(LULC)	1984			2000			2011		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
High density residential area	-0.06	0.12	-0.02	-0.38	-0.15	-0.32	-0.37	-0.19	-0.32
Low density residential area	-0.03	0.29	0.11	-0.36	-0.02	-0.24	-0.32	1.00	-0.21
Bare ground/Open space	-0.03	0.30	0.17	-0.37	-0.04	-0.21	-0.32	0.02	-0.20
Agricultural land	0.09	0.34	0.23	-0.34	0.01	-0.17	-0.30	1.00	-0.11
Public/Educational institution	-0.05	0.26	0.03	-0.36	-0.02	-0.24	-0.38	1.00	-0.25
Commercial/ Industrial service	-0.06	0.25	0.05	-0.36	-0.05	-0.25	-0.36	1.00	-0.27
Other built-up area	-0.03	0.27	0.13	-0.38	-0.03	-0.24	-0.34	1.00	-0.21
Forested land	0.04	0.29	0.23	-0.23	0.01	-0.11	-0.26	0.06	-0.06
Wetland	0.01	0.30	0.19	-0.33	0.04	-0.16	-0.30	1.00	-0.12
Water body	-0.02	0.26	0.06	-0.36	0.02	-0.27	-0.32	0.01	-0.24

The relationship between Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) was investigated for the LULC through correlation analysis as presented in Figure 5. Based on Figure 5, it was observed that LST correlate negatively with NDVI for 1984, 2000 and 2011 for Ibadan urban. The correlation can be visualized by plotting the mean LST against NDVI as shown in Figure 5. The negative correlation between LST and NDVI implies that the lower vegetation (albedo) a land cover has, the higher the land surface temperature. Thus, the correlation between land surface temperatures and NDVI reveals that changes in land cover have an indirect impact on land surface temperature.
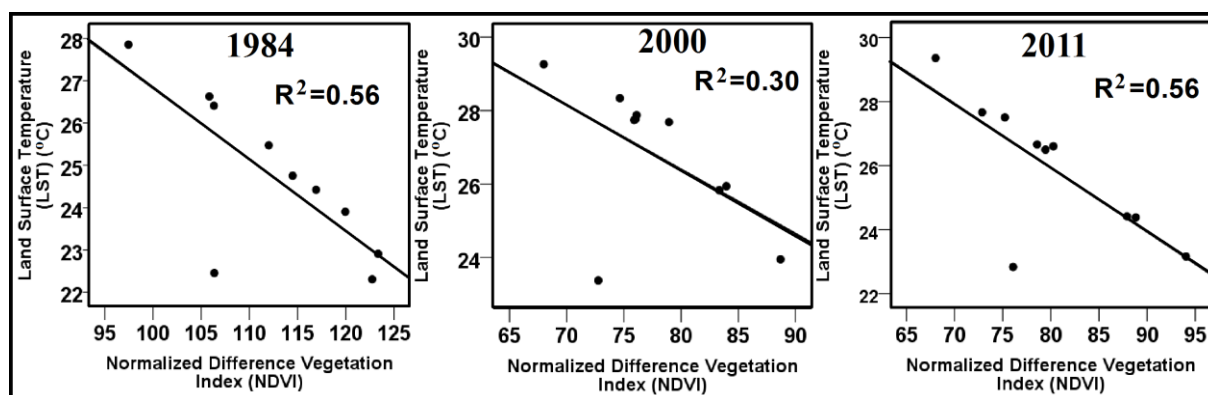

Figure 5. Correlation between Normalized Difference Vegetation index (NDVI) and Land Surface Temperature (LST) for 1984, 2000 and 2011.

4.4 Mapping Urban Heat Island areas in Ibadan between 1984 and 2011

Urban Heat Island areas were mapped from thermal imagery from Landsat TM 5 and ETM+ 7 for Ibadan as presented in Figure 6 for 1984, 2000 and 2011. Using the land use land cover (LULC) and its land surface temperature (maximum) as a criteria as presented in Table 4, Urban Heat Island areas for Ibadan was defined as 26.00ºC in 1984, 26.00ºC in 2000 and 28.00ºC for 2011.
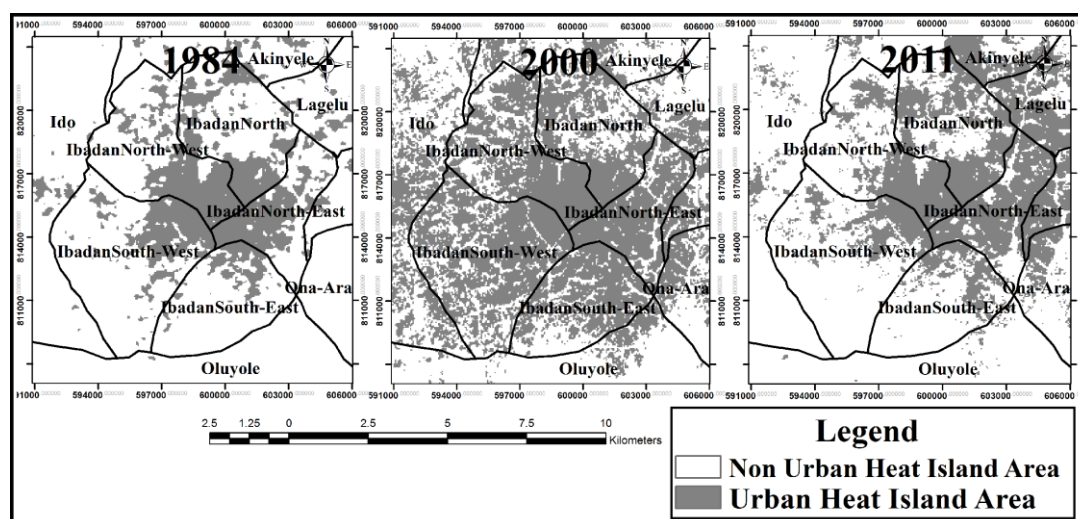

Figure 6. Urban Heat Island (UHI) areas in Ibadan urban in 1984, 2000 and 2011.

In Ibadan, high and low residential density areas, public/educational institutions and commercial /industrial services, meet up the criteria of UHIs areas between 1984 and 2011.

However, based on the above, with major comparison from previous studies available Urban Heat Island can be studied as: (1) Point location or weather station [43]; (2) Selected studies using transect research or automobile data collection [44, 45, 46, 47]; (3) weekday–weekend differences [48]; and (4) Selected areas assumed to be UHIs areas studied without bias [7]. For example, areas with high population density, high traffic, commercial and industrial areas where pollution concentration is high.

5. Conclusion

From the research human factors and urbanization has been one of the major causes of Urban Heat Island (UHI) in Ibadan. Using GIS and remote sensing approach allows for overlays and extraction of factors which aids in identification and location of Heat Island areas. A conceptual background of causes, problems and future consequences of UHI areas were x-rayed in cognizance to the peculiarity of the urban centers as regards her climate traits or indifferences. GIS techniques were used to extract present temperature which gives us a picture of what the future changes in temperature and heat island areas will look like. With temperature increase in Urban Heat Island areas, there is need to introduce measures that would reduce the heat island effects of thermal discomfort in Ibadan. According to Ibeabuchi and Oni [25], the following measures should be adopted in mitigating Urban Heat Island which includes: (a) increasing the surface albedo and introducing structures using building materials that would lead to cool rooftops. (b) Introducing more vegetation covers in Urban Heat Island areas like Old Quarter area, Alaafar road, Ode Aje road, Odo Oje Oloolu road, Ibadan Oyo road by Oke Aremo street, and Yemetu street. In particular: (1) Increase in urban vegetation e.g., trees, rooftop gardens, public parks like Mokola hills, will increase the cooling effects through evapotranspiration within and around the city. (2) Trees should be planted strategically to shade the AC condenser units, windows, and roofing. (3) Trees should be planted to shade pedestrians in major and minor roads like Lagos Ojo expressway and Orita Apeni Bere road. (c)Introducing measures that would increase wind circulation along major roads like Ibadan Oyo road and Basorun roads area in the study area. In particular, it is significant to note that: (1) Increased wind circulation patterns diffuse heat from UHI areas. (2) Large cities that plan "street canyons" to coincide with wind patterns will result in reduction of thermal discomfort of UHI. (3) While narrow roads may be preferable to increase density, wider street canyons are preferable towards heat reduction.

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