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Land Surface Temperature Analysis over Akure

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Abstract
The city of Akure has experienced massive growth in population over the past 30 years. The increased population has brought about modification in the land use and land cover leading to expansion in the urban area. This expansion has implications on the local climate of the area. This paper evaluates the urban expansion and its impact on Land Surface Temperature (LST) in the city of Akure from 1984 to 2014, using remote sensing and Geographic Information System (GIS) approach. Land use-land cover and change detection analysis were carried out for the period 1984 to 2014. Results showed that the urban settlement increased by 9709.62 hectares while the forested area decreased by 7347.2. The implication of the urban expansion on LST reveals an increase in the mean LST of the area (from 24.96 ^{o}C to 26.47 ^{o}C) with the highest LST value occurring at the city center due to limited vegetative surfaces within the area. The LST also increased across the different land uses and cover over the thirty years of study. In examining the relation between LST and vegetation, the NDVI and LST revealed a strong negative correlation (value of 0.94 and 0.924) between the two for each study period respectively. It is therefore imperative that with the increase in population and the corresponding increase in urban settlement, policies preserving vegetative surfaces (forested areas) should be implemented at every level.
Keywords: Land Surface Temperature, Population, Urban expansion

1. Introduction

It is widely recognized that land-use/cover change (LUCC) at local, regional, and global scales is one of the crucial driving factors of global climate change (Pielke, 2005). Land use and land cover changes play an important role in local and regional environment condition of a particular territory and they are linked to global environmental change (Oyinloye, 2013). Land use and land cover are important phenomena in understanding the interactions of human activities with its environment. In order to manage these phenomena, it is necessary to map different themes from time to time (Oyinloye and Kufoniyi, 2011). Land use patterns are recognized as influential elements in hydrological and meteorological processes (Cambell, 1996). Land surface temperature (LST) is an important climatic factor in both environmental and climate studies. It represents the temperature recorded at the interface between the earth surface and the immediate atmosphere (Valiente, 2009). Land Surface temperature derived from TIR band data has been found to provide vital and useful information on the state of the land surface and is widely implemented in formulating the energy and water budgets at the surface-atmosphere interface (Park *et al*., 2005). Thermal infrared remote sensing data have been widely used to retrieve land surface temperature for analyzing LST patterns and its relationships with surface characteristics (Zhan *et al*., 2015). The city of Akure has experienced massive growth in population over the past 30 years. The increased population has brought about modification in the land use and land cover leading to expansion in the urban area. Several studies have been conducted on the analysis of land use land cover of Akure (Oyinloye and Kufoniyi, 2011; Balogun *et al*., 2011; Oyinloye, 2013; Ibitolu *et al*., 2014; Balogun and Samakinwa, 2015). The studies were over different time intervals. Oyinloye and Kufoniyi (2011), analyzed the land use and land cover dynamics of Akure over a period of thirty years from 1972 – 2002; Balogun *et al*, (2011) mapped out the land use land cover LULC of Akure between 1986-2007, a period of twenty one years, with a view of detecting the land consumption rate and the changes that has taken place. Few studies have however looked at the urban expansion relating it to land surface temperature over Akure. Balogun and Samakinwa (2015) investigated the variability of the land surface temperature with respect to different land use land cover types over a period of twenty years. This study therefore seeks to analyze the land surface temperature relating to land use land cover in Akure over a period of thirty years 1984 – 2014.

2 DATA AND METHODS

2.1 DATA

This study employed the use of cloud free remotely sensed Landsat TM and OLI/TIRS satellite imageries of Akure for 1984 and 2014 acquired from earth explorer (table 1).

2.2 IMAGE CLASSIFICATION

Using the signature editor tool of the Erdas Imagine software, supervised classification was carried out on the study area image. Sample pixels representing the different land use/cover were identified, selected and merged in the signature editor. Under the supervised classification viewer, the maximum likelihood scheme was chosen for the classification. A classified image was then produced showing the spatial distribution of the different land use land cover.

The study area image was classified into five different classes; built – up, forest, grassland, rock outcrops and bare soil.

2.3 LAND SURFACE TEMPERATURE

Figure 1 shows the flowchart for the estimation of land surface temperature from the satellite image

(i) Spectral radiance, L;$_\lambda$

$$L_\lambda = \left(\frac{LMAX - LMIN}{QCALMAX - QCALMIN}\right) * (DN - QCALMIN) + LMIN \quad (1a)$$

$$L_\lambda = M_L * Q_{cal} + A_L \quad (1b)$$

Equation 1a represents spectral radiance for landsat 7 while equation 1b represents spectral radiance for landsat 8. Where; DN is the digital number of each pixel, LMAX and LMIN are the calibration constants, QCALMAX and QCALMIN are the highest and lowest range of values for rescaled radiance in DN obtained from the metadata; M_L represents the band specific multiplicative rescaling factor, Q_{CAL} is the band image and A_L is the band specific addictive rescaling factor

(ii) Reflectivity, ρ_λ ;

$$\rho_\lambda = \frac{\pi . L_\lambda}{ESUN_\lambda . \cos\theta . d_r} \quad (2)$$

Equation 2 applies to landsat 7.

Where; L_λ is the spectral radiance from equation 1a, $ESUN_\lambda$ is the mean solar exo-atmospheric irradiance for each band (W/m^2/µm), cos θ is the cosine of the solar incidence angle and d_r is the inverse squared relative earth-sun distance.

(iii) The land surface temperature was derived using equation 3

$$T_S = \frac{T_{bb}}{\varepsilon^{0.25}} \quad (3)$$

Where ε is the emissivity and T_{bb} is the effective at satellite temperature calculated from equation 4

$$T_{bb} = \frac{K_2}{ln\left(\frac{K_1}{L_6} + 1\right)} \quad (4)$$

Where K_1 and K_2 are calibration constants for the landsat image given in table 2. L_6 is the spectral radiance for the thermal band

2.4 NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

$$\varepsilon = 1.009 + 0.047 * ln(NDVI) \quad (5)$$

Where NDVI is the Normalized Difference Vegetation Index computed from the Infrared and Near-infrared bands of the satellite image using equation 6

$$NDVI = \frac{(\rho_4 - \rho_3)}{(\rho_4 + \rho_3)} \quad (6)$$

3. RESULT AND DISCUSSION

The land use land cover map of Akure for 1984 and 2014 is presented in Figure 2 (a) and (b) respectively. It was observed that in 1984, the vegetative covers (forest and grassland) dominates majority of the land use/cover of the city of Akure compared to the other land use land covers. In 2014, a major expansion of the built-up area outwards from the center of the city was observed. This could be attributed to the increase in population from 1984 to 2014. The population of Akure increased from 157,947 in 1990 to about 500,000 in 2006 (NPC reports, 2006), and has been estimated to increase annually by more than 5%. The increase in population could be attributed to the evolvement of the city which was characterized by the establishment of both governmental and non-governmental organizations, including State and Federal ministries, banks, manufacturing firms, service sector, and educational institutions. Tertiary institutions like the Federal University of Technology, Federal College of Agriculture, Ondo State School of Health Technology and Millennium College of Health Technology were established in the state leading to an influx of students from across the country. The increase in population brought about urban expansion as revealed by the increase in built-up settlements; the surrounding areas were developed as settlements. The distribution of the land use/cover by area (in hectares) in revealed in Figure 3. Built-up area increased from 2,726.28 to 12,435.9 hectares; forest decreased from 44,097.8 to 36,750.7 hectares; grassland increased from 24,139.5 to 24,822.5 hectares; rock outcrop decreased from 26,073 to 18, 223.6 hectares; while bare soil increased from 944.73 to 5,748.84 hectares. The change in area for each of the land use land cover is presented in Figure 4. The built-up, grassland and bare soil increased by 9709.62, 683 and 4804.11 hectares respectively while the forest and rock outcrops decreased by 7347.2 and 7849.4 hectares respectively. From the change detection (table 3); built-up, bare soil and grassland show increase of 11.87, 16.95 and 0.09 %

per year while forest and rock outcrop decrease, -0.56 and -1.0 % per year. In order to assess the accuracy of the classification, accuracy assessment was carried out for the classified images. The overall classification accuracy was 81.67% for 1984 and 84.17% for 2014 thus indicating reasonable classification accuracy.

Figure 5 (a) and (b) shows the Land Surface Temperature (LST) derived from LandSat for 11th December, 1984 and 14th December, 2014 respectively. It represents the spatial distribution of Land Surface Temperature across different land use /cover types. High LST values correspond to built-up and rock outcrops, while the low LST values were observed over vegetative surfaces. This could be attributed to the fact that built-up areas are characterized with high concentration of buildings, structure, machines and people. This causes higher temperature due to modification of the reflective (albedo), absorptive, storage and emissive characteristics of city-surface components (Ogunsote *et al*., 2002). Weng *et al*, (2008) indicated that biophysical variables (NDVI, vegetation fraction, impervious surface, soil fraction) are significant in explaining the spatial variations of LST. Impervious surface coverage is an indicator of human activity intensity, which is a characteristic nature of the built-up area. Urban Impervious surface has a warming effect on urban land surface temperature (Nie and Xu, 2015). Increase in impervious surfaces result into increase in surface temperature (Xiao *et al*., 2008). In other to reveal changes in the Land Surface Temperature (LST) over the period of thirty years, the mean values of the Land Surface Temperature for 1984 and 2014 for the land use land cover were plotted as showed in Figure 6. It was observed that the mean land surface temperature of all the land use land cover increased from 1984 to 2014.

Figure 7 (a) and (b) shows the Normalized Difference Vegetation Index (NDVI) for 11th December, 1984 and 14th December, 2014 respectively in Akure. It reveals the spatial distribution of NDVI across the study area. The highest NDVI value was observed over the vegetative surface (forest region) while the lowest value is over the built-up region for each period of study. Generally, healthy vegetation absorbs most of the visible light that falls on it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. Bare soils on the other hand reflect moderately in both the red and infrared portion of the electromagnetic spectrum. The built-up area consists of little vegetation compared to the forest and grassland. This explains the low and high values observed over the built-up and vegetative surface respectively. The increase in the surface area of the lowest value from 11th December, 1984 to 14th December, 2014 corresponds to increase in the area for the built-up region covering the same period, therefore revealing vegetation cover change.

The land surface temperature (^{o}C) and Normalized Differential Vegetation Index (NDVI) distribution over the different land use/cover is revealed in Figure 8 (a) and (b). High Land Surface Temperature (LST) values were observed over built-up area corresponding to low NDVI values over the land use/cover. Over the vegetative areas, low Land Surface Temperature (LST) was observed corresponding to high NDVI values. Extracting the land surface temperature and NDVI values across the different land uses, the scatter plot of LST – NDVI was plotted. The correlation between land surface temperature and normalized difference vegetation index is revealed in Figure 9 (a) and (b). The plot reveals strong negative correlations of 0.94 and 0.924 over Akure for 11th December, 1984 and 14th December, 2014 respectively. The results are consistent with those reported by Balogun and Samakinwa (2015) for Akure between the period of 1986, 2002 and 2006. The result also agrees with other studies carried out globally on the LST – NDVI relationship (Olthof and Latifovic, 2007; Sun and Kafatos, 2007; Julien and Sobrino, 2009; Gorgani et al., 2013). Nevertheless, it is important to note that the correlations between LST and vegetation depend on the season-of-year and time of day (Sun and Kafatos, 2007). Studies have revealed, that the correlation between LST - NDVI and regression coefficient from NDVI to LST can be positive. A large number of water and climate related applications such as drought monitoring, are based on space borne – derived relationships between land surface temperature and the normalized difference vegetation index (NDVI) (Karnieli *et al*., 2010).

4. Conclusion

Land use land cover analysis was carried out over a thirty year period over Akure in order to examine changes in vegetation cover. The analysis showed an increase in built-up, bare soil and grassland while forest and rock outcrops decreased over a thirty year period (11th December, 1984 - 14th December, 2014). The analysis revealed the implication of population increase on land use; upon increase in the population of Akure, the built-up settlement increased while the forest area decreased. This was as a result of conversion of natural vegetative surfaces into settlements, as the natural vegetative surfaces were replaced by impervious surfaces. The implication of this was revealed by the land surface temperature (LST) and Normalized Difference Vegetation Index (NDVI) estimation over the study area of Akure. Higher land surface temperatures were recorded by the manmade structures while lower land surface temperature values were observed over the vegetative areas. The correlation between the Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) showed strong negative correlation of 0.94 and 0.924 over Akure for 11th December, 1984 and 14th December, 2014 respectively, indicating that the built-up settlements with high Land Surface Temperature (LST) revealed low NDVI while the forested area with high NDVI corresponds to the low LST estimated over the sector. This implies that vegetation cover reduces the Land Surface Temperature (LST) over a land surface and vegetative surfaces such as parks and forest reserves should be preserved in the city.

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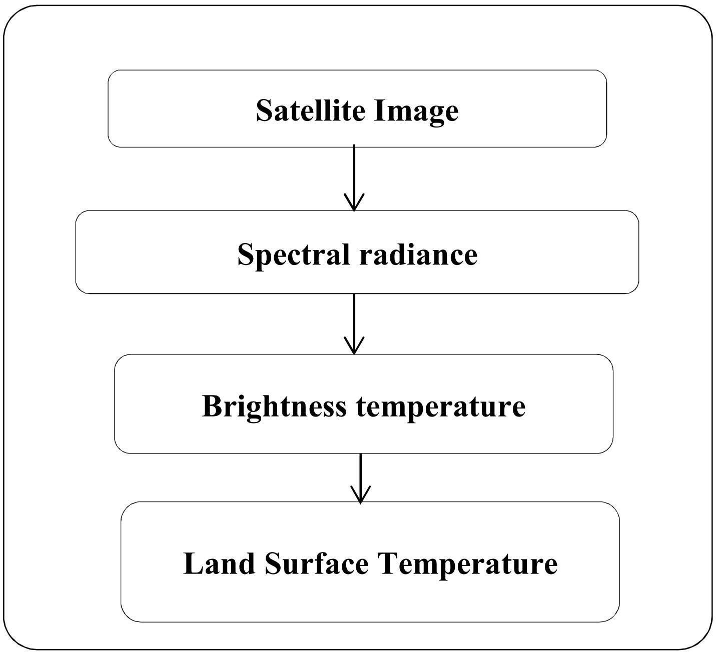

Figure 1: Flowchart for Land Surface Temperature (LST) estimation

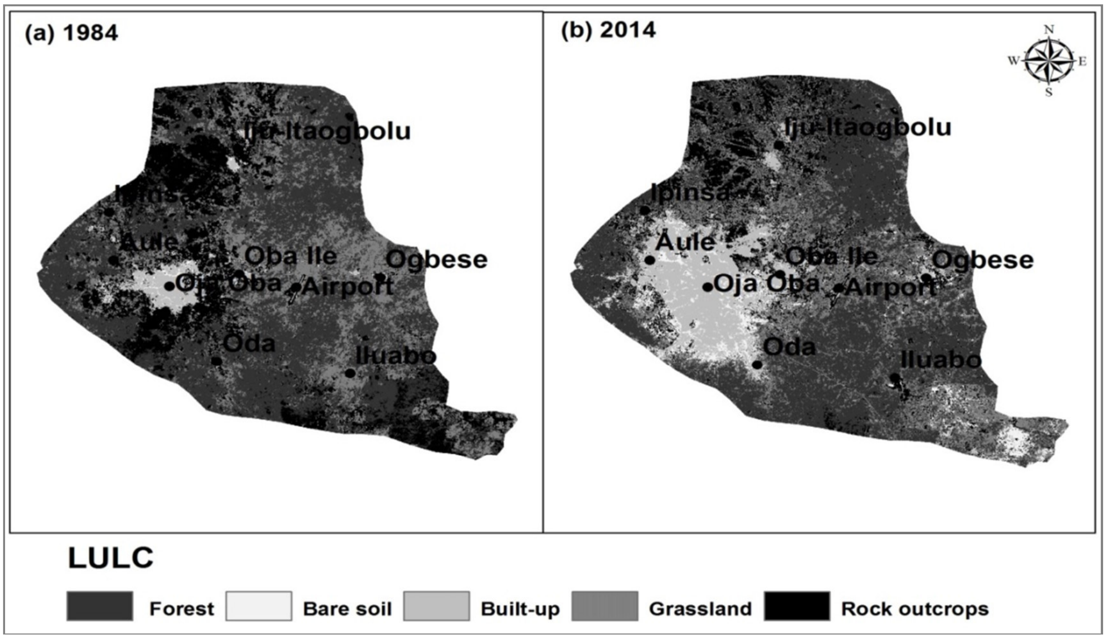

Figure 2: Map of Land Use Land Cover Classification for Akure (a) 11th December, 1984 and (b) 14th December, 2014

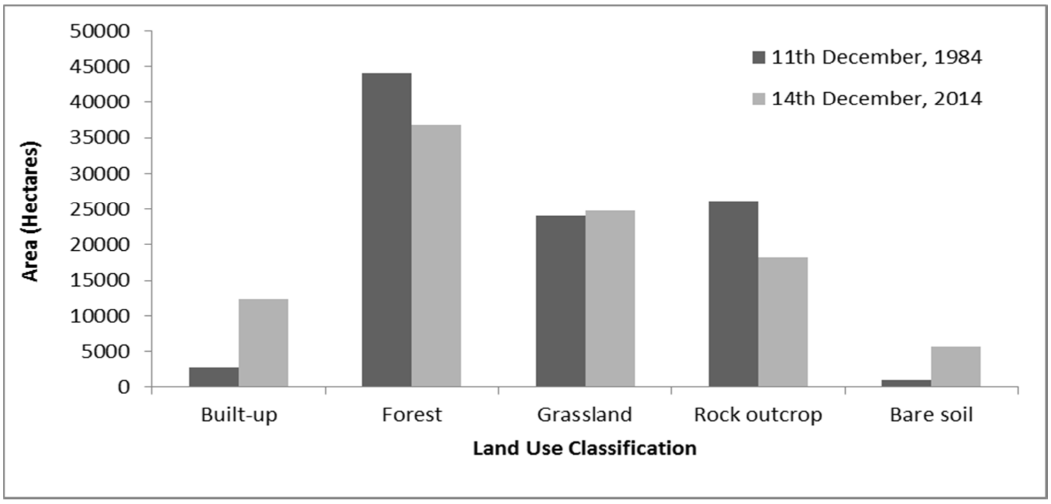

Figure 3: Distribution of land use by area (hectares) for Akure - 11th December, 1984 and 14th December, 2014

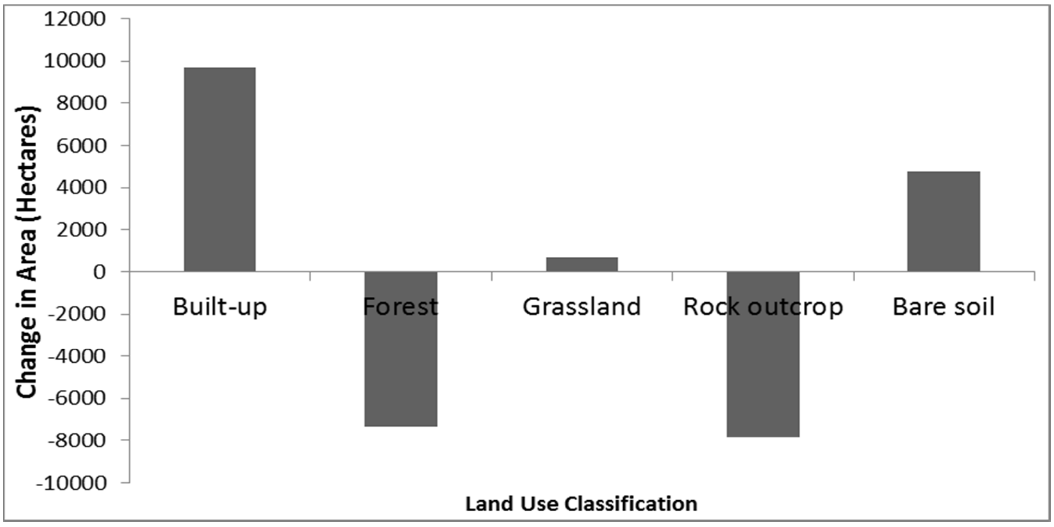

Figure 4: Change detection by land use in area (hectares) for 11th December, 1984 to 14th December, 2014

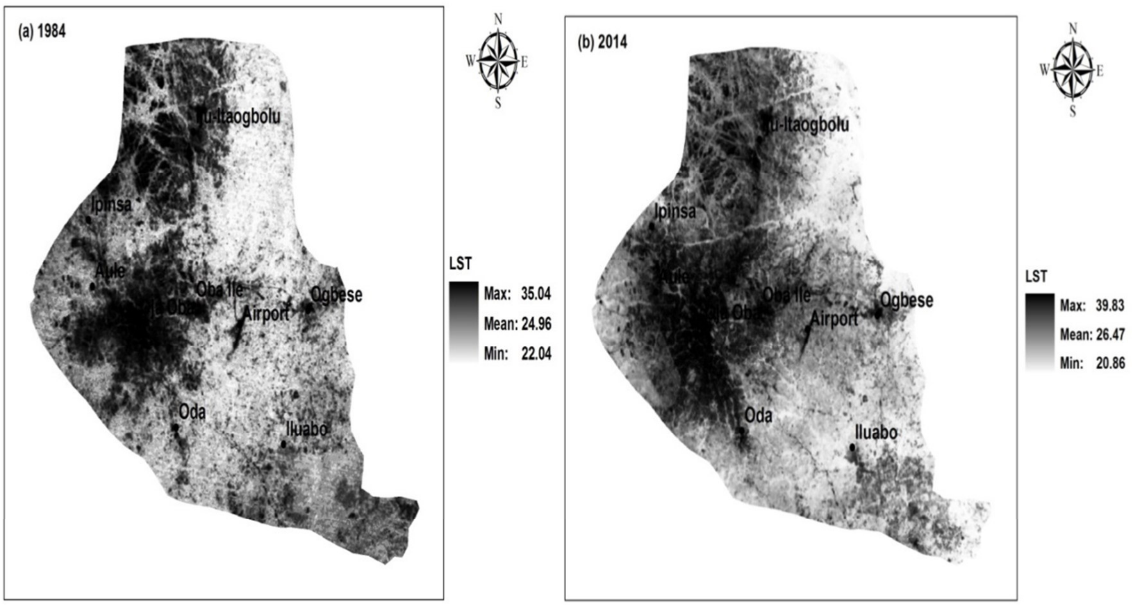

Figure 5: Land Surface Temperature (LST) in ^{o}C for (a) 11th December, 1984 and (b) 14th December, 2014 in Akure

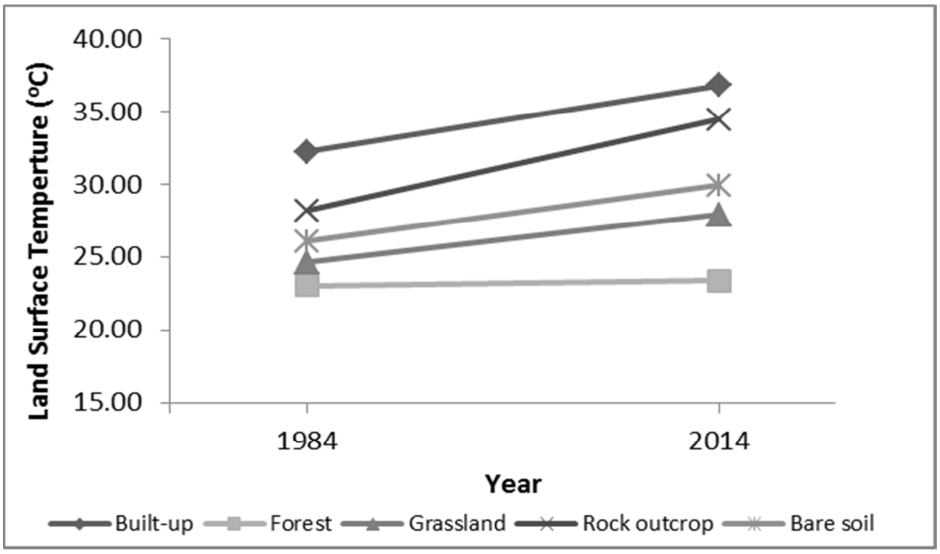

Figure 6: Land Surface Temperature (^{o}C) over the different land use land covers in 1984 and 2014 for Akure

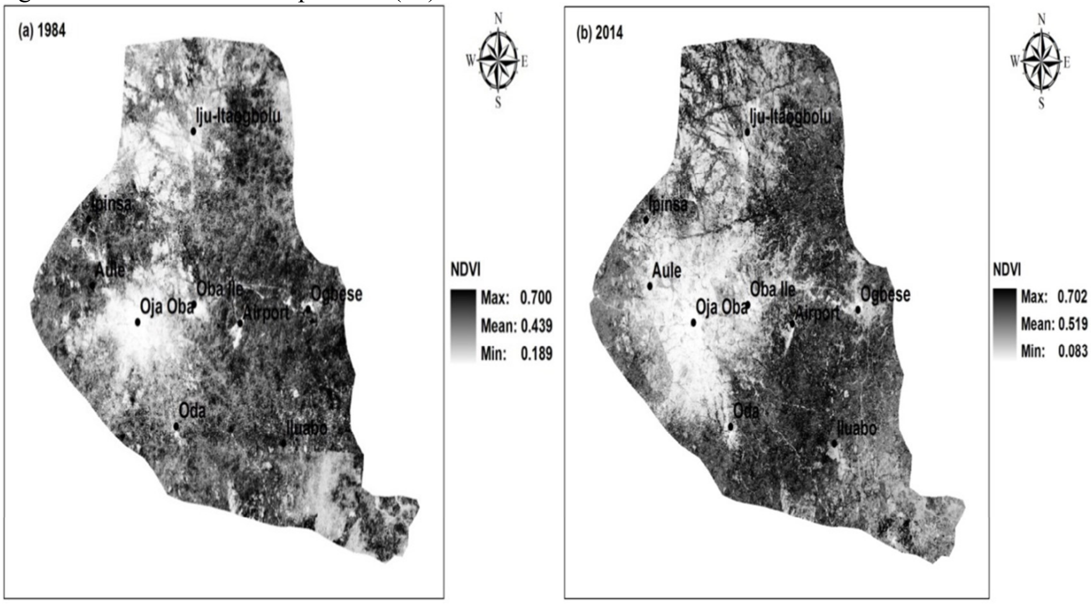

Figure 7: Normalized Difference Vegetation Index (NDVI) (a) 11th December, 1984 and (b) 14th December, 2014 in Akure.

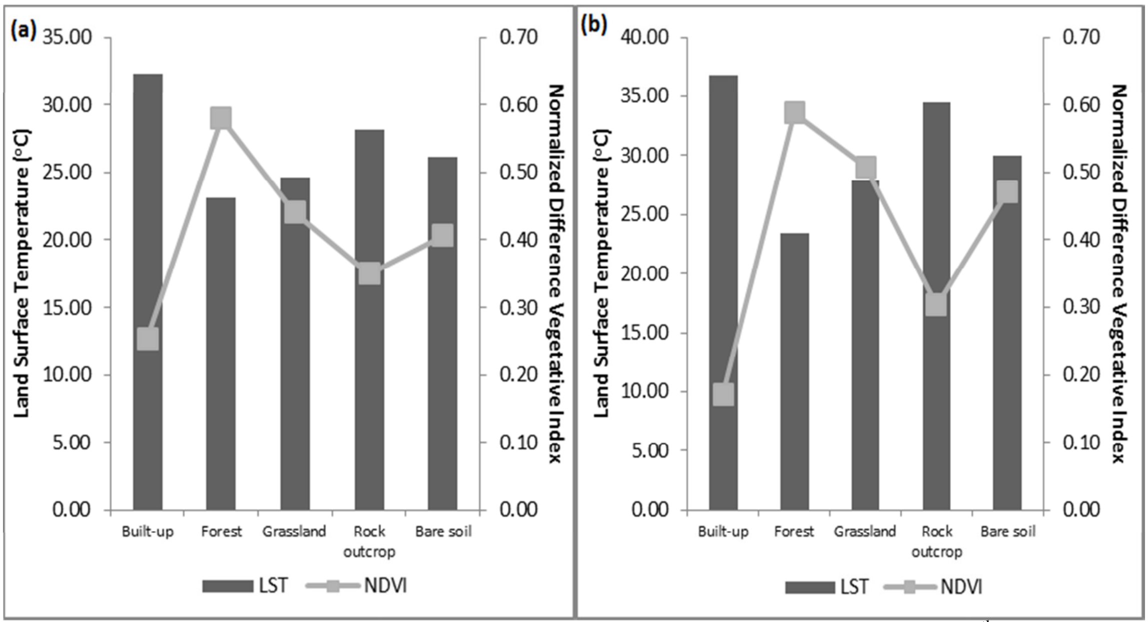

Figure 8: Distribution of Land Surface Temperature and NDVI over land use/cover for (a) 11th December, 1984 and (b) 14th December, 2014 in Akure

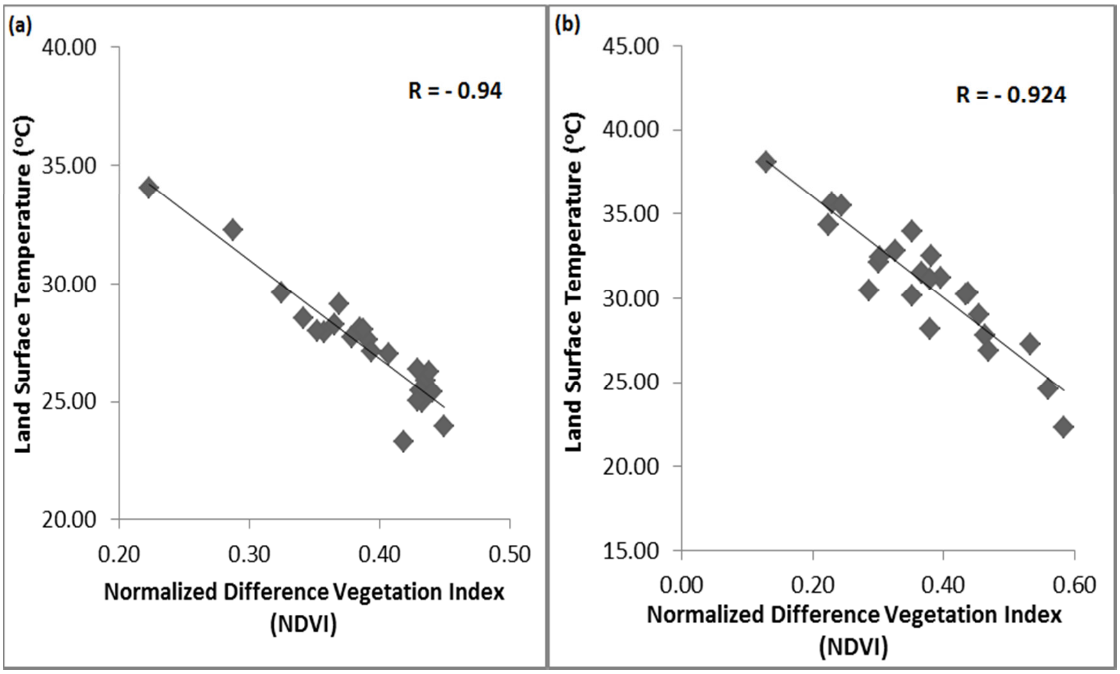

Figure 9: Scatter plots of LST and NDVI for (a) 11th December, 1984 and (b) 14th December, 2014 in Akure

Table 1: Dataset used for the study

DATA	Path	Row	Source	Date acquired	Resolution (m)
LandSat5 TM	190	55	Earth explorer	11th December, 1984	30 120 (30)
LandSat8 OLI/TIRS	190	55	Earth explorer	14th December, 2014	30 100 (30)

Table 2: LandSat calibration constants

Satellite	K_1	K_2
LandSat5 TM Band 6	607.76	1260.56
LandSat8 OLS/TIRS Band 10	774.89	1321.08

Table 3: Change Detection of Land Use/Cover

Land Cover Type	**11th December, 1984 - 14th December, 2014 (30 years)**				
	Change in area (Hectares)	**Change Extent (C_e)**	**Percentage change (%)**	**Mean area change (Hectares/year)**	**Mean percentage change (%/year)**
Built-up	9709.62	0.78	356.15	323.65	11.87
Forest	-7347.2	-0.20	-16.66	-244.91	-0.56
Grassland	683	0.03	2.83	22.77	0.09
Rock outcrop	-7849.4	-0.43	-30.11	-261.65	-1.00
Bare soil	4804.11	0.84	508.52	160.14	16.95