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http://dx.doi.org/10.4314/fje.v7i1.2

DETERMINATION OF LAND SURFACE TEMPERATURE (LST) AND POTENTIAL URBAN HEAT ISLAND EFFECT IN PARTS OF LAGOS STATE USING SATELLITE IMAGERIES

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Abstract
Temperature is an important component of the climate. The temperature of a developing city or state is constantly changing. The trend in temperature change in Nigeria is not consistent. Changes in temperature appear to be closely related to concentrations of atmospheric carbon dioxide. The degree of concentration depends on human interventions and the amount of sunlight reaching the earth's surface. Lagos State particularly in recent time has experienced decrease in vegetation and water pervious surfaces, which reduces surface temperature through evapotranspiration. This is as a result of rapid urbanization arising from inundating rural-urban migration. One of the implications is that anthropogenic heat is released to the environment due to energy consumption and increased impervious surface coverage thereby increasing the surface and atmospheric temperatures. LandSat Satellite imageries have been used to estimate Land Surface Temperature (LST) and urban thermal conditions. The mean LST result shows that, there is a significant increase in the temperature values from 1984 to 2002 (28.40^{0}C-28.86^{0}C). However, in 2006 the temperature decreases significantly to 28.37^{0}C below 2002 temperatures in all LGAs. This variation could be attributed to the economic crisis/power outage in Nigeria which left manufacturing companies out of production/manufacturing between 2002 and 2006. Findings from this study reveals that there is a relationship between the surface temperature and the various Land Cover types. It shows a broad classification of the Land Cover types into Water bodies, Vegetation and Built-up areas respectively. With the spatial resolution and temporal coverage of two Landsat data of the environment, the derivation of the temperature information was achieved.
KEYWORDS: *Land Surface Temperature, Landuse/Landcover, Heat Island, Lagos State, Spectral Radiance, Satellite Imageries*

Introduction

Satellite images have many applications in meteorology, agriculture, geology, forestry, biodiversity conservation, regional planning, education, intelligence, warfare and temperature determination to mention a few. Images can be in visible colors and in other spectra. There are also elevation maps, usually made by radar imaging. Interpretation and analysis of satellite imagery are conducted using software packages like ERDAS Imagine or ENVI (Environment for Visualizing Imageries). Satellite imagery is also used in seismology and oceanography in deducing changes to land formation, water depth and sea bed, by color caused by earthquakes, volcanoes, and tsunamis (Lovholt et al., 2006).

In recent time, researches have explored satellite data in land surface temperature derivation. David (2008) used Landsat TM data to estimate temperatures from a fire at the Chernobyl nuclear power plant. His result detected shortwave length infrared thermal radiance which was interpreted to come from sources at around 1130-1430 K. A new range of distribution of temperatures of the hottest visible material was suggested. A comparative study of Land Surface Temperature (LST) over parts of the

Singhbhum Shear Zone in India was undertaken using various emissivity and temperature retrieval algorithms applied on visible and near infrared (VNIR) and thermal infrared (TIR) bands of high resolution Landsat-7 ETM+ imagery. Minimum LST observed over dense forest was about 26 °C and maximum LST observed over rock body about 38 °C. The estimated LST showed that rock bodies, bare soils and built-up areas exhibit higher surface temperatures, while water bodies, agricultural croplands and dense vegetations have lower surface temperatures during the daytime (Srivastava et. al., 2009). Strong correlation was found between LST and spectral radiance of Band 6 of Landsat-7 ETM+. Jiansheng and Wang (2009) modelled surface temperature and brightness temperature in southeast New England by adding surface emissivity derived from the conventional image classification with solar zenith angle. Mustard *et al*. (1999) quantified thermal effluent impact using satellite data. The findings of that study reveals that Mount Hope Bay had anomalously high temperatures throughout the year in the upper estuary and was on average $0{\cdot}8^0$C warmer than the rest of the upper estuary which was implicated in a large decline in fish population in the environment. The total area affected is 36 km^2. Javed *et al*. (2008) estimated land surface temperature over Delhi using Landsat-7 ETM+ and observed a strong correlation between surface temperature with Normalized Difference Vegetation Index (NDVI) over different LU/LC classes. Sobrino *et al.,* (2004) used three methods to retrieve LST from thermal infrared data supplied by band 6 of the Thematic Mapper (TM) (sensor on board the Landsat5 satellite). The first was the estimation of the land surface temperature from the radioactive transfer equation using in-situ radio sounding data. The other two were the mono-window algorithm developed by Qin *et al* (2001). Thermal remote sensing methodology was explored in studies carried out by Voogt and Oke (2003), Gallo *et al*. (1993), Carson *et al*. (1994), Balling and Brazell (1988). Further studies have been conducted in converting Landsat TM and ETM+ thermal bands to temperature.

Justification for the Study

Lagos is regarded as one of the fastest growing urban agglomerations in the world (Millington *et al.,* 2006). The temperature of Lagos State is changing and there is no detailed and original work on LST using Satellite imageries in the area. The temperature change has strong impact on the environment, economy, agriculture, hydrology, and bio-geo-chemical. This study is necessary to estimate LST and to gain knowledge of temperature variations across the State. Urban Sprawl in the city has lead to replacement of vegetal cover by residential buildings, industries and impervious surfaces. All these and climate change scenarios are believed to have impact on temperature of Lagos State. A study of this nature, will serve for further research, planning and environmental sustainability.

The Study Area

The study area is Lagos State and is situated in the southwest of Nigeria; this elongated state spans the Guinea coast of the Atlantic Ocean for over 180km, from the Republic of Benin on the west to its boundary with Ogun state in the east. It extends approximately from latitude 6°2'North to 6°4'North, and from longitude 2°45'East to 4°20'East. The administrative boundary of Lagos State is shown in Figure 1. Lagos has a total coverage area of 3,577km^2 of which about 787sq. km or 22 percent is water. Lagos

State is ranking as the second most populous city in Africa. UN (2007) reported that the city has a population of 9.5 million.

Figure 1: Administrative boundary of Lagos State

Materials and Methods

Materials:

A subset of Landsat TM acquired on December 18, 1984 and December 27, 2002; and a subset of Landsat ETM of December 28, 2006 all with a satellite pass of path 191 and row 55 that covers some parts of Lagos State were used in this study. Figure 2 is a Landsat data of the environment showing study area boundary. Both Landsat TM and ETM have 30m spatial resolution at the visible and near infrared spectral region(10.4-12.5µm). However, at the thermal infrared spectral region, they differ with TM having 120m and ETM having 60m spatial resolution respectively. Landsat ETM has enhancements with two bands at the thermal infrared region (Band 6_1&6_2). These bands are in two gain states, one with a high and the other with a low gain both having 60m spatial resolution. The imageries were acquired through the USGS Earth Resource Observation Systems Data Centre, which has corrected the radiometric and geometrical distortions of the images to a quality level of 1G before delivery. Three software packages were used to classify and to complete the processing and analysis namely: ENVI 4.8, IDL 8.0 and ARCGIS 9.3.

Figure 2: LandSat ETM showing the boundary of Lagos State

Methods

Several processing steps were carried out in order to classify the LandCover and determine the surface temperature on the imageries. The ENVI software was used to classify the LandCover, IDL was used to process the surface temperature from the image and then classified in ENVI, and ARCGIS 9.3 was used to analyze the data and map creation. In the Land Cover classification, a band sequence of 5,4,3 was used to produce a composite multi-spectral imagery which was used to classify the imagery. An unsupervised classification of the imagery using the K-means method was carried out for three classes. The classes are Built-up, Vegetation and Water bodies.

For surface temperature determination, the thermal bands of the imageries were used for the analysis. Weng *et al*. (2004) described steps to be followed in determining surface temperature. The first step is to process the data by converting the DN(Digital Numbers) to radiance. The radiance is calculated using the equation:

$$CV_R = G(CV_{DN}) + B \qquad (1)$$

where:
CV_R is the cell value as radiance
CV_{DN} is the cell value digital number
G is the gain
B is the bias (or offset)
The next step is to convert the spectral radiance to satellite brightness temperature (i.e., blackbody temperature, TB) under the assumption of uniform emissivity (Landsat Project Science Office, 2002). The conversion formula is:

$$TB = \frac{K_2}{\ln\left(\frac{K_1 * \varepsilon}{CV_R} + 1\right)} \qquad (2)$$

where:
T_B is in degrees Kelvin; CV_R is the cell value as radiance; e is emissivity (typically 0.95)
K_1 = 607.76 for Landsat TM and 666.09 for Landsat ETM; K_2 = 1260.56 for Landsat TM and 1282.71 for Landsat ETM
Finally, the conversion of brightness temperature (T_B) to Land Surface Temperature is performed with Artis and Carnahan, (1982) models. The equation is given thus:

$$S_t = \frac{T_B}{1 + \left(\lambda \times {T_B}/{\rho}\right) \ln \varepsilon} \qquad (3)$$

λ is wavelength of emitted radiance (λ = 11.5μm) (Markham & Barker, 1985)
ρ = h*c/σ ($1.438*10^{-2}$ mK),
σ = Boltzman constant ($1.38* 10^{-23}$ J/K),
h = Planck's constant ($6.626*10^{-34}$ Js), and
c = velocity of light ($3.0*10^{8}$ m/s)
ε = 0.95

These equations were programmed in the script in the IDL software. Radiance values were extracted from the thermal band of the imagery and keyed into the program thus generating the temperature values in degrees Celsius. A table was created showing the radiance value with their equivalent temperature value. Thus, for any radiance value generated the temperature value can be automatically derived. This method assumes that all surfaces have an emissivity of 0.95. A more complete analysis could be done if different emissivities are used for different surfaces.

Temperature features were extracted across different local government areas. Pixel locator embedded in ENVI software was used to generate points (X,Y coordinates) for selected locations in the study area.

Table 1: Radiance value (pixel number) with the equivalent temperature value

Results and Discussion

Pixel No.	Temp. (°C)	Pixel No.	Temp. (°C)	Pixel No.	Temp. (°C)	Pixel No.	Temp. (°C)	Pixel No.	Temp. (°C)
120	19.3522	121	19.8217	122	20.2894	123	20.7553	124	21.2194
125	21.6818	126	22.1425	127	22.6015	128	23.0587	129	23.5143
130	23.9683	131	24.4206	132	24.8713	133	25.3204	134	25.768
135	26.214	136	26.6584	137	27.1013	138	27.5427	139	27.9826
140	28.421	141	28.858	142	29.2935	143	29.7275	144	30.1602
145	30.5915	146	31.0214	147	31.4498	148	31.8769	149	32.3027
150	32.7272	151	33.1503	152	33.5721	153	33.9927	154	34.4119
155	34.8298	156	35.2466	157	35.662	158	36.0763	159	36.4893
160	36.9011	161	37.3117	162	37.7211	163	38.1293	164	38.5364
165	38.9423	166	39.347	167	39.7506	168	40.1531	169	40.5546
170	40.9548	171	41.354	172	41.7521	173	42.1492	174	42.5451
175	42.94	176	43.3339	177	43.7267	178	44.1184	179	44.5092
180	44.899								

This study has derived temperature and land cover information from LandSat data. From the Maps (Figures 3-5) generated, it is observed that there is a relationship between the surface temperature and the various LandCover types. It shows a broad classification of the LandCover types into Waterbodies, Vegetation and Built-up areas respectively. The built-up areas have the highest temperature range of values because of population growth, human activities like industrialization, deforestation, burning of natural gas, coal and oil which increase the level of CO_2 and CO.

These gases are constituents of the green house gases that have been increased and subsequently more infra red radiation trapped and held which gradually increases the temperature of the earth's surface and the air in the lower atmosphere and causes global warming. It is also observed that the wetlands and water body share the same range of temperature which perhaps could be due largely to the fact that wetlands play an important role in the regulation of global climate by sequestering and releasing significant amounts of carbon.

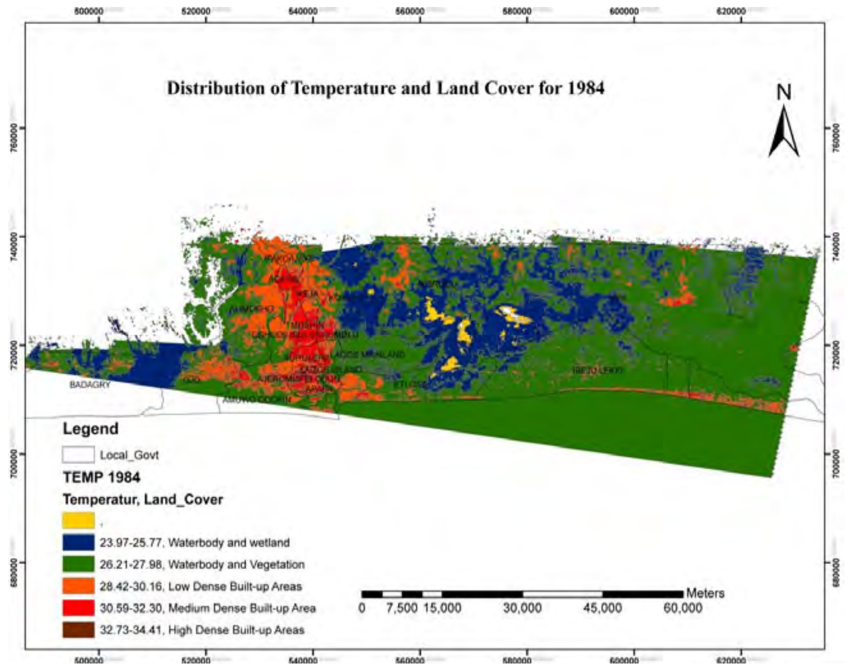

Figure 3: The relationship between the temperature and Land Cover over the Lagos for 1984

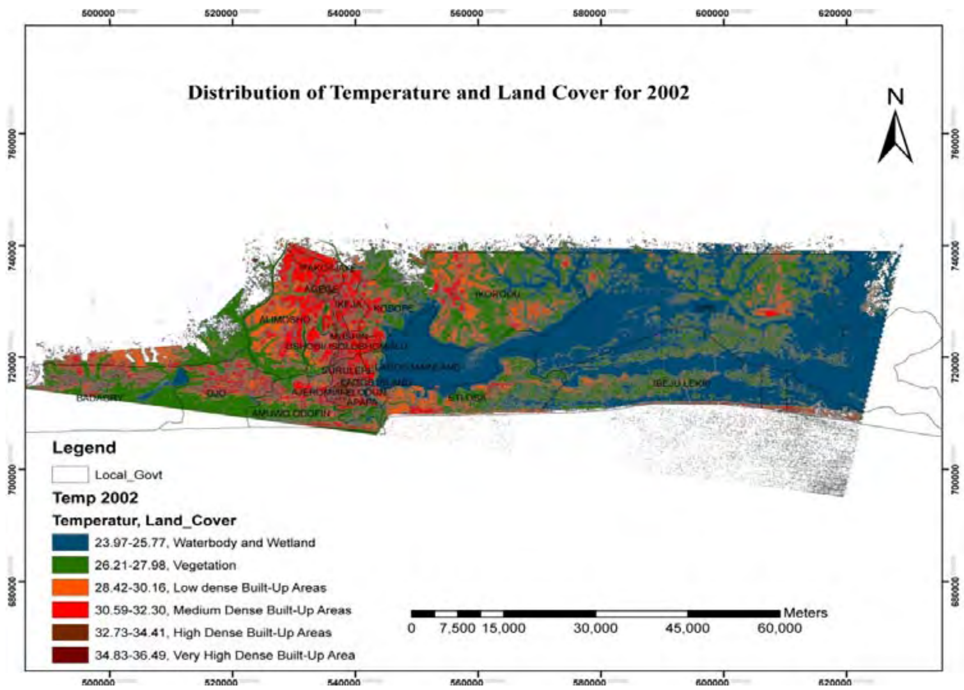

Figure 4: The relationship between the temperature and Land Cover over the Lagos for 2002

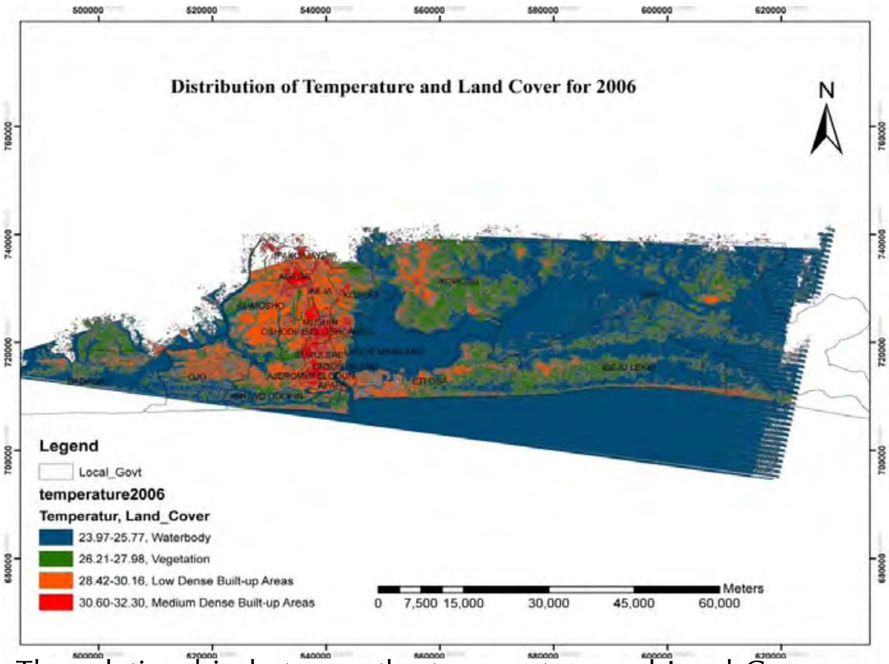

Figure 5: The relationship between the temperature and Land Cover over the Lagos for 2006

Table 2: Temperature values of selected features across different local government areas (LGAs) of Lagos for 1984, 2002 and 2006.

COORDINATES	**TEMPERATURE VALUE (◦c)**			**FEATURE TYPE**	**LOCAL GOVT AREA**
	1984	2002	2006		
538445.1390,713896.1250	32.3027	32.2727	30.5915	BUILT-UP	Ajeromi/Ifelodun
536753.6050,712529.3650	32.3027	33.1503	31.0214	BUILT-UP	"
538025.6390.712272.2520	32.3027	33.1503	31.0214	BUILT-UP	"
539155.3740,714163.6230	31.877	31.45	32.727	VEGETATION	"
536100.2150,713605.7240	27.101	27.543	29.294	VEGETATION	"
537335.5620,715266.1370	29.294	29.728	31.45	VEGETATION	
537487.3920,711578.0160	28.421	27.5427	26.214	WATERBODY	
538628.8800,711468.5580	27.5427	27.1013	25.768	WATERBODY	
538581.9690,712281.6730	29.2935	29.7275	28.421	WATERBODY	
542772.0400,721668.8620	31.4498	31.8769	30.5915	BUILT-UP	Shomolu
544382.1630,721628.2710	26.214	25.768	24.871	WATER BODY	"
540920.3690,720988.1010	31.0214	30.5915	30.1602	BUILT-UP	"
543520.8770,723378.530	31.0214	31.8769	31.4498	BUILT-UP	"
541296.4810,723186.0910	27.543	27.101	29.294	VEGETATION	"
540947.6000,724378.7910	27.1013	28.421	27.5427	VEGETATION	
541519.4390,722989.5390	27.1013	28.858	28.421	VEGETATION	
544378.6360,722186.2400	26.214	26.6584	25.768	WATERBODY	
544923.2450,721382.9420	26.214	24.8713	25.768	WATERBODY	
543294.2260,730031.1140	30.1602	31.8769	30.1602	BUILT-UP	Kosofe
547198.2220,727989.3700	24.421	25.768	25.768	VEGETATION	Kosofe
541478.9450,733056.5830	30.5915	31.8769	31.0214	BUILT-UP	"
544461.1930,723591.1860	30.5915	31.8769	31.0214	BUILT-UP	"
549405.1340,727739.7190	24.871	25.768	24.421	WATER BODY	"

550944.3420,728215.8320	24.8713	24.8713	25.3204	WATERBODY	
545282.3920,721948.7880	25.768	24.8713	25.3204	WATERBODY	
542473.0270,732451.4900	25.768	25.768	25.768	VEGETATION	
547400.2210,726011.5620	25.768	26.6584	25.768	VEGETATION	
535534.5440,728728.3360	28.858	27.101	27.101	VEGETATION	IKEJA
540257.1800,734216.6040	29.7275	31.4498	30.5915	BUILT-UP	"
537513.4180,729388.9730	31.0214	31.8769	30.1602	BUILT-UP	"
539805.6750,725117.0410	31.4498	30.5915	32.7272	BUILT-UP	"
540917.0720,727513.4910	26.6584	25.768	25.768	VEGETATION	
538867.9330,735432.1940	26.214	27.5427	27.5427	VEGETATION	
534700.1950,733487.2500	31.0214	33.5721	30.5915	BUILT-UP	Agege
536297.8280,731577.0360	31.4498	33.5721	30.5915	BUILT-UP	"
534236.3610,734630.0770	30.16	28.421	31.877	VEGETATION	"
534839.1200,730361.4460	31.4498	32.7272	31.0214	BUILT-UP	"
533332.9930,732649.4200	27.5427	30.1602	28.858	VEGETATION	"
534126.7340,734566.6120	29.2935	31.0214	30.1602	VEGETATION	"
555871.0210,731345.7520	31.4498	33.1503	31.4498	BUILT-UP	Ikorodu
574149.3840,736897,5920	30.1602	31.4498	30.1602	BUILT-UP	"
551492.2140,727420.1660	24.871	25.32	24.871	WATER BODY	"
568308.6810,732892.5090	25.32	25.32	24.871	VEGETATION	"
COORDINATES	**TEMPERATURE VALUE (◦c)**			**FEATURE TYPE**	**LOCAL GOVT AREA**
566419.5150,725793.9130	27.9826	31.8769	31.0214	BUILT-UP	"
550319.1810,730534.3300	24.8713	26.214	25.3204	VEGETATION	"
568554.8380,732840.4780	25.3204	25.3204	25.3204	VEGETATION	"
560161.4590,722521.7010	25.768	25.768	25.768	WATERBODY	"
551173.3100,729594.7880	23.5143	24.8713	25.3204	WATERBODY	"
543444.4170,713519.6090	31.4498	31.4498	30.1602	BUILT-UP	Lagos Island
544282.3030,714418.3610	26.214	25.768	25.768	WATER BODY	"
544812.3880,712611.3660	30.1602	29.7275	28.858	BUILT-UP	"
543108.0300,714551.1950	31.4498	30.1602	30.1602	BUILT-UP	"
541679.0790,713900.4630	26.214	25.3204	25.3204	WATERBODY	"
543335.4370,712439.7930	26.6584	25.768	25.768	WATERBODY	"
MEAN	**28.39589**	**28.85765**	**28.37168**		

Table 3: Average values of each feature for the 3 periods in different LGAs

Location	**Built- Up Areas**			**Vegetal Cover**			**Water body**		
	1984	**2002**	**2006**	**1984**	**2002**	**2006**	**1984**	**2002**	**2006**
Ajeromi	32.3	32.9	30.9	29.4	29.6	31.2	29.4	28.1	26.8
Somolu	31.2	31.5	30.7	27.2	28.1	28.4	26.2	25.8	25.5
Ikeja	30.5	31.9	30.7	27.2	26.8	26.8	***	***	***
Kosofe	30.7	31.3	31.2	25.3	26.1	25.8	25.2	25.2	25.0
Agege	31.3	33.3	30.7	29.0	29.9	30.3	***	***	***
Ikorodu	29.9	32.2	30.9	25.2	25.6	25.2	24.7	25.3	25.3
Lagos Island	31.0	30.5	29.7	***	***	***	26.4	25.6	25.6

(*** imply almost no water body and vegetal cover in the location)

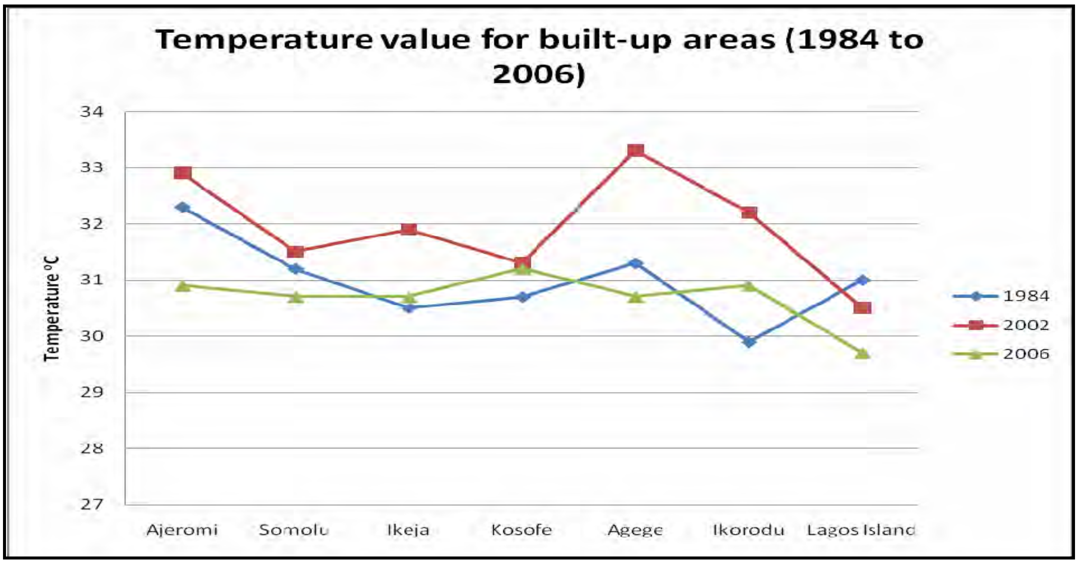

Figure 6: Temperature Variation for Built-Up Areas 1984, 2002 and 2006

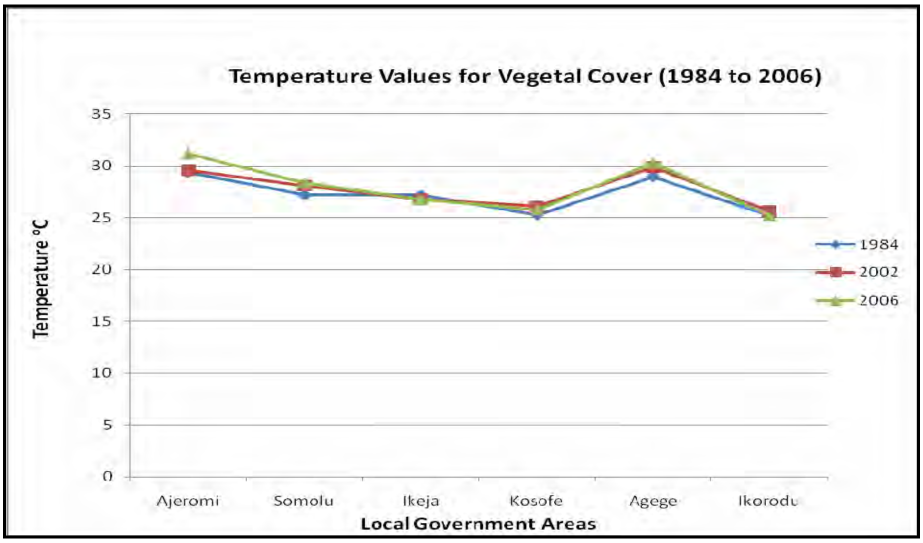

Figure 7: Temperature Variation for Vegetal Cover 1984, 2002 and 2006

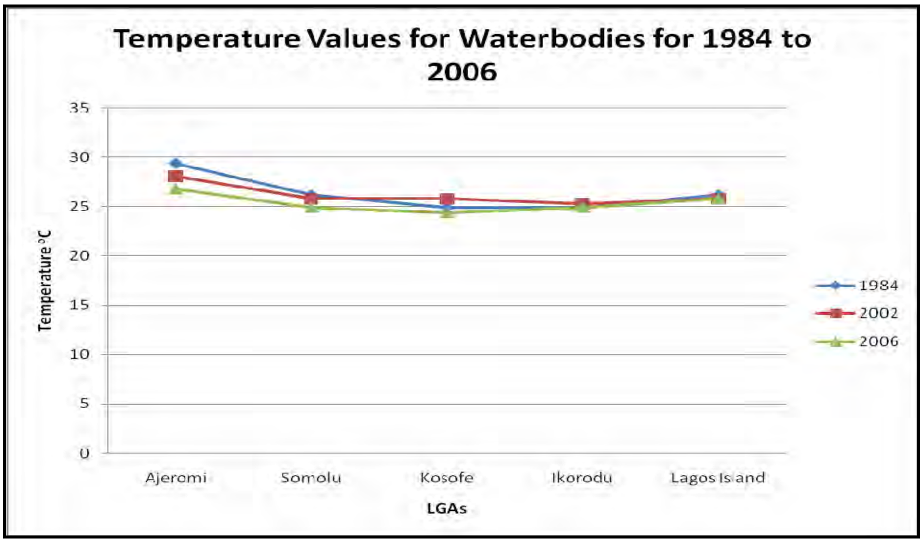

Figure 8: Temperature Variation for Water bodies 1984, 2002 and 2006

Temperature values of selected features across different local government areas (LGAs) of Lagos State for 1984, 2002 and 2006 was determined (Table 2). On the average (Table 3 & 4), from 1984 to 2002, there is a significant increase in the temperature values. However, in 2006 the temperature decreases significantly below 2002 temperatures in all LGAs. This variation could be attributed to the economic crisis/power outage in Nigeria which left manufacturing companies closed down between 2002 and 2006. This shows that there is relationship between number of industries and industrial enhanced temperature. Figure 7 shows distribution of built up areas and Industrial Locations within Lagos. The industrial locations are spread across the built up areas within Lagos , this consequently explains the reason for the high temperature values of the built up areas because of the increase in carbon dioxide content being released into the environment which is a cause for the increase in temperature. Areas like Agege, Mushin, Ajeromi Ifelodun and parts of Ifako Ijaiye Local government areas with high temperature values clearly depict population enhanced temperature while Badagry Local Government with very high temperature value is as a result of industries enhanced temperature (figures 10-12).

Clearly, Lagos is a mega city with concentration of industries. The distribution of industries built up areas will definitely have impact on the LST of the State. Figure 9 reveals that low dense built up areas has the lowest temperature values (28^0C-30^0C) against the very high dense built up areas with temperature range of 34^0C to 36^0C. Relationship between area covered and temperature is displayed in figure 13.

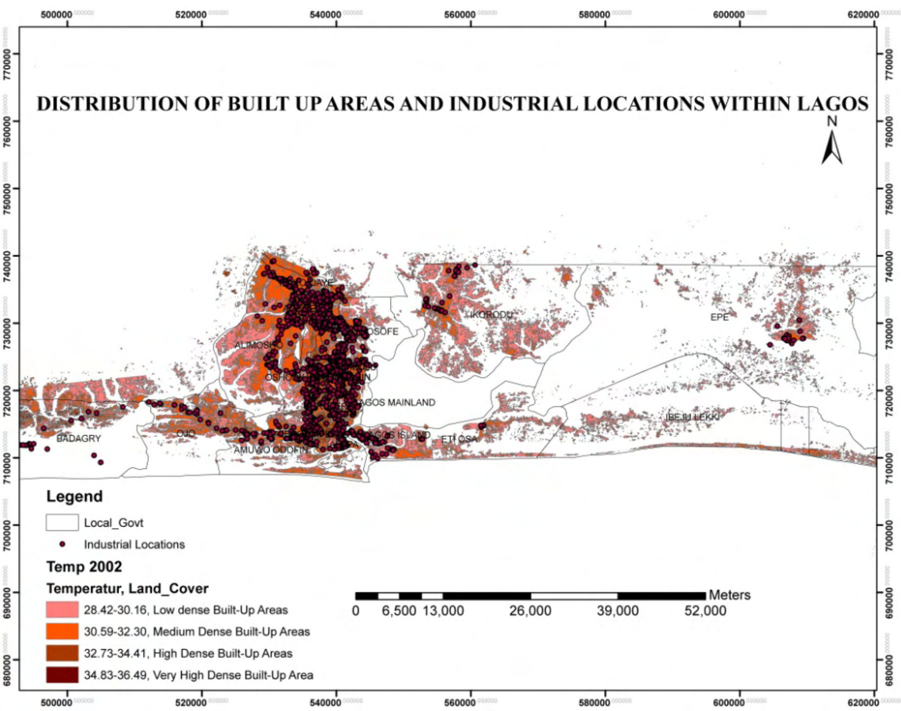

Figure 9: Distribution of built up areas and Industrial Locations within Lagos

Table 4: Differences in Temperature between the 3 years in Numerical Term

Land Cover	**LST (^0C)**			**Change (^0C)**	
	1984	**2002**	**2006**	('84 - '02)	('02 - '06)
Built-Up	31.0	31.9	30.8	0.9	-1.1
Vegetal Cover	27.2	27.7	28.0	0.5	0.3
Water bodies	26.4	26.0	25.6	-0.4	-0.4
Mean of Mean	**28.2**	**28.5**	**28.1**	**0.3**	**-0.4**

(**-** imply decrease in temperature value)

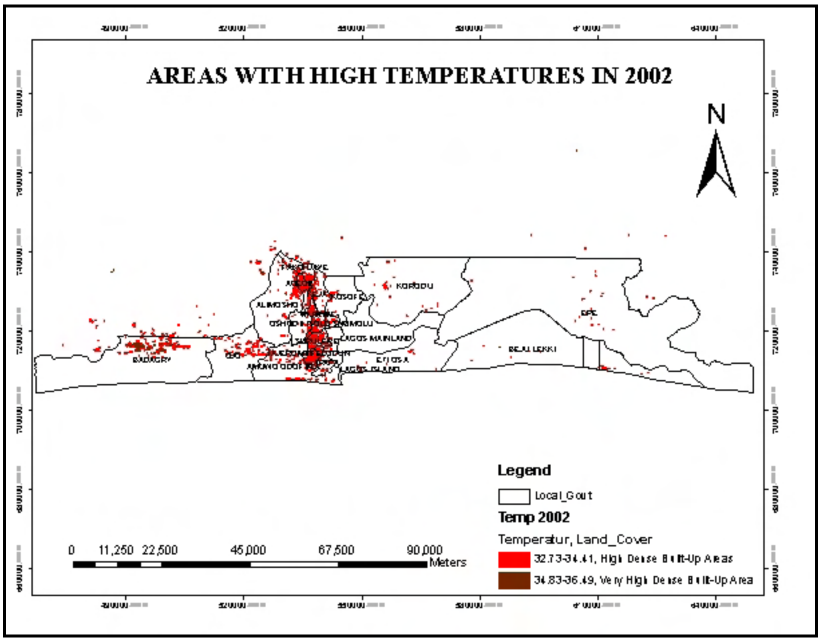

Figure 10: Agege, Ajeromi- Ifelodun, Ikeja, and Mushin LGA with High temperature values in 2002.

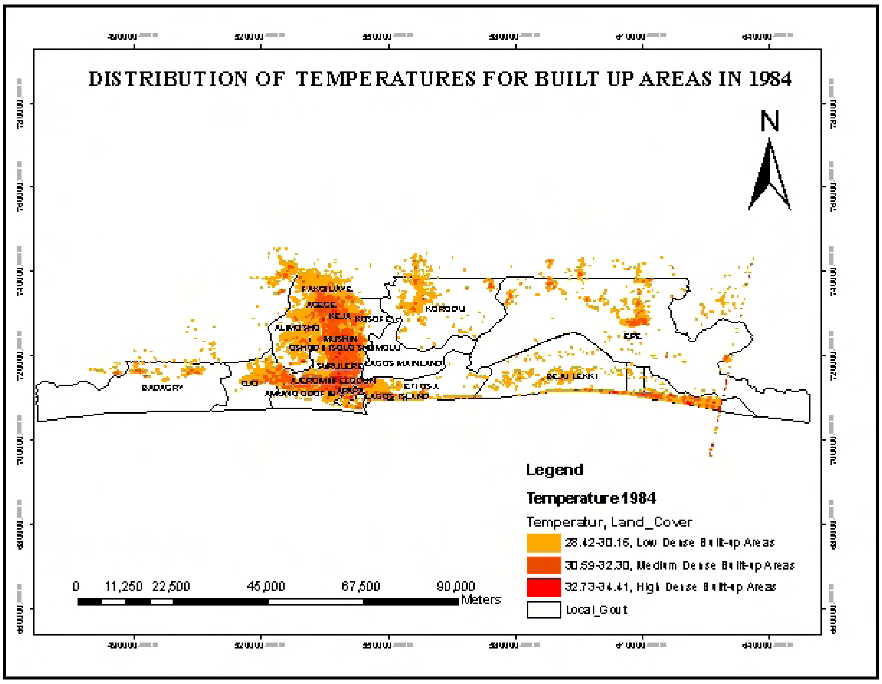

Figure 11: The spread of the temperature range values for built-up areas across Lagos State in 1984

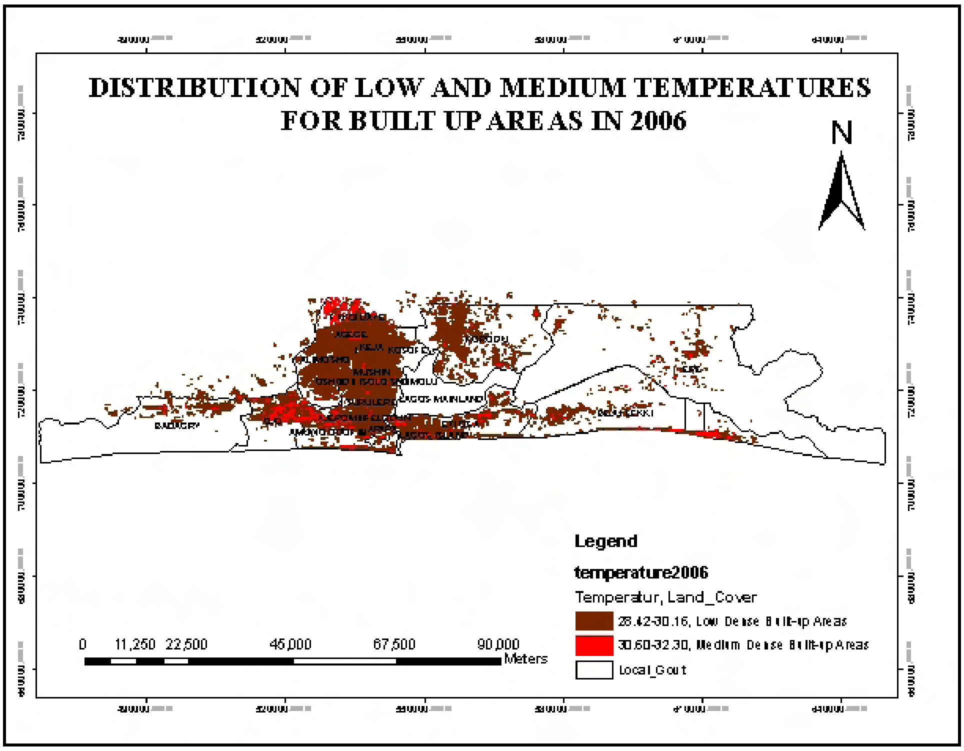

Figure 12: Distribution of Low and Medium temperature values for built-up areas across Lagos State in 2006.

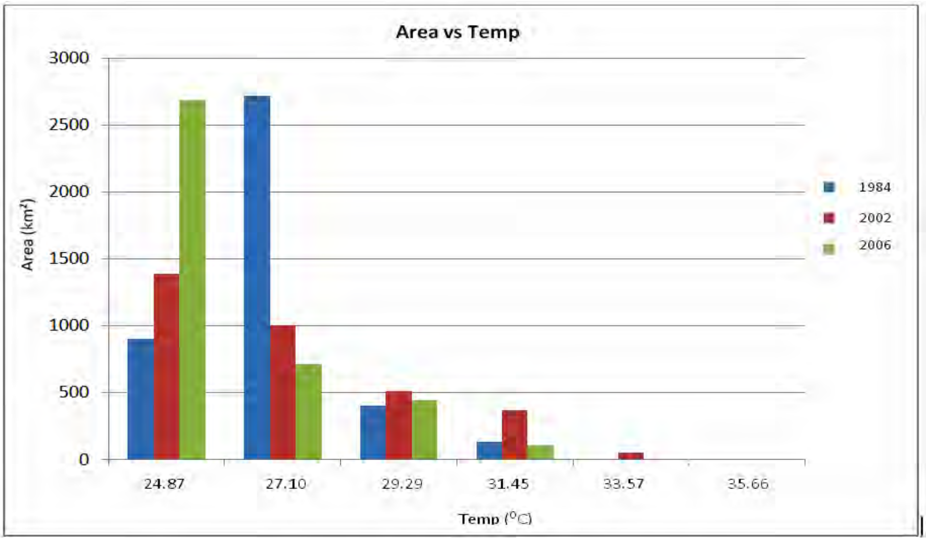

Figure 13: Relationship between the area covered and the temperature

Conclusion

Landsat imageries have been used to determine and extract temperature information of locations within the imagery. A comparative analysis has also been carried out for different years to show variations in temperature and its subsequent effect on the environment. The study has shown that:

- Temperature values can be extracted for any location from the satellite imagery
- Population increase and Industrialization in the built-up areas are major factors that increase the temperature of any area.
- Environmental factors like cloud cover, wind, amount of rainfall, wetland have a way of causing variation in the temperature values.
- Temperature values extracted can be used to carry out LandCover classification
- The mean LST for the 3 years considered are 28.40^0C, 28.86^0C and 28.37^0C for 1984, 2002 and 2006 respectively (Table 2).
- While the LST of water bodies decreased with a constant value of 0.4^0C (1984-2002) and from (2002 - 2006), the mean LST of vegetal cover was seen to appreciate by 0.5^0C and 0.3^0C (1984-2002) and (2002 - 2006) respectively.

Recommendation

There is a significant increase in the temperature values from 1984 to 2002. However, in 2006 the temperature decreases significantly below 2002 temperatures in all LGAs. This variation could be attributed to the economic crisis/power outage in Nigeria which left manufacturing companies out of production/manufacturing between 2002 and 2006. This shows that there is relationship between number of industries, carbon production and industrial enhanced temperature. A further study on modelling this relationship mathematically is therefore recommended.

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