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AN ASSESSMENT OF URBAN HEAT ISLAND OF LOKOJA TOWN AND SURROUNDINGS USING LANDSAT ETM DATA.

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ABSTRACT

The urban centre and its suburban environment are largely influenced by changes driven by people as a result of urbanization and other anthropogenic activities. Urbanization impacts on air and water quality, local climate and biodiversity. This study assesses the Urban Heat Island (UHI) of Lokoja town and surroundings from LandSat ETM satellite imagery of 2001 using remote sensing techniques. Band 3, 4 and 6 of the imagery were use in the estimation of NDVI, land surface emissivity and surface temperature. The results show that urban heat island in Lokoja town is significant, with average Land surface temperature values range from 301.13K to 336.14K., and maximum urban/suburban temperature difference reaching 10.9^{o}C. This suggests that vegetation is the principal determinant controlling the spatial distribution of land surface heat flux. This approach was found to be more effective in assessing urban heat island than using the conventional "in situ" temperature estimation.

INTRODUCTION

The rapid growth in human population and economic output per capita have been an unprecedented features of this industrial era (Cohen, 1995 and Sieferie, 2001), impacting great consequences on the global environment over the past century (Rosa et al, 2004). Urbanisation had led to significant effects and alteration of local climate, and in particular creates a significant heat island effect (Landsberg, 1981, Kalnay and Cai, 2003 and Zhou et al, 2004). The urban heat island effect has been the subject of numerous studies in recent decade, because it is associated with the temperatures of central urban location rising with several degrees higher than those of nearby rural areas of similar elevation (Chou, 1995).

The urbanization and human activities have been the main determinants inducing changes in the physical characteristics of the surface. The most significant are the differences in the thermal properties of the radiating surfaces and a decreased rate of evapotranspiration in the urban environment. The thermal properties of built-up land surfaces, soil and impervious surface result in more solar energy being stored and converted to sensible heat, and the removal of shrubs and trees reduces the natural cooling effects of shading and evapotranspiration (Pickett et al, 2001). Urban topography, surface roughness, morphology of buildings and anthropogenic activities contribute by reducing outgoing longwave radiation, hinder sensible heat loss, hinder distribution of heat and generate heat respectively (Oke, 1982, Bonan, 2002 and Ifatimehin, 2007).

All these alter the surface energy balance with a consequent increase in land surface temperature [average ambient temperature in urban systems is generally 2-3 degrees higher than the surrounding nonurban environment (Pickett, 1997)] in the urban environment. This then leads to the increase in sensible heat flux at the expense of latent heat flux, thereby forcing the development of meteorological events such as increased precipitation, which poses threat to the environment and the human population (Zhao and Wang, 2002). It exacerbate urban air pollution alter rainfall pattern in and around urban centres, and change the composition of biodiversity (Nowak *et al,* 2002) However, it also contributes to global warming (Changnon, 1992).

Until recently, the isolated locations and with *in situ* measurements of air temperatures were conducted in the various studies of Urban Heat Island effects (Oguntoyinbo, 1978, Weng, 2001, Streuker, 2002 and Adebayo and Zemba, 2003). This approach has major limiting factors in the quantitative description of the areal extent and in ascertaining the exact distribution of the variation in micro climates in Nigeria (Adebayo and Zemba, 2003). However, remote sensing technology with its earth monitoring sensors has become possible to study the effects of urban heat island remotely on both local and global scales (Gallo *et al,* 1993; Lo *et al,* 1997; Yang et al, 1997; Owen *et al,* 1998; Zhao and Wang, 2002; Streutker, 2002; and Liu and Zhang, 2003).

The objective of this study is to use this novel approach provided by remote sensing to:

1. determine the surface temperature of the different land use/cover of Lokoja town;
2. determine the surface temperature of Lokoja town and surroundings;
3. examine the urban heat island of Lokoja town and surrounding.

THE STUDY AREA

Lokoja town, the administrative capital of Kogi State lies between 7°45'27.56"-7°51'04.34"N and 6°41'55.64"-6°45'36.58"E within the lower Niger trough. It has an estimated landmass of 63.82 sq. km and with population of 81.673 persons based on 1991 population growth rate of 2.5% (Fig 1).

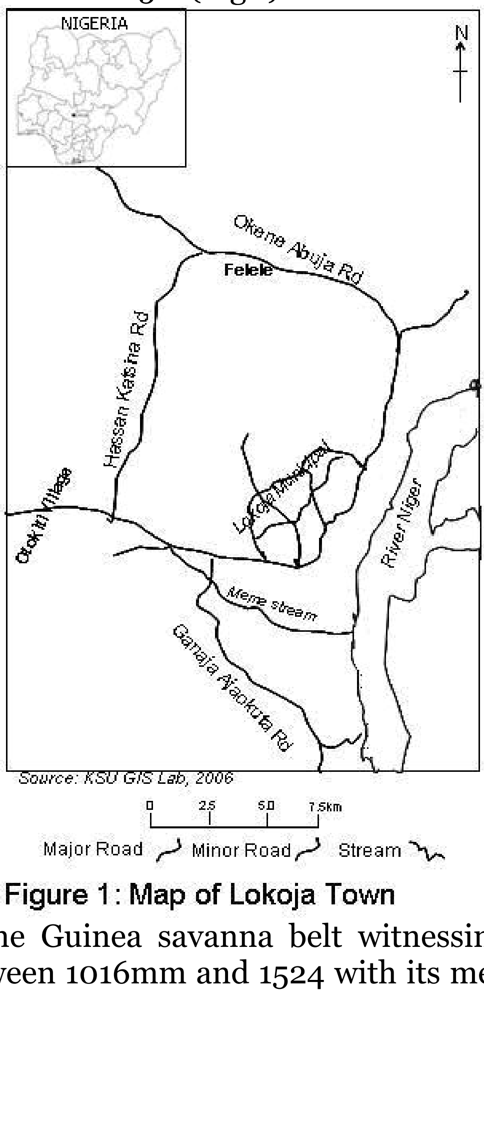

Figure 1: Map of Lokoja Town

It is situated in the Guinea savanna belt witnessing the Aw type of climate. Annual Rainfall is between 1016mm and 1524 with its mean annual temperature not falling below $27^{o}7$ C. The town is sandwiched to the West and East by the Patti ridge and River Niger respectively.

MATERIALS AND METHODS OF THE STUDY

Data Used

The digital data used in this study were collected by LandSat ETM on 17th November 2001 with 30m spatial resolution. The spectral characteristics are shown in Table 1.

Table 1: LandSat ETM 2001 spectral consideration

BAND	WAVELENGTH (m)	SPECTRAL LOCATION/REGION		Spatial Resolution (meter)
2	0.52 – 0.60	Green	Visible	30
3.	0.63 – 0.69	Red		
4.	0.76 – 0.90	Near-Infra-Red		
6	10.4 – 12.5	Thermal-Infra-Red		120

Source: Based on the landSat ETM 2001 image characteristics.

Method of land use/cover Classification

With the aid of IDRISI32 software in a computer hardware with the following specifications: Mercury Pro workstation with a Pentium IV 3.2 GHZ processor, RAM 512 MB, 80 gigabytes hard disk capacity and a 21 inch monitor. The band 2,3 and 4 of the acquired Landsat ETM image were enhanced using histogram equalization, rectified to a common UTM coordinate system, and then radiometrically corrected. A supervised classification with a maximum likelihood algorithm was conducted to classify the image using three bands of green (2), red (3) and near-infrared (4) (as indicated in Table 1). Training sample sets were collected based ground truth data gathered during field checks. On completion it was run on mosaic. Ifatimehin (2007) used this same method in his previous work on temperature estimation as shown in Figure 2 and 3.

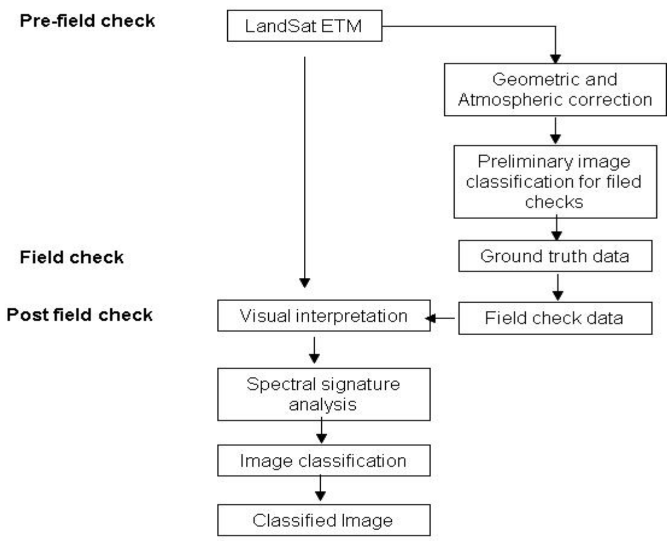

Figure 2: Flowchart for Land use/cover classification

Source: Ifatimehin snd Ufuah (2007)

Method of deriving surface temperature.

The radiometrically corrected LandSat ETM band 3, 4 and the thermal infrared data (band 6) were use to for this purpose. The following methods were adopted:

i. Digital Number (DN) conversion to radiance:

$$L_{\lambda}=\frac{(L_{min} - L_{max}) \times DN}{255}+\text{offset}$$

ii. Conversion from radiance to reflectance (Surface albedo):

$$r_0=\frac{(rp - rp_{min})}{t}$$

Where t is transmisivity = 0.976204 – 0.08308T_o *where* T_o is the near surface temperature. While rp is the broadband reflectance=

$$rp=\frac{\sum ESUN \times rp(\lambda)}{\sum ESUN_{\lambda}}$$

Where ESUN=mean solar exo atmospheric irradiance
rp (λ_1) is the planetary reflectance=

$$rp(\lambda)=\frac{\pi \times L_{\lambda} \times d^2}{\sum ESUN_{\lambda} \times CosQ}$$

L_{λ}=spectral radiance at the sensor apecture
d=earth sun distance
CosQ=solar Zenith angle
t=one way atmospheric transmittance

iii. The NDVI image was computed for 2001 from the band 3 and band 4 reflectance data using the formula below:

$$NDVI=\frac{r4 - r3}{r4 + r3}$$

iv. Emissivity, εo= (1.094 + 0.047 x ln(NDVI))

v. T_a =16.9684 + 0.90967T_o, T_a is the mean atmospheric temperature

vi. Effective satellite temperature T_s:

$$T_s=\frac{K_2}{\ln(K_1/L\lambda)+1}$$

vii. Therefore, the surface temperature (T) can be estimated using this formula

$$T=\frac{1}{C}[\alpha(1-C-D)+(b(1-C-D)+C+D)T_s-DT_a]$$

$$C=t\varepsilon$$

$$D=(1-t)[1+t(1-\varepsilon)$$

Where λ = wavelength of emitted radiance = 11.5μm (Markam and Barker, 1985), $\alpha=hc/k$ (1.438 x 10^{-2}mK), k=Stefan Boltzmann's constant

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($1.38 \times 10^{-23} JK^{-1}$), h=Planck's constant ($6.26 x10^{-34} Js$), and c=velocity of light ($2.998 x10^{8} s^{-1}$), a = -67.345 and 0.4658

Figure 3 shows the flowchart for the computation of surface temperature (T^s)

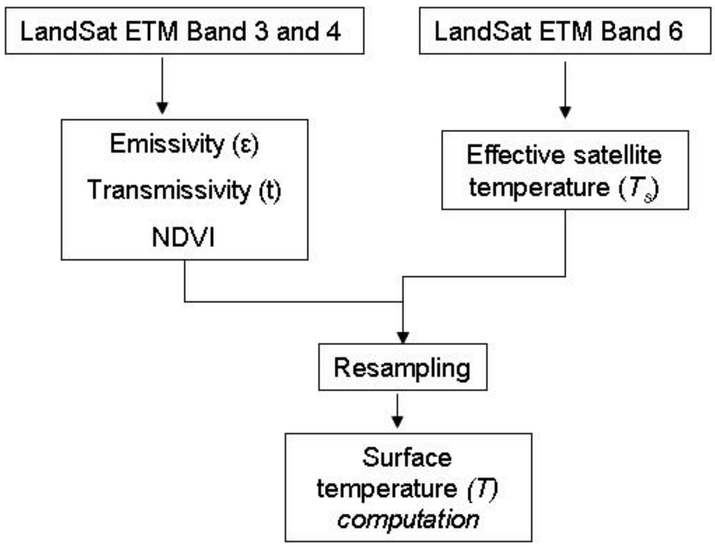

Figure 3: Flowchart for estimating surface temperature

Source: Adopted from Wubet, 2003

RESULTS AND DISCUSSION

The classified LandSat ETM imagery as shown in Figure 4 and Table 2 indicated that cropland area (58.37%) dominated the entire townscape of Lokoja, while the municipal area is about 14%, vacant land (Bare and undeveloped land) 3.81%, vegetation (15.87%) and water bodies (7.81%).

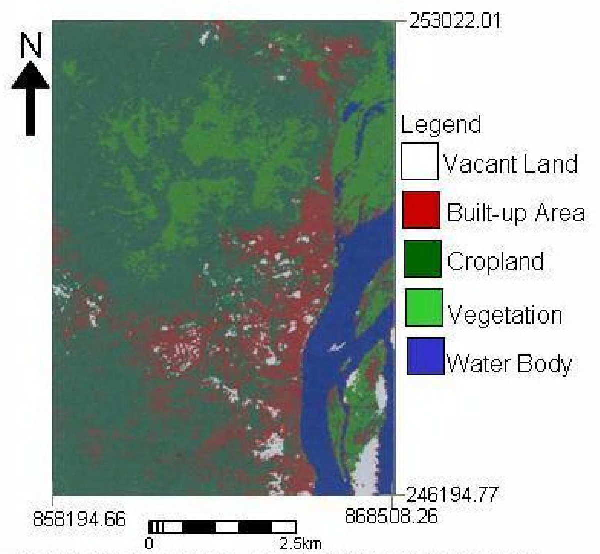

Figure 4: Classified LandSat ETM 2001 Imagery

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Table 2: Lokoja Town under different land use/cover, 2001

Land use/cover	2001	
	Area (sq.km)	%
Vacant Area	2.43	3.81
Built-up Area	9.41	14.75
Cropland Area	37.25	58.37
Vegetation	10.13	15.87
Water body	4.60	7.21

Source: Ifatimehin, 2007.

The Thermal signatures of each land use/cover studied revealed the average values of surface radiant temperature for each of these land use/cover type is shown in Table 3. There was an obvious gradual thermal change as one progressed from the municipal area (336.14K) out into the suburban area (301.23 K) as shown in figure 4. This implies that the built-up area is majorly dominated by impervious surfaces such as metal, concrete and probably stone which are non-evaporating and non-transpiring. And also they exhibit a high potential for absorption and radiation of heat alike with blackbodies, thereby having the highest temperature.

The vacant area has the second highest temperature because of the bare soils surfaces with are barren of vegetation.

Table 3: Landsat ETM 2001 derived emissivity and surface temperature for different land use/cover

Land use/cover	Surface emissivity			Surface temperature (K)		
	Min	Max	Avg	Min	Max	Avg
Vacant Land	0.920	0.982	0.950	314.56	328.69	321.63
Built-up Area	0.923	0.981	0.952	331.82	340.46	336.14
CropLand	0.922	0.980	0.951	301.57	313.55	307.56
Vegetation	0.920	0.99	0.955	291.71	310.74	301.13
Water	0.925	0.98	0.953	294.93	311.18	303.06
		Total Surface temperature				1,569.52
		Average Surface temperature				313.90

Source: Ifatimehin, 2007

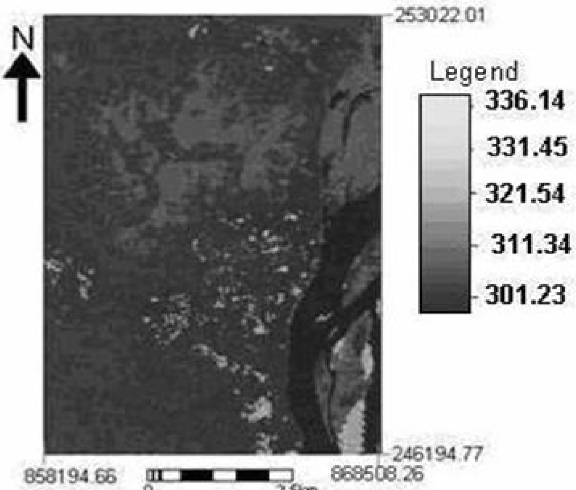

Figure 5: Land surface temperature map using LandSat ETM 2001

Table 2 and figure 5 reveal that thick vegetated areas have the least temperature values and thereby suggest that the higher the biomass a land cover had, the lower the land surface temperature of the particular land cover. The minimum and maximum urban/suburban temperature difference approximately reaches 6.8°C and 9.6°C respectively. The implication here is that with the rapid urban growth witnessed in Lokoja, vegetation and cropland areas would soon starts dwindling (Ifatimehin and Ufuah, 2007) and the heat will continue to build-up in the municipal and the surroundings and decreases as one moves away from the urban-rural fringe into the rural areas.

CONCLUSION

From this study, the urban heat island in Lokoja town was assessed using appropriate methodologies for deriving surface temperature parameters from LandSat ETM data. There was a significant urban heat island effect on the town and thereby showed the role of vegetation as a regulatory cooling feature in the ecosystem. The high difference in the maximum urban/suburban temperature is because atmospheric correction was not carried out on the image after the other two corrections (geometric and radiometric) were done. This was due to the absence of appropriate software packages (6S, MODTRAN and LOWTRAN) for the corrections.

REFERENCES

Adebayo, A.A. and Zemba, A.A. (2003): Analysis of micro climatic variations in Jimeta – Yola, Nigeria, *Global Journal of Social Sciences,* Vol.2(1), Pg. 19 – 88

Bonan, G.B. (2002): *Ecological climatology*; Cambridge Uni. Press, Cambridge.

Changnon, S.A. (1992): Inadvertent weather modification in urban areas: lessons for global climate change. *Bulletin of the American Meteorological Society*, Vol.73, Pp621-627.

Chou, S. (1995): *An introduction to urban climatology*. East China Normal University Press, Pp 1-13

Cohen, J.E. (1995): *How many people can the Earth Support*? W.W. Norton & Co., New York.

Gallo, K.P; McNab, A.L, Karl, T.R; Brown, J.F; Hood, J.J and Tarpley, J.D. (1993): The use of NOAA AVHRR data for assessment of the urban heat-island effect. *International Journal of Remote Sensing*, Vol. 14, Pp2223-2230.

Ifatimehin, O.O. (2007): Estimating Surface temperature of Lokoja Town using Geoinformatic. *International Journal of Ecology and Environmental Dynamics* (In press).

Ifatimehin, O.O. and Ufuah, M.E. (2007): A GIS application on urban expansion and loss of vegetation cover in Lokoja Town, Kogi State; *Zaria Geographers* (in Press).

Kalney, E. and Cai, M. (2003): Impact of urbanization and land-use change on climate. *Nature* Vol.423 Pp528-531

Liu, S and Zhang, W. (2003): A remote sensing study of the urbam thermal effect on Zhangye and its surroundings Oasis area. *Remote Sensing for Land and Resources*, Vol. 58, Pp 17-21

Lo, C.P.; Quattrochi, D.A and Luvall, J.C. (1997): Application of high resolution thermal infrared remote sensing and GIS to assess the urban heat island effect. *International Journal of Remote Sensing*, Vol. 18 (2), Pp. 287-304

Landsberg, H.E. (1981): *The urban Climate*. Academic Press, New York, Pp 6

Markham, B.L and Barker, J.K (1985): Spectral characteristics of the LANDSAT thematic Mapper sensors, *International Journal of remote Sensing*, Vol.6, pg. 697 - 716

Nowak, D.J; Crane, D.E; Stevens, J.C and Ibarra, M. (2002): *Brooklyn's Urban Forest*. Technical Report, US Department of Agriculture and forest service, pp 45

Oguntoyinbo, J.S. (1978): Aspects of urban Micro – Climate: The case of Ibadan, in Sada, P.O. and Oguntoyinbo, J.S. (eds) *Urbanization, Process and Problems in Nigeria,* University Press, Ibadan.

Oke, T.R. (1982): The energetic basis of the urban heat island. *Quartely Journal of the Royal Meteorological Society*, Vol.108, Pp1-24

Owen, T.W.; Carlson, T.N and Gillies, R.R. (1998): An assessment of satellite remotely-sensed land cover parameters in quantitatively describing the climatic effect of urbanization. *International Journal of Remote Sensing*, Vol. 19(9), Pp 1663-1681

Pickett, S.T.A; Cadenasso, M.L; Grove, J.M, Nilon, C.H.; Pouyat, R.V.Zipperer, W.C. and Costanza, R. (2001): Urban ecological systems: linking terrestrial ecological, physical; and socioeconomic components of metropolitan areas. *Annal review of Ecology and Systematics,* Vol.32, Pp127-157

Pickett, S.T.A; Burch Jr, W.R; Dalton, S.E.; Foresman, T.W; Grove, J.M. and Rowntree, R. (1997): A conceptual framework for the study of human ecosystems in urban areas. *Urban Ecosystems*, Vol.1 (4), Pp185-199.

Rosa, E.A; York, R and Dietz, T. (2004): Tracking the Anthropogenic Drivers of Ecological impacts; Ambio- A Journal of the Human Enviroment, Vol. xxxiii (8), Pp 509-512

Sieferie, R.P. (2001): *The Subterranean Forest: Ecology Systems and the Industrial Revolution*. The White House Press, Cmabridge, U.K

Streutker, D.R. (2002): A remote sensing study of the urban heat island of Houston, Texas. *International Journal of remote Sensing*, Vol. 23, Pp 2595-2608

Weng, Q. (2001): A remote sensing – GIS evaluation of urban expansion and its impacts on surface temperature in the Zhujiang Delta, China, *International Journal of Remote Sensing,* Vol.22(10), Pg. 1999 – 2014

Yang, D.; Wang, S.; and Wang, Y. (1994): Analyses of climatic variation and heat island on Lanzhou. *Journal of Lanzhou University*, Vol.30(4), Pp. 161-167.

Zhao, J and Wang, N. (2002): Remore Sensing analysis of urbanization effect on climate in Lanzhou. *Arid Land Geography*, Vol.25(1), Pp. 90-95.

Zhou, L.M; Dickson, R.E. and Tian, Y.H. (2004): Evidence for a significant urbanization effect on climate in China. *P Nalt Acad Sci USA* Vol.101, Pp 9540-9544.