AN ASSESSMENT OF THE MICRO-CLIMATIC VARIATIONS IN LOKOJA, NIGERIA: A REMOTE SENSING APPROACH

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Abstract

This study investigates the thermal variations of the different land use/cover types in urban Lokoja town retrieved from Landsat TM imagery of 1987. Band 2, 3, 4 and 6 of the imagery were used in the classification, estimation of NDVI, land surface emissivity values, and satellite sensor temperature. The Qin et al's mono window algorithm was employed to obtain the land surface temperatures of the different land use/cover types classified. The results indicate that there is a significant variation in temperatures among the different land use/cover types in Lokoja. The built up area and the vacant area have the highest land surface temperatures of 59.5°C and 58.5 °C respectively, while vegetation, water bodies and cultivated land have the least with 26.5 °C, 28.5 °C and 34°C respective I y-with (he urban/suburban temperature difference reaching 29.3 °C This suggests that anthropogenic activity is the major factor responsible for variations in the micro climate and vegetation a regulatory cooling feature of the ecosystem. This novel approach will limit the problems associated with data generated through the in situ measurement.

Introduction

Man's interaction with his environment has been recognized as a major determinant in the modification of the biosphere. The control human actions such as rapid growth in population and economic output per capita in .this industrial era are the source of most contemporary changes in the state and flow of the biosphere, and thereby have great consequences on the global environment (Cohen, 1995; Fasal, 2001; Sieferie, "2001; Rosa et al, 2004 and Ifatimehin and Ufuah, 2007). Urbanisation is most responsible in the transformation of the natural landscape through the construction of mass of buildings and impervious surfaces in a variety of shapes and orientation (Ojo, 1977) and therefore, alters the local climate (Adebayo and Zemba, 2003).

The most significant characteristics of man's induced changes in the urban environment are the variation in thermal properties of the built-up land surfaces, soil and impervious surfaces which result in more solar energy being stored and converted to sensible heat, and also the removal of shrubs and trees which serve as natural cooling effects of shading and evapotranspiration (Pickett et al, 2001). The urban environment with its anthropogenic activities contribute to the reduction in outgoing longwave radiation by hindering the loss of sensible heat and distribution of heat (Oke, 1982; Bonan, 2002 and Ifatimehin, 2007a), which result in the build up of ambient land surface temperature in the urban centres of 2 - 3 degrees higher than the surrounding suburban environment (Pickett, 1997), where there is a relatively greater cover of vegetation, cultivated lands as well as greater areas of wet soils (Adebayo and Zemba, 2003 and Ifatimehin, 2007b).

This resulting variation in the distribution of the varying thermal conductivities and heat capacities of objects across the urban environment and its environs, is most responsible in the creation of cooler climate in the surroundings than those in the cities (Adebayo and Zemba, 2003). Therefore, micro climatic variation is then noticeable and urban heat island effect becomes significant.

The application of remote sensing in the study of urban heat island effect may be new in Nigeria but not in the developed countries as indicated by Adebayo and Zemba (2003). However, its application will bring more improvement in the generation of precise data on the elements of climate in urban centres and their surrounding areas (Oguntoyinbo, 1978) and will address the limitations of the in situ approach in the quantitative description of areal extent and help in ascertaining the exact spatial variation in the distribution of micro climates on both local and global scale,s as witnessed by Gallo et al, 1993; Lo et al, 1997; Yang et al, 1997; Owen et al, 1998; Zhao and Wang, 2002; Streutker, 2002; Liu and Zhang, 2003 and Ifatimehin, 2007b.

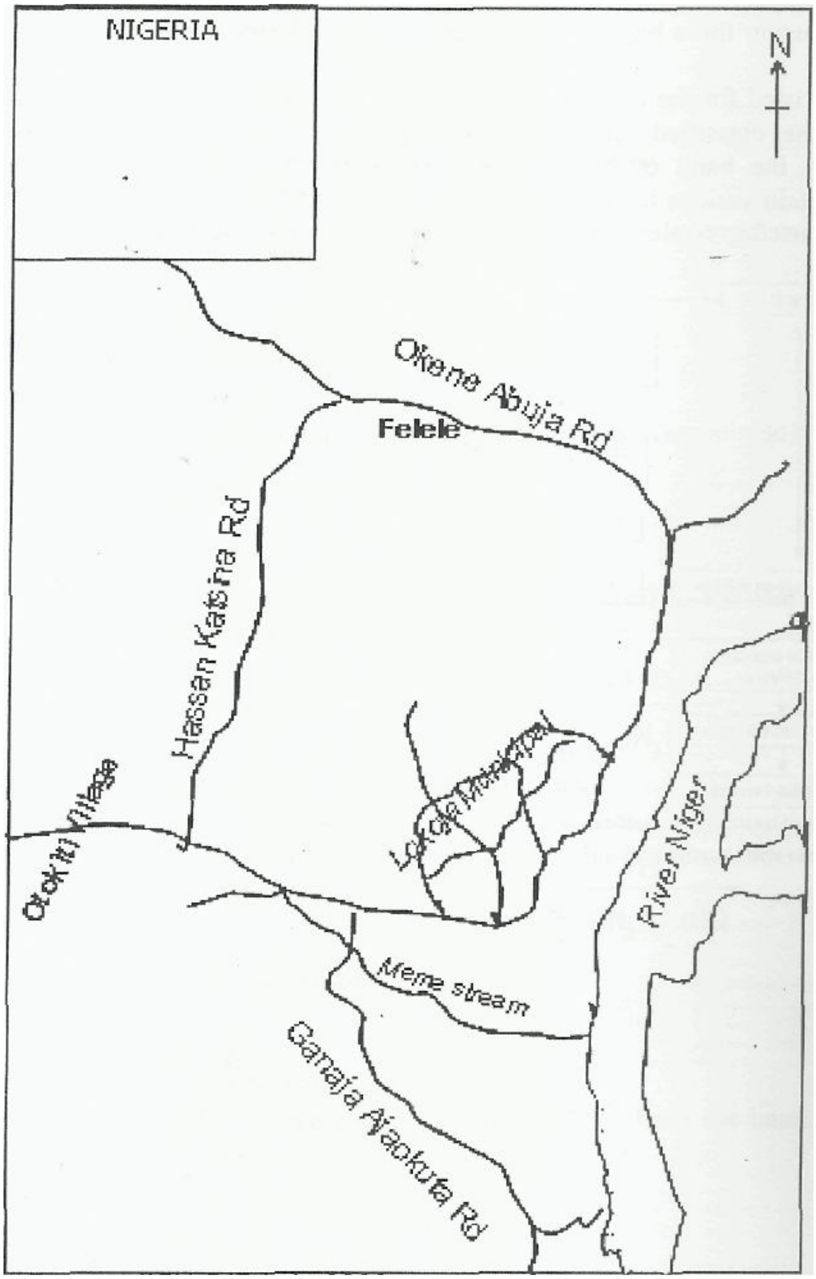
The objectives of this study are to apply Remote Sensing to:

1. determine the surface temperature of the different land uses/cover of Lokoja town; and

2. examine the micro climate of Lokoja town ant! its surroundings.

Study Area

Lokoja town, the administrative capital of Kogi State lies between 7°45'27.56"-7°51'04.34"N and 6°4r55.64"-6°45'36.58"E within the lower Niger trough. It has an estimated landmass of 63.82 sq. km and with an estimated population of 101,251 based on 2006 population census (Fig 1). It is situated in the Guinea savanna belt witnessing the Aw type of climate. Annual rainfall is between 1036mm and 1524 with its mean annual temperature not falling below 27°7 C. The town is sandwiched in the west and east by the Patti ridge and River Niger respectively.



Source: KSU GfS Lab, 2006

MajorRoad

Figure 1 : Map of Lokoja Town

Material and Methods

The LandSat TM image of 10lh December 1987 with a 30m spatial resolution at the visible and near infrared spectral region.and 120m spatial resolution at the thermal infrared region, was used for this study. It was processed using Idrisi 32 image processing software in a computer system with the following specifications: Mercury Pro workstation with a Pentium IV 3.2 GHZ processor, 512 MB memory, 80 gigabytes hard disk capacity and a 21 inch monitor. The band 2,3,4 and 6 were enhanced using histogram equalization, rectified to a common UTM coordinate system (WGS84), and then radiometrically corrected. An unsupervised classification with a maximum likelihood algorithm was conducted to classify the image using three bands: band 2 (green), band 3 (red) and band 4 (near-infrared).

The Bands 3 and 4 were used for the estimation of the NDVI and then used to estimate the land surface emissitivities of the classified land use/cover types, while the effective satellite temperature was extracted from the band 6. Finally, the Qin et al's mono-window algorithm developed in 2001was used to obtain various land use/cover types land surface temperatures. Figures 2 and 3 show the charts for land use/cover classification and estimation of land surface temperatures respectively.

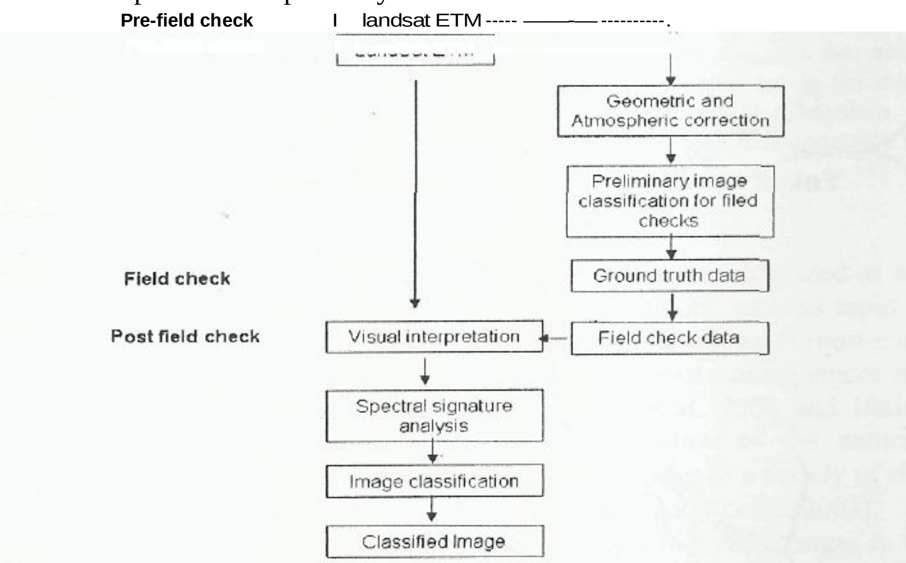
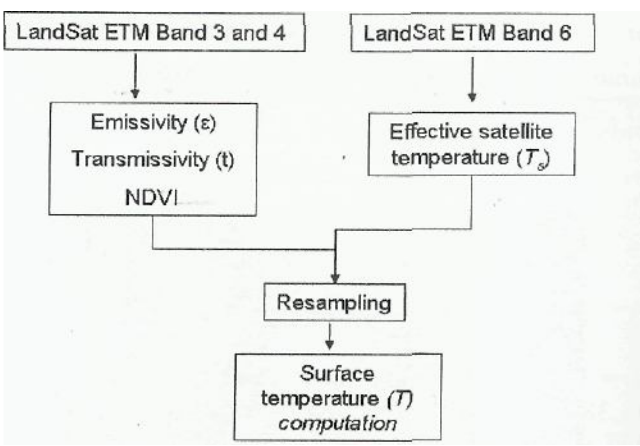


Figure 2: Flowchart for Land use/cover classification

Source: Ifatimehin snd Ufueh (2007)



Figures: Flowchart for estimating surface temperature Source: Adopted ***from*** *Wubet, 2003*

Method of Deriving Land Surface Temperature

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 = 0.954204 -0.081377; *where* T; is the near surface temperature. While rp i the broadband reflectance=

$$\frac{£ESUNxrp(A)}{ZESUN_A}$$

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

$$7TxL_x xd^2$$

Lr=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, eo= (1 .094 + 0.047 x In(NDVI))

v. T_a =16.7345 + 0.9165277'$_0$, T_a is the mean atmospheric temperature

vi. Effective satellite temperature TV

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

$$\ln(K/U)+1$$

C=tE

$$D=(1-t)[1+t(U)$$

Where A, = wavelength of emitted radiance = 11.5(im (Markam and Barker, 1985), *a=hc/k* (1.438 x 10"^{2}mK), k-Stefan Boltzmann's constant (1.38 x 10"^{23}JK"), h-Planck's constant (6.26xlO'^{34}Js), and c=velocity of light.(2.998xlOV^1), a =.-67.345.and.0.4658.

Results and Discussion

The classified LandSat TM imagery of 1987 indicates that natural vegetation dominates the entire landscape with 63.01 per cent, followed by cultivated lanrl with 28.55 per cent, while built-up of Lokoja is 1.44 per cent as shown in Table I.

Table 1: Lokoja Town Under Different Land Use/Cover Q987)

Land use type	1987	
	Area (km)	%
Vacant Land	1.86	2.91
Built-up Area	0.73	1.44
Cultivate Land	18.22	28.55
Natural Vegetation	40.21	63.01
Water body	2.80	4.39
Total	63.82	100

Source: Ifatimehin 2007

The thermal signatures of each land use/cover types studied revealed the average values of surface radiant temperature for each of this land use/cover. Table 2 indicates an obvious gradual thermal change as one progressed from the city centre (59.5°C) were buildings and impervious surfaces dominates the suburban area (26.5°C) where vegetation, wet soils and cropland are dominant. This implies that the non-evaporating and non-transpiring objects that litter the urban center of Lokoja are responsible for the high thermal differences noticed because they have the potential to absorb and radiate heat like blackbodies and thereby create a variation in the micro climate as heat is built up.

Tabie 2: LandSat TM 1987 Derived LSE and LST for Different land use/cover Type

Land use/cover	LSE			LST (°C)		
	Min	Max	Avg	Min	Max	Avg
Vacant Land	0.920	0.981	0.951	51	66	58.5
Built-up Area	0.924	0.983	0.954	52	67	59.5
Cultivated land	0.922	0.985	0.954	29	39	34
Vegetation	0.920	0.99	0.955	19	34	26.5
Water bodies	0.924	0.981	0.953	21	36	28.5
		Total LST -				L207
		Average LST				41.4

Source: Ifatimehin, 2007

The vacant areas to build up heat and have a temperature as high as 58.5°C. This land use type is devoid of vegetation because it had been cleared for either construction of houses or left barren exposing bare soils by land speculators.

On comparison with the suburban areas, the vegetated areas have the least temperature value and therefore, confirms that evaporating and transpiring bodies have a natural cooling effect on the environment and this suggests the lower temperatures witnessed in cultivated land and water bodies.

Figure 4 shows the distribution of land surface temperature of the different land use/cover types However, the urban centre average temperature is 59°C while the average for the suburban areas is 29.7°C, leaving a difference as high as 29.3°C. This variation indicates that the micro climatic situation in Lokoja is very significant and heat will continue to build up as urban expansion and
anthropogenic activities continue. '

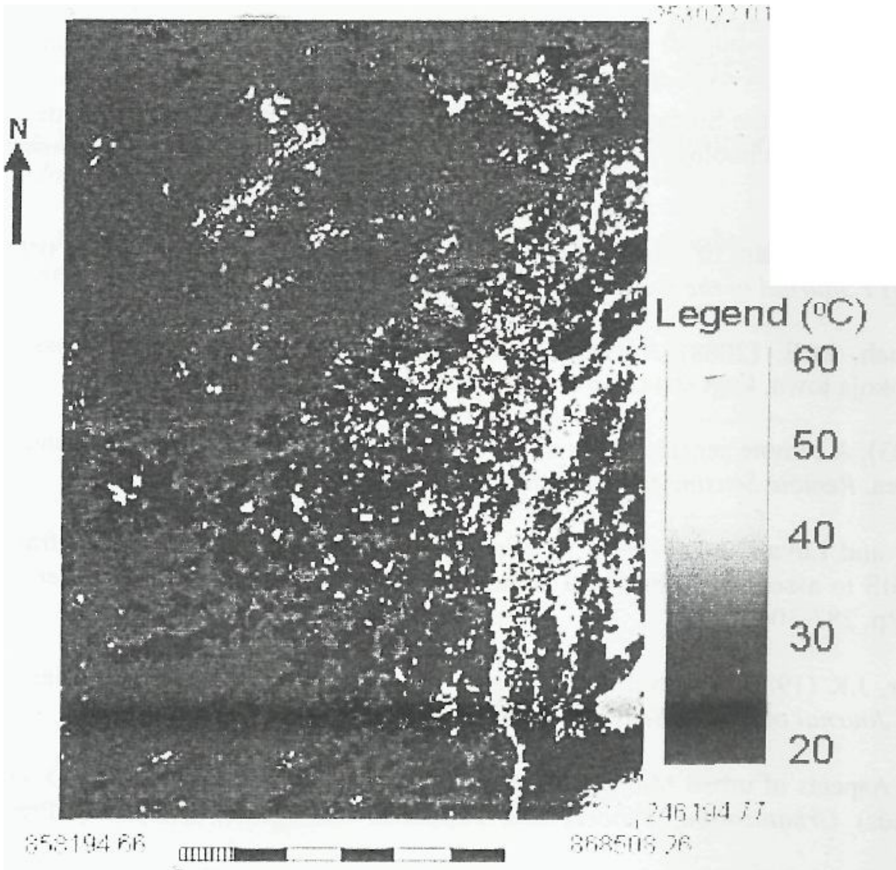


Figure 4: Land Surface Temperature map using LandSatTM 1987

Conclusion

This study reveals a significant variation in the micro climate of Lokoja town as far back as 1987 using satellite imagery. The morphology and thermal conductivities of the various buildings account for this variation in temperature. It also reemphasizes the role of vegetation as a regulatory cooling feature of the ecosystem which can be tampered with when anthropogenic activities increase as urbanization intensify. The high differences noticed in the variation of the micro climate as a result of the high values in temperature, can be attributed to the inability to correct the imagery of atmospheric impurities that stood between the sensor and the mapped object. This is as a result of the absence of software packages such as 6S, MODTRAN and LOWTRAN, for the correction.

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