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Full Length Research Paper

An evaluation of the effect of land use/cover change on the surface temperature of Lokoja town, Nigeria

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This research integrated remote sensing and Geographic Information Systems (GIS) to identified land use/cover types in Lokoja, including their temporal transformation and association with surface temperatures from the LandSat TM and LandSat ETM imageries of 1987 and 2001 respectively. As the built-up area increased in size (2667.6%) so was the surface temperature (6.48°C), vacant land (872%: 9.65°C), cultivated land (104.4%: 1.2°C) and water bodies (64.3%:0.94°C) while vegetation cover increased by 2.44°C while its area extent decreased (316.7%). These changes were responsible for the rise in the mean surface temperature from 38.39°C in 1987 to 42.61°C in 2001, indicating a 4.22°C increase in 14 years. The study revealed a direct relationship between the changing pattern among the various landuse/cover types and the variations in the surface temperatures of these landuse/cover types within the study period. If the rate of decline in vegetation covers is not checked, Lokoja may witness continuous increase in its radiant surface temperature as the cooling effect of vegetation cover is lost to impervious surfaces that litter the urban landscape. Therefore, policies that will help to provide more vegetation cover should be adopted to curb the effect of urban heat island on the environment and health of the residents.

Key words: GIS, land Sat, landuse/cover, remote sensing, temperature, thermal.

INTRODUCTION

Globally, human induced environmental transformation and its attending impacts are mostly associated with the accelerated economic growth in an urbanizing environment (Fasal, 2000; Weng, 2001, Jonathan et al., 2005; Ifatimehin, 2007). Steffen et al. (1992) and Jonathan et al. (2005) listed some of the induced environmental problems associated with urbanization as: declining biodiversity; poor water and soil quality; increased runoff and sedimentation rates; transformation of the global carbon cycle and hydrologic cycle; and climate change. The rapid land use changes by the growing population reduce natural vegetation cover and have transformed a large proportion of the biophysical state of the earth surface, which serves as sources and sinks for most of the material and energy movements and interaction within the environment (Weng, 2001).

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 a natural cooling effects of shading and evapotranspiration (Pickett et al., 2001) and contribute to the reduction in outgoing longwave radiation by hindering the lost of sensible heat and distribution of heat (Oke, 1982; Bonan, 2002; Ifatimehin, 2007). The reduced vegetation cover, increased in impervious surface area and the morphology of buildings in the urban centres, combines to lower evaporative cooling by storing heat during the day and releaseing such during the night to warm the surface air (Bonan, 2002). A built up of ambient land surface tempe-rature in the urban centres of 2 – 3 degrees higher than the surrounding suburban environment (Pickett, 1997) are witnessed in relatively areas greater cover of vege-tation, cultivated lands and as well as greater areas of wet soils (Adebayo and Zemba, 2003; Ifatimehin, 2008). These

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thermal differences are contributing to the development of a micro climatic condition otherwise referred as the urban heat island.

The land use/cover pattern of Lokoja town had changed tremendously (Amujabi, 2006; Ifatimehin and Ufuah, 2006) due to its position as the seat of Government. This status had provided economic opportunities to residents and migrants and this is a factor transformation of its landscape.

Remote sensing and Geographic Information Systems are becoming powerful and effective tools in the collection of multispectral, multiresolution and multitemporal data. The collected data are transformed into valuable information for effective evaluation and monitoring of environmental processes and impacts analysis. On this note, this study intends to use these tools to achieve the following objectives:

i) To determine the various landuse/cover types of Lokoja.
ii) To evaluate landuse/cover change pattern over the study period.
iii) To estimate the surface temperature of each landuse/cover types.
iv) To analyze how these changes in landuse/cover had after the surface temperature of Lokoja.

Study area

Lokoja town 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% (Figure 1). It is situated in the Guinea savanna belt witnessing the Aw type of climate. Annual rainfall is between 1016 mm and 1524 with its mean annual temperature not falling below 27°7 C. The town is sandwiched to the west and east by the Patti ridge and River Niger respectively.

MATERIALS AND METHODS

The LandSat TM image and LandSat ETM image of 10th December 1987 and 17th November 2001 respectively with a 30 m spatial resolution at the visible and near infrared spectral region and 120 m spatial at the thermal infrared region were used for this study.

Land use/cover change detection

The band 2, 3 and 4 of the acquired imageries were enhanced using histogram equalization, rectified to a common UTM coordinate system (WGS84) based on the 1: 250000 Topographic landuse map (sheet 61) of 1992 of Kabba and then radiometrically corrected. A supervised classification with a maximum likelihood algorithm was conducted to classify the imageries using three bands of green (2), red (3) and near-infrared (4). Training sample sets were collected based on 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.

Surface temperature estimation

The radiometrically corrected LandSat Imageries 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:

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

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

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

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 and 1987 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

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

$$C = t\varepsilon$$

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

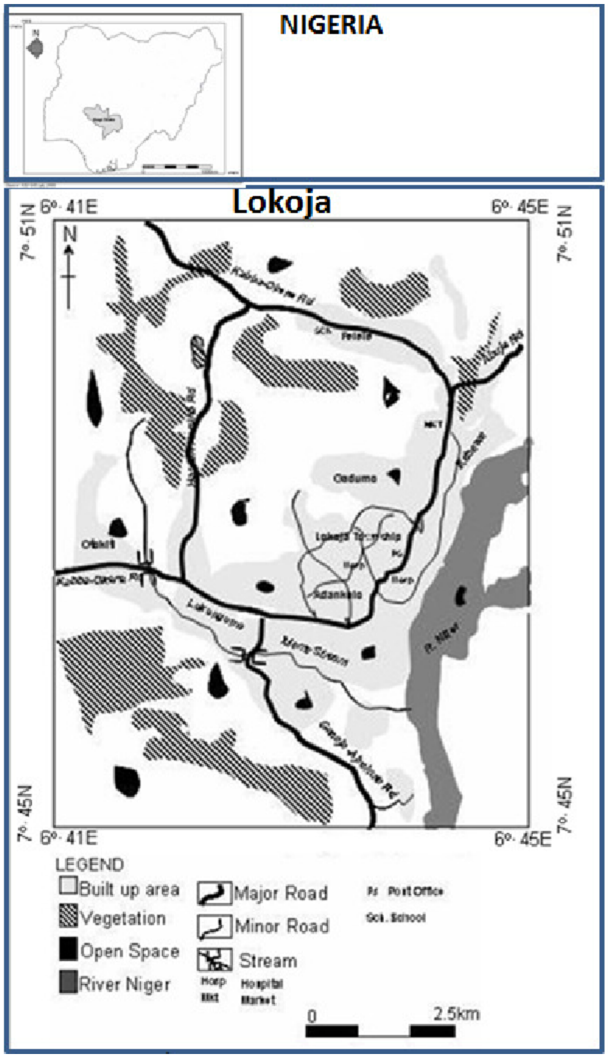

Figure 1. The study area.
Source: KSU Lab, 2006.

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 (1.38 x 10^{-23} JK^{-1}), h = Planck's constant (6.26 x 10^{-34}Js), and c = velocity of light (2.998 x $10^{8}s^{-1}$), a = -67.345 and 0.4658 Figure 3 shows the flowchart for the computation of surface temperature (T^S)

RESULT AND DISCUSSION

Land use/cover change in Lokoja Town, 1987 – 2001 From the classified LandSat imageries of 1987 and 2001, five land uses/cover were identified. Table 1 shows these land use/cover types of Lokoja in the two periods of study and the changes they had undergone within the span of 14 years.

The various land use types in the study area recorded significant increase during the study period with the exception of vegetation cover. The built-up area shows a substantial increase (2667.6%) followed by vacant land

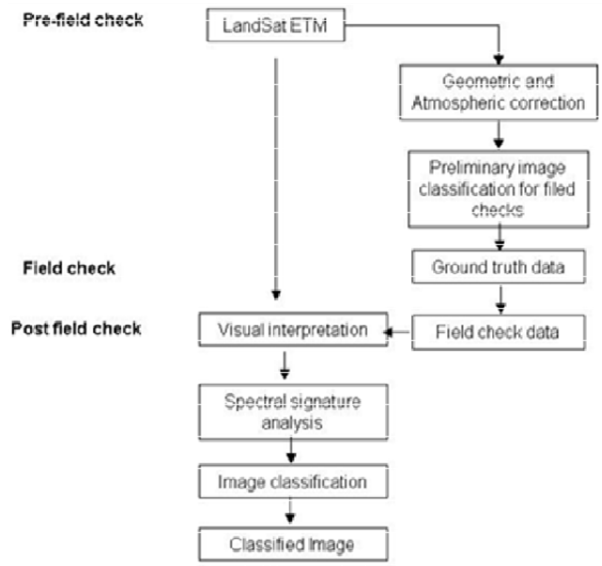

Figure 3. Flow chart for estimating surface temperatures.
Source: Ifatimehin (2008).

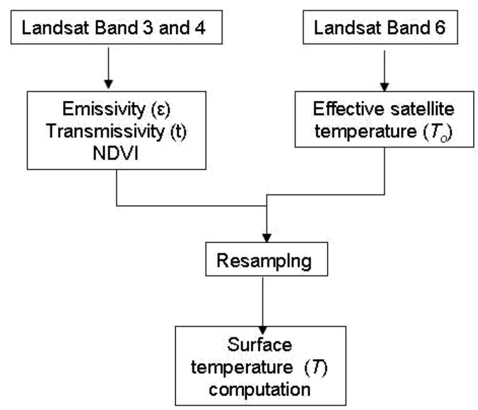

Figure 2. Flowchart for land use/cover classification.
Source: Adapted from Wubert, 2003.

(872%), cultivated land (104.4%) and others such as water bodies (Rivers, stream etc) had the least (64.3%), while vegetation cover (-316.7%) showed a significant decrease over the years.

These changes as shown in Table 2, imply that the various land use/cover gains witnessed by built-up area, cultivated land, vacant land and water bodies were at the expense of vegetation as it loses 1.09 ha to vacant land, 7.75 ha to built – up area, 21.44 ha to cultivated land and 1.80 ha to water bodies. This rapid depletion of vegetation cover results in the reduction of the natural cooling effects of shading and evapotranspiration of plants and shrubs.

Surface temperatures of land use types

The thermal signature of each of the land use/cover type

Table 1. Lokoja town under different land use/cover types, 1987 – 2001.

Land use type	1987		2001		% change 1987-2001	Annual increase (%)
	Area (km^2)	%	Area (km^2)	%		
Vacant Land	0.25	0.39	2.43	3.81	872	62.3
Built-up Area	0.34	0.53	9.41	14.74	2667.6	190.5
Cultivate Land	18.22	28.55	37.25	58.37	104.4	7.5
Vegetation cover	42.21	66.14	10.13	15.87	-316.7	-22.6
Water bodies	2.80	4.39	4.60	7.21	64.3	4.6
Total	63.82	100	6382	100		

Source: Authors, 2007 [Based on LandSat TM (1987) and LandSat ETM (2001)].

Table 2. Land transformation in Lokoja (1987 - 2001).

		Vacant Land	Built-up Area	Cultivated Land	Vegetation	Water bodies	2005
Vacant Land	1	0.25	0.04	1.17	1.09	-	2.43
Built-up Area	2	0.12	0.34	1.24	7.75	-	9.41
Cultivated land	3	-	-	18.22	21.44	-	37.25
Vegetation	4				42.21		10.13
Water bodies	5				1.80	2.80	4.60

Source: Authors, 2007.

Notes: Figures in Bold (diagonally) are area under that particular land use in 1987, while figures in the same column represent the shift in area to other land uses. Similarly, figures in the same row are increase in area captured from the land uses.

Table 3. Average surface temperatures in degrees Celsius by land cover.

Land Use/Cover	Surface temperature (^{O}C)		Change (^{O}C)	Average of total change in Temperature over 14 years
	1987	2001		
Vacant Land	48.42	58.07	9.65	
Built-up area	56.51	62.99	6.48	
Cultivated Land	33.21	34.41	1.2	4.22
Vegetation cover	25.63	28.07	2.44	
Water bodies	28.6	29.5	0.94	
Total	191.96	213.04		
Mean Surface Temperature	38.39	42.61		

Source: Authors, 2007.

was studied. Table 3 shows the average values of surface radiant temperature for each of the land use/cover type in 1987 and 2001. It is clear that for both years, built-up area exhibits the highest surface radiant temperature (56.51^{O}C in 1987 and 62.99^{O}C in 2001), followed by vacant land (48.42^{O}C in 1987 and 58.07^{O}C in 2001). This implies that the increase in non-evaporating and non-transpiring surfaces such as stone, metal and concrete bring up the surface radiant temperature. The lowest radiant temperature in 1987 is exhibited by vegetation (25.63^{O}C), followed by water bodies (28.6^{O}C) and cultivated land (33.21^{O}C). This pattern differs with that in 2001; vegetation cover (28.07^{O}C), water bodies (29.5^{O}C) and cultivated land (34.41^{O}C). From this study, the resulting mean surface of temperatures for the 1987 and 2001 are 38.39 and 42.21^{O}C respectively.

It is evident from Table 1, 2 and 3 that vegetation covers had shown a considerably low radiant temperature in both years, because dense vegetation can reduce amount of heat stored in the soil and surface structures through transpiration. The cultivated land with its sparse vegetation (crops) and exposed bared soil showed a significant increase in temperature over vegetation. In effect surface soil water and vegetation contributed to the broad variation in the surface radiant temperatures of both vegetation cover and cultivated land. Land use/cover changes do have intense effect on the surface radiant temperature of a location. The resulting GIS analysis showed that land use/cover changes witnessed in Lokoja town are due to conversion of vegetation cover to other landuse/cover types within the study period and this had given rise to an average increase of 4.22^{o}C in surface radiant temperature. The implication here is that with the annual rate of increase of the built-up area (190.5%) and annual rate of decline of vegetation cover (22.6%), surface radiant temperature will be on the increase and this may create an environment for urban heat island.

Conclusion

The variations in surface temperatures of the identified landuse/cover types of Lokoja suggest that urbanization is the key factor responsible for land transformation in the study area. Although, the increase in rate of surface temperature has its attending effects on both the environment and the health of residents. Therefore, land surfaces should be should be kept under permanent vegetation cover to minimize the increase in surface temperatures of the landuse/cover and types which may also affects the mean surface temperature of Lokoja. Thus, adopting policies of regulating the decline of vegetation to the urban land transformation processes should be encourage and environmental education should be reawakened to achieve the desired sustainable development with respect to environmental resource planning and management.

However, the computed surface temperature may be higher, as atmospheric correction was not done on the imageries. This was due to the absence of appropriate software packages (MODTRAN, LOWTRAN) for the corrections.

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