Analysis of Surface Urban Heat Island in Makurdi, Nigeria

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1.0 Introduction

- Surface urban heat island (SUHI) is fundamental in urban climatology. It controls surface heat and water exchange with the atmosphere (Yuan and Bauer, 2007), modulates air temperature of the lowest layers of the urban atmosphere, and influences the internal climates of buildings and the comfort of city dwellers (Voogt and Oke, 2003).
- SUHI is a consequence of ecological footprints of cities which lead to radical and irreversible changes in land use/land cover (LULC).
- The physical basis of the SUHI relates to the conversion of natural surface materials (vegetation, water, agricultural lands) with higher thermal inertia to developed surface materials (buildings, roads and other infrastructure) with lower thermal inertia (Weng, Lu and Liang, 2006).
- The study examines the spatial, seasonal and temporal variations and patterns of magnitude, intensity, structure and spatial extent of SUHI in the context of LULC in Makurdi, north central Nigeria.

2.0 Application of Remote Sensing & GIS in SUHI Studies

- Remote sensing, in conjunction with geographic information system (GIS), has been widely recognized and applied as a powerful and effective tool in detecting land use/land cover change, the basis for the inadvertent climatic modification of cities (Weng, 2001).
- GIS technology provides a flexible environment for entering, analyzing and displaying digital data from various sources necessary for urban feature identification, change detection and database development (Weng, 2001).
- Remote sensing is a global application methodology for assessing UHI effect of cities even in regions where pairs of urban &rural temperature records aren't available (Gallo *et al*., 1993).
- The method, unlike the conventional methods, is useful in simultaneously portraying the details of SUHI distribution characteristics.

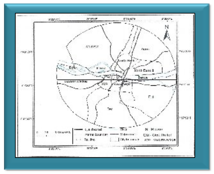
3.0 Data and Methodology

- A total of Twelve (12) Landsat TM/ETM+ images of the study area (figure 1) were acquired for April, June and January of 1991, 1996, 2001 and 2006 from Landsat path 187/188 and row 054/055.
- Land use/land cover (LULC) types were derived from the Landsat TM/ETM+ images using supervised classification method.
- The SUHI characteristics (magnitude, intensity, structure and spatial extent) were derived from land surface temperature (ST). The ST was simulated from thermal infrared (TIR) band (band 6) of the 12 Landsat TM/ETM+ images using the procedure of Chen et al. (2006).
- The ST profiles, centering on latitude 7° 44 30 N and longitude 8° 33 00 E provided data for analysis of SUHI structure and spatial extent (figure 1).
- Landsat TM/ETM+ images were analyzed using Integrated Land and Water Information System (ILWIS) 3.3, ERDAS Imagine 8.6 and ArcGIS 9.3 software.

Figure 1: Location and facts of Makurdi

Makurdi, capital of Benue State, is located between latitudes 7° 35 – 7° 53 N and longitudes 8° 24 - 8° 42 E in North central Nigeria. The city covers a land area of 800km^2 and has a population of 300 000 people (2006 census data).

The city lies entirely in the flood plains of Benue River which bisects the city into northern and southern parts. It is subdivided into eleven political divisions or "Council Wards" namely Agan, Bar, Clerk/Market, Fiidi, Mbalagh, Mission, Modern Market, North Bank 1, North Bank 2, Wadata/Ankpa and Wailomayo.



4.0 Results

4.1 Land Use/Land Cover (LULC) Characteristics in Makurdi, 1991 – 2006

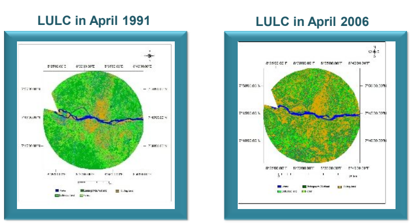


Figure 2: LULC in Makurdi

- A total of five (5) LULC types were classified in the study area namely water (blue), forest (light green), undergrowth/wetland (green), cultivated land (olive green) and built-up land (gold).
- The area of water has decreased by 4km^2, representing 19%, from 21km^2 in 1991 to 17km^2 in 2006. The area of forest has also declined by 37km^2 (28%) from 133 km^2 in 1991 to 96km^2 in 2006. Similarly the areas of undergrowth/wetland and cultivated have lost 119km^2 (32%) and 19km^2 (14%) from 370km^2 and 138km^2 in 1991 to 251km^2 and 119km^2 in 2006 respectively. Conversely, the area of built-up land has increased by 179km^2 (130%) from 138km^2 in 1991 to 317km^2 in 2006.
- The decrease in natural land materials and simultaneously increase in developed land from 1991 – 2006 in the study area is attributed to urban growth and development.

4.2 Variations in Surface Urban Heat Island Magnitude and Intensity

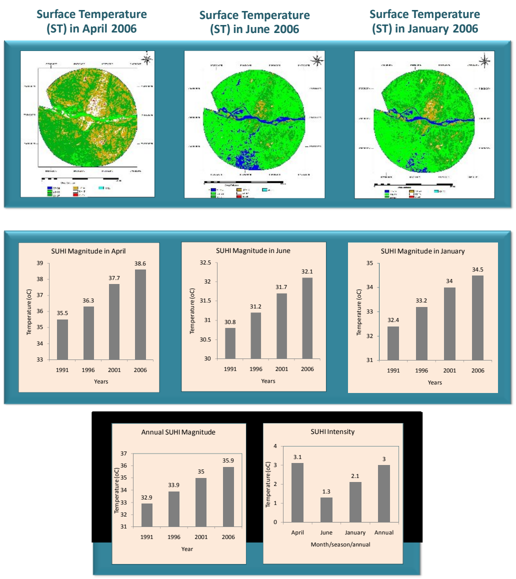


Figure 3: Variations in SUHI Magnitude and Intensity

- Spatially, the SUHI magnitude varied from 27.5°C in water bodies to 50.7°C over built-up and developed areas, representing maximum SUHI intensity of 23.2°C.
- The monthly SUHI magnitudes ranged from 35.5°C – 38.8°C (April), 30.8°C – 31.4°C (June) and 32.°C – 34.5°C (January) from 1991 – 2006, representing SUHI intensities of 3.1°C (April), 1.3°C (June) and 2.1°C (January).
- The annual SUHI magnitude has increased from 32.9°C in 1991 to 35.9°C in 2006 with SUHI intensity of 3.0°C.
- The results of variations and patterns of magnitudes and intensities of SUHI showed a strong influence of changes in LULC in the study area(Figure 2).

4.3 The structure of SUHI

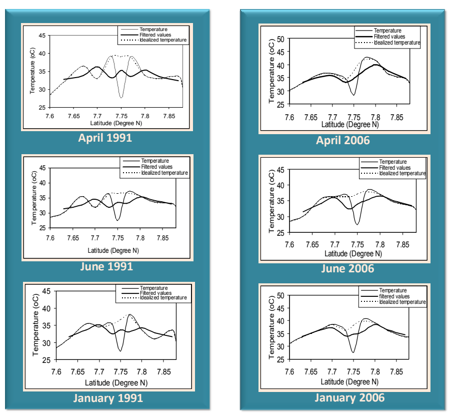


Figure 4: The SUHI Structure: North-south ST profiles

- The north-south ST profiles indicate two-island structure of SUHI in the study area. Two warm cores occurred on each side of Benue river which formed a cool spot.
- The magnitudes of the warm cores however varied from 36°C – 41°C with the cool spot having surface temperature of 27.5°C.
- The occurrence of warm cores and cool spot was consistent in all the months/seasons and years.
- When the pixels of Benue River was assumed to be urbanized, the ST profile (idealized) showed the general one-island structure with one warm core.

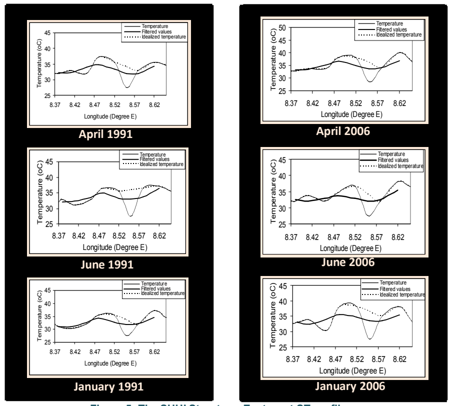


Figure 5: The SUHI Structure: East-west ST profiles

- The structure of SUHI using east-west ST profiles was similar to that using the north – south ST profiles.
- However, the idealized ST profile showed rather a diffused one-island structure in most of the months and years.

4.4 Spatial extent of SUHI

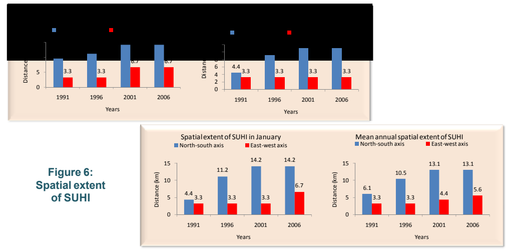


Figure 6: Spatial extent of SUHI

The rural/urban ST divide of 35°C was derived by superimposing April ST maps on April LULC maps and was adopted as SUHI signature. Generally, the spatial extent of SUHI signature (km) was:

- Higher in the N-S axis and least in E-W axis owing to the extent of urban growth.
- Higher in April and least in June due to seasonal variations in solar energy receipt, vegetation vigor, surface and soil moisture.
- Higher in 2006 and least in 1991 which is attributed to the annual trend in urbanization in the study area.

5.0 Implication

The increase in SUHI magnitude and intensity in the study area may:

- Worsen human discomfort through increase in both indoor and outdoor temperature.
- Aggravate the demand for energy for cooling as air temperature increases.
- Enhance green house gasses (ghgs) emission due to increase in energy consumption. Emission of ghgs may lead to air pollution.
- Be relevant in urban planning in the city.

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