Impacts of Land Use/Cover Change on Land Surface Temperature Using Remotely Sensed Data and GIS (2000-2017) Case Study: Nyala City- Sudan

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Abstract
Replacement of natural surfaces by artificial ones due to urban growth contributes to increase land surface temperature particularly in cities. Therefore, this research aimed to study the Influences of land use/cover change (LULCC) on land surface temperature (LST) in Nyala city, South Darfur state – Sudan during two different periods of summer (May) 2000 and 2017. In this study, remote sensing and geographical information system (GIS) techniques were applied to retrieve the land surface temperature (LST). Landsat (TM, and TIR) Satellite imagery products were used to provide quantitative information on the effect of land use change on land surface temperature. Bands 5, 4 and 3 of (OLI) and 4, 3, and 2 of (TM) were used for urban interpretation. The results show that, the maximum LST has decreased by 1.6095°C in 2017 which might be attributed to possible variations in weather conditions, whereas the minimum LST is increased by 9.9678°C through the study period. The researchers conclude that, remote sensing and GIS technologies are effective tools for monitoring land use change and its impact on LST.

Keywords: Land use/cover change (LULCC), Land surface temperature (LST), Landsat TM (thematic mapper), Operational Land Imager (OLI) of Landsat 8, & TIR (thermal infrared).

1. Introduction
The replacement of natural vegetation by city surfaces (heat absorbents) such as buildings, paved surfaces, parking lots, etc., due to urban expansion causes an increase of surface and atmospheric temperature in urban areas than in the surrounding rural areas, this phenomenon is known as Urban Heat Island (UHI). It is most noticeable at night than during the day, particularly when the wind is weak (Solecki et al., 2005). These changes dramatically altered the cooling effect by trees from evapotranspiration, emission properties of the surface, removal of carbon dioxide during photosynthesis, radiation and thermal convection, which caused a noticeable increase in the land surface temperature (Voogt, 2003 and Santos, 2013).

The Land Surface Temperature (LST) is the radiative skin temperature of the ground, which is a mixture of vegetation and bare soil temperatures. Both respond rapidly to changes in incoming solar radiation due to cloud cover, aerosol loads modifications and diurnal variation of light. It is affected by thermal properties, surface roughness, soil properties, hydraulic properties (Brovkin et al., 2006 & Ferreira et al., 2012); and is regulated by other factors including availability of water for evaporative cooling, wind speed, etc., which regulates the power of sensible and latent heat fluxes (van Leeuwen et al., 2011).

Nyala, the capital city of South Darfur state, Sudan, is the second most populated city in Sudan after the capital Khartoum; it accommodates a population of around 2,960,000.
people (Nations, 2011). Therefore is considered as a part of a global trend towards urbanization. It consists of some IDPs camps accounts for more than 200,000 people; the largest one is Kalma camp with 91,800 inhabitants, Otash camp houses 57,000, Derieg camp 23,000, Beleil camp 21,000, and Sereif camp consists of 17,000 people (Anne et al., 2011). As a result, the city has grown up dramatically due to population growth during the periods of the drought, conflicts and displacement, poverty, land degradation; in addition to the arrival of large humanitarian agencies, leading to uncontrolled growth of the city. This leads to a significant impact on the local climate, which in turn can contribute to the global climate change. Therefore, the purpose of this study is to identify the impacts of LST upon the environment by the application of remote sensing and geographical information system (GIS) because they are helpful tools for urban planners and environmental scientists by providing the critical information about the land surface temperature.

Many researchers worldwide found that land use change has a significant impact on LST; thus, built up areas observed higher LST than wetland, agriculture and vegetated areas, leading to adverse effects on urban microclimate (Honglin and Qihao, 2007; Ramachandra et al., 2012; Youneszadeh et al., 2015; Farshad et al., 2015; SK Akher and Subhra C., 2017; Han et al 2018; Igan and Williams, 2018).

2. Materials and Methods

2.1 Study Area

The study was carried out in Nyala city, the capital of South Darfur State, Sudan. It lies within geographical coordinates 12°2′11″N 24°52′37″E [1] and elevation of 2,208 ft (673 cm) above the sea level (Chauhan, 2013) (Figure). It accommodates about 565,734 inhabitants [2] It lies within the tropical and subtropical desert climate with an average annual temperature around 78.0°F (25.6°C), May is the warmest with average temperature exceeding 87.0°F (30.6°C); whereas January is the coolest with an average temperature of 73.0°F (22.8°C). The main annual precipitation is approximately 17.3” (439.4 mm). The highest precipitation on average falls on August with 5.7” (144.8 mm) [3].

![Figure 1: Location of the Study Area](image)

2.2 Data Sources & Image Processing

Data were obtained from the Landsat satellite archives of GLOVIS, Landsat 4-5 Thematic Mapper (TM) images, and Operational Land Imager (OLI) of Landsat 8. The boundary of the study area was adjusted to the Landsat images. The land-cover mapping was derived using ENVI 5 software, with the aid of satellite remote sensing obtained in (May) the summer of 2000 and 2017 under clear atmospheric condition (zero cloud). Bands 5, 4 and 3 of (OLI) and 4, 3, and 2 of (TM) were used for urban interpretation. Spectrally, this combination of bands is preferred because of the ability to discriminate compositional differences of vegetation and bare land. A supervised classification method based on a maximum likelihood was applied to classify the spectral inputs (both visible and near-infrared). The derived classes were combined into final four land use/cover classes, these classes are vegetation, urban, wadi, and bare land.
(Figure 2). Band 6 (the thermal band) was used for both images to calculate Land surface temperature (LST). ENVI 5 band math tool with different equations were applied to convert digital numbers (DNs) for the thermal bands to brightness temperatures through the following methods.

DNs were converted to radiance (CVR1) using gain and bias values by the following formula:

\[ CVR1 = \text{gain} \times \text{DN} + \text{bias} \]  

CVR1 is the cell value as radiance, DN is the cell value digital number, gain is the gain value for a specific band and bias is the bias value for a specific band, then the radiance value was converted to Kelvin by using the following formula:

\[ T = \frac{k2}{\ln \left( \frac{k1 \times \varepsilon}{CVR1 + 1} \right)} \]  

T is degrees Kelvin, CVR1 is cell value as radiance, \( \varepsilon \) is emissivity (typically 0.95), \( K1 = 607.76 \) and \( K2 = 1260.56 \) (Landsat 7 Handbook, 2010).

Then Kelvin was converted to Celsius by subtracting 273 from the Kelvin using ENVI 5.

3. Results & Discussion

Figure 3 below shows that bare land has the highest LST value in 2000 ranged from 26.752 to 52.1827 °C, whereas in 2017 ranged from 36.7198 to 50.5732 °C. The areas with higher values of LST represented in dark yellow to reddish, particularly, bare land areas with low vegetation, whereas, the lowest values of LST was represented by pale to dark blue. The maximum LST has decreased by 1.6095 °C in 2017 which might be attributed to possible variations in weather conditions, whereas the minimum LST has increased by 9.9678oC throughout the study period.

4. Conclusions

Results revealed that land use change has significant effects on surface temperature increase or decrease in Nyala city; where urban areas experienced relatively slight changes in LST. This result is inconsistence with findings by many researchers that urban areas always increase LST; this might be due to similar thermal characteristics of the city fringes (shanty towns...
as well as IDPs camps) with vegetated areas. Such homes were mainly constructed from local materials such as trees and agricultural residues (Sorgam and Millet). Areas along the main channel of water (Wadi) and green vegetation around it showed the lowest LST in dark blue color.

4. Conclusions

In conclusion, the researchers convince the effectiveness of remote sensing and GIS technologies for monitoring and providing information about land use change and its impacts on LST. Different LST for different land classes could be useful tool for sustainable development of the city through urban.

References


Links: