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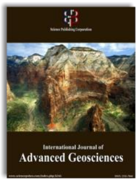

Mapping land surface temperature in Nigeria using Modis data

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Abstract

In developing countries such as Nigeria, rapid land degradation is an unavoidable phenomenon. Nigeria is experiencing significant growth as its population clusters continue to expand due to migration from rural areas. Unfortunately, one of the negative consequences of this de-velopment is the increase in impervious areas, which results in higher land surface temperatures (LST). A number of studies have highlight-ed the utilization of Landsat thermal data and the usefulness of MODIS data in the preparation of LST maps. This current study aimed to produce LST maps for Nigeria using 8-day average MODIS MOD11A2 images for the years 2001, 2011, and 2015, al-lowing for an as-sessment of the average LST for the country. Analysis of the LST maps reveals that the average temperature in Nigeria is 32°C, with the highest and lowest LSTs recorded as 43°C and 20°C respectively within the selected years. These results indicate that impervious areas contain a greater number of pixels falling into the high to very high-class category. It is crucial to adopt appropriate climate change mitiga-tion measures in light of these findings.

Keywords: *Nigeria; Land Surface Temperature; MODIS Data; Climate Change; Sustainability.*

1. Introduction

Satellite-derived remote sensing data offer a wealth of information on land cover, vegetation, rainfall, temperature, and various climate factors. These datasets, with their availability dating back to the 1980s, serve as valuable resources for conducting historical analyses of changing landscapes. One significant parameter derived from these data is land surface temperature (LST), which plays a crucial role in surface-atmosphere interactions. LST has found widespread application in diverse scientific fields like climatology, hydrology, agricul-ture, public health, and environmental science (Peng et al., 2018; Phan et al., 2019; NourEldeen et al., 2020). The alteration of terrain materials and energy balances due to changes in Land Surface Temperature (LST) can lead to variations in surface air temperature, pre-cipitation, and vegetation cover. This, in turn, has a significant impact on both regional and global environmental protection and evolu-tion (Wilson et al., 2003; Vancutsem et al., 2010). Extreme climate events, along with the continuous expansion of land desertification area and vegetation degradation, directly pose a threat to regional ecological security (Chen et al., 2016; Xu et al., 2020). Consequently, LST serves as a crucial quantitative parameter in addressing ecological environment issues.

A significant amount of research has been conducted on the dynamics of surface air temperature (SAT) with respect to spatiotemporal variations of land surface temperature (LST). Due to the scarcity of long time series remote sensing data, LST fluctuation is the subject of few investigations. According to certain research, there is a substantial association between SAT and the ground surface temperature measured at zero centimeter depth from meteorological stations. The temperature rises at a faster pace and with a greater magnitude than SAT (Jiang et al., 2015; Wang et al., 2016The GST data possesses the benefits of extensive long-term data and consistent measurements. However, the variance in Land Surface Temperature (LST) across different regions is greatly influenced by solar radiation, surface albe-do, soil thermal properties, and vegetation cover (Xu & Shen, 2013; Yang et al., 2019). The conventional ground site observations alone do not provide an accurate depiction of the spatiotemporal patterns of LST over a large area (Li et al., 2013).

The thermal infrared (TIR) remote sensing has become the unique way to obtain the spatially continuous LST from regional to global scale (Ndossi & Avdan, 2016). The LST products, such as MODIS, are widely considered as the most suitable data source for estimating land surface temperature (LST). This is primarily due to the availability of free access to the data, its high observation frequency, and moderate spatial resolution (Phan et al., 2019; NourEldeen et al., 2020). Previous studies have primarily focused on exploring the rela-tionship between LST, vegetation index, and urban heat island using time series MODIS- LST data (Mukherjee et al., 2016; Hereher, 2017; Wei et al., 2018).

LST serves as a valuable indicator of surface energy balance due to its crucial role in the physics of land-surface processes. It encapsu-lates the outcomes of interactions between the surface and the atmosphere, including the exchange of energy fluxes. The determination of LST relies on measuring the radiation emitted by the land surface using MODIS at precise viewing angles. To enhance our understanding of the Earth system on a global scale, the Earth Observing System (EOS) provides surface kinetic temperatures with specified accuracies of 0.3 K for oceans and 1 K for land. Remarkable advancements have been achieved in the past decade regarding the estimation of land surface emissivity and temperature through the analysis of thermal infrared data obtained from airborne sources.

The emissivity through channels can be estimated by this temperature. Recently, thermal log residuals and alpha residuals have been developed as other techniques to extract emissivity information from multispectral thermal infrared data. Several split-window methods have been devised to retrieve sea-surface temperature and land-surface temperature from NOAA AVHRR data. However, a significant challenge in using these split-window LST methods is the requirement of precise knowledge of the surface emissivity's in the bands, with an accuracy better than 0.01.

The primary aim of this research paper is to evaluate the characteristics of land surface temperature and their spatio-temporal variations across the study area. The specific objectives are to analyze the spatial and temporal changes in surface temperature between the study years of 2001, 2011, and 2015. Additionally, this study seeks to generate a land surface temperature map based on patterns derived from the Moderate Resolution Imaging Spectroradiometer (MODIS). Moreover, it aims to ascertain the mean, minimum, and maximum spatio-temporal temperatures for both Nigeria as a whole and its individual states. This dataset comprises an 8-day composite of 1-2 day observation intervals, with a spatial resolution of 1000m.

2. Study area

Fig. 1: Map of Africa with Location of Nigeria.

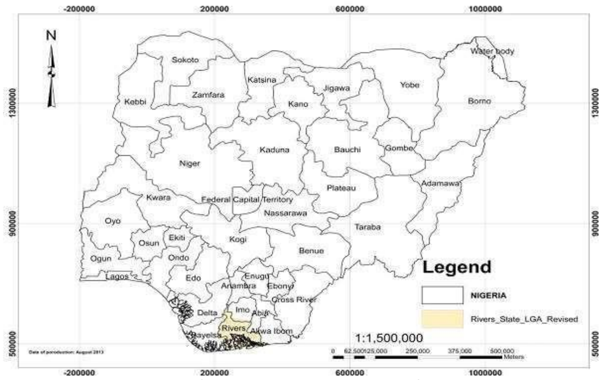

Fig. 2: Map of Nigeria with Location of Rivers State.

Nigeria spans across a latitudinal range from approximately 14°N to 4°N and a longitudinal extent from 15°E to 3°E, covering a total area of 356,669 square miles. This vast stretch encompasses various distinct climatic regions. Firstly, there is a narrow coastal belt consisting of mangrove swamps, followed by a relatively broader section characterized by rolling hills and tropical rainforests. Moving further inland, Nigeria boasts a larger dry central plateau adorned with open woodlands and savannas. Lastly, on the fringes of the Sahel, there lies a strip of semi-desert. Within this diverse landscape, Lagos is situated in the coastal belt, while Abuja is located in the central plateau. Nigeria spans across a latitudinal range from approximately 14°N to 4°N and a longitudinal extent from 15°E to 3°E, covering a total area of 356,669 square miles. This vast stretch encompasses various distinct climatic regions. Firstly, there is a narrow coastal belt consisting of mangrove swamps, followed by a relatively broader section characterized by rolling hills and tropical rainforests. Moving further inland, Nigeria boasts a larger dry central plateau adorned with open woodlands and savannas. Lastly, on the fringes of the Sahel, there lies a strip of semi-desert. Within this diverse landscape, Lagos is situated in the coastal belt, while Abuja is located in the central plateau.

Nigeria boasts a diverse landscape, resulting in distinct climate zones across the country. The coastal region, including Lagos, experiences moderate to high temperatures ranging from the mid-70s to the low 90s for most of the year. This area receives heavy rainfall, with an average of 70 inches per year. The rainy season in Nigeria is well-defined, particularly along the coast, where the heaviest rains occur from May to October. Although humidity remains high throughout the year, it declines during the winter months. Moving towards the central plateau, where Abuja is situated, temperatures soar above 100°F between March and June. Abuja generally has a hot and humid climate during the rainy season, which lasts from June to September. The annual rainfall in Abuja averages around 50 inches. However, during the cooler months of December and January, humidity decreases significantly, and night temperatures often dip into the 60s. In contrast, northern Nigeria experiences a comparatively drier climate, with an average rainfall as low as 20 inches per year in the far north.

3. Methodology

3.1. Data used

Thermal remote sensing images captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) were employed for analysis. The dataset utilized an 8-day composite comprised of observations taken every 1-2 days, with a spatial resolution of 1000m. Subsequently, the administrative border of Nigeria was isolated using the Google engine archive. To calculate the mean, minimum, and maximum temperature, the administrative map of level one and zero were accessed in Esri shape files.

3.2. Methods

The 8-day average MODIS MOD11A2 LST images for the years 2001, 2011, and 2015 were processed and converted from raw DN values to degrees Celsius

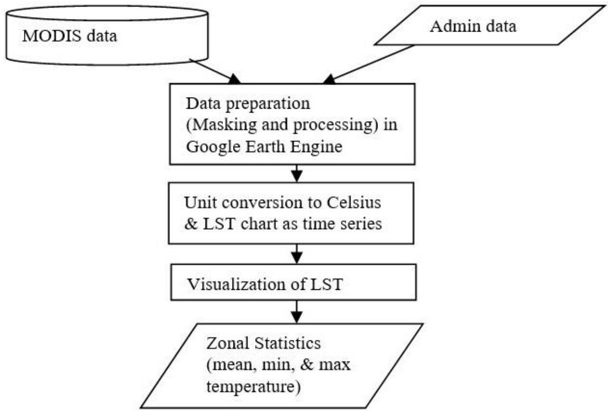

Fig. 4: Methodology Workflow

These images were then downloaded in geotiff format. In order to calculate the average LST for each mentioned year, the Zonal statistics tool was utilized within the QGIS software. This tool was used for pixel averaging to determine the mean, minimum, and maximum temperatures. The resulting time series LST data for the years 2001, 2011, and 2015 were then processed further, converted to jpeg format, and downloaded.

This process presents an automated method for identifying variations using Sentinel-1 Ground Range Detected (GRD) data in Google

4. Results

Fig. 4-6 displays the land surface temperature maps that were created for the years 2001, 2011, and 2015.

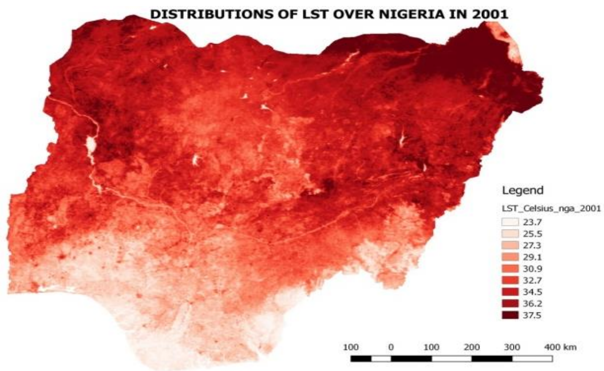

Fig. 4: Distributions of MODIS LST Over Nigeria in 2001.

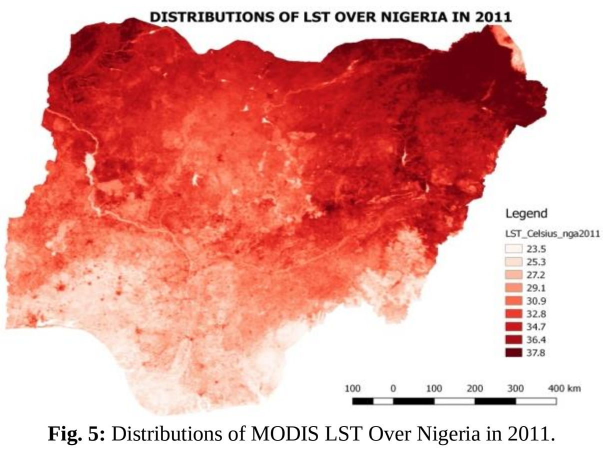

Fig. 5: Distributions of MODIS LST Over Nigeria in 2011.

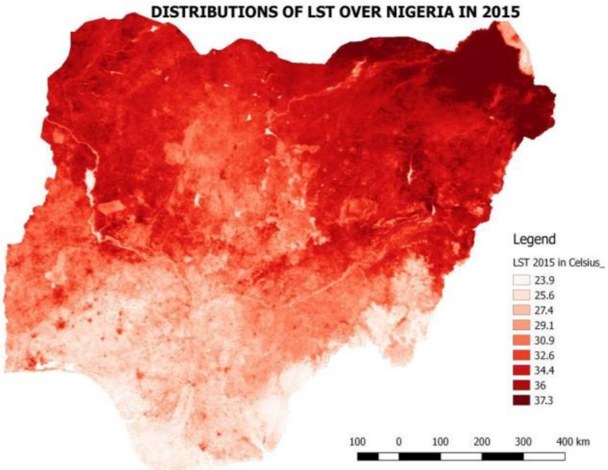

Fig. 6: Distributions of MODIS LST Over Nigeria in 2015.

Fig. 7: Time Series LST of MODIS Data Over Nigeria in 2001.

Fig. 8: Time Series LST of MODIS Data Over Nigeria in 2011.

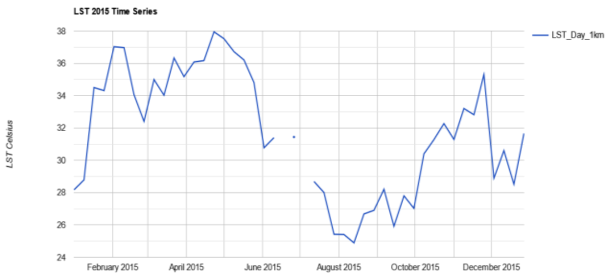

Fig. 9: Time Series LST of MODIS Data Over Nigeria in 2011.

Furthermore, Fig 7-9 above presents the land surface temperature (LST) time series graphs in jpeg format, illustrating the data for the years 2001, 2011, and 2015.
The zonal statistics function was employed to compute the average land surface temperature (LST) in Celsius, as well as determine the minimum and maximum LST in Celsius for Nigeria and its respective states in the years 2001, 2011, and 2015.

Table 1: Nigeria LST for 2001, 2011 and 2015

Year	Average LST in Celsius	Minimum LST in Celsius	Maximum LST in Celsius
2001	32	21	43
2011	32	20	43
2015	32	20	42

5. Discussion and conclusion

According to the analysis of LST maps and graphs depicted in figures 4-6 and 7-9, it was determined that the highest and lowest recorded LSTs were 23.9°C and 37.3°C, respectively. Consequently, the LST was divided into nine categories, with the classification starting from the lowest temperature range. Figure 3 illustrates that open lands and vegetated areas consistently exhibited lower LSTs compared to impervious areas. This trend was observed throughout the selected years, indicating that the southern part of the country consistently experienced very low LSTs. For the years 2001, 2011, and 2015, the average temperature for Nigeria remained at 32°C, with the maximum temperature recorded at 43°C as shown in Table 1.

The land surface temperature maps for the years 2001, 2011, and 2015 were prepared using thermal images from MODISMOD11A2. The findings from these maps clearly demonstrate that the Northern region exhibits higher LST, while areas with open lands and vegetation in the Southern region have lower LST. These LST maps, generated for different years as part of this study, will serve as valuable tools for planners and policy makers in monitoring the continuous changes in specific areas or regions. This will enable them to identify locations where climate change mitigation measures can be implemented effectively.

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