DOI: https://dx.doi.org/10.4314/gjpas.v30i3.6

GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 30, 2024: 325-331
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INFLUENCE OF LAND USE/LAND COVER ON LAND SURFACE TEMPERATURE IN IBADAN METROPOLIS IN OYO STATE

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(Received 29 July 2024; Revision Accepted 15 August 2024)

ABSTRACT

The study evaluated the changes in land use and land cover (LULC) during a 23-year period and its resulting effects on the temperature in Oyo State metropolis. Landsat 8 images of the study area for 2000 and 2023 were downloaded and analyzed to observe and quantify these changes through the use of supervised classification method. Furthermore, the land surface temperature was computed using relevant formula. Within 23 years, the percentage of bare land, built-up areas and waterbody climbed from 0.48%, 38.51%, and 0.20% to 0.59%, 50.20%, and 0.66% respectively, while the percentage of vegetation declined from 60.82% to 48.54% according to the result. Additionally, in 2000, the land surface temperature ranged from 18.82°C to 28.25°C, and in 2023, it varied between 19.89°C and 32.21°C. Over the course of the 23-year study, it became clear that changes in the state's land cover and land use impacted on the rising temperatures, which were mostly brought on by a decline in vegetation cover. The study finds that Oyo State's metropolitan area is warmer than it was twenty-three years ago and as a result, it suggests that the government should support urban forestry initiatives.

INTRODUCTION

The climate surrounding cities is regularly altered by human activity, including urbanization (Bharath et al., 2013). A number of factors, including overpopulation, infrastructural development, and changes in land use have significant impact on the climate (Adeyeri et al., 2015). Changes to this interaction often cause an imbalance in surface energy, which has serious environmental repercussions (Pielke et al., 2002). These changes affect the land surface temperature, heat storage, absorption of solar radiation and urban heat island, among other things. Urban heat island (UHI) occurs when metropolitan areas get warmer than the surrounding rural areas and it is one urban issue caused by climatic variability. This phenomenon is caused by the various forms of land use and land cover (LULC) that are present on the surfaces of various places within the cities. The optical characteristics of each LULC, such as its ability to absorb, reflect, and emit radiometric light, give rise to distinct interactions with sun energy. One of the main reasons for urbanization is that cities offer amenities and economic opportunities to its residents, making them the center of attraction for everyone.

The third most populous city in Nigeria, Ibadan, is located in the Oyo State metropolitan and is known for its rapid industrialization and economic activities (Ayininuola & Olalusi, 2004). In an effort to determine the surface temperature of Ibadan, Oguntoyinbo (1980) measured the surrounding area's temperature as well as that of the airport.

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He discovered a noticeable difference in temperature, ranging from 5°C to 7.5°C. He also mentioned how the time of day and the season affected the surface temperature. Locally, land surface temperature was defined as the typical surface air temperature, typically monitored in an open field with a thermometer set in a box three meters above the grass (Sun, 2008).

Only a limited geographic area was taken into consideration for this measurement, which was a point measurement. Researchers have also attempted to place a thermometer on a car that is driven around the town, while readings were taken intermittently (Huang et al., 2013). These methods of detecting land surface temperature could be time-consuming, tedious, and prone to errors. In the same vein, these difficulties have impeded our understanding of the regional and global exchanges between land and atmosphere. A significant shift in science and technology has opened up the field of remote sensing to better understand the gap between environmental processes on a local, regional, and global scale. According to Kim and Liang (2010), remote sensing is a crucial tool for community modeling, surface energy balance estimation, and land surface models.

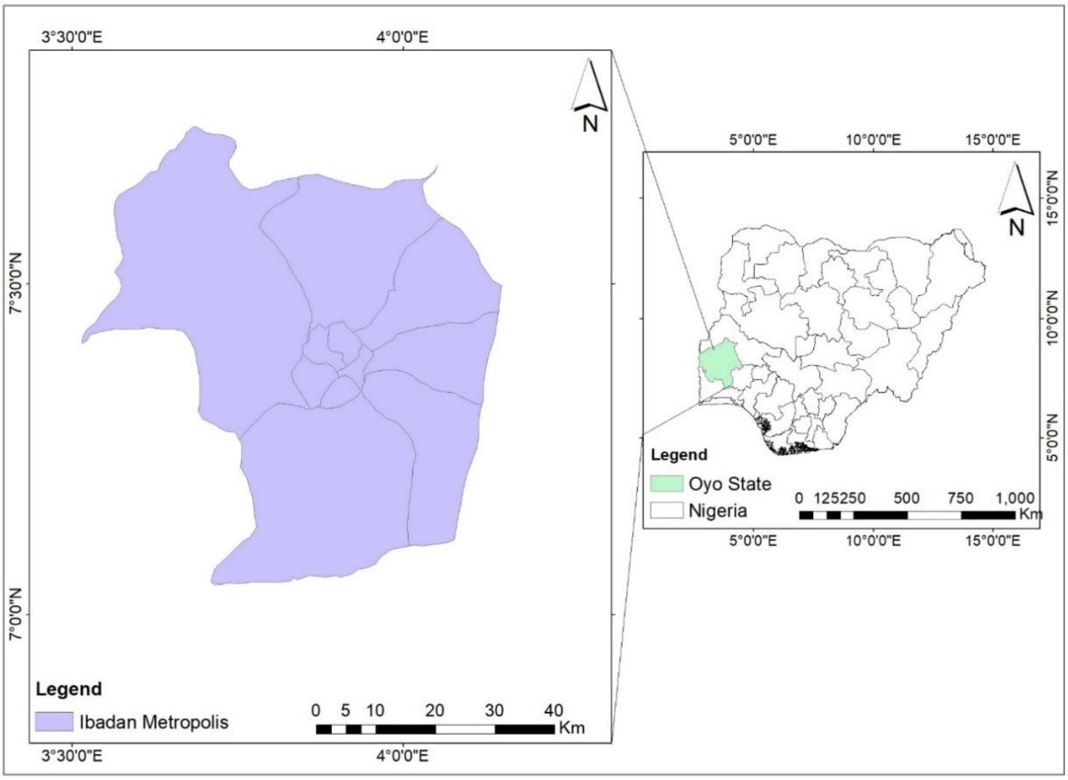
In order to measure the state of the earth's surface, remotely sensed data or information are collected on a regular basis at a greater resolution (Owen et al., 1998). Numerous researchers worldwide have used remote sensing to learn more about the regional variance of land surface temperature (Weng, Lu & Schubring 2004). Numerous studies (Joshi and Bhatt (2012); Nivedha et al., 2017) use the Normalized Difference Vegetative Index (NDVI) technique to estimate Land Surface Temperature (LST), and this research project likewise aim to adopt the same approach.

STUDY AREA

Oyo State Metropolis

Ibadan, which occupies 240 km³ of land and is the largest metropolis in West Africa and Africa overall, is located in Oyo state, Nigeria. Situated about 210 meters above sea level, the site's rugged terrain makes it a defensible position. Location-wise, it is about 145 kilometers northeast of Lagos, between latitudes 7° 05N and 7° 25N and longitudes 32° 40 E and 32° 55 E. It also has an average elevation of 200 meters above sea level, tucked between savanna and secondary rainforest. It receives drainage from the Ogunpa, Ona, and Ogbere main river basins. The mean annual rainfall is 1250 mm, and its climate is classified as primary tropical (UNCHS/UNEP, 1997).

High relative humidity, comparatively steady temperatures, and flora typical of the derived savannah vegetation zone also define the city. Farmlands with mixed crops, secondary forests, and tropical vegetation groupings are among the ecological types found in the zone (Ajao et al. 2002).



Source: Office of Surveyor General of the Federation (OSGOF, 2014)

Figure 1: Map of Oyo State Metropolis

Data Collection and Analysis

Landsat images were obtained from the United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov) for Oyo State. The path and row were 191 and 055 respectively. The images were classified into land-use/land-cover (LULC) types using the ArcGIS 10.5 software. Thereafter, the Maximum Likelihood algorithm supervised classification was used to create the Land-use Land cover (LULC) maps.

Land Surface Temperature (LST)

The retrieval of LST followed the single-channel method (Obiefuna et al. 2013). The key stages of the methodology are as follows:

Conversion of digital number (DN) to spectral radiance

The formula for converting DN in Landsat 7 to spectral radiance is given by Zareie et al. (2016):

$$L\lambda = ((Lmax - Lmin)/(QCalMax - QCalMin)) \times (Qcal - Qcalmin) + Lmin \quad \textbf{(1)}$$

where:

Lλ is spectral radiance at the sensor's aperture (W m−2 sr−1 μm−1),

Qcal is a quantized calibrated pixel value in DN,

Lmin is spectral radiance scaled to Qcalmin,

Lmax is spectral radiance scaled to Qcal¬max,

Qcalmin is the minimum quantized calibrated pixel value (corresponding to Lmin) in DN,

Qcalmax is the maximum quantized calibrated pixel value (corresponding to Lmax) in DN.

The formula to derive the spectral radiance for Landsat 8 is given by USGS (2015):

$$L\lambda = ML \times Qcal + AL \quad \textbf{(2)}$$

where:

ML is Radiance multiplicative scaling factor for the band,

AL is Radiance additive scaling factor for the band.

The values for Lmin, Lmax, Qcalmin, Qcalmax, ML and AL will be derived from the Landsat metadata file.

Conversion of spectral radiance to top-of-atmosphere (TOA) brightness temperature

After calculating the spectral radiance (Lλ), the TOA brightness temperature was calculated. The TOA approximation formula is given by Zareie et al. (2016).

$$T = K2 / log(1 + K1 / L\lambda) \quad \textbf{(3)}$$

where:

T is TOA brightness temperature (K),

K1 (W cm−2 sr−1 μm−1) and K2 (K) are pre-launch calibration constants.

Conversion of brightness temperature to LST

The brightness temperature was subsequently converted to LST using the equation below (Hamoodi et al. 2019).

$$S\tau = T/(1 + (\lambda \times T / (\rho) \, log \, \mathcal{E})) \quad \textbf{(4)}$$

where:

Sτ is LST (K)

λ is the Wavelength of emitted radiance (11.5 μm),

ε is Land surface emissivity (typically 0.95),

ρ = h × c / σ = 1.438 × 10−2 m K (σ = Boltz¬mann constant = 1.38 × 10−23 J K−1, h = Planck's constant = 6.626 × 10−34 J s, c = velocity of light = 2.998 × 108 m s−1).

Finally, the LST in Kelvin was converted to degree Celsius by subtracting from 273.15

RESULT AND DISCUSSION

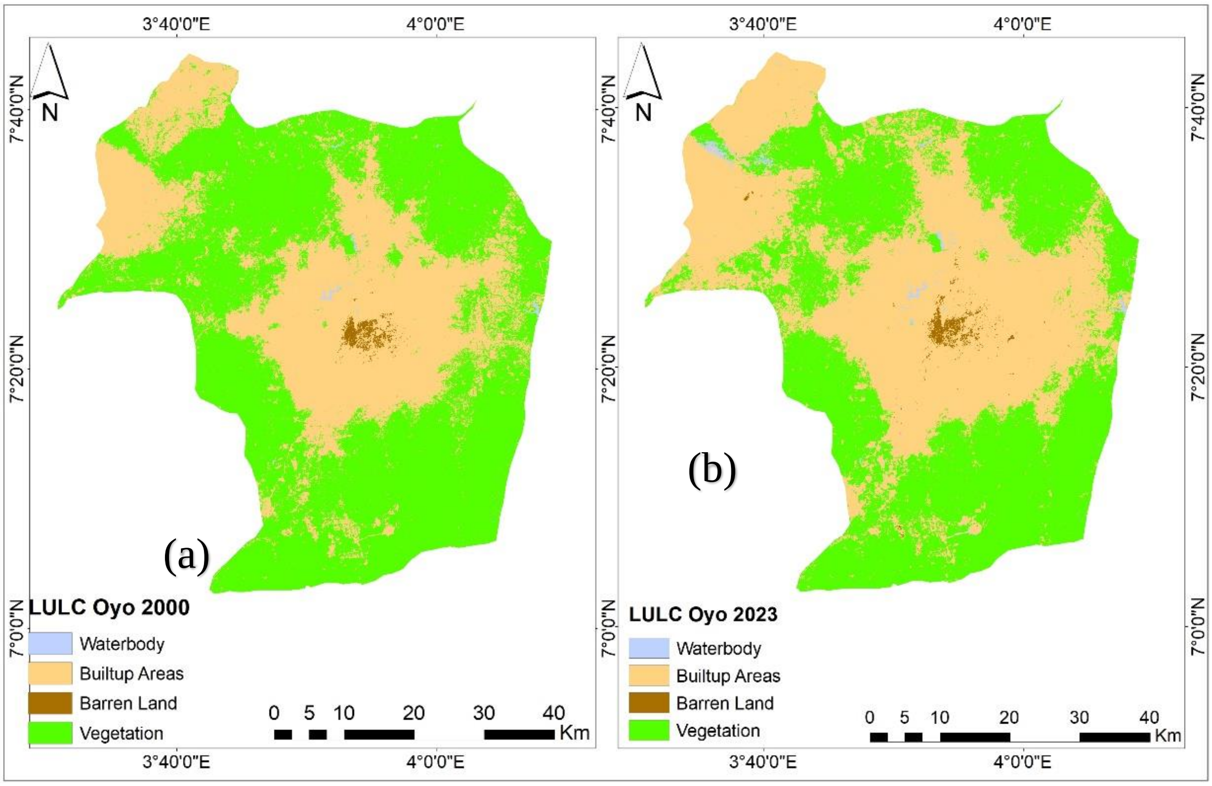


Figure 2: Land Use/Land Cover Change for Oyo in 2000 and 2023

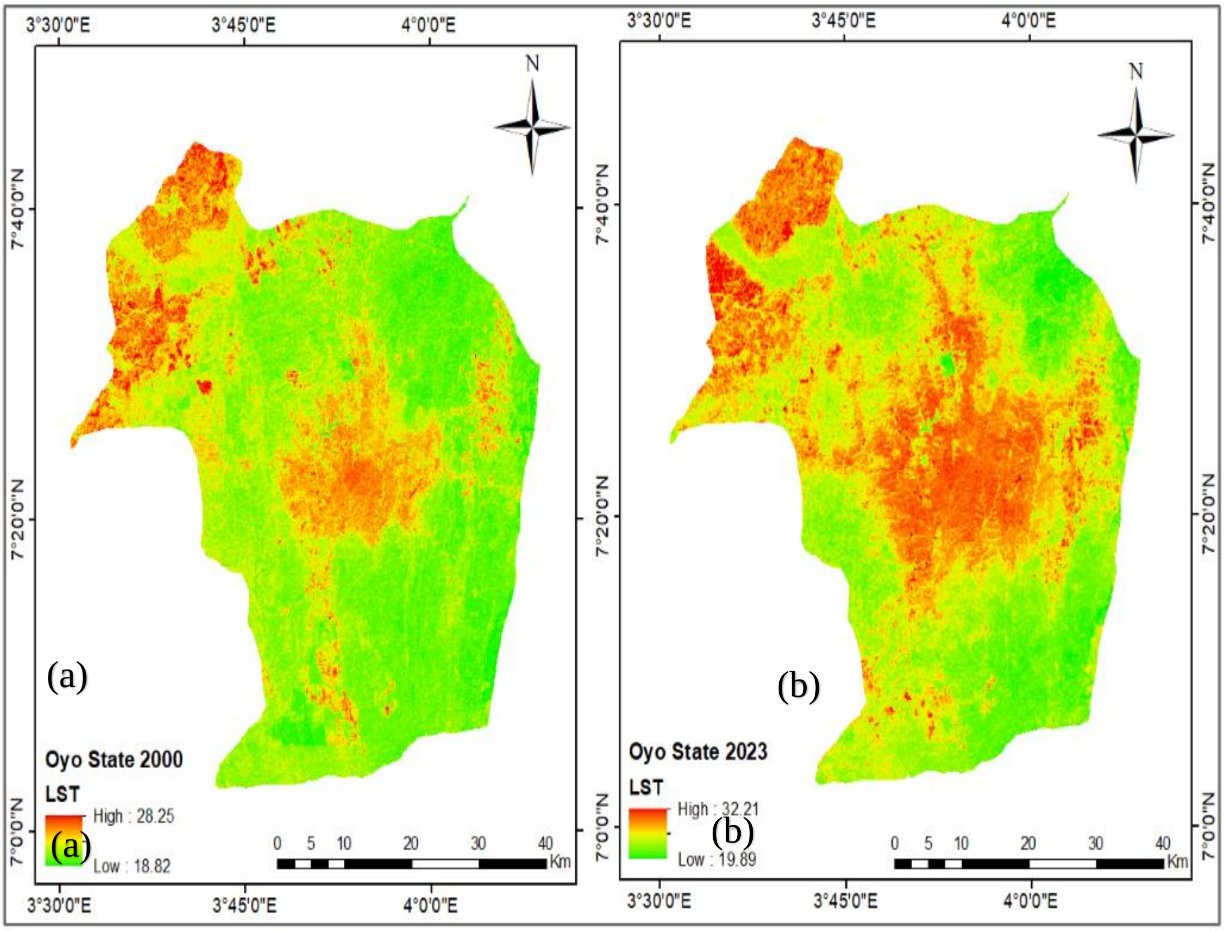


Figure 3: Land Surface Temperature of Oyo State in 2000 and 2023

Table 1: Table showing the percentage coverage of Land Use/ Land Cover for Lagos and Oyo Metropolis in 2000 and 2023

Land Use/ Land Cover	2000 Km^2 (%)	2023 Km^2 (%)
Barren Land	15.35 (0.48)	18.95 (0.59)
Built-up Areas	1234.28 (38.51)	1609.28 (50.20)
Vegetation	1949.51 (60.82)	1556.03 (48.54)
Waterbody	6.31 (0.20)	21.21 (0.66)
Total	3205.46 (100)	3205.47 (100)

Figure 2 (a) and (b) showed the Land Use/ Land Cover change map of Ibadan in year 2000 and 2023. The variation in the study areas were clearly visible on the map during the period of years studied. From the map, there were four land class types namely Waterbody, Built-up areas, Barren land and Vegetation. These land class types spread across the study areas in varying proportions.

Table 1 showed the variation of land use/land cover change in Oyo State metropolis between 2000 and 2023. In Oyo State, 0.48%, 38.51%, 60.82% and 0.2% covered barren land, built-up areas, vegetation and waterbody respectively in figure 2(a). In figure 2(b), the study area covered 0.59%, 50.20%, 48.54% and 0.66% in the same order. This indicated that there was noticeable change in the land use/land cover type. Among the land use types, barren land, built-up areas and waterbodies rose by 0.11%, 11.69% and 0.46%, whereas vegetation reduced by 12.29%. This implied that more vegetated lands were lost and used up for building houses, while few were covered by barren land and waterbodies.

Figure 3 (a) and (b) showed the results of land surface temperature in Oyo State. It revealed that there was marked variation in temperature between the years 2000 and 2023. This showed how temperature varied in Oyo state for 23 years.

In Oyo state, land surface temperature ranged from 18.82°C to 28.25°C and 19.13°C to 32.21°C in 2000 and 2023 respectively. This revealed that there was an increase of 0.31°C in the minimum temperature range, while in the maximum temperature range, there was a 3.96°C increase within 23 years. This likewise confirmed that Oyo state is becoming warmer than it used to be 23yrs ago. Fashae *et al.,* (2020) deduced that decrease in vegetation over an area will inadvertently lead to temperature increase, which is also evident from the result obtained in this study.

Abubakar *et al.,* (2021), who assessed the land use and land cover change over Ibadan metropolis from 1999 to 2019, also noted that the increase in human activities brought marked reduction in vegetation, which been replaced with other land use features like barren land and built-up areas. Dontree (2010) confirmed that global warming increase is associated with vegetation reduction particularly around city centres as a result of heavy commercial activities contributing to greenhouse effect, such as fuel combustion used in transportation, manufacturing, commerce, etc.

The combined result of the land use/ land cover type and the land surface temperature in the study area has shown that the effect of reduced vegetation impacted on the temperature. This implied that the more the vegetation in an area, the lower the temperature becomes, while the lesser the vegetation becomes, the higher the temperature, which thus showed that an inverse relationship exist between vegetation and temperature (Fashae et al., 2020). As a result of urbanization, more vegetative lands have been cleared to give space for more infrastructures. The results showed that there was a general increase in the temperature in the state, confirming the impact of climate change as well as land use impact.

CONCLUSION AND RECOMMENDATION

The study assessed land use/land cover and land surface temperature over Ibadan metropolis within 23 years apart using the Geographic Information System (GIS) and Remote Sensing approach through the analysis of satellite images. The result categorized land use/land cover into four classes namely, built-up areas, barren land, vegetation and waterbody. Within the 23 years, built-up areas, barren land and waterbody increased while vegetation decreased significantly indicating that the land was utilized for building and other related human activities like mining. The result also showed that temperature also increased significantly within the period of the year studied which was as a result of decrease in vegetation which also confirmed that there is an inverse relationship between vegetation and temperature. Thus, the study suggests that urban forestry be practiced on barren lands using certain tree species in order to increase vegetative lands. Additionally, the state government should design well-organized layouts that accommodate trees within the streets of Ibadan Metropolis.

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