PRINT ISSN 1119-8362
Electronic ISSN 2659-1502

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 27 (9) 1995-2001 September 2023

Impact of Land Use and Land Cover on Land Surface Temperature of Oluyole Local Government, Ibadan Oyo State, Nigeria

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ABSTRACT: The replacement of natural surfaces with synthetic materials that aggravate the environment is synonymous to urban spaces. Therefore, the objective of this paper is to evaluate the impact of land use and land cover on the land surface temperature (LST) of Oluyole Local Government Area in Ibadan, Nigeria using Landsat satellite images over a 20-year period (2000-2019). Data obtained were classified using the Maximum Likelihood algorithm supervised classification to create the Land-use Land cover (LULC) maps. Thereafter, the Land Surface Temperature (LST) was retrieved using the single-channel method. The study area experienced shifts in land cover classes, including an increase in grassland (27.35%) and built-up (17.88%) areas, and a marginal decline in forest cover (1.91%). These changes corresponded to temperature variations, with an observed increase in LST of both minimum and maximum values (4.22ºC and 4.01ºC) between year 2000 and 2019 respectively. Forest conservation and sustainable land use practices are recommended to mitigate adverse climate effects associated with urban sprawl and land cover and land use change. This research contributes valuable insights for policymakers and urban planners aiming to balance development with environmental conservation and climate resilience.

DOI: https://dx.doi.org/10.4314/jasem.v27i9.15

Cite this paper as OGIDAN, O. A; FADIPE, O. B; EKAUN, A. A; ADENUGA, D. A (2023). Impact of Land Use and Land Cover on Land Surface Temperature of Oluyole Local Government, Ibadan Oyo State, Nigeria. *J. Appl. Sci. Environ. Manage.* 27 (9) 1995-2001

Dates: Received: 25 August 2023; Revised: 14 September 2023; Accepted: 21 September 2023 Published: 30 September 2023

Keywords: vegetation; built-up areas; land use; urban

Urban land use has a significant impact on regional climate, with researchers focusing on understanding the processes that contribute to climate change due to anthropogenic activities (Jahan *et al*., 2021). The regional climate change can be attributed to the conversion of natural vegetated surfaces into impermeable built-up surfaces, which is the consequence of urbanization, by replacing natural surfaces with man-made constructions such as industrial and residential buildings, roadways, parking lots, and impervious surfaces (Argueso *et al*., 2013). According to Ibrahim (2017), the replacement of natural surfaces with built-up regions has resultant effects on the amount of humidity in the air, which is directly related to atmospheric temperature. Purwanto and Kurniawan (2016) noted that the changes in land cover and land use are critical in regulating temperature. Vegetation helps ensure the ecosystem's long-term viability by sidestepping soil erosion, minimizing nutrient loss, and sustaining the hydrological cycle, as a result, land cover change has emerged as one of the key markers of environmental vulnerability (Nzoiwu *et al*., 2017). However, the land cover changes show the variations in the composition of vegetation, water, and built-up areas (Pal and Ziaul, 2017), and it affects the climate by influencing land surface albedo, evapotranspiration, surface roughness, and changing atmospheric carbon dioxide concentrations (Purwanto and Kurniawan, 2016). According to Voogt and Oke (2003), changes in land cover by virtue of urbanization increase the land surface temperature thereby altering the near-surface

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urban microclimate and influencing urban people's thermal comfort. Molotoks *et al.* (2021) opined that the increasing global population plays a huge role in the land cover changes that inadvertently lead to global warming.

Land Surface Temperature (LST) is a key variable in climate and environmental studies, and it is one of the consequences of land use land cover change (Qiu *et al*., 2018). Land cover varieties have different surface reflectance and topography, resulting in variances in the LST. As urbanization expands, the anthropogenic activities are intensified which further accelerates the modification of urban surfaces and subsequent alteration of atmospheric thermal properties (Gohain *et al*., 2021). Impervious built-up surfaces store solar heat during the day and re-radiate it at night, causing land surface temperatures to climb dramatically from late afternoon to late night (Babalola and Akinsanola, 2016). Vegetation is the primary source of humidity, and the extra heat stored in built-up surfaces combined with a lack of humidity in the air significantly enhances LST when vegetated surfaces are present and are repurposed as built-up surfaces (Igun and Williams, 2018). GIS and Remote Sensing (RS) are common techniques for investigating LULC changes and accompanying LST (Jahan *et al.*, 2021). Multispectral bands are important in remote sensing optical satellite image research for the progress of LULC change applications. Since the 1960s, multispectral Landsat images with more than three bands have been employed as source data for LULC change applications (Sicre *et al*., 2020). The global patterns of shifting land use and land cover are caused by a variety of factors. Due to cities' expanding development, different types of structures are important factors that influence land-use patterns (Acheampong *et al*., 2018). Peri-urban areas in developing nations have many challenges including a lack of logical growth patterns, unsustainable urbanisation, inadequate resource management, encroachment on marginal land, and the proliferation of informal settlements. The degradation of the environment and a poor quality of life are inextricably related to all these problems. In light of this, it is necessary to monitor the usage and cover of land in peri-urban areas. For planning, mitigating, and managing the aforementioned impacts, land use/cover analysis using remote sensing (RS) satellite data has been extensively used (Otokiti *et al*., 2020). It has also been used to document and understand the impact of urban growth. Ibadan, a fast-developing metropolitan city, is impacted by temperature change, which affects the climate, economy, farming, hydrology, and bio-geocompound. This study is important to evaluate the changes in the land cover, estimate the LST and acquire information on the effect of land cover and land use on the LST. An investigation of this nature will serve for additional examination, arrangement, and ecological maintainability. Hence, the objective of this study is to evaluate the impact of land use and land cover on the land surface temperature in Oluyole Local Government area, Ibadan Oyo State, Nigeria.

MATERIALS AND METHODS

Study Area: The study area is in Ibadan, the capital of Oyo State. It is the most populated metropolitan area in Nigeria with a population of 2,550,593 after Lagos and Kano. Also, it is one of the largest cities in Africa (National Population Census, 2006). For administrative and governance purposes, Ibadan is an embodiment of 11 Local Government Areas (LGAs).

Six of these Local Government Areas are located in peri-urban or rural areas while the remaining five are located in urban areas (Dar-Al-Handasah, 2018). Out of the six LGAs that makeup Ibadan peri-urban areas, Oluyole LGA was selected because it is a major industrial hub and the transit LGA to the commercial capital city of Nigeria, Lagos.

Oluyole LGA occupies an area of 761 sq. km. with a population of 202,725 (National Population Census, 2006). It is located approximately on Latitudes 7º3`0``N, 7º21`0``N, and Longitudes 3º42`0``E to 4º3`0``E. A handful number of manufacturing companies and quarry sites are located in the local government area as well as a major forest reserve, Onigambari Forest Reserve.

Data acquisition: Following the methodology of Ferrelli *et al*. (2018), images with high cloud cover were removed. Landsat scene 191/055 from two average time periods — 2000 (Enhanced Thematic Mapper (ETM+)) and 2019 (Operational Land Imager (OLI)/Thermal Infrared Sensor (TIRS))—was used to maximise the coverage of the available scenes. The USGS has already ortho-rectified to Level 1 and geometrically corrected these images (Gutman *et al*. 2013). The images typically cover the months of the dry season. The WGS 84 UTM Zone 31N datum and a Universal Transverse Mercator (UTM) coordinate system defines the 30 m pixel spacing of the Landsat imageries. Ground truth information were collected and combined with the images to assess the accuracy of image classification.

Land Use/ Land Cover (LULC): Landsat images were obtained from the USGS website (https://earthexplorer.usgs.gov) for the study in Ibadan. For the two LGAs, the study specifically examined Landsat satellite images between the year 2000 and 2019. After that, 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.

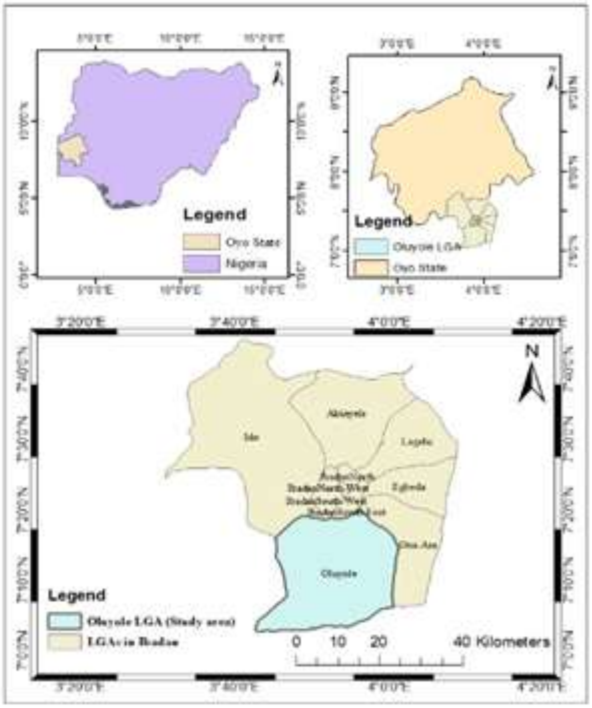

Fig 1: Map of the study area

Land Surface Temperature (LST): LST Retrieval: The retrieval of LST follow the single-channel method (Oguz 2013, Obiefuna *et al*. 2018). 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):

$$L_\lambda = \left(\frac{Lmax - Lmin}{QCal_{Max} - QCal_{Min}}\right) \times (QCal - QCal_{Min}) + L_{min}$$

Where: $L\lambda$ 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 $QCal_{Min}$, $Lmax$ is spectral radiance scaled to $QCal_{Max}$, $QCal_{Min}$ is the minimum quantized calibrated pixel value (corresponding to $Lmin$) in DN, $QCal_{Max}$ 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):

$$L_\lambda = M_L \times Q_{cal} + A_L$$

Where: M_L is Radiance multiplicative scaling factor for the band; A_L is Radiance additive scaling factor for the band.

The values for $Lmin$, $Lmax$, $QCal_{Min}$, $QCal_{Max}$, M_L and A_L were derived from the Landsat metadata file.

Conversion of spectral radiance to top-of-atmosphere (TOA) brightness temperature: After calculating the spectral radiance (L_λ), the TOA brightness temperature was calculated. The TOA approximation formula is given by Dewan and Corner (2012) and Guha *et al*. (2020):

$$T = \frac{K_2}{\log(1 + {}^{K_1}/_{L_\lambda})}$$

Where: *T* is TOA brightness temperature (K), K_1(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 (Ullah *et al*. 2019):

$$S_\tau = \frac{T}{1 + (\lambda \times {}^{T}/_{\rho}) log\varepsilon}$$

Where: *Sτ* is LST (K), *T* is TOA brightness temperature (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 = Boltzmann 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.

RESULTS AND DISCUSSION

Table 1 shows the LULC and area statistics of Oluyole LGA. The land use and land cover (LULC) categorized map from 2000 for Oluyole Local Government Area (LGA) shows that the most dominant land cover class was forest, making up 43% of the total land area. This was mostly found in the eastern and southern parts of the LGA, with some scattered in the western and northern areas. The second highest land cover class is grassland, which made up 21% of the total area and was primarily found in the eastern part of the LGA. Built-up areas, which mainly appeared in the northern part of the LGA, made up 15% of the total land area.

Table 1: LULC classes and Area statistics for Oluyole LGA by year of investigation

	2000		2019	
Classes	Area (sq. km)	%	Area (sq. km)	%
Grassland	129.79	21	165.34	26
Bare soil	88.31	14	46.78	7
Forested area	268.44	43	263.30	42
Built-up	91.36	15	107.70	17
Water bodies	46.84	7	46.84	7
Total	624.75	100	624.75	100

In 2019, the LULC categorized map for Oluyole LGA shows that the dominant land cover is forest, making up 42% of the total area, followed by grassland at 26%, built-up areas at 17%, and bare soil and water bodies at 7%. Table 2 reveals the land cover changes over the period of study. The size of these land cover classes has changed over the 20 years of the study, with the biggest increase in grassland (27.35%) followed by the built-up areas (16.34%), and there was a huge decline in the bare soil (41.53%). The forest cover marginally decreased by 1.91% while the size of the water bodies did not change.

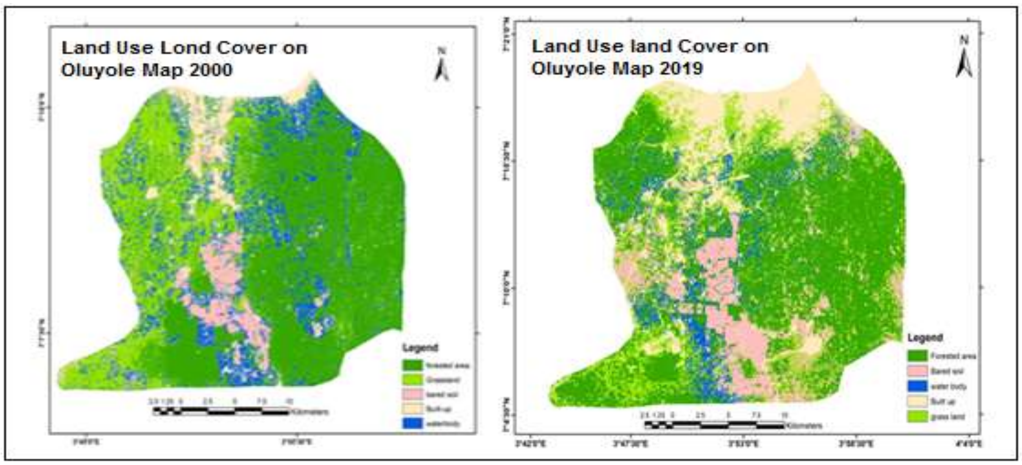

Fig 2: Classified LULC maps of Oluyole LGA 2000/2019

Table 2: Land cover changes in Oluyole LGA

Classes	Area in 2000 (sq. km)	Area in 2019 (sq. km)	Change in Area (sq.km)	Change in Area (%)
Grassland	129.79	165.34	35.55	27.35
Bare soil	88.31	46.78	-41.53	-47.03
Forest	268.44	263.30	-5.14	-1.91
Built-up	91.36	107.70	16.34	17.88
Waterbody	46.84	46.84	0.00	0.00

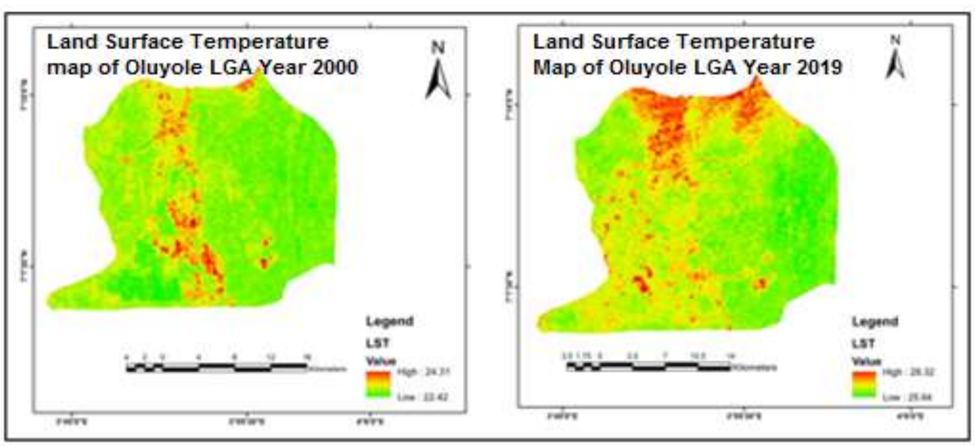

Fig 3: Map of land surface temperature in Oluyole LGA 2000/2019

The land surface temperature of Oluyole LGA ranged between 22.42ºC and 24.31ºC in year 2000 (Figure 3) compared to 25.64ºC and 28.32ºC in year 2019. This shows that there were 4.22ºC and 4.01ºC increases in the minimum and maximum land surface temperature between year 2000 and 2019 respectively. Urban expansion is a major consequence of the LULC changing process, which leads to the spatial variation of land surface temperature (Weng *et al*., 2004). It is observed that during the study period, the Oluyole Local Government Area studied experienced an increase in human settlements (due to urban sprawl) as well as an increase in grassland (mainly agricultural lands) and bare soils. The northern part of the LGA is linked to the city centre, which denote the concentration of the human settlement in the region. The built-up area in Oluyole LGA increased by 17.88%, which aligns with the findings of Idowu *et al*. (2020) in their study in Minna, Nigeria. This is expected because as peri-urban areas are developed, the demand for resources to meet human needs increases, resulting in the creation of new areas and the cultivation of fertile lands (Kleeman *et al*., 2017). The increase in the grassland cover by 27.35% can be attributed to intensification of subsistence and commercial farming in the environs, and the landscape beautification embarked by some factories in the LGA, as observed during reconnaissance survey. There was no difference in the land area covered by water bodies between 2000 and 2019, which could be due to infrastructure activities that require the conservation of water for usage. The existence of a forest reserve in the local government area can help conserve the surface water levels in the area. Hydrological processes such rainfall patterns, evaporation, infiltration, and runoff are the main factors that affect surface water cover, and the hydrological balance may continue to be largely stable despite changes in land cover, maintaining a constant water cover (Foley *et al*., 2005). Agricultural irrigation, reservoir management, and water storage are a few examples of land use techniques that can artificially maintain or control surface water cover (Mahmood *et al*., 2014). Additionally, surface water cover can be strongly impacted by climatic factors, particularly long-term precipitation patterns (Nijhawan and Howard, 2022). According to Downing *et al*. (2006), water bodies may keep their water levels constant despite changes in land cover if the study area receives consistent and enough rainfall. There was a marginal decrease in the forest cover by 1.91% in the study area, this might be due to sustainable or selective felling of trees in the forest reserve, which is contrary to Adedeji (2015) who observed a decline in the forest cover through conversion to croplands and the locals' utilization of the space for non-forest uses. Furthermore, Haastrup (2020) noted that the availability of fast-growing trees species which are easily propagated via the wind dispersal of their seeds are abundant in the Onigambari forest reserve located within the study area. The establishment of private forest reserve in the local government area as identified during reconnaissance survey can atone for the possible forest loss in the reserve. With the increase in the built environment and marginal decline in the forest cover in the study area, the minimum and maximum land surface temperature increased by 4.22^{o}C and 4.01^{o}C, this aligns with the results of numerous studies. For example, in a study carried out in Suez (Egypt), there was an increase in the land surface temperature by 4.5^{o}C between 1984 and 2014 (Ahmed 2018); an increase of 3.2^{o}C at the Galle Municipal Council (Sri Lanka) between 1996 and 2019 (Dissanayake, 2020).

Conclusion: The findings of the offer the necessary background knowledge for planning land use and sustainable development. Using Geographic Information System (GIS) and Remote Sensing tools, this study illustrates the levels and trends of peri-urbanization in Oluyole Local Government Area of Ibadan in year 2000 and 2019. It is obvious that the existing forest area and water body should be protected against further degradation to preserve the ecosystem and to prevent further negative effects from climate change in the coming years after it has been established that there has been a persistent increase in built-up land, grassland.

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