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# An Assessment of Spatio-Temporal Pattern of Land Surface Temperature (LST) in Taraba Central Senatorial District Taraba State Nigeria

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## Abstract

*This study examines the spatio-temporal variations of Land Surface Temperature (LST) in Taraba Central Senatorial District, Nigeria, from 1987 to 2022, using remote sensing and GIS techniques. The research assesses LST trends in relation to land use/land cover (LULC) changes, highlighting the impact of deforestation, agricultural expansion, and urbanization on surface temperature dynamics. Landsat satellite imagery was analyzed to retrieve LST values and detect patterns of thermal variation across different land-use types. The findings reveal a significant increase in LST over time, with a notable reduction in cooler temperature zones and an expansion of hotter areas, particularly in built-up and deforested regions. Vegetated areas maintained lower LST, underscoring the role of natural land cover in temperature regulation. These results emphasize the need for sustainable land management strategies, afforestation programs, and climate adaptation policies to mitigate rising temperatures and promote environmental sustainability. The study demonstrates the effectiveness of geospatial techniques in monitoring LST variations and provides critical insights for policymakers and environmental planners in addressing climate-related challenges in the region..*

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## Introduction

Land Surface Temperature (LST) is a crucial environmental variable that significantly influences ecological processes, climate dynamics, and human well-being. It serves as a key indicator of urbanization, land-use/land-cover (LULC) changes, and surface energy balance, making it a vital parameter for understanding environmental changes [1]. In recent decades, increasing anthropogenic activities such as deforestation, agricultural expansion, and urban devel opment have significantly altered land surface characteristics, leading to changes in LST patterns [2]. The assessment of spatio-temporal variations in LST provides essential insights into surface energy dynamics, heat distribution, and environmental sustainability, particularly in regions experiencing rapid land-use transitions.

Taraba Central Senatorial District, Nigeria, is an ecologically diverse region characterized by varying climatic conditions, topographic features, and land-use practices. However, rapid deforestation, urban expansion, and agricultural intensification in the region have led to significant modifications in land surface properties, which in turn affect LST patterns. Rising LST is often associated with land degradation, altered microclimates, and biodiversity loss, making it a critical concern for environmental management and sustainable land-use planning [3]. Understanding the spatial and temporal dynamics of LST in the region is essential for evaluating the impact of land-use changes on thermal conditions and ecosystem health.

Advancements in remote sensing and Geographic Information System (GIS) technologies have revolutionized the assessment of LST by enabling large-scale monitoring of temperature variations across different land-use types [4]. Multi-temporal satellite imagery from platforms such as Landsat and MODIS provide valuable datasets for analyzing LST trends over time, facilitating the identification of hotspots and temperature anomalies linked to land-use transformations [5]. By integrating remotely sensed data with geospatial analysis techniques, this study aims to assess the spatio-temporal patterns of LST in Taraba Central Senatorial District from 1987 to 2022, examining the relationship between LULC changes and temperature variations over the study period.

This research is significant in several ways. First, it contributes to the growing body of knowledge on land-atmosphere interactions in Nigeria, offering empirical evidence on how LST patterns are influenced by land-use dynamics. Second, it provides critical insights for climate adaptation and mitigation strategies by identifying areas vulnerable to excessive warming. Third, it supports sustainable environmental planning by informing policymakers on the implications of land transformation for regional thermal conditions. Despite the increasing attention given to LST studies globally, there remains a dearth of research on the spatio-temporal patterns of LST in Taraba Central Senatorial District, necessitating an in-depth analysis of its variations over time.

This study employs a combination of remote sensing, GIS techniques, and statistical analyses to examine the spatial and temporal variations in LST across different land-use types. It seeks to answer key research questions, including: (i) How has LST changed spatially and temporally in Taraba Central Senatorial District between 1987 and 2022? (ii) What is the relationship between LULC changes and LST variations in the study area? (iii) What are the potential environmental and socio-economic implications of LST changes in the region? The findings from this research will provide a scientific basis for developing policies aimed at mitigating temperature rise, enhancing environmental sustainability, and improving land-use management in the region.

### Statement of the Research Problem

Land Surface Temperature (LST) is a key environmental variable that reflects the thermal properties of the Earth's surface and plays a crucial role in understanding climate change, land-use dynamics, and urban heat effects [1]. Changes in LST are primarily driven by anthropogenic land-use/land-cover (LULC) modifications, such as deforestation, agricultural expansion, and urbanization, which alter the surface energy balance and contribute to regional climate variations [2]. In many developing regions, including Nigeria, rapid land-use transitions have significantly influenced LST patterns, yet there is limited empirical evidence on the extent and impact of these changes, particularly in ecologically sensitive and socio-economically important areas like Taraba Central Senatorial District.

Taraba Central Senatorial District, known for its diverse ecological landscape, is experiencing increasing pressure from land-use changes driven by population growth, agricultural intensification, and infrastructural development. These changes have profound implications for LST variations, which in turn affect local climate conditions, biodiversity, and agricultural productivity. Rising surface temperatures can exacerbate heat stress, modify precipitation patterns, and reduce soil moisture content, thereby threatening both natural ecosystems and human livelihoods [3]. Despite these concerns, there is a lack of systematic research assessing the spatio-temporal variations of LST in the region over an extended period.

Remote sensing technologies and Geographic Information System (GIS) tools have enabled large-scale monitoring of LST dynamics, providing valuable insights into how temperature patterns evolve in response to land-use changes [4]. However, studies focusing on LST trends in Taraba Central Senatorial District remain scarce, creating a knowledge gap that hinders effective climate adaptation and land-use planning strategies. Without a comprehensive assessment of LST variations over time, policymakers and environmental managers lack the necessary data to develop targeted interventions for mitigating temperature-related environmental and socio-economic challenges.

Furthermore, existing studies on LST in Nigeria have largely focused on urban centers, with limited attention given to semi-urban and rural landscapes where land-use changes also significantly alter surface thermal properties [5]. The absence of region-specific data makes it difficult to understand localized LST trends and their implications for sustainable development in Taraba State. This research, therefore, seeks to bridge this gap by examining the spatial and temporal patterns of LST in Taraba Central Senatorial District from 1987 to 2022, analyzing the relationship between LULC changes and temperature variations. The findings from this study will provide critical insights for environmental sustainability, climate resilience, and land-use policy formulation in the region.

## Conceptual Framework

The Urban Climate System Concept provides a suitable conceptual framework for assessing the spatio-temporal pattern of Land Surface Temperature (LST) in Taraba Central Senatorial District, Nigeria. This concept integrates multiple environmental and anthropogenic factors influencing surface temperatures over time, making it particularly relevant for understanding the interactions between land-use/land-cover (LULC) changes and temperature variations [6] The Urban Climate System Concept is rooted in the idea that land surface temperatures are influenced by a combination of biophysical and human-induced factors, including land-cover modifications, vegetation loss, urban expansion, and atmospheric conditions [7]. The framework posits that LST variations are driven by interactions between surface characteristics, energy fluxes, and atmospheric conditions, forming a feedback system that influences local and regional climates. The concept has been widely applied in studies examining the Urban Heat Island (UHI) effect, but its principles are equally relevant to semi-urban and rural landscapes where LULC changes significantly alter thermal properties of the land surface [8].

For this study, the Urban Climate System Concept helps to explain how changes in vegetation cover, built-up areas, and agricultural expansion affect the absorption, retention, and emission of heat energy over time. It also allows for the incorporation of satellite-based thermal remote sensing data, which is essential for analyzing LST trends in relation to LULC patterns [1]. By integrating this concept, the research will provide a comprehensive understanding of how land-use transitions contribute to temperature variations, which is crucial for environmental management, climate adaptation, and sustainable land-use planning in Taraba Central Senatorial District.

However, a notable limitation of the Urban Climate System Concept is its primary focus on urban settings, which may require modifications when applied to mixed land-use regions like Taraba Central. Additionally, the framework does not fully account for microclimatic influences such as elevation variations and local wind patterns, which can also play a role in LST fluctuations. Despite these constraints, the concept remains a robust theoretical foundation for analyzing LST patterns in response to LULC dynamics over time.

## Theoretical Framework

The Surface Energy Balance (SEB) Theory provides a suitable theoretical framework for assessing the spatio-temporal pattern of Land Surface Temperature (LST) in Taraba Central Senatorial District, Nigeria. This theory is grounded in the principles of energy exchange at the Earth's surface, explaining how different land-use/land-cover (LULC) types influence surface temperatures by modifying energy absorption, storage, and re-radiation [1,6].

The SEB theory posits that land surface temperature is primarily controlled by the balance between incoming solar radiation, outgoing terrestrial radiation, sensible and latent heat fluxes, and ground heat storage [9]. The fundamental energy balance equation can be expressed as:

Rn=H+LE+GR_n = H + LE + G

where:

- RnR_n is net radiation,
- HH is sensible heat flux (heat transferred between the surface and the atmosphere),
- LELE is latent heat flux (energy used in evaporation or transpiration), and
- GG is ground heat flux (energy stored in the subsurface).

This theory is particularly relevant to LST studies because different land-cover types (e.g., vegetation, water bodies, built-up areas) alter the energy balance in distinct ways. For instance, urbanization tends to increase HH (sensible heat) due to reduced vegetation and impervious surfaces, whereas vegetated areas enhance LELE (latent heat) by promoting evapotranspiration, which cools the surface [5,7]. In the context of Taraba Central Senatorial District, where land-use changes include agricultural expansion, deforestation, and urbanization, the SEB theory provides a structured approach to understanding how these transformations influence LST over time.

The SEB theory is widely applied in remote sensing-based LST assessments, as it enables the interpretation of thermal infrared satellite data in relation to land surface properties [4]. By integrating this theory with satellite-derived LST measurements, researchers can analyze spatial and temporal variations, identify hotspots, and assess the impact of land-use change on local microclimates.

Despite its strengths, a limitation of the SEB theory is that it does not explicitly account for complex atmospheric interactions, such as cloud cover, wind dynamics, and anthropogenic heat emissions, which can also influence LST patterns [10]. However, when combined with empirical data and geospatial analysis, the SEB framework remains a powerful tool for investigating temperature variations across different landscapes.

## Methodology

The research employed an integrated methodology combining remote sensing, Geographic Information System (GIS) techniques, and statistical analysis to assess the spatio-temporal variations of Land Surface Temperature (LST) in Taraba Central Senatorial District, Nigeria, from 1987 to 2022. The study involved multiple steps, including data acquisition, image preprocessing, LST retrieval, land use/land cover (LULC) classification, change detection analysis, and statistical evaluation. These steps ensured an accurate assessment of how LST has changed over time and its relationship with land-use transformations in the region.

The first stage involved data acquisition, which focused on obtaining multi-temporal satellite imagery from the United States Geological Survey (USGS) Earth Explorer platform. The study used three different Landsat datasets: Landsat 5 Thematic Mapper (TM) for 1987, Landsat 7 Enhanced Thematic Mapper Plus (ETM+) for 2001, and Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) for 2022. The thermal infrared (TIR) bands from these datasets were particularly crucial for extracting LST values. For Landsat 5 and 7, Band 6 (10.40–12.50 µm) was used, while for Landsat 8, Bands 10 and 11 (10.60–11.19 µm & 11.50–12.51 µm) were utilized due to their improved radiometric resolution (Sobrino et al., 2004). Additionally, a Shuttle Radar Topography Mission (SRTM) 30m Digital Elevation Model (DEM) was acquired to assess the influence of elevation on LST variations, as topographic differences can significantly affect temperature distribution (Voogt & Oke, 2003). Climatic and ancillary data were sourced from NASA Power Data Access Viewer and DivaGIS to obtain historical temperature and precipitation records, which provided a contextual understanding of climate variations in the study area. Other supporting datasets included administrative boundary shapefiles and official land-use records to ensure accurate spatial delineation of the study region.

Following data acquisition, the next critical step was image preprocessing, which was essential for ensuring data consistency and accuracy. Radiometric and atmospheric correction were performed using the Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) model in ENVI software to eliminate distortions caused by atmospheric particles, such as water vapor, aerosols, and gases. This correction was crucial for normalizing the spectral reflectance of the satellite images across different time periods [3]. Geometric correction was conducted using image-to-image registration with Ground Control Points (GCPs) to align multi-temporal images spatially. This step prevented errors that could arise due to shifts in satellite positioning over different acquisition periods. Additionally, cloud masking was carried out using the Function of Mask (Fmask) algorithm to remove cloud-contaminated pixels, ensuring that only clear-sky pixels were used for LST computation [2]. These preprocessing steps enhanced the accuracy and reliability of the extracted thermal data.

Land Surface Temperature (LST) Retrieval

Land Surface Temperature (LST) retrieval was a key component of the research and was conducted using a three-step process: conversion of Digital Numbers (DN) to spectral radiance, transformation of spectral radiance to at-satellite brightness temperature (BT), and correction for land surface emissivity (LSE). First, DN values from the thermal infrared bands were converted into spectral radiance using the equation:

$L\lambda = M\_L \times Q\_cal + A\_L$,

where $L\lambda$ represents spectral radiance, M_L is the band-specific multiplicative rescaling factor, Q_cal is the quantized DN value, and A_L is the additive rescaling factor provided in Landsat metadata [8].

Satellite images are used to retrieve LST from the earth surface. For the fact that Satellite images are subject to distortions, such images need to be reprocessed before they can be used for the purpose. Therefore, pre-processing of images is an important aspect of LST retrieval from satellite images.

## Image Pre-Processing

In raw or yet to be reprocessed images, each of the pixels has a digital number which corresponds to a particular feature or measure on the earth. To retrieve reliable LST data from these raw images, the digital number must first be converted to physical quantities, radiance and brightness temperature for the study (Giannini et al, 2015). The presence of moisture or any other particles in the atmosphere can result into atmospheric distortions on images which must be corrected before use. The images can be converted to Top of Atmosphere (TOA) radiance using the following expression (Giannini et al, 2015):

$$L_\lambda = \left( \frac{L_{MAX_\lambda} - L_{MIN_\lambda}}{Q_{cal_{MAX}}} \right) Q_{cal} + L_{MIN_\lambda} \quad (1)$$

Where:

$Q_{cal}$ is quantized calibrated pixel value in DNs.

$L_{MIN_\lambda}$ is spectral radiance corresponding to $Q_{calMIN}$ (DN = 0).

$L_{MAX_\lambda}$ is spectral radiance corresponding to $Q_{calMAX}$ (DN = 255).

In this study, Dark Object Subtraction (DOS) of the image-based correction method will be adopted because the method does not require field data collection before the correction can be effected but only the images.

Using the DOS, surface reflectance can be computed by the following expression:

$$\rho_{sup}(\lambda) = \frac{\pi\left[L_{sat}(\lambda) - L_p(\lambda)\right]d^2}{E_0(\lambda)\cos(\upsilon_z)} \quad (2)$$

$$L_p(\lambda) = L_{min}(\lambda) - L_{1\%}(\lambda),$$

$E_0(\lambda)$ is the solar atmospheric irradiance ($E_{SUN\lambda}$).

$Lmin(\lambda)$ is the radiance that corresponds to a digital count value for which the sum of all pixels with digital counts lower or equal to this value is equal to 0.01% of all the pixels from the considered image. $L_{1\%}(\lambda)$ is the dark object radiance and can be computed with following expression:

$$L_{1\%}(\lambda) = \frac{0.01.\cos(\upsilon_z).E_0(\lambda)}{\pi.d^2} \quad (3)$$

The output images are the corrected images which will be used for retrieval of LST

### Retrieval of Land Surface Temperature (LST) from Landsat TM & ETM+

Retrieval of LST from Landsat images involves two steps:
Retrieval of Satellite Brightness Temperature (BT)
Retrieval of surface emissivity (Ɛ)

### Retrieval of Satellite Brightness Temperature (BT) from Landsat TM &ETM+

According to [11], two-step processes are always involved in the processing of the brightness temperature from the Landsat-5TM images: The first step is the transformation of the digital numbers (DNs) of Band 6 into radiation luminance through the formula:

$$R_{TM6} = \frac{V}{255}(R_{max} - R_{min}) + R_{min} \quad (4)$$

Where:

V represents the DN of Band 6,

$$R_{max} = 1.896(mW * cm^{-2} * sr^{-1})$$

$$R_{min} = 0.1534(mW * cm^{-2} * sr^{-1})$$

The second step involves the transformation of the radiation luminance into at-satellite brightness temperature (BT) in Celsius (°C), using the equation:

$$BT = \frac{K1}{(In(K2/(R_{TM6}/b)+1))} - 273.15 \quad (5)$$

K1 = 1260.56K and K2 = 607.66 (mW ∗ cm−2 ∗ sr−1 μm−1 )
b represents the effective spectral range when the sensor's response is considerably higher than 50%, (b = 1.239).

### Retrieval of Satellite Brightness Temperature (BT) from Landsat 8 (OLI/TIRS)

From the Landsat user's handbook in the first step in LST retrieval from Landsat 8 is to transform the DN of the thermal infrared band into spectral radiance (Lλ) by using the following equation [11]:

$$L_{\lambda} = M_{LQcal} + A_L \quad (6)$$

Where:

- Lλ is the TOA spectral radiation in watts/ (m2 ∗ ster ∗ μm),
- $M_L$ is the band specific multiplicative rescaling factor from the metadata,
- $A_L$ is the band specific additive rescaling factor,
- $Q_{cal}$ represents the symbolized values of quantized and calibrated standard product pixels (D).

The second step is to convert the band radiance into BT in Celsius using the following conversion formula:

$$BT = \frac{K2}{In(K1/L_{\lambda}+1)} - 273.15 \quad (7)$$

Where:

BT is the satellite brightness temperature in Celsius,

K1 and K2 represent thermal conversion from the metadata

### Retrieval of Surface Emissivity (Ɛ)

Chemical composition, structure, water content, and surface roughness of the earth surface are some of the several environmental factors which control the surface emissivity [11]. opined that land surface emissivity affects the satellite measurements in three ways: emissivity causes reduction of surface emitted radiance, it makes non-black surfaces to reflect radiance and anisotropy of reflectivity and emissivity might reduce or increase total surface radiance.

Complete brightness temperature on images assumes that the earth is a blackbody, but no part of the earth is a blackbody. Therefore, brightness temperature on images can lead to errors in surface temperature. To minimize these errors, emissivity correction is important in order to retrieve reliable LST from satellite images. The following equation

$$\varepsilon = m.PV + n \quad (8)$$

Where:
m = 0.004
n = 0.986

PV is the proportion of vegetation extracted from

$$PV = \left[\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right]$$

equation:

$$NDVI = \left[\frac{NIR - RED}{NIR + RED}\right] \quad (9)$$

Where:

- NDVI is the normalized difference vegetation index.
- NDVImin = are the minimum values of the NDVI
- NDVImin = are the minimum values of the NDVI
- Emissivity of the corrected LST images will be retrieved using equation:

$$LST = \frac{BT}{1 + (\lambda(BT) * In(\varepsilon)/\rho)} \quad (10)$$

Where:

LST = Celsius,

BT = the at-sensor brightness temperature in Celsius.

λ (11.5 µm) = the emitted radiance: ρ = h ∗ c/σ = 1.438 ∗ 10− 2 mK,

σ is the Stefan–Boltzmann constant,

h is Planck's constant,

c is the velocity of light,

ε is the land surface emissivity (LSE).

Following classification, change detection and spatial analysis techniques were applied to quantify the relationship between LULC changes and LST variations. Post-classification comparison was conducted to evaluate the transformation of land-use classes over the study period, while image differencing was used to detect variations in LST by subtracting the temperature values of earlier years from later years. Change Vector Analysis (CVA) was applied to assess the magnitude and direction of LULC and LST changes, providing insights into the spatial distribution of temperature increases. Hotspot analysis was performed to identify areas with the most significant temperature rises, highlighting locations where deforestation, agricultural expansion, and urbanization had the greatest impact on thermal conditions [7]. The spatial patterns of LST were then mapped using ArcGIS software to visualize temperature variations across the study region.

To further analyze LST trends, statistical analysis was conducted using descriptive statistics, correlation analysis, and regression modeling. Descriptive statistics were used to compute mean, standard deviation, and coefficient of variation of LST values for each land-use category. Pearson correlation analysis was employed to examine the relationship between LST and NDVI, assessing how vegetation changes influenced surface temperatures. Additionally, Geographically Weighted Regression (GWR) was used to identify spatial variations in LST determinants, revealing localized factors contributing to temperature fluctuations [9]. These statistical analyses provided a quantitative understanding of the drivers of LST changes and their implications for environmental management.

By integrating remote sensing, GIS, and statistical modeling, the research provided a comprehensive assessment of how LST has evolved over time in response to land-use dynamics. The combination of multi-temporal satellite analysis, rigorous image preprocessing, advanced classification techniques, and geostatistical evaluation ensured the accuracy and reliability of the study's findings. The methodological approach adopted in this study aligns with best practices in climate change research and urban heat island studies, reinforcing the value of geospatial techniques in environmental monitoring and land-use planning.

## Result of the Findings

### Spatio-Temporal Pattern of Land Surface Temperature

This study assessed the spatio-temporal variations in Land Surface Temperature (LST) across the Taraba Central Senatorial District between 1987 and 2022 using remote sensing and GIS techniques. The findings reveal a consistent increase in LST over the study period, characterized by a substantial reduction in cooler temperature zones and an expansion of hotter areas, particularly in regions experiencing urbanization, deforestation, and agricultural expansion. The spatial distribution of LST for the years 1987, 2001, and 2022 illustrates how land use/land cover (LULC) changes have significantly influenced temperature variations.

Figure 1 in the year 1987, the north-eastern part of the study area experienced high temperature. The

Figure 1 also shows that in 1987, cooler temperature zones (10°C–20°C) covered approximately 1,169.2 km² (3.64%) of the total study area, primarily in vegetated and water-covered regions such as parts of Kurmi, Gashaka, and Sardauna Local Government Areas (LGAs). The moderate temperature range (21°C–30°C) dominated the landscape, covering 16,428.18 km² (51.16%), mainly in agricultural and forested regions. High-temperature zones (31°C–40°C) accounted for 14,452.54 km² (45.01%), while extreme heat areas (above 41°C) were almost negligible, covering only 60.76 km² (0.19%).

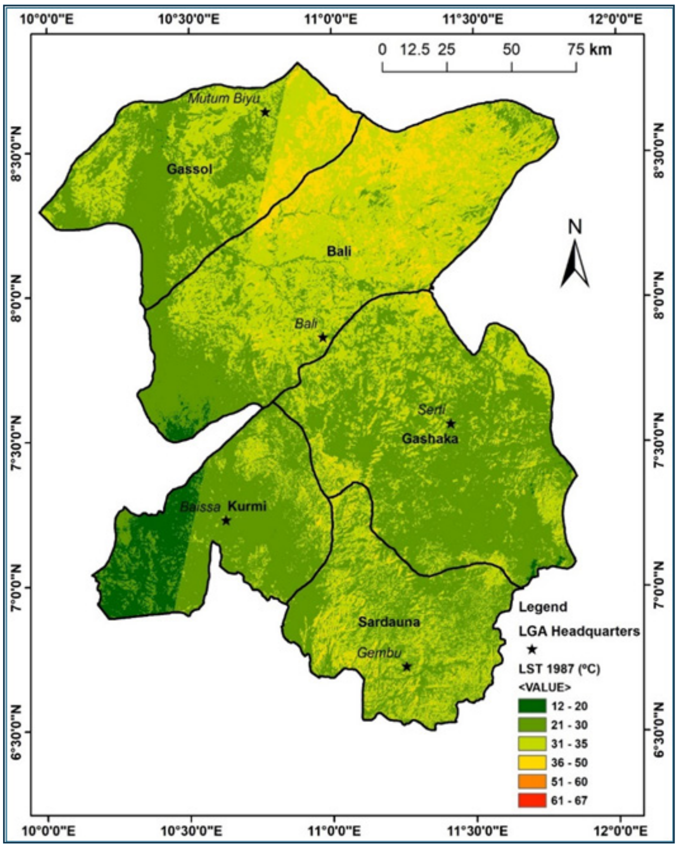


**Figure 1: Land Surface Temperature Map of 1987 Taraba Central Zone.**
**Source: GIS/RS Analysis (2024)**

However, Figure 2 shows that by 2001, the area covered by cooler temperatures had drastically reduced to 121.71 km² (0.38%), indicating a significant loss of cool zones due to land-use changes. The 21°C–30°C range expanded substantially, covering 21,604.73 km² (67.28%), likely due to the transition of forested land into agricultural fields. High-temperature areas (31°C–40°C) declined to 9,844.24 km² (30.66%), reflecting a temporary increase in land cover that retained lower temperatures. There was also a notice able expansion of extreme heat zones (41°C–50°C), which increased to 540.15 km² (1.68%), particularlyin deforested and newly developed regions.

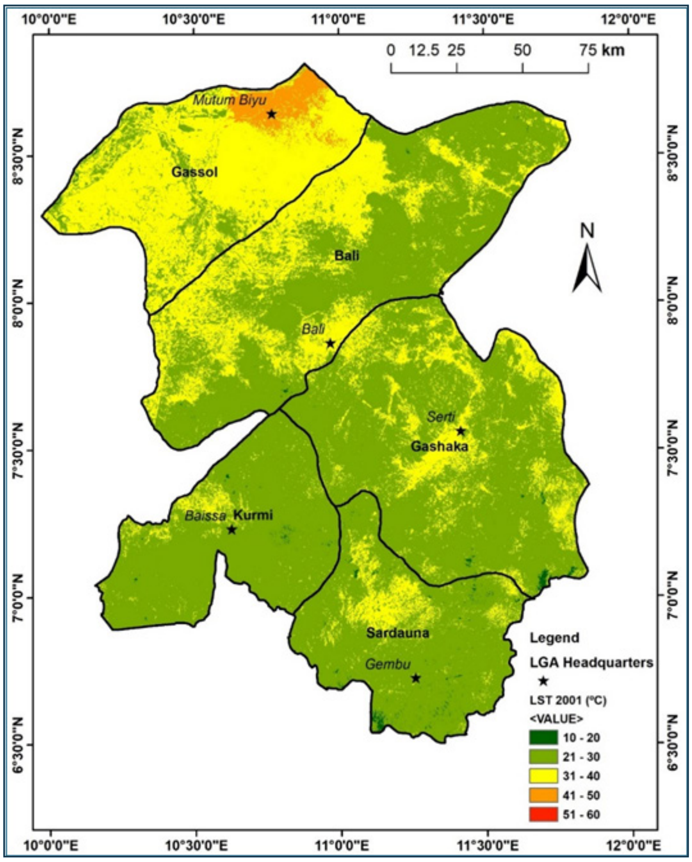


**Figure 2: Land Surface Temperature Map of 2001 Taraba Central Zone.**
**Source: GIS/RS Analysis (2024)**

The Figure 3 reveals that by 2022, the cooler temperature areas (10°C–20°C) were almost eliminated, covering only 38.77 km² (0.12%), signifying substantial warming. The 21°C–30°C range shrank to 17,477.35 km² (54.43%), suggesting a shift toward higher temperature ranges. Hotter zones (31°C–40°C) rebounded, covering 14,581.75 km² (45.41%), indicating increased land degradation and loss of vegetation cover. The extreme heat zones (41°C–50°C) declined slightly to 12.88 km² (0.04%), possibly due to changes in atmospheric conditions and local climate variability. These findings indicate a long-term warming trend, with a marked decline in low-temperature areas and an expansion of high-temperature zones, consistent with global climate change patterns [2,3].

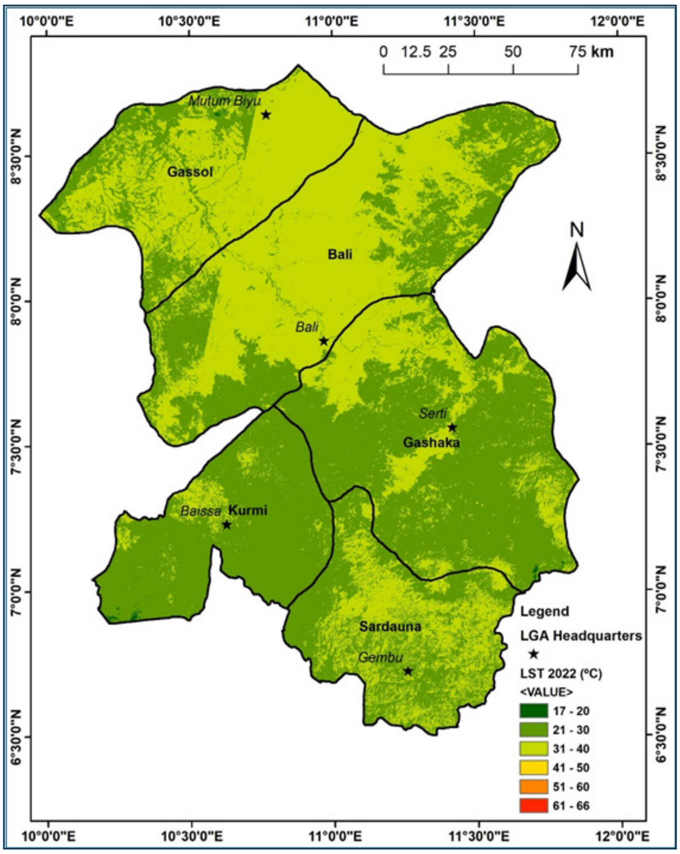


**Figure 3: Land Surface Temperature Map of 2022 Taraba Central Zone.**
**Source: GIS/RS Analysis (2024)**

The changes in LST align closely with land use/land cover transformations, driven primarily by deforestation, agricultural expansion, and urbanization. The study found that deforested areas experienced the most significant LST increases, particularly in Bali, Gashaka, and Sardauna LGAs. This pattern is consistent with previous studies that have established a strong relationship between deforestation and rising surface temperatures [1,5]. Built-up areas in Gassol, Mutum Biyu, and Jalingo have also recorded higher LST values due to impervious surfaces that absorb and retain heat, contributing to localized warming effects, similar to findings in urban heat island (UHI) studies [2]. In contrast, areas converted to farmland exhibited moderate temperatures, suggesting that croplands have a mixed effect on LST depending on vegetation cover and soil exposure. These results support the Surface Energy Balance (SEB) Theory, which explains how variations in land cover influence temperature by altering the balance between absorbed solar radiation and emitted heat energy [6].

Spatial analysis of LST hotspots in Table 1 revealed progressive warming trends, with significant changes in temperature distribution over the decades. In 1987, the coolest regions were concentrated in Kurmi, Sardauna, and parts of Gashaka, while hotspots were found in the northeastern part of the study area. By 2001, the northwestern and northern regions, particularly Gassol LGA, Mutum Biyu, Namnai, and Tutare, had become the most heated zones due to increased deforestation and land conversion. In 2022, LST hotspots had expanded, with the northeast and northwest regions exhibiting the highest temperatures, while low-temperature areas were restricted to a few pockets in Kurmi, Gashaka, and Sardauna. These findings align with global observations that vegetation loss and urbanization contribute to localized heating, reinforcing the urban heat island effect [7].

**Table 1: Spatial coverage of 1987, 2001 and 2022 LST**

| LST Range | 1987 in km² | 2001 in km² | 2022 in km² | 1987 in (%) | 2001 in (%) | 2022 in (%) |
|---|---|---|---|---|---|---|
| 10ºC-20ºC | 1169.2 | 121.7135 | 38.7666 | 3.64 | 0.38 | 0.12 |
| 21ºC - 30ºC | 16428.18 | 21604.73 | 17477.35 | 51.16 | 67.28 | 54.43 |
| 31ºC - 40ºC | 14452.54 | 9844.238 | 14581.75 | 45.01 | 30.66 | 45.41 |
| 41ºC - 50ºC | 60.761 | 540.148 | 12.8828 | 0.19 | 1.68 | 0.0401 |
| 51ºC - 60ºC | 0.1053 | 0 | 0.0684 | 0.00032 | 0 | 0.00021 |
| >61ºC | 0.0441 | 0 | 0.0117 | 0.00013 | 0 | 0.00004 |
| Total | 32110.83 | 32110.83 | 32110.83 | 100 | 100 | 100 |

**Source: Data Analysis, 2024.**

Statistical analysis of LST variability, as presented in Table 1, further highlights the spatial and temporal shifts in temperature ranges. The cooler temperature range (10°C–20°C) declined significantly from 3.64% of the total area in 1987 to only 0.12% in 2022. The moderate temperature range (21°C–30°C) peaked in 2001 at 67.28% but declined to 54.43% in 2022, indicating a transition toward higher temperatures. Meanwhile, the hotter temperature range (31°C–40°C) increased from 30.66% in 2001 to 45.41% in 2022, confirming a progressive warming trend. These findings are consistent with research by [4] who observed similar LST increases in regions undergoing rapid deforestation and urbanization.

The results of this study demonstrate a significant warming trend in Taraba Central Senatorial District over the past three decades, largely driven by land-use changes, deforestation, and urban expansion. The loss of cooler temperature zones and the expansion of hotter areas highlight the urgent need for climate adaptation strategies, including reforestation, sustainable land management, and urban greening programs. The findings provide a scientific basis for policy interventions aimed at mitigating the effects of rising temperatures in the region. Future research should incorporate climate modeling and socio-economic factors to provide a more holistic understanding of LST dynamics and their broader implications for environmental sustainability.

## Discussion of the Findings

The findings of this study reveal a significant increase in Land Surface Temperature (LST) across the Taraba Central Senatorial District between 1987 and 2022. The spatial distribution of LST indicates a reduction in cooler areas (10°C–20°C) and an expansion of hotter zones (31°C–40°C), particularly in urban and deforested regions. These results align with previous studies that have demonstrated the impact of land use/land cover (LULC) changes on surface temperature dynamics [1,3].

## LST Trends and Land Use/Land Cover Changes

The study's findings show that areas experiencing urbanization and agricultural expansion exhibit higher LST values, while forested and vegetated regions maintain lower temperatures. This pattern is consistent with the results of who reported that deforestation and impervious surface expansion contribute to increased heat retention. Similarly, [2,5] found a strong correlation between LST rise and vegetation loss in urban areas. The study also supports the Urban Climate System Concept, which explains how human-induced land modifications influence thermal conditions [7].

The increase in LST observed in Taraba aligns with global trends. Studies in China and India have shown that rapid land-use changes lead to significant temperature increases [2,8]. However, while global research has focused primarily on urban heat island (UHI) effects, this study highlights LST changes in a mixed landscape of urban, semi-urban, and rural environments. The findings also differ from research in some temperate regions, where afforestation and climate policies have helped mitigate LST increases [4].

## Implications for Climate and Environmental Management

The progressive warming trend in Taraba Central poses environmental and socio-economic challenges, including heat stress, reduced agricultural productivity, and biodiversity loss. Similar studies have shown that rising LST can lead to increased evapotranspiration rates and soil moisture depletion, exacerbating drought conditions [9]. This highlights the need for targeted climate adaptation strategies, such as afforestation programs and sustainable land-use policies. Overall, the study reinforces the critical role of remote sensing and GIS in assessing LST variations. The observed LST trends emphasize the urgency of adopting climate-smart land management practices to mitigate further warming.

## Conclusion

This study examined the spatio-temporal patterns of Land Surface Temperature (LST) in Taraba Central Senatorial District from 1987 to 2022. The findings indicate a significant rise in LST over the years, with a decline in cooler areas and an increase in hotter zones. These changes are strongly linked to deforestation, agricultural expansion, and urbanization, which have altered the land surface properties, leading to increased heat absorption and retention. The results show that vegetated areas and water bodies consistently maintained lower LST, while built-up and bare land experienced significant temperature increases. The expansion of high-temperature zones suggests a growing environmental challenge, potentially affecting local climate, biodiversity, and livelihoods. This study highlights the critical role of geospatial techniques in monitoring land-use changes and their thermal effects. To mitigate rising temperatures, sustainable land management strategies, afforestation programs, and climate adaptation policies should be prioritized.

## Recommendations

Based on the Findings of the Study, the Following Recommendations are Made:

- Afforestation and Reforestation Programs: To mitigate rising land surface temperatures, large-scale tree planting initiatives should be promoted, particularly in areas experiencing significant vegetation loss. Native tree species should be prioritized to enhance carbon sequestration and reduce surface heating.
- Sustainable Land Use Planning: Urban expansion and agricultural activities should be regulated through proper zoning and environmental impact assessments. Policies should encourage green infrastructure development, such as urban parks and green belts, to moderate temperature in creases.
- Enhanced Agricultural Practices: Farmers should adopt climate-smart agricultural techniques, such as agroforestry, conservation tillage, and cover cropping, to minimize land degradation and surface temperature rise. Incentives should be provided for sustainable land management.
- Geospatial Monitoring and Climate Data Integration: Regular use of remote sensing and GIS tools should be institutionalized to monitor LST trends and land-use changes. These data should inform climate adaptation strategies and early warning systems for environmental degradation.
- Public Awareness and Policy Implementation: Government agencies and stakeholders should increase public awareness of the effects of land-use changes on LST. Strict enforcement of environmental regulations, coupled with community-based initiatives, will promote sustainable land management practices.

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