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Assessment of the Impact of Changes in Land-use Land-Cover and Land Surface Temperature on Vegetal Resources in Taraba State Central Zone Nigeria (1987 to 2022)

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Abstract

This study assesses the impact of land-use and land-cover (LULC) changes and land surface temperature (LST) variations on vegetal resources in the Taraba State Central Zone, Nigeria, from 1987 to 2022. Using multi-temporal remote sensing data and geospatial analysis, the research examines LULC transformations, temperature dynamics, and their implications for vegetation health and distribution. Findings reveal significant deforestation, agricultural expansion, and urbanization, leading to a marked decline in vegetal cover. Built-up areas and bare land increased, contributing to higher LST, particularly in urbanized and deforested regions. A weakening correlation between the Normalized Difference Vegetation Index (NDVI) and LST over time suggests that other environmental factors, including climate change and land degradation, are influencing temperature patterns beyond vegetation loss. The study also finds that elevation-related temperature regulation has diminished, indicating that anthropogenic activities now play a more dominant role in temperature variations. These changes have resulted in biodiversity loss, increased soil degradation, and disrupted hydrological cycles, adversely affecting ecosystem stability and local livelihoods. Comparisons with previous studies indicate alignment with global trends of urban heat islands and deforestation-driven warming, though variations exist due to limited afforestation efforts and regional socio-economic dynamics. The study underscores the need for sustainable land management, afforestation programs, and climate adaptation strategies to mitigate environmental degradation. These findings provide critical insights for policymakers and environmental planners in addressing climate-induced vegetation changes in Nigeria's savanna-forest transition zone.

Keywords: Deforestation, Land-use and Land-cover Change, Land Surface Temperature, Vegetal Resources, Sustainable Land Management.

Introduction

Land-use and land-cover (LULC) changes have profound environmental, ecological, and socio-economic implications, particularly in regions where rapid anthropogenic activities alter natural landscapes. These changes influence land surface temperature (LST) dynamics, thereby affecting the composition, distribution, and productivity of vegetal resources [1]. In sub-Saharan Africa, including Nigeria, deforestation, urbanization, agricultural expansion, and infrastructure development have significantly altered the LULC patterns, leading to an increase in LST and subsequent ecological transformations [2, 3]. The Taraba State Central Zone, situated in the transitional belt between Nigeria's Sudan and Guinea savanna biomes, has witnessed extensive land-use transformations over the past three decades, yet the extent to which these changes have impacted vegetal resources remains poorly understood.

Changes in LULC alter surface albedo, evapotranspiration rates, and soil moisture content, all of which regulate LST [4]. For instance, the conversion of forested or vegetated landscapes to impervious surfaces such as roads and settlements reduces heat dissipation, resulting in elevated LST [5]. Conversely, afforestation and reforestation initiatives contribute to localized cooling effects through increased transpiration and shading [6]. These thermal variations directly influence vegetation phenology, species composition, and biomass productivity, ultimately affecting ecosystem services such as carbon sequestration, habitat provision, and soil stability [7]. The interplay between LULC dynamics, LST, and vegetal resources is particularly relevant in Taraba State, where agriculture and forestry are central to local livelihoods and biodiversity conservation efforts.

Despite global advancements in remote sensing and geospatial analytics for monitoring land-use transformations, empirical assessments of LULC-LST interactions and their ecological consequences remain sparse in Nigeria. Previous studies have primarily focused on broad LULC trends or LST variations independently, without explicitly linking these changes to the health and distribution of vegetal resources [8, 9]. This gap underscores the need for integrated geospatial analyses that quantify LULC transitions, model their impact on LST, and assess the resultant effects on vegetation within Taraba's central ecological zone.

This study aims to assess the impact of LULC changes and LST variations on vegetal resources in the Taraba State Central Zone between 1987 and 2022. Specifically, it seeks to (i) analyze spatiotemporal LULC changes using multi-temporal remote sensing data, (ii) examine LST variations in response to LULC transformations, and (iii) evaluate the implications of these changes on vegetal resource availability and sustainability. The findings will provide critical insights for environmental management, land-use planning, and climate adaptation strategies in Nigeria's savanna-forest transition zone.

Statement of the Research Problem

Land-use and land-cover (LULC) changes, driven by anthropogenic activities and natural processes, have significant implications for ecosystems, climate patterns, and biodiversity [2, 10]. In Nigeria, rapid urbanization, agricultural expansion, deforestation, and infrastructural development have altered the natural landscape, affecting land surface temperature (LST) and leading to profound ecological consequences [8, 9]. The Taraba State Central Zone, characterized by diverse vegetation ranging from Guinea savanna to forested areas, has witnessed extensive LULC transformations over the past three decades. However, the extent to which these changes impact LST and consequently affect vegetal resources remains poorly understood.

LULC changes influence land-atmosphere interactions by modifying albedo, evapotranspiration, and surface roughness, which in turn regulate LST [3, 4]. Deforestation and land conversion to agricultural and urban uses generally increase LST, leading to altered microclimatic conditions that affect vegetation health, growth patterns, and biomass productivity [5, 6]. Higher LST accelerates evapotranspiration, exacerbates soil moisture loss, and contributes to heat stress in plants, potentially reducing species diversity and ecosystem resilience [7]. In semi-arid and transitional zones like central Taraba, where vegetation plays a crucial role in sustaining local livelihoods and regulating regional climate, such shifts can have long-term ecological and socio-economic consequences.

Despite the critical role of vegetal resources in biodiversity conservation, carbon sequestration, and rural economies, there is a limited understanding of how LULC-driven LST variations impact vegetation dynamics in the Taraba State Central Zone. Existing studies in Nigeria have primarily examined either LULC changes or LST trends without explicitly linking these factors to vegetation health and distribution [8, 11]. Furthermore, few studies employ long-term multi-temporal geospatial analyses to assess these interactions comprehensively.

This research addresses a crucial gap by integrating geospatial techniques, remote sensing, and ecological assessments to examine the spatiotemporal impacts of LULC changes and LST variations on vegetal resources between 1987 and 2022. It seeks to provide empirical insights into how human-induced landscape modifications alter the thermal environment and affect vegetation productivity and sustainability in the region. Given the increasing environmental pressures due to climate change and land-use intensification, understanding these dynamics is essential for developing targeted conservation strategies, sustainable land management policies, and climate adaptation frameworks in Taraba State and similar ecologically sensitive regions in sub-Saharan Africa.

Conceptual Framework

This study is anchored on the Coupled Human-Environment System Framework which is a widely recognized approach for analyzing the interactions between human and natural systems [12]. It provides a structured methodology for understanding the reciprocal relationship between human-induced land-use and land-cover (LULC) changes, environmental processes such as land surface temperature (LST) variations, and their effects on vegetal resources. In the context of this study ''Assessment of the Impact of Changes in Land-use Land-cover and Land Surface Temperature on Vegetal Resources in Taraba State Central Zone, Nigeria (1987–2022)'' this framework is relevant for examining how anthropogenic activities (e.g., deforestation, agriculture, and urban expansion) interact with climate dynamics to influence vegetation patterns. By using the Coupled Human-Environment System Framework, this study integrates remote sensing, GIS, and ecological assessments to evaluate how LULC changes modify LST and, in turn, affect vegetation distribution, species composition, and biomass productivity in Taraba State.

The Coupled Human-Environment System Framework is based on three key principles: (1) Bidirectional Interactions, where human activities alter environmental conditions, and these environmental changes, in turn, affect human behaviors and land-use decisions (2) Feedback Loops, where changes in land use (e.g., deforestation for agriculture) lead to temperature variations, which then affect vegetation cover and ecosystem services, potentially influencing further human land-use choices; and (3) Spatial and Temporal Scales, which account for environmental changes occurring at multiple scales (local, regional, and global) and over extended periods [12, 13]. Applying this framework to LULC change and vegetation dynamics in Taraba State enables an assessment of historical trends (1987–2022), spatial heterogeneity, and feedback effects in land-use decisions and climate conditions.

The interactions between LULC changes, LST variations, and vegetal resources in Taraba State can be structured as follows:

(1) Human Drivers of LULC Change, including agricultural expansion (conversion of forests and grasslands to farmlands due to population growth and food demand), urbanization (expansion of settlements and infrastructure leading to impervious surfaces that increase LST), deforestation (logging for timber and fuelwood extraction, reducing vegetation cover), and policy and socioeconomic factors (government policies, land tenure systems, and economic activities influencing land-use decisions). (2) Environmental Consequences (Land Surface Temperature Changes), where increased LST results from urban expansion and deforestation reducing evapotranspiration, and altered microclimate conditions affect regional climate patterns. (3) Impacts on Vegetal Resources, including vegetation stress and productivity decline due to higher temperatures increasing evapotranspiration rates, leading to moisture stress and reduced biomass, loss of biodiversity through habitat destruction and fragmentation altering species composition, and changes in ecosystem services such as decreased vegetation cover affecting carbon sequestration, soil stabilization, and hydrological balance [7]. By structuring the study within this framework, it becomes possible to analyze how human-induced land changes influence vegetation through the intermediary effect of LST variations.

The Coupled Human-Environment System Framework is particularly suited for this study because (1) It Integrates Human and Environmental Factors, allowing for an analysis of socio-economic, policy-driven, and natural processes influencing vegetation change; (2) It Provides a Long-Term Perspective, accommodating the study period (1987–2022) and temporal changes in feedback mechanisms; (3) It Supports Multi-Scale Analysis, enabling examination at local (Taraba State), regional (Nigeria), and global (climate change implications) scales; and (4) It Aligns with Remote Sensing and GIS Applications, making it ideal for spatial analysis of land-use and temperature changes.

While the Coupled Human-Environment System Framework provides a comprehensive approach, it has several limitations. First, Complexity of Interactions—the framework involves multiple interdependent variables, making it difficult to establish direct causal relationships. Second, Data Limitations—accurate long-term data on socio-economic drivers (e.g., land tenure changes, policy shifts) may be scarce, affecting model accuracy. Third, Uncertainty in Climate Feedbacks—the impact of LST on vegetation is also influenced by external climate factors (e.g., rainfall variability), which the framework does not fully isolate. Fourth, Policy Implementation Challenges—while the framework highlights human-environment linkages, it does not inherently suggest specific governance or mitigation strategies. Despite these limitations, the framework remains highly applicable due to its integrative nature, enabling a holistic understanding of LULC dynamics, temperature changes, and vegetation responses in Taraba State.

The Coupled Human-Environment System Framework provides a robust foundation for analyzing the interrelationships between land-use land-cover changes, land surface temperature variations, and vegetation resources in Taraba State. By employing this framework, the study captures the complex feedback loops between anthropogenic activities, climate dynamics, and ecological responses, offering insights into sustainable land management. This study contributes to environmental and climate change research by quantifying these linkages using geospatial techniques, remote sensing, and ecological assessments, ultimately informing policy recommendations for sustainable land-use planning and vegetation conservation in Taraba State and beyond.

Theoretical Framework

The Land Change Science (LCS) Theory provides a robust theoretical foundation for analyzing the drivers, processes, and consequences of land-use and land-cover (LULC) changes and their environmental impacts, including alterations in land surface temperature (LST) and vegetation dynamics [13, 14]. This theory, which emerged from the interdisciplinary field of land system science, posits that land-use transitions result from complex interactions between socio-economic, political, and environmental factors, leading to cascading effects on ecosystems. It is particularly relevant to this study as it provides an analytical framework to assess how human activities such as deforestation, urban expansion, and agricultural intensification drive LULC changes, influence LST, and subsequently affect vegetal resources in Taraba State.

LCS theory emphasizes three core components: Patterns of Land-Use and Land-Cover Change, which examines how land transitions manifest over space and time, aligning with the study's temporal analysis (1987–2022) using geospatial techniques; Drivers of Change, which identifies anthropogenic (e.g., population growth, economic activities, land policies) and environmental (e.g., climate variability, soil degradation) forces shaping land transformation; and Consequences of Land Change, which provides a foundation for assessing the environmental effects of LULC changes, including shifts in LST and their impact on vegetation health, productivity, and biodiversity [13]. By applying LCS theory, this study investigates the interplay between human-induced LULC changes, LST variations, and their ecological consequences on vegetation resources. This aligns with previous research demonstrating that deforestation and urban expansion increase LST, thereby exacerbating vegetation stress and altering ecosystem functionality [5].

In this study, LCS theory is employed to characterize spatio-temporal LULC changes from 1987 to 2022 using remote sensing and GIS, examine the influence of LULC on LST by evaluating how different land-use types contribute to LST variations and their influence on vegetation conditions, and assess the ecological consequences on vegetation resources by linking land transitions and temperature changes to vegetation health, productivity, and ecosystem services. The strengths of LCS theory include its integrative approach, which considers both human and environmental drivers of land change, its spatial and temporal scalability, making it ideal for long-term geospatial studies, and its applicability to policy and land management, providing a basis for sustainable land-use planning. However, its limitations include the difficulty in isolating direct causality due to multiple interacting factors such as rainfall variability and soil conditions, the challenges of data availability, particularly for historical socio-economic drivers, and its limited prescriptive capacity, as it focuses on analysis rather than policy solutions.

Despite these constraints, LCS theory remains a robust theoretical foundation for this study as it provides a structured approach for examining how LULC changes, mediated by LST variations, impact vegetal resources over time. By integrating remote sensing, GIS, and ecological assessment within the LCS framework, this research contributes to advancing knowledge on land transformation dynamics and their implications for ecosystem sustainability in Taraba State.

Methodology

This study integrates remote sensing, geographic information system (GIS) techniques, field surveys, and statistical analyses to assess the impact of changes in land-use land-cover (LULC) and land surface temperature (LST) on vegetal resources over a 35-year period (1987–2022). A longitudinal research design is adopted to analyze spatiotemporal changes in LULC and LST and their implications for vegetation health. The methodology is structured into three major phases: land-use land-cover classification and change detection, land surface temperature estimation and trend analysis, and assessment of the impact on vegetal resources.

Multi-temporal satellite imagery is obtained from reliable sources, including Landsat Thematic Mapper (TM) for 1987 and 2000, Enhanced Thematic Mapper Plus (ETM+) for 2010, and Operational Land Imager (OLI) for 2022, all sourced from the United States Geological Survey (USGS) Earth Explorer. MODIS Land Surface Temperature (MOD11A2 V6) data is incorporated to complement Landsat-derived LST measurements, ensuring consistency in temperature trend analysis. Climate data is sourced from the Nigerian Meteorological Agency (NiMet) to evaluate correlations between climate variability and observed LST trends. Ancillary datasets such as topographic maps from the Nigerian Survey Department are used for terrain correction, while vegetation indices such as the Normalized Difference Vegetation Index (NDVI) from MODIS and Landsat are employed to assess vegetation dynamics. Field survey data is collected through GPS-based validation of LULC classes, ground-truthing of vegetation health, and direct field observations [14].

Software and Tools Used

The study utilized ArcGIS 10.8 and ENVI 5.3 for image classification, LST calculations, and spatial analysis. MODIS LST data was processed using Google Earth Engine. Statistical analysis was conducted in SPSS 26 and Microsoft Excel, while field validation was supported by GPS handheld devices. Remote sensing indices such as NDVI, NDBI, and NDWI were computed using Raster Calculator in ArcGIS.

Land-Use Land-Cover Classification and Change Detection

Preprocessing of satellite imagery was carried out to correct for atmospheric distortions, radiometric errors, and geometric misalignments. The images were subsetted to focus on the study area, and cloud masking techniques were applied to improve classification accuracy. A supervised classification approach using the Maximum Likelihood Classification (MLC) algorithm was implemented in ArcGIS 10.8 and ENVI 5.3 software to classify LULC types into four broad categories: vegetation, bare surface, built-up areas, and water bodies. Training samples were selected for each LULC class based on prior knowledge of the area and field observations. The classification accuracy was assessed using a confusion matrix, and the Kappa coefficient was computed to measure classification reliability. Post-classification change detection analysis was performed using a pixel-based approach, generating transition matrices to quantify LULC changes over time. The Normalized Difference Built-up Index (NDBI) was used to extract built-up areas, while the Normalized Difference Water Index (NDWI) was used to delineate water bodies.

Land Surface Temperature (LST) Estimation and Trend Analysis

LST was estimated from Landsat thermal infrared (TIR) bands using a three-step process: (1) conversion of digital numbers (DN) to spectral radiance, (2) conversion of radiance to brightness temperature, and (3) application of emissivity correction to derive land surface temperature. The conversion of DN to spectral radiance was carried out using the radiometric rescaling equation:

The digital number (DN) to radiance LTM conversion

$$LTM = 0.124+0.00563\times DN$$

The radiance to equivalent blackbody temperature TTMSurface at the satellite using.

$$TTMSurface = [K2/(K1\text{-}\ln LTM)] -273$$

The coefficients K1 and K2 depend on the range of blackbody temperatures, for Landsat TM.

The additional correction for spectral emissivity (ε) which is required to account for the non-uniform emissivity of the land surface will be carried out using surface emissivity for the specified land covers derived from the land cover analysis. The emissivity corrected land surface temperature (Ts) will then be computed as stated by Setturu et al., (2014).

$$Ts = T\_B/(1+(\lambda\times T\_(B\ )/\rho)\ln).$$

where, λ is the wavelength of emitted radiance for which the peak response and the average of the limiting wavelengths, $\rho = h\times c\ \sigma\ (1.438.\ 10^{-2}\ m\cdot K)$, σ=Stefan Boltzmann's constant (5.67×10^{-8} Wm-2 K-4=1.38 × 10-23 J/K), h=Planck's constant (6.626 × 10-34 Jsec), c=velocity of light (2.998×10^{8} m/sec), and ε is spectral emissivity. T_B will be obtained using the equation below

Where; TB is effective at-satellite temperature in degree Kelvin, Lλ is the spectral radiance in W/m2/sr/μm, K2 and K1 are prelaunch calibration constants, the value for this constant.

Vegetation and Ecological Assessments

The impact of LULC and LST changes on vegetation was assessed using the Normalized Difference Vegetation Index (NDVI), which was computed from Landsat bands using the formula:
For Landsat TM and ETM+:

Where:
IR = Infrared Band (Band 4)
R = Red Band (Band 3)
The formula and the bands are therefore expressed as:

For Landsat OLI:
Where:
IR = Infrared Band (Band 5)
R = Red Band (Band 4)

The formula and the bands are therefore expressed as:

NDVI values were classified into vegetation health categories: dense vegetation (NDVI > 0.5), moderate vegetation (NDVI 0.2–0.5), and sparse vegetation (NDVI < 0.2). Vegetation cover extraction was performed in ArcGIS using raster calculation techniques. The relationship between NDVI and LST was examined using regression analysis, where NDVI was treated as the independent variable and LST as the dependent variable. A negative correlation was expected, indicating that higher temperatures were associated with reduced vegetation density.

Extraction of Water body

NDWI is determined by the Green and NIR bands. Bands 2 and 4 represent the Green and NIR respectively in Landsat 5 TM and Landsat 7 ETM+ data. Bands 3 and 5 are the Green and NIR bands, respectively in Landsat 8 OLI/TIRS data. The raster calculator module of ArcGIS 5 software will be used to process the appropriate bands to extract the built-up areas in the study area through NDWI.

For Landsat TM and ETM+:

Where:

Green = Green Band (Band 2)

NIR = Near Infrared Band (Band 4)

The formula and the bands are therefore expressed as:

(3)

For Landsat 8 OLI:

Where:

Green = Green Band (Band 3)

NIR = Near Infrared Band (Band 5)

The formula and the bands are therefore expressed as:

Statistical Analysis

Descriptive statistical measures, including mean, standard deviation, and variance, were used to summarize LST and NDVI trends over time. Inferential statistical methods were employed to quantify relationships between variables. Linear regression analysis was used to examine the correlation between NDVI and LST over time using the equation:

LST=β0+β1(NDVI)+ϵLST = \beta_0 + \beta_1(NDVI) + \epsilon where β1\beta_1 represents the effect of vegetation density on LST. The coefficient of determination (R^2) was used to assess the strength of the relationship. A time-series analysis was conducted to model LST and NDVI trends from 1987 to 2022. Spatial correlation analysis was performed using geostatistical interpolation techniques in ArcGIS to identify temperature-vegetation interaction zones. Additionally, the elevation-LST relationship was examined through multiple regression models, testing whether elevation differences influenced temperature variations across the study area. The results were visualized using box plots, scatter plots, and spatial overlays in GIS.

Field Validation and Accuracy Assessment

Field validation was carried out to verify LULC classification accuracy and assess vegetation conditions. A stratified random sampling approach was used to select ground-truth points based on LULC categories. GPS coordinates of validation sites were collected and compared with classified images. The Overall Accuracy and Kappa Coefficient were computed to measure classification reliability. Vegetation health was assessed using direct field observations and spectral reflectance comparisons. Qualitative surveys were conducted with local farmers and environmental stakeholders to gather insights on observed land-use changes and their ecological effects.

Result of the Findings

The findings of this study reveal significant transformations in land-use and land-cover (LULC) patterns in Taraba State Central Zone over the study period from 1987 to 2022, with profound implications for land surface temperature (LST) and vegetal resources. The results indicate that extensive deforestation, agricultural expansion, urbanization, and land degradation have driven notable LULC changes. Vegetation cover has declined substantially over the years, with large portions of forested and savanna lands being converted to agricultural fields and built-up areas. Agricultural land has expanded rapidly as population growth and economic activities have increased the demand for food production. Similarly, urbanization has resulted in a marked increase in impervious surfaces such as roads, buildings, and other infrastructure, leading to reduced evapotranspiration and increased heat retention. The study also observed a significant rise in bare land, which is indicative of soil exposure and possible degradation due to deforestation, overgrazing, and intensive land use. These transformations highlight substantial anthropogenic pressures on the region's natural ecosystems, affecting biodiversity and environmental sustainability.

Land surface temperature (LST) analysis revealed a consistent increase in temperature over time, with notable warming trends associated with LULC changes. Areas with reduced vegetation cover, such as urban and agricultural lands, exhibited significantly higher LST values, whereas forested and vegetated regions maintained lower temperatures. The study confirmed the urban heat island (UHI) effect, where the expansion of built-up areas has resulted in localized warming, particularly in major towns and cities. The highest LST increases were recorded in areas that experienced deforestation, largely due to the loss of tree canopies that typically regulate surface temperatures through shading and evapotranspiration. The findings further indicate that as natural vegetation cover diminishes, the region becomes increasingly vulnerable to heat stress, which affects both the ecosystem and local livelihoods. The role of forests and other vegetative covers in moderating temperature is evident, but ongoing deforestation and land-use changes have considerably weakened this cooling effect over time.

Relationship between NDVI and LST

The analysis of the relationship between the Normalized Difference Vegetation Index (NDVI) and LST over three-time periods (1987, 2001, and 2022) presented in figure 1 showed a consistent inverse correlation, confirming that areas with higher vegetation density tend to have lower surface temperatures. In 1987, a moderate negative relationship was observed, indicating that vegetation played a role in regulating temperature. By 2001, this relationship became stronger, with NDVI explaining approximately 48.81% of LST variations, reinforcing the idea that denser vegetation has a significant cooling effect. However, by 2022, the correlation had weakened ($R^2 = 0.3115$), suggesting that while vegetation still influences temperature regulation, other factors such as increased urbanization, land degradation, and broader climatic changes have begun to play a more dominant role. The weakening correlation suggests a shift in the balance between vegetation and temperature control, with human-induced changes becoming more pronounced.

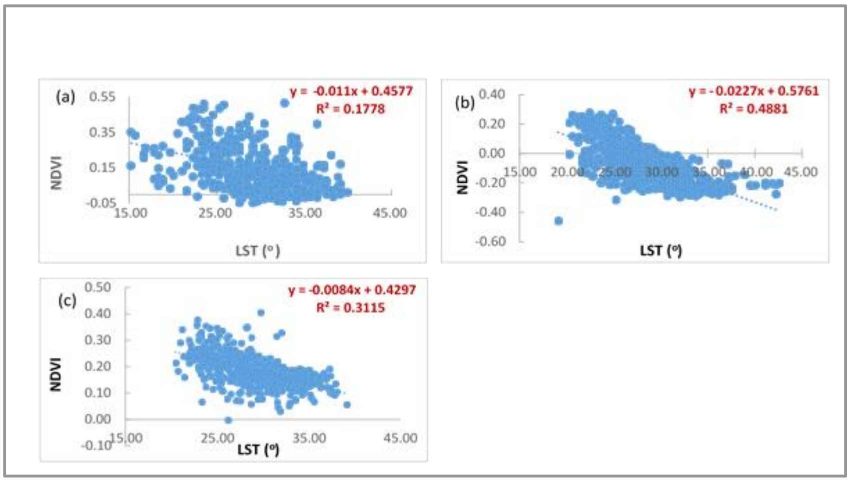

Figure 1: The relationship between NDVI values and LST (a) 1987, (b) 2001 and (c) 2022.

Relationship between Elevation(m) and LST

The regression analysis between elevation and LST in Fig. 2 revealed varying patterns over time. In 1987, there was a very weak relationship between elevation and LST, indicating that elevation had little impact on temperature variations in the region. By 2001, a strong negative correlation was observed, meaning that higher elevations experienced significantly lower temperatures. This finding aligns with the general principle that altitude influences temperature due to thinner air and lower atmospheric pressure at higher elevations. However, by 2022, the correlation had weakened again, suggesting that other environmental factors, particularly land-use changes and increased urbanization, had begun to override the cooling effects typically associated with higher elevations. The reduction in vegetation cover and the expansion of impervious surfaces have contributed to this trend, diminishing the natural cooling effect of elevation in some areas.

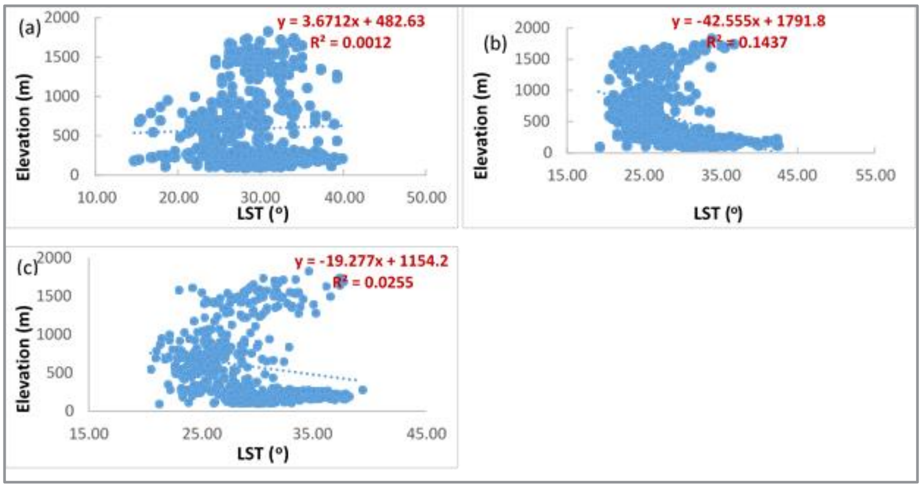

Figure 2: The relationship between Elevation values and LST (a) 1987, (b) 2001 and (c) 2022.

Relationship between Elevation(m) and NDVI

The relationship between elevation and NDVI in Fig. 3 also exhibited weak correlations across the study periods. In 1987, there was a slight positive association, with higher NDVI values observed at higher elevations, but the correlation was weak, indicating that elevation alone was not a strong determinant of vegetation density. By 2001, a similarly weak relationship persisted, suggesting that land-use changes had a more substantial impact on vegetation distribution than elevation. In 2022, a slight positive correlation was again observed, with higher NDVI values at higher elevations, but the explanatory power remained low ($R^2 = 0.0428$). This indicates that while vegetation density may be somewhat higher in elevated areas, human activities such as deforestation, agricultural expansion, and urban development are more significant drivers of vegetation loss and degradation in the region.

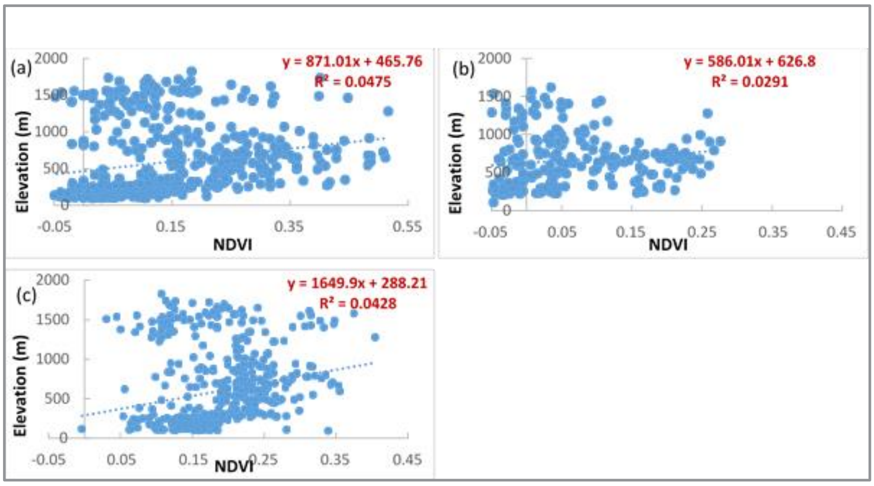

Figure 3: The relationship between Elevation values and NDVI (a) 1987, (b) 2001 and (c) 2022

The impact of these changes on vegetal resources has been profound, affecting biodiversity, soil health, and ecosystem stability. The decline in natural vegetation has led to a reduction in biodiversity, particularly in forested and savanna ecosystems where habitat loss has disrupted ecological balance. Higher LST and the expansion of bare land have contributed to increased soil degradation, reducing soil moisture levels and increasing susceptibility to erosion. These changes have also disrupted the local water cycle, affecting hydrological processes and water availability for agricultural and domestic use. Furthermore, deforestation has reduced the region's capacity for carbon sequestration, exacerbating climate change impacts. The combined effect of these changes has serious implications for local livelihoods, particularly for communities that rely on agriculture, forestry, and natural resources for sustenance and economic activities. The findings of this study underscore the urgent need for sustainable land-use planning, climate adaptation strategies, and environmental conservation efforts to mitigate the adverse effects of LULC changes and LST increases on vegetal resources in Taraba State Central Zone.

Discussion of Results

The findings of this study indicate significant changes in land-use and land-cover (LULC) patterns in the Taraba State Central Zone between 1987 and 2022, with corresponding variations in land surface temperature (LST) and their impacts on vegetal resources. These findings have notable similarities and differences when compared to previous studies, highlighting both regional and local factors that contribute to environmental changes.

One of the key findings of this research is the substantial decline in vegetation cover over the study period. This is largely driven by deforestation, agricultural expansion, and urbanization, leading to a loss of natural habitats and increased impervious surfaces. This trend aligns with the findings of Ogunmodede et al (2019) who observed similar patterns of deforestation and land-use intensification in other parts of Nigeria. In both studies, agricultural expansion was found to be a major driver of vegetation loss, contributing to increased LST and a decrease in the cooling effect that vegetation typically provides. This relationship between vegetation loss and LST increase is consistent with the studies by Peng et al. (2012) and Kalisa et al. (2021), who also found that urbanization and land degradation lead to higher LST due to reduced evapotranspiration and increased heat retention.

The study also observed a marked increase in built-up areas, further exacerbating the urban heat island (UHI) effect. This finding agrees with previous studies, such as Zhang et al. (2021), who reported that the expansion of built-up areas tends to increase LST, especially in rapidly growing urban centers. However, unlike some urban areas where urban greening and afforestation programs have helped mitigate the UHI effect, Taraba State has seen limited afforestation efforts, which has likely contributed to the more pronounced temperature increases observed in this study [7].

Another notable finding was the weakening relationship between the Normalized Difference Vegetation Index (NDVI) and LST over time. In the early years (1987 and 2001), a moderate inverse relationship was observed, with higher vegetation density associated with lower temperatures, supporting the idea that vegetation can cool the land surface through shading and transpiration. However, by 2022, this relationship weakened (R^2 = 0.3115), suggesting that other factors, such as climate variability and intensified human activities, have become more influential in determining LST. This weakening of the NDVI-LST relationship is consistent with findings by Wu et al. (2020), who observed a diminishing role of vegetation in temperature regulation as urbanization and deforestation increased. However, this contrasts with studies in temperate climates where reforestation and afforestation efforts have had a stronger impact on reducing surface temperatures [15]. In Taraba State, the lack of effective reforestation strategies has likely limited the potential for vegetation to regulate LST effectively.

The relationship between elevation and LST, observed to be stronger in 2001, showed that higher elevations tended to have lower temperatures. This finding is consistent with general climatic principles, where higher elevations usually experience cooler temperatures due to thinner atmospheric layers [3]. However, by 2022, the correlation weakened, suggesting that land-use changes, particularly deforestation and urbanization, have diminished the cooling effects typically associated with elevated areas. This result contrasts with Turner et al. (2003), who emphasized that elevation has a consistent influence on local microclimates, especially in regions where topographical features are preserved [16]. In Taraba State, increasing human activities, such as agriculture and infrastructure development, appear to be overriding the natural temperature regulation effects of elevation.

Similarly, the relationship between elevation and NDVI was weak across all time periods, implying that vegetation density in Taraba State is more influenced by human activities than by elevation. This finding aligns with Ayanlade et al. (2017), who found that vegetation distribution in Nigeria is often driven by anthropogenic factors, particularly deforestation and agricultural practices, rather than natural variables like elevation. This differs from the findings of Ujoh et al. (2021), who observed a stronger link between elevation and vegetation in other regions of Nigeria, where topographical features played a more significant role in vegetation distribution. In Taraba, however, land-use changes, especially in the higher elevations, have likely disrupted the natural vegetation patterns, diminishing the influence of elevation [17].

The impact of these land-use and temperature changes on vegetal resources has been substantial. Biodiversity loss, soil degradation, and disruption of hydrological cycles have been observed, particularly in areas where deforestation and agricultural activities have intensified. These findings support those of Foley et al. (2005), who highlighted that land-use changes often result in significant ecosystem alterations, including reduced biodiversity and carbon sequestration capacity. Similarly, the increase in soil erosion and reduced moisture retention in the soil, as observed in this study, mirrors the findings of Lambin & Meyfroidt (2011), who identified soil degradation as a major consequence of land-use changes in sub-Saharan Africa. In addition, the disruption of local water cycles due to reduced vegetation cover aligns with Hua et al. (2022), who emphasized the role of forest cover in maintaining hydrological balance [18].

However, this study also presents unique regional findings. Unlike studies in other African regions where targeted reforestation efforts have helped mitigate environmental degradation, Taraba State has seen limited afforestation initiatives, which has contributed to continued hydrological instability and an increased vulnerability to climate change [6]. This underscores the importance of localized climate adaptation strategies and effective land management practices that incorporate afforestation and reforestation efforts to restore the ecosystem.

In conclusion, the findings of this study largely align with previous research on the relationships between LULC changes, LST variations, and vegetation dynamics, while also highlighting unique regional challenges in Taraba State. The study suggests that anthropogenic activities, particularly agricultural expansion, urbanization, and deforestation, have significantly altered the natural climate-regulating functions of vegetation, leading to increased LST, soil degradation, and biodiversity loss. These findings emphasize the need for integrated land-use planning and climate adaptation strategies tailored to the specific environmental and socio-economic conditions of Taraba State. The research highlights the importance of afforestation, sustainable land management, and climate-resilient agriculture in mitigating the adverse effects of land-use changes and temperature increases on vegetal resources.

Conclusion

This study highlights significant land-use and land-cover (LULC) changes in the Taraba State Central Zone from 1987 to 2022 and their impact on land surface temperature (LST) and vegetal resources. The findings reveal extensive deforestation, agricultural expansion, and urbanization, leading to a marked decline in vegetation cover. Increased built-up areas and bare land have resulted in higher LST due to reduced evapotranspiration and increased heat retention. The correlation between the Normalized Difference Vegetation Index (NDVI) and LST has weakened over time, suggesting that human activities and climate variability have increasingly influenced temperature dynamics beyond vegetation loss. Furthermore, elevation's influence on temperature moderation has declined due to intensified land-use changes. Rising LST in urbanized and deforested areas has contributed to biodiversity loss, soil degradation, and hydrological disruptions, affecting ecosystem stability and agricultural productivity. These environmental changes pose serious challenges to sustainable land management and climate resilience in the region. The study aligns with global research on LULC-induced warming and vegetation loss but highlights regional variations due to limited afforestation efforts. Addressing these challenges requires integrated land-use policies, afforestation programs, and climate adaptation strategies to mitigate environmental degradation and ensure the sustainability of vegetal resources in Taraba State.

Recommendations

Based on the findings of this study, the following recommendations are made;

- Afforestation and Reforestation: Large-scale tree planting programs should be implemented to restore degraded lands, enhance carbon sequestration, and regulate LST. Community-driven afforestation efforts should be encouraged to ensure long-term sustainability.
- Sustainable Land-Use Planning: Urban expansion, agriculture, and other land-use changes should be regulated through strict policies and environmentally friendly planning strategies. The integration of green infrastructure, such as urban forests and buffer zones, can help mitigate the urban heat island effect.
- Climate-Smart Agriculture: Farmers should be encouraged to adopt sustainable practices such as agroforestry, conservation farming, and controlled land clearing to minimize deforestation, reduce soil degradation, and maintain ecosystem balance.
- Strengthening Environmental Policies and Monitoring: Government agencies should enforce existing environmental laws, regulate deforestation, and integrate geospatial technologies for real-time monitoring of LULC and LST changes to guide policy interventions.
- Public Awareness and Community Engagement: Local communities should be educated on the impacts of deforestation and climate change on vegetation and livelihoods. Community-based conservation initiatives should be promoted to ensure grassroots participation in environmental sustainability efforts.

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