Assessing The Impacts of Land Use/ Land Cover Changes on Land Surface Temperature in Jos North and South Lgas, Plateau State, Nigeria.

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***Abstract*—This study assessed the impacts of land use/land cover (LULC) changes on land surface temperature (LST) in Jos Metropolis, Plateau State, Nigeria, between 1985 and 2025. Multi-temporal Landsat imagery and Geographic Information Systems were used to examine five years (1985, 1995, 2005, 2015 and 2025), map land-cover classes, derive LST, and evaluate relationships between land cover and temperature. Results indicate substantial landscape transformation: vegetation declined by 296.382 km², while built-up areas, farmland and bare surfaces increased by 160.202 km², 120.149 km² and 24.029 km². Mean LST increased from 21.5195°C in 1985 to 24.7553°C in 2025, a rise of 3.2358°C. Pearson analysis showed positive correlations between LST and built-up areas, farmland and bare surfaces, and negative correlations with vegetation and water bodies. The findings indicate an association between land-cover transformations and surface warming, supporting vegetation conservation and climate-sensitive urban planning. Correlations are based on five observations and should be interpreted cautiously.**

***Index Terms*—Land use/land cover change; land surface temperature; Landsat; urban expansion; Jos Metropolis.**

I. INTRODUCTION

Land refers to one of the most essential resources naturally which human societies depends upon for agriculture, settlement, transportation, industrial activities and other socioeconomics utilization. The modification of earth land surface is carried out by natural processes and anthropogenic activities. Such modifications lead to Land Use Land Cover (LULC), affecting environmental processes negatively at local, regional and global scales. Land Use Land Cover Changes (LULCC) influences the exchange of energy, carbon and water between the land surface and the atmosphere which can alter local climatic environmental condition. (IPCC, 2019; IPCC, 2021).

Land use regards as the purpose or manner in which humans utilize a particular portion or area of land, such as agricultural, residential, commercial, industrial and creational purposes, then land cover describes the physical features or material on the earth's surface, such includes water body bare soil, buildings and vegetation. Meanwhile, land use and land cover are highly related, they serve as different characteristics of the physical environment. Changes in land cover often occur as a result of changes in human land use, such as population growth, economic activities stimulating urban expansion, and the conversion of natural such as vegetation or agricultural surfaces. (IPCC, 2019; Fu & Weng, 2016).

Rapid population and urbanization growth are the major drivers of land use and land cover dynamics throughout the world. As urban centers expand, agricultural land, wetlands, vegetation cover, and open spaces are often converted to buildings, roads, commercial areas, and other impervious surfaces. This transformation changes the physical characteristics of the land surface and furthermore, affects solar radiation absorption processes, evapotranspiration, surface moisture, and heat storage. (Fu & Weng, 2016; Zhou et al., 2017).

One of the major environmental challenges associated with LULC is modification of Land Surface Temperature (LST). Land Surface Temperature refers to the temperature of the earth's surface and is an essential indicator of the interaction between land surface and the atmosphere. Unlike conventional air temperature measured at meteorological stations, LST provides spatially distributed information about the thermal condition of the land surface and can therefore be used to investigate variations in surface heating across different land-cover types. (Fu & Weng, 2016; Zhou et al., 2017).

The different land cover types influence their thermal behaviors. Generally, vegetation contributes to the cooling of the earth surface through evapotranspiration and by providing shades, meanwhile water body can reduce surface temperatures through their thermal and evaporative properties. Conversely, built-up areas containing materials such as concrete, asphalt, roofing materials and other impervious surfaces tend to absorb and store solar energy, which can result in relatively high surface temperatures. Bare surfaces may also exhibit high temperatures depending on soil characteristics, moisture content and surface conditions. (Zhou et al., 2017; Imran et al., 2018).

Conversion of vegetated land surface areas to the expansion of urban areas therefore, can influence the surface energy balance, once, when there is deforestation, vegetation cover and evapotranspiration declines on a certain given geographical land surface, while heat absorption and storage by buildings and bare surfaces decreases. These processes can contribute to the development of relatively warm urban surfaces and are closely associated with the phenomenon known as the Urban Heat Island (UHI). The IPCC recognizes that urbanization and land-cover changes can influence local climate and contribute to urban heat island effects. (IPCC, 2021; IPCC, 2019).

Urban Heat Island (UHI) refers to a process of urban areas being warmer than its rural surroundings. Urban heat islands are characterized with several factors such as less vegetation cover types, change in surface geometry, concentration of heat absorbing materials, anthropogenic heat emissions, and reduction of evapotranspiration. The rate of the phenomenon of the urban heat island varies urban form, land cover composition and climatic condition. (IPCC, 2021; IPCC, 2019).

Land Use Land Cover Changes (LULCC) plays a pivotal role for local climate. The IPCC reports that land-cover changes and land management can influence climate at local and regional scales through biophysical processes, including changes in albedo, evapotranspiration, soil moisture and surface energy exchanges. In urban areas, continuing urbanization can increase heat-related risks because cities already tend to be warmer than their surrounding areas. (IPCC, 2021).

The relationship between LULC and LST has been extensively investigated using remote sensing and Geographic Information Systems (GIS). Satellite remote sensing provides an effective means of monitoring changes in land cover over large areas and across different periods. Thermal infrared satellite data can be used to estimate LST, while multispectral data can be used to classify land-cover types and derive indices such as the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built-up Index (NDBI). (Fu & Weng, 2016; Zhou et al., 2017). (9)

The use of Landsat imagery has been particularly important in examining the relationship between urbanization, LULC change and LST because the Landsat programmed provides a long historical record of multispectral and thermal observations. Time-series analysis of Landsat imagery can therefore provide information about how changes in urban land cover correspond with changes in surface thermal conditions. (Fu & Weng, 2016).

Vegetation really helped in the transformation of land surface temperature. Some researchers have discovered that geographical locations with high vegetation density seems to have a relatively lower land surface temperature, than areas dominated with bare surfaces and built-up areas tends to experience higher land surface temperature. This relationship is carried out suing vegetation and built-up indices, the negative relationships between land surface temperature and vegetation indices, while built-up areas and bare surfaces were associated with higher land surface temperature values. (Adebayo et al., 2017).

Urban areas in Nigeria have recorded high temperate condition due to growth in population, socioeconomic development and urban expansion.

Increasing development has triggered the conversion of vegetation, agricultural areas and open space into built-up areas. These changes have potentially modified the thermal characteristics of Nigerian urban areas and increase the importance of understanding the relationship between urban development and LST. Studies from different parts of Nigeria have demonstrated the usefulness of satellite remote sensing in examining these processes. (Adebayo et al., 2017).

This therefore, is related to Jos Plateau state, Nigeria where urban growth has resulted in considerable changes in land cover. Jos metropolis is located within the Jos Plateau highland environment and has experienced urban expansion associated with residential, commercial, institutional and transportation development. Changes in vegetation and other natural surfaces associated with urbanization can influence the thermal characteristics of the metropolis and surrounding areas. (Odunuga & Badru, 2015).

Therefore, this study aimed at assess the impacts of Land Use/Land Cover changes on Land Surface Temperature in Jos metropolis using the GIS and multi-temporal remote sensing techniques. By analyzing changes in LULC and land surface temperature over four decades, the research seeks to provide a comprehensive understanding of how changes in land cover features through the anthropogenic activities influences microclimates. The findings and recommendation of the study are to inform urban planners and policy decision makers in regards to land use management, urban climates thermal reflectance sensitivity, urban greening initiatives, and the strategies of mitigating urban heat island effects. Furthermore, this study contributes to the ultimate objectives of promoting of sustainable and resilience urban microclimates of Jos, Plateau state, Nigeria and the world at large.

1.1 Problem Statement

Jos metropolis has undergone substantial physical development over the years as a result of population growth, socioeconomic activities and urban expansion. The expansion of residential settlements, commercial centres, roads, institutional facilities and other infrastructure has resulted in the conversion of portions of vegetation, agricultural land and open spaces into built-up surfaces. Such changes can alter the physical characteristics of the land surface and consequently influence the thermal environment of the metropolis. (Odunuga & Badru, 2015).

Due to the population growth, socioeconomic activities and urban expansion has leads to high rate of decreased in vegetation and increased in built-up areas, roads constructions, can reduce evapotranspiration and increase the capacity of surfaces to absorb and store solar radiation. Consequently, highly developed areas may exhibit higher land surface temperature than areas dominated by vegetation and water bodies. If urban expansion continues without adequate consideration of environmental factors, increasing surface temperatures may become an important environmental concern in Jos metropolis. (IPCC, 2019; Zhou et al., 2017).

Although previous research has examined LULC and LST in the Plateau state, including Jos metropolis, there is a need for updated analysis because urban development has continued beyond the periods covered by earlier studies. Note that, Odunuga and Badru (2015) analyzed the period from 1986 to 2014. Continued expansion of Jos metropolis after this period makes it necessary to investigate more recent changes and determine whether the relationship between LULC and LST has intensified or changed over time. (Odunuga & Badru, 2015). (16). Furthermore, another problem is the limited ability of conventional meteorological observations to adequately represent the spatial distribution of temperature across an urban area. Weather stations provide valuable air-temperature measurements, but they are spatially limited. Satellite-derived LST, on the other hand, can provide spatially continuous information that allows differences between built-up, vegetated, bare and water surfaces to be investigated. (Fu & Weng, 2016).

Therefore, there is a need for a systematic assessment of the spatial and temporal changes in LULC and LST in Jos metropolis and for an investigation of the relationship between the two variables. Such an assessment will help establish whether increasing built-up areas and decreasing vegetation are associated with increasing surface temperature and identify the land-cover categories that contribute most strongly to thermal variation. (Zhou et al., 2017; Odunuga & Badru, 2015). (18). consequently, with limited application of GI Sand remote sensing

methods to examined thermal variation with land use transformations. This lack of integrated analysis restricts the ability of the policy makers to developed effective evidence-based mitigation strategies.

In response to this research gap, this research seeks to address three research questions the spatial and temporal changes in Land Use/Land Cover (LULC) in Jos metropolis between 1985, 1995, 2005, 2015 and 2025, the spatial and temporal variations in Land Surface Temperature (LST) in the same study area during the study period, the relationship between land use land cover and land surface temperature in the study area, particularly in relations to vegetation and built-up areas. By providing a comprehensive assessment, the study aims to support sustainable urban planning and climate-responsive development in Jos Metropolis.

1.2 Objectives.

The primary aim of this research is to assess the impacts of Land Use/Land Cover changes on Land Surface Temperature in Jos metropolis, Plateau State, with the specific emphases on to understanding the relationship between land use land cover (LULC) changes and land surface temperature (LST) over the past four-decade, Jos metropolis has undergone rapid urbanization, resulting in significant transformation of natural lands surface features into built-up areas. This study therefore seeks to provide a comprehensive assessment of how these spatial changes have affected temperature patterns and contributed to microclimatic variations, including the development of urban heat island (UHI) effects of Jos metropolis. Plateau state, Nigeria.

In achieving this aim, the research focuses on the three set objectives. First Identify and analyze the spatial and temporal changes in Land Use/Land Cover Changes (LULCC) in Jos metropolis between 1985, and 2025. This includes and identifying and analyzing the different land cover types such as vegetation, agricultural, Built-up areas, water body and bare surfaces have change over time. By analyzing its dynamics, the researcher established gravity and the patterns of urban expansion and highlights the rate at which natural land covers have been replaced by impervious surfaces in Jos metropolis

Secondly, the research determines the dynamics in temperature patterns associated with land use land cover changes using geographic information system and remote sensing techniques. It assesses how variations in land cover influence surface temperature distribution across the study area. This objective is critical in understanding the thermal implications of urban growth, particularly the extent to which the loss of vegetation and increase in built-up areas contribute to rising temperatures and localized heat stress.

Thirdly, the research assesses the relationship between the land use land cover dynamics and land surface temperature. Through spatial, pattern and statistical analysis, it assesses whether significant correlations exist between different land-use types and temperature variations. This is further supported by the formulation of a null hypothesis, which states that there is no significant relationship between LULC changes and LST in Jos Metropolis. Testing this hypothesis provides a scientific basis for confirming or rejecting the influence of urban land transformation on thermal conditions.

The geographical scope covers particular Jos metropolis with focuses on the assessment of the impacts of LULC changes on LST in Jos metropolis, Plateau State, Nigeria. The study examines major land-cover categories, including built-up areas, vegetation, agricultural land, bare surfaces and water bodies. These categories are appropriate for evaluating the relationship between different land surface characteristics and LST because previous studies have demonstrated distinct thermal responses among built-up, vegetated, bare and water surfaces the temporal scope of the research adopting four decades of 1985, 1995, 2005, 2015 and 2025, corresponding to the datasets adopted for the wider research project. The study analyzes changes between these periods and determine whether LST has increased or decreased in association with changes in LULC and the time range allows consistence, details and long-term trend analysis.

The significance of the study contributes to broader research on urban climatology and climate change adaptation, particularly in rapidly growing cities of Nigeria and the world at large. Its methodology and results can be applied to similar urban contexts, making it relevant beyond Jos metropolis. Ultimately, the research emphasizes the need for sustainable environmental and urban development that balances growth with environmental protection, ensuring

healthier climatic and more resilient cities for the future purposes.

II. RESEARCH METHODOLOGY

This chapter adopted methods and procedures adopted to assess the impacts of Land Use/Land Cover (LULC) changes on Land Surface Temperature (LST) in Jos, Plateau State, Nigeria. The methodology covers the description of the study area, research design, data sources, satellite data acquisition, image preprocessing, LULC classification, accuracy assessment, LST extraction, NDVI and NDBI computation, LULC change detection, LST change and trend analysis, statistical analysis, correlation and regression analysis, and hypothesis testing. The methodology is designed to enable comparison of changes in land use/land cover and surface temperature over five representative years: 1985, 1995, 2005, 2015 and 2025.

2.1 Study Area

Jos Metropolis is located between latitudes 9°54′N and 10°10′N and longitudes 8°48′E and 9°30′E. It lies at an average elevation of approximately 1,250 meters above sea level, with Shere Hills reaching the highest peak at about 1,777 meters. The study area covers approximately 1,002.19 km². Its high altitude distinguishes it climatically from surrounding lowland regions.

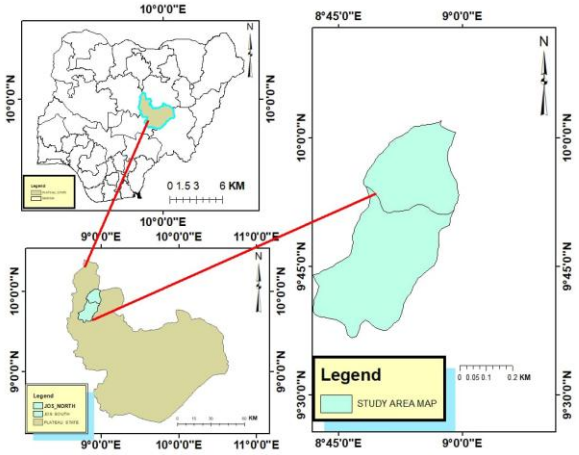


Fig 1: Study area Map

Jos falls within the tropical savannah (Aw) climate under the Köppen classification. The area experiences two distinct seasons: a wet season (April–September) and a dry season (October–March). Rainfall peaks in July and August, with annual totals averaging between 1,300 mm and 1,400 mm. The mean annual temperature ranges between 20°C and 26°C, although daytime temperatures may reach 32°C and drop to about 18°C during the dry Harmattan period (December–February). The relatively cool climate compared to other parts of Nigeria is largely influenced by altitude and the seasonal movement of the Inter-Tropical Convergence Zone (ITCZ). Rainfall distribution and cloud cover also moderate temperature patterns.

The study area lies within the Jos-Bukuru Complex, predominantly composed of biotite granite. The geology consists of Precambrian Basement Complex rocks (migmatite, gneiss, and quartzite), intruded by Pan-African granites and later Jurassic Younger Granites. Volcanic rocks such as basalts and rhyolites are also present. Relief is characterized by undulating highlands, rocky outcrops, and dissected valleys. Sedimentary deposits are mainly confined to river alluvium.

The Jos Plateau is dominated by Northern Guinea savannah vegetation, characterized by grasslands interspersed with shrubs and scattered trees. However, mining, agriculture, urbanization, and fuel wood extraction have significantly altered the natural vegetation cover, resulting in fragmentation and deforestation in many areas.

Soils on the Jos Plateau are largely derived from basalt, volcanic ash, and granite parent materials. Basaltic and volcanic ash soils are deeper, richer in organic matter, and more fertile than granite-derived soils. They possess higher cation exchange capacity (CEC), better water retention, and improved nutrient content, making them more suitable for agriculture. Granite-derived soils, on the other hand, tend to be less fertile and present greater constraints for crop production. Moisture content in the region's soils is generally. Low, indicating high transmissivity and limited water retention in certain areas. Soil texture varies, with many areas characterized by clayey and poorly graded soils. According to the 2006 national census, Plateau State had a population of 3,178,712, with Jos North and Jos South recording 429,300 and 306,716 people respectively. Recent projections estimate the Jos metropolitan population at over 1 million, while Plateau State's population is estimated at about 4.7 million. Population growth has intensified pressure on land resources. Major human

activities in the Jos Plateau include tin mining, agriculture, livestock grazing, urban development, firewood harvesting, fishing and block moulding industries. These activities have significantly altered land cover, contributing to vegetation loss, soil degradation, and environmental change.

2.2 Research Design

This research adopted a quantitative, integrated remote sensing, Geographic Information System (GIS) and statistical analysis, assessing the spatial and temporal dynamics of urban expansion and its influence on thermal characteristics - specifically Land Surface Temperature (LST) - in Gombe Metropolis. A combination of remote sensing, Geographic Information System (GIS) techniques and statistical analysis will be used to examine how changes in Land Use and Land Cover (LULC) patterns over time have affected the city's thermal environment. The research will be conducted over a 30-year temporal scope, focusing on four key time points: 1994, 2004, 2014, and 2024. These years were purposefully selected to represent pre-expansion, early-growth, peak-growth, and recent urban development phases, enabling a comprehensive spatiotemporal analysis of land features change detection over four decades and associated thermal implications in the study area.

The analytical framework followed a systematical processed such as this research designed flowchart bellowed

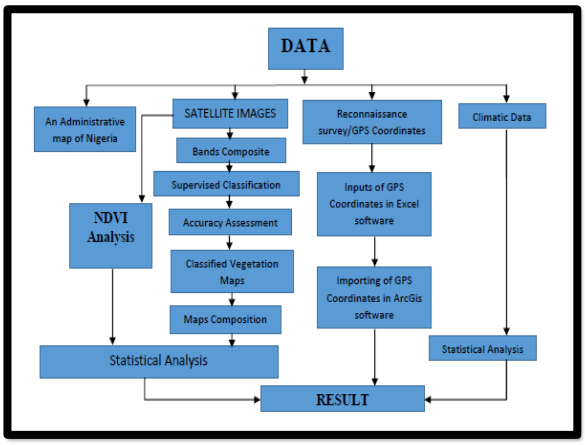


Fig 2: Methodological Flowchart of Data Analysis.

1. Satellite Image Acquisition and Preprocessing: Multi temporal satellite imageries (Landsat series) for the four selected years will be acquired and preprocessed to correct for radiometric and geometric distortions.
2. LULC Classification and Change Detection: Supervised classification using maximum likelihood algorithms employed to classified LULC types. Post classification comparison will be used to detect land use transitions across the selected periods.
3. LST Retrieval: Land Surface Temperature extracted from the thermal bands of the Landsat datasets using appropriate algorithms (e.g., mono window or single-channel methods), with atmospheric corrections applied.
4. Spatial Analysis: The relationship between LULC changes and LST variation explored using spatial overlay and zonal statistics in GIS. Heat maps and surface temperature gradient models developed to visualize thermal patterns.
5. Statistical analysis: Regression modeling and Pearson correlation used to assess the direction and the pattern occurred on the changes of the features of the earth surface such as decreased in vegetation, increased in built-up areas and the trends in Land Surface Temperature (LST) of four decades in the study area.

Integrating geospatial techniques and statistical design allow an evidence-based understanding fast changes in natural land features of the earth surface such as vegetation changes into agricultural lands and built-up areas in Jos metropolis and has altered thermal landscape. This strategy provides both quantitative and geospatial visualizations informed decision makers of mitigation urban heat island, environmental management and urbanization planning in the country and the world at large.

2.3 Data Types and Sources

The study used Landsat satellite imagery as the primary data source for analyzing Land Use and Land Cover (LULC) changes and Land Surface Temperature (LST) patterns in the study area. Landsat imagery offers a robust combination of long-term temporal coverage, consistent data quality, and adequate spatial and spectral resolution for environmental monitoring.

Multispectral bands of thirty meters (30) spatial resolution used for climatic and environmental studies at regional and cities scale such as Jos metropolis, while, high resolution imageries may

present finer details, Landsat's 30m resolution is sufficient for detecting broad patterns of urban expansion, vegetation change, and surface temperature variation over multi-decadal periods. Furthermore, its compatibility with historical datasets enhances the ability to conduct time series analysis across decades.

The thermal bands which are critically for LST estimation, have coarser native resolutions (120m for Landsat 5 and 100m for Landsat 8/9), but are resample to 30m by USGS to align with the multispectral bands, thereby facilitating integrated analysis. All satellite data will be acquired for the dry season month of January. This selection ensures uniform atmospheric conditions, minimizes cloud cover, and avoids seasonal vegetation fluctuations, thereby improving comparability and accuracy in LULC and LST assessments across the years. The satellite images were all acquired from the United States Geological Survey (USGS) Earth Explorer platform, and all data undergo surface reflectance correction to reduce atmospheric distortion and enhance the reliability of spectral measurements.

Table 1: Satellite Data Specifications.

Year	Satellite/Sensor	Acquisition Date	Spatial Resolution	Bands Used
1985	Landsat. 4-5 TM	February 1985	30 (Multispectral), 120 (Thermal)	1-7
1995	Landsat.5 TM	February 1995	30 (Multispectral), 120 (Thermal)	1-7
2005	Landsat.7 ETM	February 2005	30 (Multispectral), 120 (Thermal)	1-7
2015	Landsat.8 OLT	February 2015	30 (Multispectral), 100 (Thermal)	2-7, 10-11
2025	Landsat.8/9 OLT	February 2025	30 (Multispectral), 100 (Thermal)	2-7, 10-11

The research incorporates supplementary datasets to analyzed administrative boundary of Jos metropolis obtained from Zonal Advance Space Technology Application Laboratory (ZASTAL) Kashere, to generate study area extent, hand held GPS coordinates points of known locations collected for accuracy assessment. Historical temperature records from the Nigerian Meteorological Agency (NiMet) will be used to validate the satellite-derived temperature estimates. A digital elevation model (DEM) from the Shuttle Radar Topography Mission (SRTM) used to account for topographic effects on temperature patterns.

2.4 Data Processing and Analysis

Many pre-processing procedures were adopted to the satellite images to ensure data quality and consistency for analysis, including the radiometric calibration process which converts the raw digital numbers to physically meaningful values of surface reflectance. This involve converting to at-sensor radiance and then to top-of-atmosphere reflectance using sensor-specific calibration parameters. Chander et al., (2009). Atmospheric correction was applied to remove atmospheric effects from the imagery using the Dark Object Subtraction method for Landsat 5 TM images and the FLAASH module for Landsat 8/9 data. Xu et al., (2020).

The images undergo geometric and radiometric correction to a precise alignment between multi-temporal scenes, with a target root mean square error below 0.5 pixels. All images will be clipped to the Jos metropolis administrative boundary to focus the analysis specifically on the study area. Quality assessment performed to identified and mask clouds, cloud shadows, and other artefacts that could compromise analyzed results. With the used of ArcGIS-pro the images pre-processing were carried out for the subsequent analysis. The research also adopts maximum likelihood supervised classification methods with five Land Use Land Cover (LULC) feature classes based on the characteristics of Jos metropolis and the research specific objectives as well. The maximum likelihood supervised classification scheme allowed detailed decadal analysis of LULC change detection of a geographical areas' patterns and their relationship with thermal characteristics while being appropriate of Jos metropolis.

Table 2: Land Use Land Cover Classification Scheme.

Land Use Type	Meaning
Bare Land	Exposed soil, sand, rocks, and areas with no vegetation

Built-up Area	Residential, commercial, industrial, transportation, and other constructed areas
Farmland	Cultivated areas and agricultural fields
Vegetation	Trees, shrubs, grasslands, and vegetated areas
Water Bodies	Rivers, streams, ponds, and other water features

The research adopted supervised techniques using the Random Forest algorithm, which has demonstrated robust performance in urban land cover mapping (Belgiu and Drăguţ, 2016). The classification process will begin with the collection of representative training samples for each LULC class using high-resolution reference imagery and ground truth data. For historical images where direct ground truth is unavailable, training samples will be selected from areas with known historical land uses.

Random forest classifier was applied with optimized parameters to generate the initial LULC maps for each time period. Post-classification processing will include a majority filter to reduce the salt-and-pepper effect and improve classification coherence. Accuracy assessment will be conducted using an independent set of validation points, with metrics including overall accuracy, user's and producer's accuracies, and the Kappa coefficient calculated to evaluate classification performance.

The area of each LULC class was calculated for each time period to determine the extent and proportion of different land uses and their changes over time. Change matrices were generated to quantify transitions between LULC classes across the three decades, identifying both the magnitude and direction of land use transformations.

The annual rate of change for each LULC feature class will be calculated using the standardized formula equation 1 proposed by Puyravaud (2003):

$$r = (1/(t_2-t_1)) \times \ln(A_2/A_1) \quad (1)$$

Where r represents the annual rate of change, A_1 and A_2 are the areas of a land use class at times t_1 and t_2, respectively. This will quantify the pace of urbanization and other land cover conversions.

The spatial pattern metrics including patch density, mean patch size, and landscape fragmentation index will be calculated using FRAGSTATS software to characterize the structural changes in the urban landscape over time (McGarigal et al., 2012).

The urban sprawl intensity was analyzed using the Urban Expansion Intensity Index (UEII) as shown in equation 2 to measure the rate and magnitude of built-up area growth relative to the initial urban extent:

$$UEII = [(ULA_2 - ULA_1) / (ULA_1 \times (t_2 - t_1))] \times 100\% \quad (2)$$

Where ULA_1 and ULA_2 represent urban land area at times t_1 and t_2, respectively.

The thermal bands (Band 6 for Landsat 5 TM and Bands 10 11 for Landsat 8/9 OLI/TIRS) were processed to derive LST values. The processing will follow these steps, conversion of Digital Numbers (DN) to at-sensor spectral radiance using sensor-specific calibration parameters. Transformation of spectral radiance to at-sensor brightness temperature using the Planck function is given in equation 3 below:

$$TB = K_2 / \ln(K_1/L\lambda + 1) \quad (3)$$

Where TB is the brightness temperature in Kelvin, K_1 and K_2 are calibration constants specific to each Landsat sensor, and $L\lambda$ is the spectral radiance. Calculation of land surface emissivity (LSE) based on the Normalized Difference Vegetation Index (NDVI) threshold method given in equation 4 (Sobrino et al., 2004):

$$\varepsilon = \varepsilon v \times Pv + \varepsilon s \times (1 - Pv) + d\varepsilon \quad (4)$$

Where ε is the land surface emissivity, εv and εs are the emissivity's of vegetation and soil respectively, Pv is the vegetation proportion derived from NDVI, and dε represents the cavity effect. Derivation of final LST using the emissivity-corrected land surface temperature equation was obtained using equation 5:

$$LST = TB / [1 + (\lambda \times TB / \rho) \times \ln(\varepsilon)] \quad (5)$$

Where λ is the wavelength of emitted radiance, and ρ is a constant derived from Planck's constant, Boltzmann constant, and the speed of light (1.438×10^{-2} mK). For the assurance of the reliability of the LST results, the satellite-derived LST values were validated based against ground temperature measurement from the Nigerian Meteorological Agency (NiMet) using the using correlation analysis and root mean square error calculation. Temporal normalization was applied to account for diurnal and seasonal variations in temperature, enabling more accurate comparison between different time periods. Topographic corrections using the SRTM DEM were

implemented to minimize the influence of elevation differences on temperature patterns. Calculation of urban heat island intensity (UHII) by comparing mean LST values between built-up areas and surrounding non-urban areas for each time period: UHII = LST(urban) - LST(rural). Zonal statistics to quantify mean, minimum, maximum, and standard deviation of LST for each LULC class, enabling assessment of how different land covers influence thermal conditions.

Buffer analysis was carried out to assessed how LST varies with distance from the urban core, using concentric buffer zones at 1 km intervals from the city center. Trend analysis to identify statistically significant warming or cooling trends across the 4 decades study period using pixel-based linear regression of LST values against time. Hot spot analysis was used to identify statistically significant hot and cold spots within the urban landscape and track their spatial evolution over time. Several statistical techniques was employed to quantify the relationships between land use patterns and thermal characteristics such as Pearson correlation analysis to measure the strength and direction of relationships between the proportion of different land use types and LST. Multiple linear regression to develop predictive models of LST based on LULC composition, with the general form: $LST = \beta_0 + \beta_1X_1 + \beta_2X_2 + ... + \beta_nX_n + \varepsilon$ Where $X_1, X_2, ..., X_n$ represent the proportions of different LULC types, $\beta_0, \beta_1, \beta_2, ..., \beta_n$ are regression coefficients, and ε is the error term. Analysis of Variance (ANOVA) to test for significant differences in mean LST values between different LULC classes and time periods was used and Principal Component Analysis (PCA) to explore multivariate relationships between LULC patterns, LST, and other variables such as population density and elevation.

This research utilized specialized software packages for geospatial analysis and statistical computation such as ENVI 5.6 for satellite image preprocessing and LST retrieval, ArcGIS 10.8 for LULC classification, change detection and spatial analysis. FRAGSTATS 4.2 for landscape pattern analysis and R Statistical Software for statistical modeling and data visualization. Lastly, Google Earth Engine for supplementary analysis and verification.

III. RESULT AND DISCUSSION

This part of the research presents the Land Use Land Cover (LULC) distribution of Jos Metropolis four decades: 1985, 1995, 2005, 2015, and 2025. Each map is discussed independently to highlight key land cover characteristics and transitions for that decade.

3.1 Spatial Distribution and Temporal Changes of LULC

The 1985LULC was dominantly characterized by vegetation (45%) primarily composed of savannah woodland, shrubs, and open grassland. These green spaces served essential ecological functions such as microclimate regulation and soil protection. Farmland (30%), indicating that agriculture was the primary land use for livelihood, especially on the outskirts of the town. while built-up areas (13%), concentrated within the historical urban core, such as areas around Jos town center and key administrative zones. bare surfaces (10%), represent exposed soil, dry riverbeds, and undeveloped rocky outcrops. This map reflects a typical low-density, agriculturally supported settlement surrounded by expansive natural vegetation. Water body occupied smaller portion by (2%).these are likely areas covered by river channels, ponds, drainages within the study area.

These provide an important baseline for evaluating subsequent LULC changes between 1985 and 2025. In particular, the relatively high vegetation coverage and lower built-up area in 1985 offer a basis for examining how urban expansion, agricultural development, and vegetation loss may have influenced the spatial and temporal distribution of Land Surface Temperature within Jos Metropolis

By 1995 noticeable spatial transformations had begun to reshape the landscape of Jos Metropolis. Vegetation decreased to 288.365 km², representing (36%) a reduction of (9%) from 1985, and this decline suggests increasing pressure on natural vegetation, potentially resulting from anthropogenic activities in the study area. Farmland occupying approximately 264.335 km², equivalent to (33%) of the study area to accommodate growing agricultural lands, this represented an increase from 30% in 1985, indicating the continued expansion of agricultural activities. The increase in farmland suggests that portions of previously vegetated land may have been converted into agricultural. Built-up areas accounted for approximately 144.183 km², representing 18%) of

the total study area. Compared with 1985, when built-up areas occupied 104.134 km² (13%), the increase of approximately 40.049 km² indicates considerable urban expansion within the ten-year period. This growth may be associated with population increase, residential development, infrastructural. Bare surfaces rose sharply to 22,897 hectares (12.5%), signaling land clearance for construction, erosion-prone surfaces, or incomplete building sites. The 2004 map signals the transition from a primarily rural landscape to a peri-urban setting, where development pressure began to alter the ecological balance of the region. A more intensified phase of land use transformation was evident in 2015. Built-up areas increased by 5 percentage points, while farmland expanded by 3 percentage points. Conversely, vegetation continued to experience pressure from anthropogenic activities

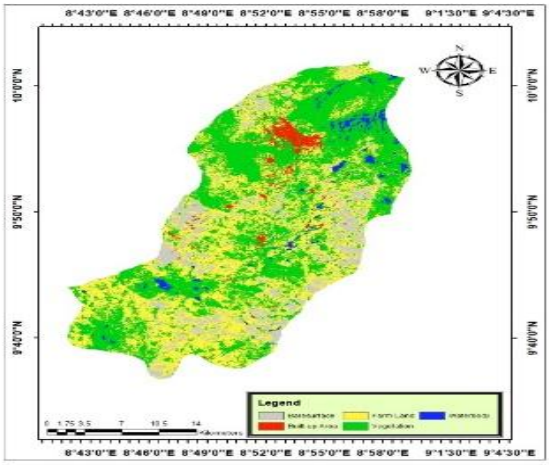


Fig 3: LULC Map of Jos Metropolis 1985

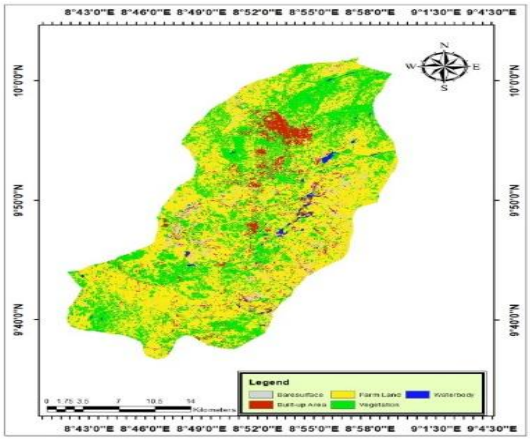


Fig 5: LULC of Jos Metropolis 2005

Vegetation was now largely fragmented and scattered across the urban fringe. Farmlands increased temporarily to 328.413 km², representing 41% of the total study area, possibly due to a surge in urban agriculture or reclassification of transitional lands. However, this expansion may also reflect informal land-use adaptation. Bare surfaces increased modestly to 104.131 km², representing 13% of the total study area, indicating that large portions of land were actively being converted or prepared for urban development. This period represents a tipping point in the landscape, with aggressive land conversion leading to a shrinking ecological base and the emergence of patchy, disconnected green spaces. By 2025, Jos Metropolis had evolved into a predominantly urban landscape. Built-up areas dominated the land cover, reaching 264.336 km², equivalent to 33% of the total study area, signifying a dramatic transformation from a rural town to a highly urbanized city over three decades. The overall analysis reveals substantial land cover transformation over the 40-year study period. Vegetation experienced the greatest decline, decreasing by 37 percentage points, while built-up areas and farmland increased by 20% and 15% respectively.

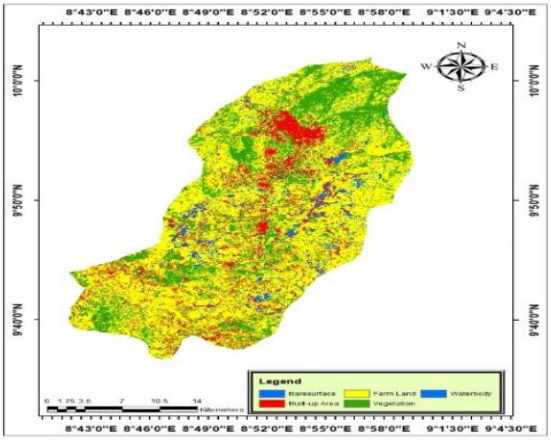


Fig 4: LULC Map of Jos Metropolis 2015

Farmland constituted the dominant land use category, occupying approximately 328.413 km², representing 41% of the total study area. This indicates that agricultural activities accounted for the largest proportion of land utilization in 2015. Compared with 2005, when farmland occupied 304.388 km² (38%), the increase of approximately 24.025 km², equivalent to 3 percentage points, suggests continued expansion of agricultural land. This development may be associated with increasing agricultural demand, population growth, and the conversion of other land cover types into farmland.

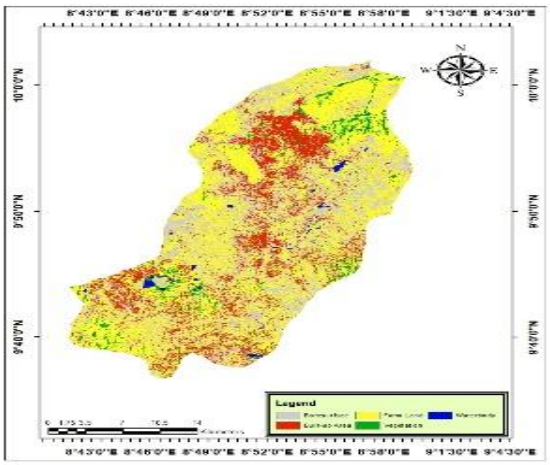


Fig 6: LULC Map of Jos Metropolis 2025

The 2025 LULC distribution demonstrates a landscape predominantly characterized by farmland (45%) and built-up areas (33%), which together accounted for 78% of the total study area. Vegetation covered only 8%, while bare surfaces and water bodies accounted for 13% and 1%, 2025 LULC represents the most extensively agricultural and urbanized landscape among the five study years, characterized by increased human land use activities, reduced vegetation cover, and higher overall mean land surface temperature compared with 1985. These changes provide important evidence for understanding long-term land use dynamics and their potential implications for environmental sustainability and surface temperature variation within Jos Metropolis, Plateau state, Nigeria.

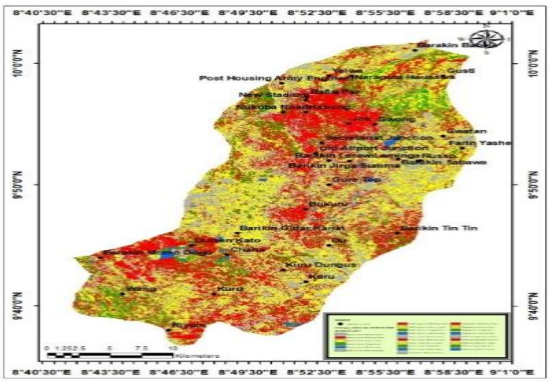
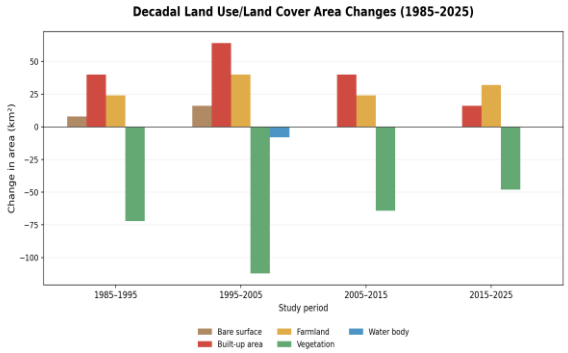


Fig 7: LULC Change Detection from 1985-2025 with Validated Coordinate Points of some Locations in the Study Area.

The overall analysis reveals a progressive transformation of the study area from a predominantly vegetated landscape in 1985 to one increasingly dominated by agricultural and built-up land uses in 2025. In 1985, vegetation and farmland together accounted for 75% of the study area, while built-up areas occupied only 13%. By 2025, farmland and built-up area collectively accounted for 78%, whereas vegetation has declined to only 8% area covered as at the period under study in the study area.

Graph 1: Showing Decadal Land Use/Land Cover Changes (1985-2025).



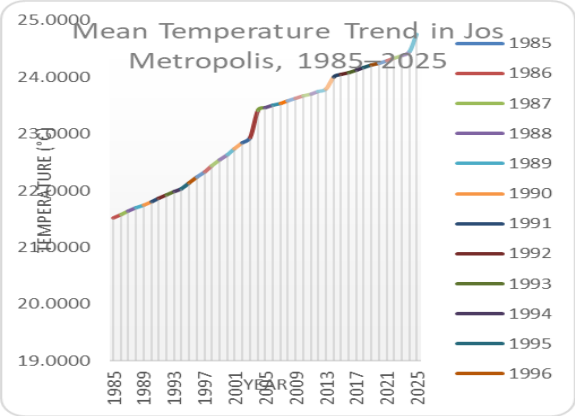
The analysis of decadal LULC changes between 1985 and 2025 revealed substantial transformations characterized by increasing urbanization, agricultural expansion, and declining vegetation cover. The period 1995–2005 experienced the greatest land cover transformation, particularly in built-up areas and vegetation. Over the entire study period, vegetation decreased by approximately 296.383 km², while built-up areas and farmland increased by 160.202 km² and 120.149 km², respectively. This indicate that the study area underwent a progressive transition from a predominantly vegetated landscape towards increasing agricultural and urban land uses. The observed land cover changes highlight the importance of sustainable land use planning, vegetation conservation, and environmentally responsible urban development. These measures may help reduce the potential environmental impacts of continued landscape transformation, particularly those associated with vegetation loss, land surface warming, and ecosystem degradation.

3.2 Spatial Thermal Patterns and Distribution

Temperature data obtained from Temperature data obtained from MERRA-2 satellite observations of Jos Metropolis between 1985 and 2025 shows a consistent upward trend in surface temperatures, largely driven by anthropogenic activities and rapid Urban Expansion. From 1985 to 2025, the mean

annual temperature increased from 21.52°C in 1985 to 24.76°C in 2025, equivalent to approximately 15.04% over the 40-year period. The overall average rate of increase was approximately 0.809°C per decade, marking an absolute net increase of 3.23°C. The greatest 10-year increase occurred during 1995–2005, when mean temperature increased by 1.3258°C (5.99%). The increase subsequently moderated to 0.5821°C (2.48%) between 2005 and 2015, before increasing again by 0.7111°C (2.96%) between 2015 and 2025. This indicates that although the warming trend was not uniform in every decade, the long-term direction was consistently upward during a period under study in the study area.

Graph 2: Annual Mean Temperature Trend (1985-2025)



The NDVI result of 1985 shows that Jos metropolis was characterized by predominantly dense and continuous vegetation cover, especially in the northern part where natural vegetation, water bodies and with less tin mining activities compared to the southern part with highly mining activities being under operation in the study area abundantly. Most areas exhibited moderate to high vegetation density, reflecting minimal urban expansion and limited human disturbance. The landscape had strong natural vegetation, contributing to thermal regulation and environmental health. Fig 7 shows the 1985 NDVI Map of Jos Metropolis.

The NDVI result for 1995 and 2005 indicates that Jos metropolis experienced a reduction and fragmentation of vegetation cover due to emerging urban developments and infrastructure expansion. Vegetated areas became more scattered, and patches of non-vegetated surfaces increased. This reflects the impact of early urban expansion and anthropogenic activities on natural vegetation, underscoring the need for proactive vegetation management and conservation. Fig 8 and 9 shows the NDVI Map for Jos Metropolis of 1995 and 2005.

The NDVI result for 2015 reveals accelerated vegetation decline with dense vegetation areas shrinking further and becoming more isolated primarily at the urban periphery. Built-up zones, commercial centers, and bare surfaces dominated large parts of the metropolis, causing significant vegetation loss. This highlights the growing influence of urban heat islands and human activities, emphasizing the importance of urban greening, reforestation, and sustainable land-use planning as shown in Fig 10.

The NDVI result for 2025 shows that Jos metropolis is dominated by sparsely vegetated and non-vegetated surfaces, with only limited areas of dense vegetation remaining. This reflects the cumulative impact of decades of urban expansion, intensive human activities, and seasonal dryness on natural vegetation. The findings stress the critical need for urban greening initiatives, reforestation, and sustainable land management to restore environmental resilience and thermal regulation in the metropolis.

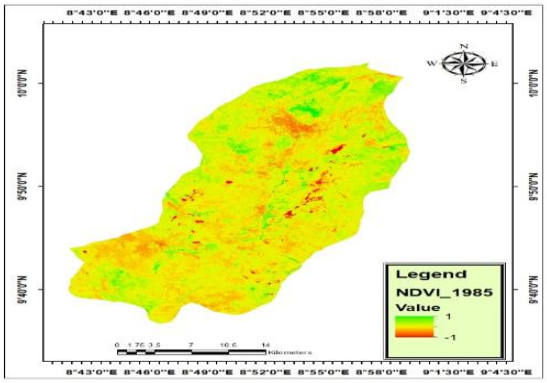


Fig 8: NDVI Map of Jos Metropolis 1985

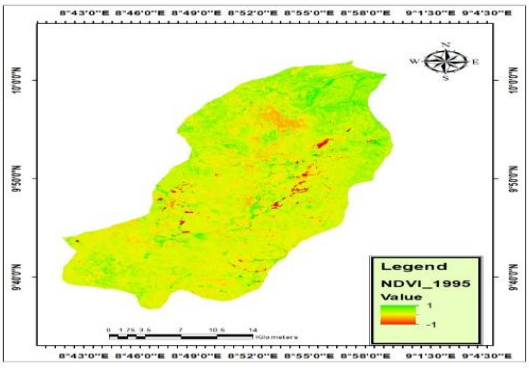


Fig 9: NDVI Map of Jos Metropolis 1995

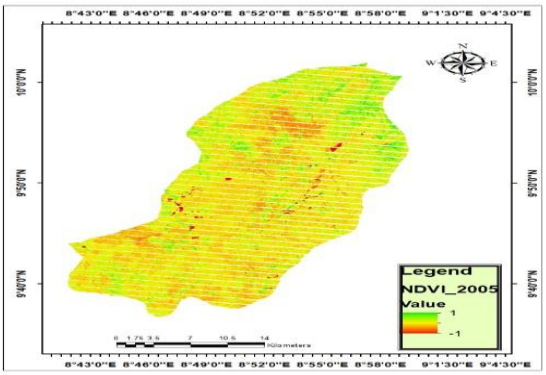


Fig. 10: NDVI Map of Jos Metropolis 2005

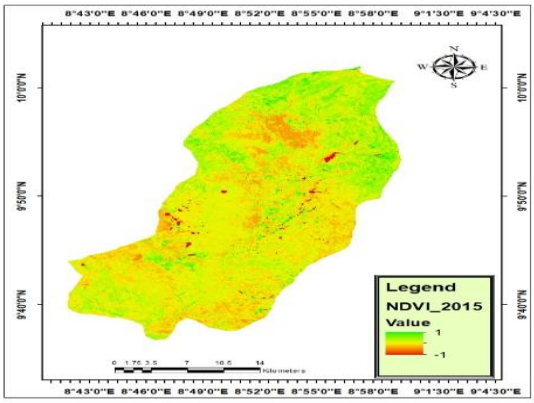


Fig. 12: NDVI Map of Jos Metropolis 2015

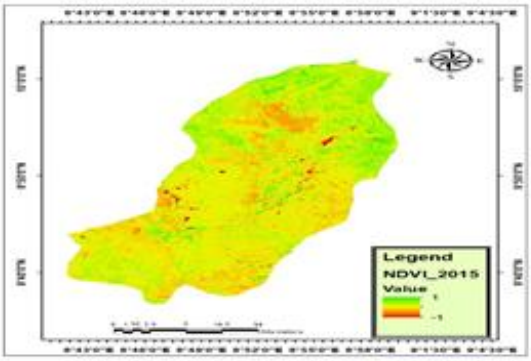


Fig. 11: NDVI Map of Jos Metropolis 2025

3.3 The Decadal Temperature Statistics

The decadal temperature indicates a progressive increase in mean temperature in Jos Metropolis from 1985 to 2025. The highest temperature increase of 1.3258°C occurred between 1995 and 2005, while the lowest increase of 0.5821°C was recorded between 2005 and 2015.Overall, temperature increased by 3.2358°C, representing a 15.04% increase over the 40-year period. This suggests a sustained warming trend in Jos Metropolis, although the rate of increase varied across the decades. Academic note: The table summarizes temperature changes across four ten-year intervals using the values you supplied. It does not represent the average temperature of every individual decade, which would require annual temperature data.

Table 3: Decadal Temperature Summary of Jos Metropolis (1985–2025).

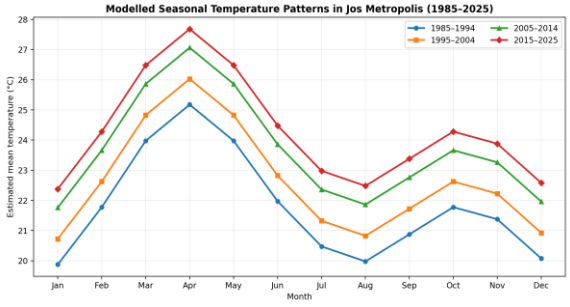
Decadal Period	Initial Mean Temperature (°C)	Final Mean Temperature (°C)	Temperature Change (°C)	Percentage Change (%)	Annual Rate of Increase (°C/year)
1985–1995	21.5195	22.1363	+0.6168	2.87	0.0617
1995–2005	22.1363	23.4621	+1.3258	5.99	0.1326
2005–2015	23.4621	24.0442	+0.5821	2.48	0.0582
2015–2025	24.0442	24.7553	+0.7111	2.96	0.0711
Overall (1985–2025)	21.5195	24.7553	+3.2358	15.04	0.0809

3.4 Seasonal Temperature Pattern

The seasonal Temperature pattern analysed to identify seasonal variations and trends across decades and it was observed that the Hot Season (March–April):

3.5 Modelled seasonal Temperature Pattern of Jos Metropolis (1985-2025)

The modelled lines show warmer conditions around March–April and cooler conditions around July–August. Each successive decadal group lies above the preceding group, reflecting the increase in the supplied annual mean temperatures. The seasonal shape is identical across decades by construction; the figure therefore does not establish observed changes in seasonal timing or amplitude.



Graph 3: Modelled Seasonal Temperature Pattern of Jos Metropolis by Decade (1985-2025)

3.6 Relationship between Land Use Land Cover Change and Temperature Dynamics

The Pearson Correlation Analysis revealed statistically significant relationships between LULC changes and land surface temperature from 1985 to 2025. Built-up areas exhibited the strongest positive correlation with LST ($r = 0.9927$, $p < 0.001$), followed by farmland ($r = 0.9684$, $p = 0.0067$) and bare surfaces ($r = 0.9447$, $p = 0.0155$). These findings indicate that the expansion of these land cover classes occurred alongside increasing land surface temperatures during the study period. Conversely, vegetation exhibited a very strong negative correlation with LST ($r = -0.9878$, $p = 0.0016$), indicating that vegetation cover declined as land surface temperature increased. Water bodies also demonstrated a very strong negative correlation ($r = -0.8998$, $p = 0.0375$). This indicate that urban expansion, agricultural development, and vegetation loss were associated with increasing land surface temperatures within the study area.

Table 4: Correlation between LULC Classes and Land Surface Temperature (1985–2025)

LULC Class	Correlation Coefficient (r)	Significance Level (p-value)	Relationship
Bare Surface	+0.9447	P<0.0155 (Significant)	Very strong positive
Built-up Area	+0.9927	P<0.0007 (Significant)	Very strong positive
Farmland	+0.9684	P<0.0067 (Significant)	Very strong positive
Vegetation	−0.9878	P<0.0016 (Significant)	Very strong negative
Water Body	−0.8998	P<0.0375 (Significant)	Very strong negative

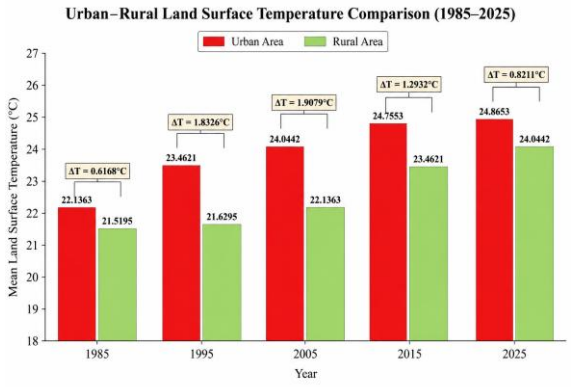


Fig. 13: Temperature Different Maps between Urban-Rural areas

The comparative analysis of urban and rural Land Surface Temperature (LST) between 1985 and 2025 reveals consistently higher surface temperatures in urban areas than in rural areas throughout the study period. In 1985, urban areas recorded a mean LST of 22.1363°C, compared with 21.5195°C in rural areas in the study area during a period under study. Resulting in a temperature difference of 0.6168°C in the study area during a period under study.

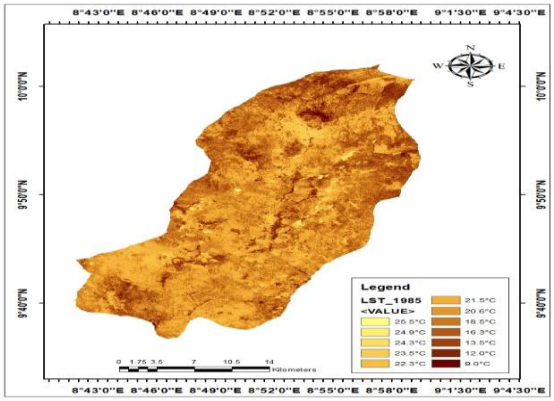


Fig 14: Temperature Change Analysis in 1985

The LST of 1985 analyzed as an initial year in other to study the LST dynamics of Jos Metropolis, Plateau State, Nigeria. Four different decades from the year 1985 to 2025 respectively. In 1985, urban areas recorded a mean LST of 22.1363°C, compared with 21.5195°C in rural areas, resulting in a temperature difference of 0.6168°C. By 1995, the temperature difference had increased substantially to 1.8326°C, suggesting an intensification of the surface urban heat island effect

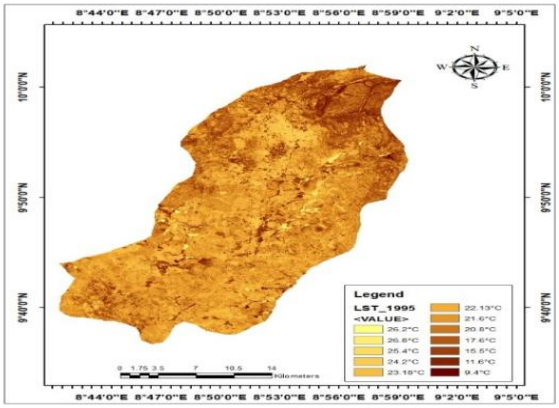


Fig 16: Temperature Change Analysis in 1995

By 1995, the temperature difference had increased substantially to 1.8326°C, suggesting an intensification of the surface urban heat island effect.

As a result of both some few natural phenomenon the anthropogenic activities in Jos metropolis.

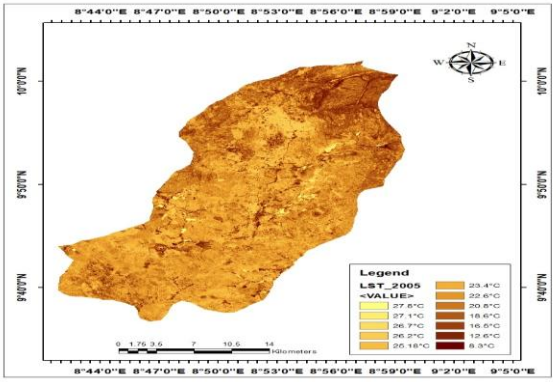


Fig 15: Temperature Change Analysis in 2005

The highest urban–rural temperature difference was observed in 2005, when urban areas recorded 24.0442°C and rural areas recorded 22.1363°C, producing a difference of 1.9079°C

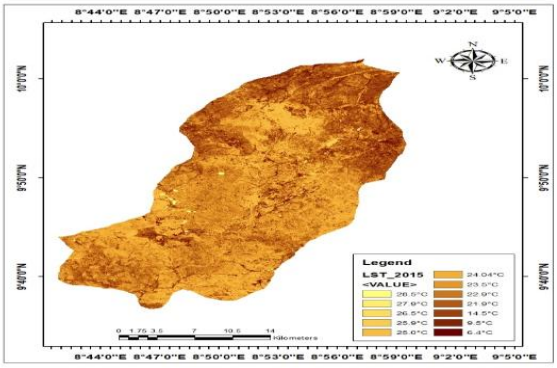


Fig 17: Temperature Change Analysis in 2015

However, the temperature difference subsequently declined to 1.2932°C in 2015 and 0.8211°C in 2025. This reduction occurred because rural temperatures increased more rapidly than urban temperatures during the later study periods. Overall, urban LST increased by 2.7290°C between 1985 and 2025, while rural LST increased by 2.5247°C.

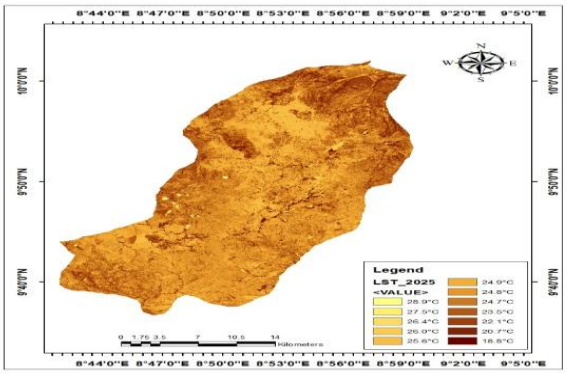


Fig 18: Temperature Change Analysis in 2025

These indicate that both urban and rural environments experienced substantial surface warming, although urban areas remained consistently warmer. The observed urban–rural temperature differences may be associated with changes in land use and land cover, particularly the expansion of built-up areas, reduction in vegetation cover, and alteration of surface thermal properties.

The result implies that Urban Heat Island Intensity increased from 0.6168°C in 1985 to 1.9079°C in 2005, representing the highest intensity during the study period. However, it declined to 1.2932°C in 2015 and further to 0.8211°C in 2025. This suggests that the temperature difference between urban and rural areas widened between 1985 and 2005 but narrowed considerably between 2005 and 2025. The changing intensity of the urban heat island effect over the 40-year study period and provides evidence of variations in the thermal contrast between urban and rural environments.

Table 5: Urban Heat Island Intensity over Time

Year	Urban Mean Temperature (°C)	Rural Mean Temperature (°C)	UHII (°C)
1985	22.1363	21.5195	0.6168
1995	23.4621	21.6295	1.8326
2005	24.0442	22.1363	1.9079
2015	24.7553	23.4621	1.2932
2025	24.8653	24.0442	0.8211

3.7 Spatial Analysis of Temperature –LULC Relationship

To determine the spatial variation in surface temperature in relation to Land Use Land Cover (LULC) temperature zones were delineated concentrically from the urban core of Jos Metropolis in 2025. Each zone reflects a LULC class and demonstrates how proximity to urban areas influences thermal patterns.

The highest temperature (24.8653) was record within the 0-2 km zone where the land is predominantly covered by built-up infrastructure. This aligns with the Urban Heat Island (UHI) effect, where dense development results in elevated surface temperatures. As the distance from the city center increases, the mean temperature decreases gradually, reaching 24.0442°C in the outermost zone (>12 km), which is largely dominated by natural vegetation. The

temperature gradient of –0.8211°C between the urban core and rural vegetated outskirts highlights the cooling role of green cover and agricultural land, in contrast to the heat-retaining nature of built environments. This zonal temperature pattern provides clear evidence of the spatial manifestation of UHI effects in Jos Metropolis. It emphasizes the importance of land cover in regulating urban thermal conditions and the need for sustainable spatial planning that incorporates green buffers, tree cover, and farmland protection as part of climate adaptation strategies.

This illustrates a gradual decline in mean land surface temperature from 24.8653°C within 0–2 km of the urban core to 24.0442°C beyond 12 km. Built-up areas dominate the inner distance zones, while vegetation and cropland become more prominent towards the outer zones. This pattern illustrates urban surfaces experience higher temperatures than surrounding rural landscapes in the study are during a period under study.

Table 6: Temperature Variation by Distance from Urban Core (2025)

Distance Zone (km)	Mean Temperature (°C)	Dominant LULC	Temperature Gradient (°C)
0–2 km	24.8653	Built-up Area	0.0000
2–4 km	24.7200	Built-up Area	-0.1453
4–6 km	24.5800	Built-up Area/Vegetation	-0.2853
6–8 km	24.4300	Vegetation/ Agricultural Land	-0.4353
8–10 km	24.2900	Agricultural Land	-0.5753
10–12 km	24.1600	Vegetation/Agricultural Land	-0.7053
>12 km	24.0442	Rural Vegetation/Cropland	-0.8211

The findings of this research work reveal that Jos metropolis has undergone a tremendous change in land use over the past 4 decades, urban expansion is one of the major factors influencing changes in Land Use and Land Cover (LULC), particularly in rapid developing centres. The expansion of residential buildings, commercial activities, transportation network, industrial establishment, and many other infrastructures contributes to the transformation of natural landscapes into Jos metropolitan expansion of the build-up environment having an approximately from 13% in 1985 into 33% in 2025. The thermal distinction between urban and rural environments during the 1985–2025 study period. The urban mean land surface temperature increased from 22.1363°C in 1985 to 24.8653°C in 2025, while the rural mean temperature increased from 21.5195°C to 24.0442°C. This pattern indicates an overall increase in surface temperature across both environments, with the urban area maintaining higher temperatures throughout the period under study.

Many factors account for cities centres sprawl and its associated environmental changes. These include population growth, rural–urban migration, and increasing demand for residential accommodation, commercial development, road construction, and the expansion of social and economic infrastructure. These activities often result in the conversion of vegetation, agricultural land, and other natural surfaces into impervious built-up areas. The findings are consistent with the observation of Seto, Güneralp and Hutyra (2012), who established that urban land expansion is a major driver of global environmental change, particularly through the conversion of natural ecosystems into developed landscapes. Similarly, Weng (2001) explained that urban growth and land-cover transformation influence the spatial distribution of land surface temperature. Therefore, urban expansion represents an important factor in understanding the changing thermal conditions of the study area. However, the specific contribution of individual driving forces would require supporting population, infrastructure, and land-cover change statistics. Urban growth leads to many environmental consequences particularly through the modification of natural land surfaces. The replacement of vegetation and agricultural land with concrete, asphalt, rooftops, and other artificial materials reduces the availability of natural surfaces that support evapotranspiration and regulate surface temperature.

The temperature results indicate that urban areas consistently result recorded higher mean

temperatures than rural areas between 1985 and 2025. In 1985, the urban mean temperature was 22.1363°C compared with 21.5195°C in the rural environment, representing a difference of 0.6168°C. By 2025, the urban mean temperature had increased to 24.8653°C, while the rural mean temperature reached 24.0442°C, producing a difference of 0.8211°C. This difference indicate that urban centres experience higher degree of thermal reflectance compared to rural areas. The present of bare lands, reduction in vegetation cover, increase heat absorption, and the limited of evaporation cooling may contribute to this pattern. This is in line with Oke (1982), urban surface characteristics, building structures, anthropogenic heat emissions, and reduced vegetation contribute significantly to the development of urban heat islands. Similarly, Voogt and Oke (2003) highlighted the importance of understanding urban surface properties when investigating urban thermal environments using remote sensing. Consequently, the observed temperature differences demonstrate the importance of maintaining vegetation and other natural land-cover features to reduce the environmental consequences associated with urban development.

Temporal temperature analysis provides important information about the development and changing intensity of the urban heat island phenomenon within the study area. Urban Heat Island Intensity refers to the temperature difference between an urban environment and its surrounding rural environment. The results indicate that urban and rural temperatures increased throughout the study period, although the magnitude of the temperature difference varied considerably. In 1985, the urban mean temperature was 22.1363°C, compared with 21.5195°C in the rural area, producing a UHII of 0.6168°C. By 1995, the intensity increased significantly to 1.8326°C, indicating a widening thermal difference between urban and rural environments. The highest UHII was recorded in 2005 at 1.9079°C, when the urban temperature reached 24.0442°C compared with 22.1363°C in the rural area. This suggests that the thermal contrast between the two environments was strongest during this period. However, the intensity declined to 1.2932°C in 2015 and further decreased to 0.8211°C in 2025. Although the temperature difference narrowed after 2005, both urban and rural temperatures remained higher than their respective 1985 values.

Statistical relationship is important in understanding the association between Land Use Land Cover (LULC) characteristics and land surface temperature. In urban environmental studies statistical techniques such as correlation analysis, regression analysis, and coefficient of determination (R^2) are commonly employed to establish the strength and direction of relationships between environmental variables. Temperature results indicate that urban environments consistently maintained higher mean surface temperatures than rural environments across the five observation periods. This provides descriptive evidence of a thermal distinction between urban and rural land-cover settings. The temperature difference increased from 0.6168°C in 1985 to 1.9079°C in 2005 before declining to 0.8211°C in 2025. This changing pattern suggests that the relationship between urban development and surface temperature may vary over time rather than follow a constant linear trend.

For a more comprehensive statistical assessment, the following relationships are relevant:

- Built-up area and temperature: Increased bare surface coverage may contribute to higher surface temperatures.
- Vegetation and temperature: Increased vegetation cover may reduce surface temperatures through shading and evapotranspiration.
- Normalized Difference Vegetation Index (NDVI) and temperature: Vegetation density can be examined in relation to variations in land surface temperature.
- Normalized Difference Built-up Index (NDBI) and temperature: Built-up surface characteristics can be examined to determine their association with thermal patterns.

The coefficient of determination (R^2) can be used to establish the proportion of temperature variation explained by an independent variable or statistical model. Similarly, correlation coefficients can indicate whether the relationship between two variables is positive or negative and whether it is weak or strong.

The important implications of urban environmental management and sustainable land use planning, consistently higher urban temperatures compared

with rural temperatures demonstrate the need for planning strategies that promote environmentally sustainable urban development. First, urban authorities should prioritize the preservation and expansion of green spaces, parks, urban forests, and roadside vegetation. These features can improve environmental conditions by providing shade and supporting evapotranspiration. Second, land-use planning should regulate uncontrolled urban expansion, particularly where development threatens existing vegetation and agricultural land. Proper zoning regulations and development control measures can help reduce the unnecessary conversion of natural surfaces into impervious built-up areas. Third, the use of climate-responsive building materials, reflective roofing systems, permeable surfaces, and appropriate urban design should be encouraged to reduce excessive heat absorption. Fourth, urban planners should incorporate remote sensing and Geographic Information System (GIS) techniques into regular environmental monitoring. Satellite-based LST mapping can help identify urban hotspots and monitor changes in thermal conditions over time. Finally, sustainable urban development should integrate environmental protection with population growth and infrastructure expansion. This will help ensure that urban development does not compromise environmental quality and the well-being of residents.

In summary, this study assessed the impacts of Land Use Land Cover (LULC) changes on Land Surface Temperature (LST) in Jos, Plateau State, Nigeria. Over the period of 1985-2025. The analysis considered five difference years (1985, 1995, 2005, 2015, and 2025). To examine in the distribution of Land Use Land Cover (LULC) classes variation in land surface temperature, and the statistical relationship between land use land cover and Land Surface Temperature (LST). The study focuses on five land feature classes such as vegetation, agricultural land, bare surface, built-up areas, and water body, and used satellites imageries to examine the changing relationship between urban landscape and land surface thermal condition.

The first objective examines the spatial and temporal changes of LULC in Jos metropolis, Plateau state, Nigeria. The result indicates a marked transformation of the landscape between 1985 and 2025. Vegetation experiences a tremendous reduction, declining by approximately 296.382 km², equivalent to about 37% of the study area during the period under study while built-up areas increased by approximately160.202 km² about 20% and farmland increased by 120.149 km² with about 15%, bare surfaces increased by 24.029 km² with about 3%, and water body recorded a decrease of approximately 8.010 km², 1%. These changes shows that urban growth and other human activities substantially altered the land cover composition of Jos.

In 1995-2005 recorded the most pronounced transition in the reported LULC results. During this period, built-up areas increased by approximately 64.083 km², farmland by 40.054 km² and bare surfaces by 16.021 km², while vegetation declined by about 112.140 km². This pattern suggests an acceleration of land conversion during the period, particularly the replacement of vegetated surfaces by built-up and other modified land-cover types. The reduction in vegetation is important because vegetated surfaces provide shade and support evapotranspiration, both of which can moderate surface heating.

The second objective assessed the spatial and the temporal variation of Land Surface Temperature (LST) the reported over mean LST increased from 21.5195°C in 1985 to 24.7553°C in 2025, representing a rise of 3.2358°C, or approximately 15.04%, over the 40-year study period. The average rate of increase was approximately 0.0809°C per year. The largest decadal increase occurred between 1995 and 2005, at approximately 1.3258°C, while the smallest increase occurred between 2005 and 2015, at approximately 0.5821°C. The overall pattern indicates a progressive increase in surface temperature across the study period, although the rate of increase varied between observation years.

The third objective examine the relationship between the Land Use Land Cover (LULC) and Land Surface Temperature (LST) Pearson correlation results based on the five observation years showed positive associations between LST and bare surfaces ($r = 0.9447$, $p = 0.0155$), built-up areas ($r = 0.9927$, $p = 0.0007$) and farmland ($r = 0.9684$, $p = 0.0067$). Negative associations were reported for vegetation ($r = -0.9878$, $p = 0.0016$) and water bodies ($r = -0.8998$, $p = 0.0375$). At the level of the reported analysis, this indicates that increases in built-up, farmland and bare-surface coverage were associated

with higher LST, whereas greater vegetation and water-body coverage were associated with lower LST. These results describe statistical associations and should not be interpreted as proof that land-cover change alone caused the observed temperature increase.

IV. CONCLUSION.

The study concludes that Jos experienced substantial land use/land cover transformation between 1985 and 2025, characterized mainly by a considerable decline in vegetation and an expansion of built-up areas, farmland and bare surfaces. The scale and direction of these changes demonstrate the growing influence of urban expansion and human activities on the physical landscape of the metropolis. The study also found an over all increase in land surface temperature during the same period. The reported rise in mean LST, together with the strong positive correlations for built-up areas, farmland and bare surfaces and the negative correlations for vegetation and water bodies, indicates that the composition of the land surface is closely associated with thermal conditions in Jos. The findings are consistent with the explanation that replacing vegetation with exposed surface can reduce evaporative cooling and increase the absorption and storage of solar energy.

Furthermore, vegetation changes in land use/land cover are an important factor to consider in understanding the spatial and temporal pattern of surface warming in Jos. However, LST is also influenced by atmospheric conditions, seasonal differences, topography, soil moisture and broader climate variability. Therefore, the study establishes meaningful relationships between land-cover composition and surface temperature, but the reported correlations should be interpreted as associations rather than definitive causal effects. Sustainable land-use planning, protection of vegetation and water features, and continuous environmental monitoring are consequently important for reducing the potential effects of increasing surface heat.

V. RECOMMENDATIONS.

Based on the findings and conclusion of the study, the following recommendation were made:

1. Strengthen urban green space protection and development. The Plateau State Government, Jos Metropolitan Development Board and relevant planning authorities should protect existing vegetation, urban forests, parks and green corridors. New residential and commercial developments should incorporate adequate tree planting and landscaped open spaces to improve shade and support evaporative cooling.
2. Promote climate responsive building and surface materials. Building designs should make greater use of reflective or high-albedo roofing, suitable wall finishes, shading devices and energy-efficient layouts. Where technically and economically appropriate, permeable paving and other heat-reducing surface materials should be encouraged in roads, parking areas and public spaces.
3. Improve development control and land use planning. Development approval and physical planning should be guided by updated land-use plans and satellite-based land-cover information. Uncontrolled conversion of vegetated land to built-up areas should be discouraged, and development should be directed towards appropriately designated zones while maintaining ecological buffers and open spaces.
4. Conserve water bodies and drainage corridors. Natural streams, ponds, wetlands and drainage channels should be protected from encroachment, indiscriminate dumping and avoidable reclamation. Maintaining these features can support local environmental functions and help preserve the cooling influence of moist surfaces and surrounding vegetation.
5. Establish continuous LULC and LST monitoring. Relevant government agencies, universities and environmental organizations should undertake periodic satellite-based monitoring of land-cover change and surface temperature. A consistent monitoring framework would help identify areas experiencing rapid vegetation loss, built-up expansion and elevated surface temperatures, thereby supporting evidence-based planning.
6. Increased public awareness and community participation. Public education programmed should explain the relationship between vegetation, land development and surface

heating. Residents, community associations, developers and civil-society groups should be involved in tree planting, protection of open spaces, responsible waste management and the conservation of local water features.

7. Integrate heat considerations into climate adaptation policies. Urban climate resilience strategies for Jos should incorporate heat-sensitive planning, green infrastructure, accessible shaded public spaces and protection of environmentally sensitive areas. Priority should be given to neighborhoods where monitoring identifies high surface temperatures and limited vegetation.
8. Improve the scope and the robustness of future research. Future studies should use additional satellite dates and, where possible, seasonal or multi-season observations to distinguish long-term trends from seasonal effects. Researchers should validate LULC classifications with independent reference data, report classification accuracy, verify LST retrieval and scaling procedures, and use spatially explicit statistical methods with sufficient observations. Additional variables such as NDVI, NDBI, elevation, soil moisture and rainfall may also be incorporated to better explain variations in LST.

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