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Spatiotemporal Analysis of LST in the Cities of Lubuklinggau and Palembang, 2019–2023

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ABSTRACT

Land surface temperature changes are an important indicator in identifying the impact of urbanization and land use change on the urban environment. Palembang and Lubuklinggau are two cities in South Sumatra Province with different geographic characteristics and levels of urbanization, potentially resulting in different thermal conditions. This study aims to analyze and compare the distribution of land surface temperature (LST) in the two cities in 2019 and 2023 and identify its relationship with vegetation conditions and regional development. The study used a remote sensing approach utilizing Landsat 8 and Landsat 9 imagery. The study used a remote sensing approach utilizing Landsat 8 and Landsat 9 imagery. The analysis was conducted using ENVI 5.3 and ArcGIS 10.8 for Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) calculations and for spatial and temporal analysis of LST distribution changes. The results showed that the average temperature in Lubuklinggau City increased from 20.3°C to 22.5°C, while Palembang City experienced a decrease from 29.6°C to 28.8°C. However, Palembang still had a higher surface temperature than Lubuklinggau throughout the observation period. Spatial analysis shows that areas with higher vegetation density tend to have lower surface temperatures than built-up areas. This finding suggests that land use characteristics and vegetation distribution play a significant role in shaping surface temperature patterns in urban areas. The research findings are expected to inform spatial planning and climate change mitigation strategies in South Sumatra Province.

A. INTRODUCTION

Climate change is a global environmental issue that affects various aspects of life, including changes in land surface temperature (LST). Long-term changes in atmospheric conditions are driven by both natural processes and human activities. South Sumatra Province is experiencing continued urban development and population growth, making spatial assessment of LST increasingly relevant for understanding urban thermal conditions (Fu & Weng, 2016; Gémes et al., 2016; Fajary et al., 2024).

Palembang City, as the provincial economic and administrative center, has experienced rapid physical development accompanied by expansion of built-up areas. These conditions can intensify the surface urban heat island effect because impervious materials store and reradiate heat, while reduced vegetation can weaken evaporative cooling (Rushayati et al., 2016; Putra et al., 2018; Prayuda & Kusuma, 2024).

LST is an important component of the land–atmosphere energy balance and is influenced by land cover, vegetation, soil moisture, surface emissivity, and urbanization. Thermal remote sensing using Landsat imagery provides spatially explicit information for monitoring these conditions, while the accuracy of LST retrieval depends on atmospheric correction, emissivity estimation, and the retrieval algorithm used (Mohamed et al., 2017; Tan et al., 2017; Sekertekin & Bonafoni, 2020).

Population growth in the two cities provides an additional contextual factor for interpreting urban development. However, population growth should be supported by quantitative data rather than used only as an assumption. BPS population statistics are therefore incorporated into the analysis to describe changes in population between 2019 and 2023 and to assess their consistency with the broader pattern of urban development (Badan Pusat Statistik Kota Lubuklinggau, 2019, 2024; Badan Pusat Statistik Kota Palembang, 2019, 2024).

The comparative analysis of LST in these two cities provides a basis for understanding how differences in urban structure, vegetation, and land-cover dynamics are associated with thermal conditions. The findings can support spatial planning and climate adaptation, particularly through protection of vegetation and control of built-up expansion (He et al., 2019; Logan et al., 2020; Fajary et al., 2024).

Previous studies have examined the relationship between land-cover change, vegetation, and LST using Landsat imagery. Putra et al. (2018) demonstrated the relationship between land-cover change and surface thermal conditions in Surakarta, while Utomo et al. (2017) examined the relationship between LST variation and land-cover classes in Pati. Similar relationships between NDVI, built-up land, and LST have also been reported in international studies (Guha et al., 2018; Karakuş, 2019; Alexander, 2020).

Despite these studies, comparative analyses that integrate LST, NDVI, land-cover change, and population dynamics between two cities with different urbanization characteristics within the same province remain limited. Recent Indonesian studies demonstrate the value of integrating LST, vegetation, land-cover, and urban-growth indicators, but comparative evidence for South Sumatra remains limited (Hadibasyir & Firdaus, 2023; Fajary et al., 2024; Wardahni, 2025).

B. METHODS

This study uses a quantitative approach with a focus on the analysis of land surface temperature (LST) in Palembang City and Lubuklinggau City. The analysis was carried out using remote sensing data in the form of Landsat satellite imagery and spatial data processing using Geographic Information System (GIS) software. This approach is used to identify the distribution of surface temperatures and the changes that occurred in 2019 and 2023 spatially as well as temporally

Study Area/Research Object

The study area comprises the entire administrative areas of Lubuklinggau City and Palembang City, South Sumatra Province, Indonesia. The research object is the spatial distribution of Land Surface Temperature (LST) and vegetation conditions derived from Landsat 8 and Landsat 9 OLI/TIRS satellite imagery for 2019 and 2023. The Landsat imagery covering Lubuklinggau City is located at **Path 125/Row 62**, while the imagery covering Palembang City is located at **Path 124/Row 62**. The analysis focuses on the spatial and temporal variations in LST and their relationship with vegetation density and land-cover characteristics.

Sampling Methods

The sample is in the form of secondary data from Landsat 8-9 OLI/TIRS satellite imagery in 2019 and 2023. The data contained thermal information describing LST conditions in both years of observation.

Data Types and Sources

Data is obtained entirely from secondary sources, including:

1. Landsat 8 OLI/TIRS level 1T imagery downloaded via USGS EarthExplorer.

2. Data on the administrative boundaries of Lubuklinggau City and Palembang City obtained from INA-SDI.
3. Daily temperature data for 2019 and 2023 through the Weatherspark website.

In addition, supporting data such as regional boundaries and shapefile files are used for the spatial extraction process.

Research Tools and Data

This study uses hardware in the form of a laptop that supports spatial data processing and remote sensing. The software used includes ArcGIS 10.8, ENVI 5.3, Microsoft Excel, and Microsoft Word. The research data consists of Landsat 8 OLI/TIRS imagery in 2019, Landsat 9 OLI/TIRS imagery in 2023, administrative boundary data for Palembang City and Lubuklinggau City, daily air temperature data, and other supporting data used in the Land Surface Temperature (LST) analysis process.

Data Processing Techniques

Data processing is carried out using ENVI 5.3 and ArcGIS 10.8 through the following stages.

1. Radiometric Correction

It is done to improve image quality and convert the value of the Digital Number into a radiance value using the constant rescaling of the image metadata. This stage ensures the spectral values are accurate before they are calculated into temperature.

2. Image Cutting

The image is cropped according to the administrative boundaries of Lubuklinggau City and Palembang City using the extract by mask tools in ArcGIS.

3. NDVI calculation

NDVI is used to determine the level of vegetation density in the research area. NDVI values are calculated using Near Infrared (NIR) and Red channels in Landsat imagery with the equation (Fu & Weng, 2016; Guha et al., 2018).

NDVI is used to determine the level of vegetation density in the research area. NDVI values are calculated using Near Infrared (NIR) and Red channels in Landsat imagery with the equation:

$$NDVI = \frac{NIR - red}{NIR + red} \tag{1}$$

Description:

- NIR = near-infrared channel reflectance (Band 5 Landsat 8/9)
- Red = red channel reflectance (Band 4 Landsat 8/9)

NDVI values range from -1 to +1. The higher the NDVI value, the better the vegetation density.

4. Surface Emissivity Calculation

Before calculating the emissivity, the value of the vegetation fraction (Pv) is first calculated using the equation:

$$P_V = \left(\frac{NDVI - NDVI_{MIN}}{NDVI_{MAX} + NDVI_{MIN}}\right) \tag{2}$$

Furthermore, the surface emissivity is calculated by the formula:

$$\varepsilon = 0.004\, P_V + 0.986 \tag{3}$$

Description:

- Pv = proportion of vegetation
- ε = surface emissivity

This approach is commonly used in Landsat-based LST retrieval, although the choice of emissivity model can influence the final LST estimate (Mohamed et al., 2017; Tan et al., 2017; Sekertekin & Bonafoni, 2020).

5. Brightness Temperature Calculation

Brightness Temperature is obtained from thermal radiance conversion using thermal calibration constants (K1 and K2) available in Landsat metadata. The use of Landsat thermal bands and metadata-based calibration is consistent with established Landsat LST retrieval procedures (Meng et al., 2019; Wang et al., 2019; U.S. Geological Survey, 2020).

Before calculating BT, spectral radiance is calculated by equation:

$$L\lambda = m_L \times Q_{CAL} + A_L \tag{4}$$

Description:

- Lλ = spectral radiance TOA
- ML = multiplicative rescaling factor
- AL = additive rescaling factor
- Qcal = Digital Number (DN) value

Then the Brightness Temperature is calculated using the formula:

$$BT = \frac{K_2}{In\left[\frac{K_1}{L\lambda}+1\right]} - 273.15 \tag{5}$$

Description:

- BT = Brightness Temperature (°C)
- K1 = Landsat thermal constant
- K2 = Landsat thermal constant
- Lλ = spectral radiance
- 273.15 = conversion from Kelvin to Celsius

6. LST Calculation

The final stage is to calculate the Land Surface Temperature (LST) using the equation. The single-channel and emissivity-based approaches are widely applied for Landsat LST retrieval, although algorithm selection can affect the resulting estimates (Tan et al., 2017; Sekertekin & Bonafoni, 2020).

$$LST = \frac{BT}{1\left[\frac{\lambda\ \mathrm{BT}}{\rho}\right]\mathrm{In}\ (\varepsilon)} \tag{6}$$

Description:

- LST = Land LST (°C)
- BT = Brightness Temperature
- λ = effective wavelength of Band 10 Landsat (10.895 μm)
- ρ = 14380 μm· K
- ε = surface emissivity

Data Analysis Methods

Data analysis was carried out using quantitative descriptive statistics and spatial analysis in a GIS environment. The calculated LST values for 2019 and 2023 were analyzed to determine the spatial distribution and change of LST in Palembang City and Lubuklinggau City.

Spatial analysis was performed by comparing LST maps between observation years to identify changes in the spatial distribution of thermal conditions. Descriptive statistics included minimum, maximum, and mean LST values for each city.

The average value of LST is calculated using the equation:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{7}$$

with:

- x̄ = average LST
- xi = the LST value of each pixel

The results of Landsat image processing show that LST in Lubuklinggau City changed during the 2019–2023 period. The spatial interpretation of LST should be considered together with vegetation and land-cover conditions because changes in these factors can modify the thermal environment (Putra et al., 2018; Prayuda & Kusuma, 2024).

To determine the change in LST between 2019 and 2023, an LST change analysis is used with the following equation:

$$\Delta T = T_{2023} - T_{2019} \tag{8}$$

Where:

- ΔT = LST change
- T2023 = 2023 LST
- T2019 = 2019 LST

Palembang City shows higher LST characteristics than Lubuklinggau City in the analyzed periods. Built-up areas, transportation networks, and intensive economic activities can contribute to localized thermal accumulation, while green spaces and water bodies can moderate surface heating (He et al., 2019; Farid et al., 2022; Fajary et al., 2024).

Furthermore, the analysis interpreted the relationship between LST changes and land-cover conditions, NDVI values, and population growth using the available secondary data. Population data were compared between 2019 and 2023, while spatial overlay was used to examine the co-occurrence of LST patterns with NDVI and land-cover characteristics. The analysis is descriptive and does not establish a causal effect of population growth on LST.

Analysis of land cover changes was carried out using the interpretation of Landsat imagery in 2019 and 2023. The classification of land cover is divided into several main categories, namely built-up areas, vegetation, water bodies, and open land. The results of the classification were used to determine the change in the area of each land cover class during the study period. The relationship between NDVI and LST was analyzed using a spatial interpretation approach through an overlay technique between the NDVI map and the Land LST (LST) map. This analysis aims to identify the pattern of relationship between vegetation density and LST distribution in the study area. In general, areas with high NDVI values tend to have lower surface temperatures than areas with low NDVI values.

C. RESULT AND DISCUSSION

A. Surface Temperature Distribution of Lubuklinggau City in 2019 and 2023

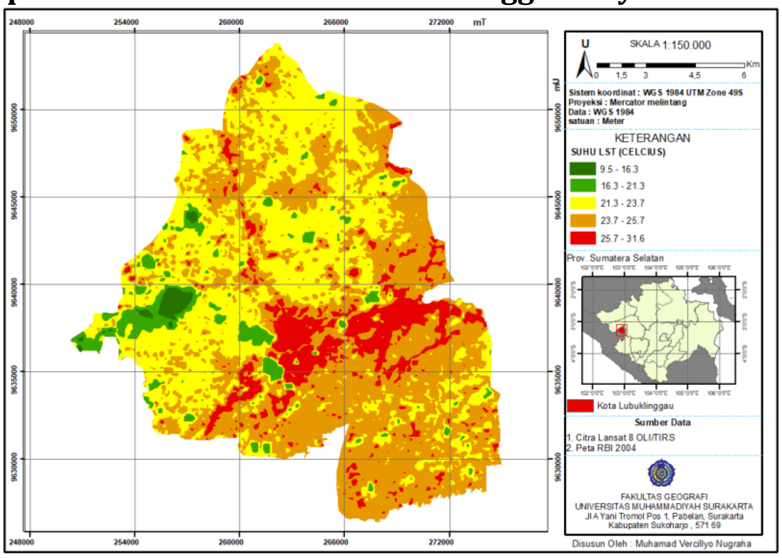

Figure 1. Land Surface Temperature (LST) Map of Lubuklinggau City, 2019

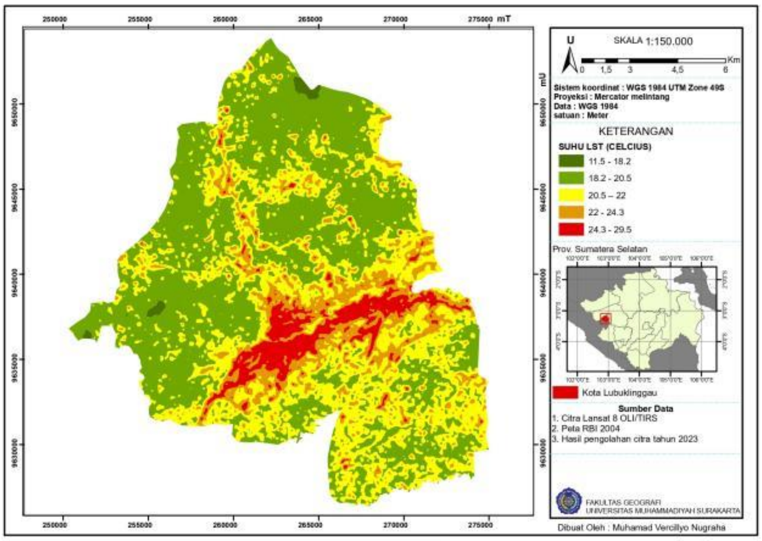

Figure 2. Land Surface Temperature (LST) Map of Lubuklinggau City, 2023

The results of Landsat image processing show that the surface temperature in Lubuklinggau City has changed during the 2019–2023 period. Based on LST analysis, the minimum temperature increased from 9.5°C in 2019 to 11.5°C in 2023, while the average temperature increased from 20.3°C to 22.5°C. An increase in average temperature of 2.2°C indicates a tendency to increase surface heat accumulation related to land use change and built-up area growth. Previous studies have similarly linked land-cover composition and vegetation to urban thermal patterns (Putra et al., 2018; Prayuda & Kusuma, 2024; Fajary et al., 2024). Changes in LST in both years are shown in Table 1 below.

Table 1. LST Statistics in Lubuklinggau City, 2019 and 2023

Temperature Category	Year 2019	Year 2023
Minimum Temperature(°C)	9.5°C	11.5°C
Maximum Temperature(°C)	31.6°C	29.5°C
Average Temperature(°C)	20.3°C	22.5°C

The increase in average temperature indicates that some regions are experiencing an increase in heat intensity even though the maximum temperature is decreasing. This condition indicates a more even temperature distribution in 2023 compared to 2019. A similar phenomenon was also found by Putra A. K. et al. who showed that changes in land cover have an effect on increasing the surface temperature of urban areas.

Table 2. Lubuklinggau City Surface Temperature Class Area

Temperature Category	Year 2019(Ha)	Year 2023(Ha)	Changes (Ha)
Very Low	328,5	199	-129,5
Low	1,792	18,324	16,532
High	17,282	4,759	-12,523
Very High	3,986	2,248	-1,738

Changes in the area of temperature classes indicate a decrease in very low temperature areas and an increase in low temperature areas. These results indicate a redistribution of surface temperature affected by changes in land cover and vegetation conditions.

B. Surface Temperature Distribution of Palembang City in 2019 and 2023

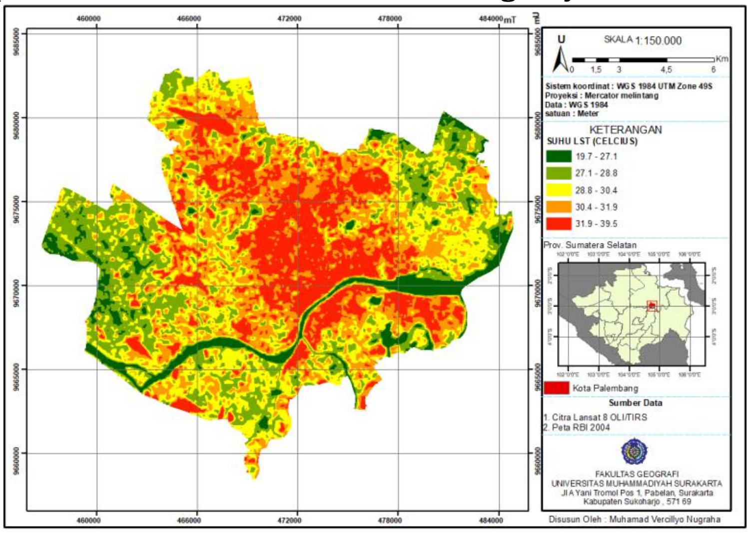

Figure 3. Land Surface Temperature (LST) Map of Palembang City, 2019

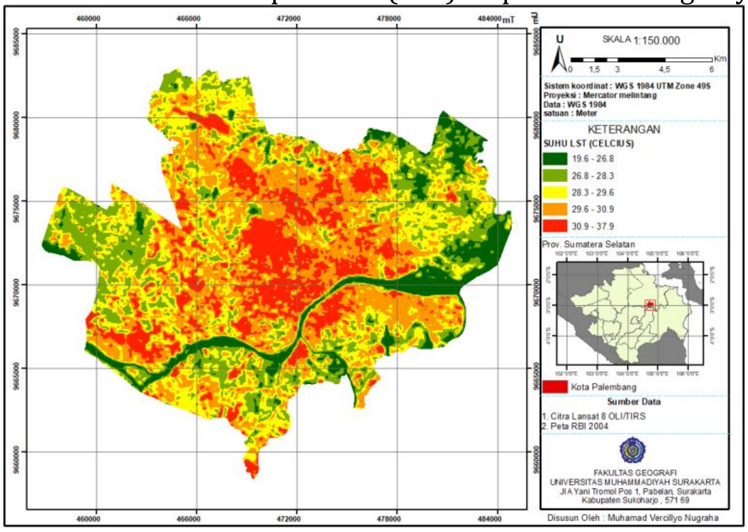

Figure 4. Land Surface Temperature (LST) Map of Palembang City, 2023

Palembang City shows higher surface temperature characteristics than Lubuklinggau City. As a metropolitan city, Palembang is dominated by built-up areas, transportation networks, and intensive economic activities that contribute to the increase in surface temperature. The surface temperature of Palembang City shows high temperature concentrations in the city center area, major transportation corridors, and areas dominated by built-up areas. Although the average temperature has decreased by 0.8°C, the maximum temperature still reaches 37.9°C, indicating the existence of the Urban Heat Island phenomenon in some parts of the city. (Rushayati et al., 2016; Ramsay et al., 2023; Fajary et al., 2024). The change in surface temperature of Palembang is shown in the following Table 3.

Table 3. Comparison of the Surface Temperature Area of Palembang City (2019–2023)

Temperature Category	Year 2019	Year 2023
Minimum Temperature(°C)	19.7°C	19.6°C
Maximum Temperature(°C)	39.5°C	37.9°C
Average Temperature(°C)	29.6°C	28.8°C

The results of the analysis showed that the average temperature in Palembang decreased by 0.8°C. However, the maximum temperature will still reach 37.9°C in 2023, indicating that the Urban Heat Island phenomenon is still occurring in some parts of the city. These findings are in line with research that states that urban areas with a predominance of waterproof materials such as concrete and asphalt tend to have a temperature surface is higher than areas dominated by vegetation.

Table 4. Surface Temperature Class Area of Palembang City

Temperature Category	Year 2019(Ha)	Year 2023(Ha)	Changes (Ha)
Very Low	2,559	3,302	0,743
Low	7,415	7,154	-0,261
High	9,492	10,939	1,447
Very High	7,828	5,999	-1,829

The increase in the area of the high temperature class of 1,447 Ha shows that some urban areas continue to experience heat accumulation even though the average urban temperature has decreased.

C. Comparison of Surface Temperatures of Lubuklinggau and Palembang (2019–2023)

Table 5. Surface Temperature Class Area of Lubuklinggau City and Palembang City, 2019-2023

City	Year	Minimum LST (°C)	Maximum LST (°C)	Mean LST (°C)
Lubuklinggau	2019	9.5	31.6	20.3
Lubuklinggau	2023	11.5	29.5	22.5
Palembang	2019	19.7	39.5	29.6
Palembang	2023	19.6	37.9	28.8

The comparison indicates that the two cities experienced different LST dynamics during 2019–2023. Lubuklinggau recorded an increase in mean LST of 2.2°C, whereas Palembang recorded a decrease of 0.8°C. The difference demonstrates that changes in LST are spatially heterogeneous and should be interpreted in relation to each city's land-cover composition, vegetation conditions, and urban development pattern.

The study further shows that higher vegetation density is spatially associated with lower LST, whereas built-up areas tend to coincide with higher LST. Population data strengthen the interpretation of urban development as contextual pressure, but the evidence does not support a causal claim that population growth alone drives LST change. This interpretation is consistent with research showing that urban thermal conditions are produced by interacting land-cover, vegetation, morphology, and anthropogenic factors (He et al., 2019; Logan et al., 2020; Fajary et al., 2024).

D. Land Use Changes in 2019–2023

Table 6. Changes in LST Class Areas in Palembang City, 2019–2023

LST Category	2019 (ha)	2023 (ha)	Change (ha)
Very Low	2559	3302	743
Low	7415	7154	-261
High	9492	10939	1447
Very High	7828	5999	-1829

The study provides an empirical basis for comparing thermal conditions across cities using a consistent remote-sensing workflow. This contribution is relevant for local spatial planning because it identifies where vegetation conservation and control of built-up expansion can be prioritized. The approach is supported by recent Indonesian applications of Landsat-derived LST for urban environmental assessment (Hadibasyir & Firdaus, 2023; Prayuda & Kusuma, 2024; Wardahni, 2025).

The main limitation is the use of only two observation years, 2019 and 2023, which limits the ability to infer a continuous temporal trend. Future research should use annual or seasonal multitemporal Landsat observations, validate LST against field or station measurements, and apply statistical models to quantify the relationships among LST, NDVI, land-cover change, population density, and other urban factors (Fu & Weng, 2016; Ramsay et al., 2023).

Meanwhile, Palembang City is still dominated by built-up areas, but the LST distribution shows variations influenced by green open spaces, water bodies, and other land-use characteristics.

E. The Relationship of NDVI and Surface Temperature Changes

NDVI and LST maps indicate that areas with high NDVI values (>0.5) generally have lower LST than areas with low NDVI values (<0.2). This pattern is observed in vegetated areas of Lubuklinggau and green open spaces in Palembang.

Areas with low NDVI and a greater proportion of built-up land generally show higher LST. The spatial pattern therefore indicates a negative association between vegetation density and LST, consistent with previous Landsat-based studies (Karakuş, 2019; Alexander, 2020).

The relationship between NDVI and LST shows a negative spatial trend: greater vegetation density is generally associated with lower LST. Vegetation can reduce surface heating through evapotranspiration and shading, although the strength of this relationship can vary with land cover, moisture, season, and urban morphology.

In Lubuklinggau City, areas with high NDVI values are mostly found in vegetation areas and green open land that have relatively low temperatures. In contrast, areas with low NDVI values are generally located in residential areas and urban activity centers that show higher temperatures.

The same pattern is also found in Palembang. Although mean LST decreased, areas with low NDVI still show high LST concentrations, indicating the influence of built-up areas on localized thermal conditions.

These results reinforce the theory that vegetation has an important function in maintaining thermal stability in urban areas so that the existence of green open spaces needs to be maintained as part of climate change mitigation strategies

F. Factors Associated with LST Changes

Changes in Land Surface Temperature (LST) in Lubuklinggau and Palembang occurred with different spatial and temporal patterns. These variations were spatially associated with differences in land-cover characteristics, vegetation density, population dynamics, topography, and urban development. Population dynamics were considered a contextual factor that may be related to the intensity of urban activities and land-use changes. However, these factors should be interpreted as associated variables rather than causal determinants because the analysis was based on observations from only two years, 2019 and 2023, and did not apply multivariate statistical modeling.

In Lubuklinggau City, the mean LST increased by approximately 2.2°C between 2019 and 2023. Spatially, areas with higher LST were generally associated with built-up areas and lower vegetation density. Population data also indicate an increase in population in several districts during the same period. Lubuklinggau Utara II increased from 38,960 inhabitants in 2019 to approximately 43,200 inhabitants in 2023, representing an increase of about 10.86%. Lubuklinggau Barat I increased from 36,562 to approximately 40,000 inhabitants, or about 9.41%. Meanwhile, Lubuklinggau Barat II experienced a slight decrease from 21,365 to approximately 21,000 inhabitants, equivalent to a decrease of about 1.71%. These population changes provide empirical information on demographic dynamics during the observation period. Nevertheless, they cannot be directly interpreted as the cause of the observed increase in LST.

In Palembang City, the mean LST decreased by approximately 0.8°C between 2019 and 2023. Nevertheless, relatively high maximum LST values and localized areas with high surface temperatures remained present. Population distribution also changed among districts. Sukarami increased its population share from 9.52% in 2019 to 11.59% in 2023, while Sematang Borang increased from 2.19% to 3.81%. In contrast, Bukit Kecil experienced a decrease in population from approximately 39,000 inhabitants in 2019 to 38,226 inhabitants in 2023, while its population share decreased from 3.02% to 2.16%. These variations indicate that demographic dynamics differed among districts. However, the decrease in mean LST in Palembang cannot be attributed solely to population changes because surface temperature is also spatially associated with land cover, vegetation density, surface characteristics, and other environmental conditions.

The differences in LST patterns between Lubuklinggau and Palembang may also reflect differences in their geographical and urban characteristics. Lubuklinggau has relatively varied topographic conditions and substantial areas of vegetation, whereas Palembang is characterized predominantly by lowland terrain and a more extensive urban environment. These characteristics provide spatial context for interpreting differences in LST distribution. However, the present study does not quantitatively estimate the independent contribution of topography, land cover, vegetation density, or urban development to LST variation.

Overall, the results indicate that LST dynamics in Lubuklinggau and Palembang were spatially associated with a combination of demographic, land-cover, vegetation, topographic, and urban characteristics. The increase in mean LST in Lubuklinggau occurred during a period when population increases were observed in several districts, whereas Palembang experienced a decrease in mean LST despite population increases in several districts. This contrasting pattern indicates that population dynamics alone do not provide a sufficient explanation for differences in LST between the two cities. Further studies using annual or seasonal multi-temporal observations, quantitative land-cover change data, NDVI–LST statistical analysis, and multivariate statistical models are needed to estimate the relative contribution of population, land-cover change, vegetation density, topography, and other environmental variables to LST variations.

G. Environmental Implications and Recommendations

Rising LST can reduce thermal comfort, increase cooling energy requirements, and worsen air quality. Therefore, mitigation efforts need to be directed to:

1. addition of green open space,
2. rehabilitation of critical land in areas experiencing rapid conversion,
3. Spatial planning based on climate adaptation,
4. The use of building materials with low emission.

The analysis indicates that LST is associated with land-use dynamics, vegetation density, and population change, but the relative contribution of each factor cannot be quantified from the current descriptive design.

D. CONCLUSION AND SUGGESTIONS

The principal contribution of this study is the comparative spatial framework that integrates Landsat-derived LST, NDVI, land-cover change, and population data to distinguish the thermal dynamics of two cities with different urban development characteristics within South Sumatra Province. The analysis demonstrates that city-level LST averages can move in different directions while localized high-LST areas persist, highlighting the importance of spatially explicit analysis for urban climate assessment.

The study further shows that higher vegetation density is spatially associated with lower LST, whereas built-up areas tend to coincide with higher LST. Population data strengthen the interpretation of urban development as contextual pressure, but the evidence does not support a causal claim that population growth alone drives LST change. Thus, the key implication is that urban thermal management should combine protection and expansion of green open space with land-cover control and climate-responsive spatial planning.

The study provides an empirical basis for comparing thermal conditions across cities using a consistent remote-sensing workflow. This contribution is relevant for local spatial planning because it identifies where vegetation conservation and control of built-up expansion can be prioritized. At the same time, the results should be interpreted within the limitations of the available observations and retrieval method.

The main limitation is the use of only two observation years, 2019 and 2023, which limits the ability to infer a continuous temporal trend. Future research should use annual or seasonal multitemporal Landsat observations, validate LST against field or station measurements, and apply statistical models to quantify the relationships among LST, NDVI, land-cover change, population density, and other urban factors.

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