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SPATIO TEMPORAL ANALYSIS TO INDICATIONS OF URBAN HEAT ISLAND IN JAMBI CITY

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ABSTRACT

The high population growth in Jambi City has resulted in land conversion from vegetation to built-up land and settlements, and the use of motorized vehicles has increased the release of carbon emissions which also increase air temperature in Jambi City. To better understand and identify the urban heat island (UHI) phenomenon, spatial and temporal analysis is needed using remote sensing data with a long series from 2000 to 2024. This study aims to examine the intensity of UHI in Jambi City by measuring the surface urban heat island index (SUHII) and the urban thermal field variance index (UTFVI) by utilizing the Land Surface Temperature (LST) and Enhanced Vegetation Index (EVI) products. Correlation analysis shows that Jambi City is an area with the highest LST and the lowest EVI index compared to the surrounding areas. The SUHI intensity in Jambi City has a positive value between 0.2 - 2.5 °C. Meanwhile, the intensity of AUHI between urban and suburban areas ranges from -0.2 - 0.3 °C during the day and -0.1 - 0.1 °C at night. The UTFVI index is in the range of 0.01 - 0.07. Although the intensity of SUHI and AUHI is not too large and the decrease in EVI value can be an indicator of UHI in Jambi City. The correlation test between LST and air temperature of the station has a sufficient category except for the correlation between LST and air temperature of the Kerinci Meteorological Station which has a very weak category.

Keywords: *atmospheric urban heat island; MODIS; surface urban heat island index; urban heat island*

INTRODUCTION

Jambi City is the capital of Jambi Province with an area of 205.38 km2. The population growth in Jambi City in the period 2017-2021 continues to increase. Each year's Population growth ranges from 0.13% to 1.31% (Jambikota.go.id). The high population growth in Jambi City will increase the number of housing units, resulting in a shift in the function of land cover to built-up land.

Changes in land cover in Jambi City significantly affect surface temperature distribution. The increase in built-up land area and the decrease in vegetated land area cause surface temperatures to increase. (Sutriani, 2020). Urban areas that are centres of economy, education, and dense settlements generally have low vegetation density and tend to have higher surface temperatures than the surrounding areas, which still have much vegetation.

Compared to other cities and districts in Jambi Province, Jambi City tends to be hotter. From the results of processing the average air temperature of the Sultan Thaha Meteorological Station in Jambi City from 1991 to 2020, it shows that there has been an average increase in air temperature in Jambi City of around 0.013 °C to 0.031 °C per year, or an increase in temperature in the last 30 years ranging from 0.3 - 0.9 °C (Fauziah. A, 2021). The difference in temperature between the city and the surrounding areas indicates the occurrence of the urban heat island phenomenon or Urban Heat Island (UHI). UHI is a phenomenon that increases air temperature in urban areas compared to the surrounding areas (Miles & Esau, 2017; Mohajerani et al., 2017).

The UHI phenomenon is divided into two types, namely surface urban heat island (SUHI) and atmospheric urban heat island (AUHI) (T.R. Oke, 1996; Singh, 2015). SUHI is the higher surface temperature in urban areas than rural areas, generally expressed in thermal images. AUHI is hot air in urban areas compared to cool air in suburban or rural areas (Lo, 2003; Vgoot, 2003; Syafitri, 2020).

The SUHI phenomenon can be detected by measuring land surface temperature (LST) using satellite imagery and remote sensing techniques. In contrast, the AUHI phenomenon is detected by the difference in air temperature (SAT) between the city and surrounding areas.

SUHI research using MODIS LST data has been widely conducted in various countries, including W. Kuang, et al, 2015a who measured the spatial pattern of land surface temperature (LST) in Beijing, China, Zhang, P., 2014 using MODIS LST spatial analysis to assess surface UHI (SUHI) and compare it with local air temperature in America.

The UHI phenomenon can result in reduced comfort levels. The Urban Thermal Field Variance Index (UTFVI) is used to evaluate the ecological impact of SUHI in urban environments. The selection of the SUHI and UTFVI methods is a method that can quantify UHI intensity spatially, by comparing it with the surrounding areas that are spatially adjacent. UTFVI is a complementary index for calculating the average SUHI in detecting areas affected by heat accumulation in urban agglomerations (Sobrino & Irakulis, 2020).

Urban climate studies, for example, the Urban Heat Island phenomenon for cities in the "inland cities" category, such as Jambi City, are rarely carried out. Remote sensing data with long spatial and temporal series can be used to understand and identify the urban heat island (UHI) phenomenon.

This study aims to examine the intensity of Surface Urban Heat Island (SUHI) in Jambi City by measuring the Surface Urban Heat Island index (SUHII) and Urban Thermal Field Variance Index (UTFVI) by utilising Land surface temperature products (LST, MOD11C3 and MYD11C3) and Enhanced vegetation index (EVI, MOD13C2 and MYD13C2) available on the MODIS Terra (MOD) and AQUA (MYD) satellites in the period 2001 to 2024. This study also discusses the intensity of surface UHI (SUHI) and atmospheric UHI (AUHI) in Jambi City so that they can be used to make policies for climate change mitigation and natural resource management.

MATERIALS AND METHODS

1. Location

   This research was conducted in Jambi City with a geographical location of 1° 36'35.093" S and 103 ° 36' 49.115" E. Jambi Province is located on the east coast, in the central part of Sumatra Island (**Figure 1**). The capital of this province is Jambi City.

2. Research Instrument

   The software used in data processing is Python programming language version 3.6.1, and for mapping visualisation using QGIS Desktop software version 3.36.1, and using Microsoft Excel for air temperature data processing (SAT)

3. Satellite Data

   The satellite data used is data from the MODIS sensor on the Terra (MOD) and AQUA (MYD) satellites, namely Land surface temperature (LST, MOD11C3 and MYD11C3) and Enhanced vegetation index (EVI,

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MOD13C2 and MYD13C2) obtained from NASA in the period 2001 to 2024. Satellite data is downloaded in .hdf format with a spatial resolution of 0.05 ° or around 5 km. A linear interpolation method is used to obtain satellite data with a higher resolution at a spatial resolution of 0.01 ° using the two closest points of the 0.05 ° grid as a reference. Spatial analysis was conducted using Jambi Province shapefile from the Geospatial Information Agency and Digital Elevation Model (DEM) Data from the US Geospatial Agency with a resolution of 1 km.

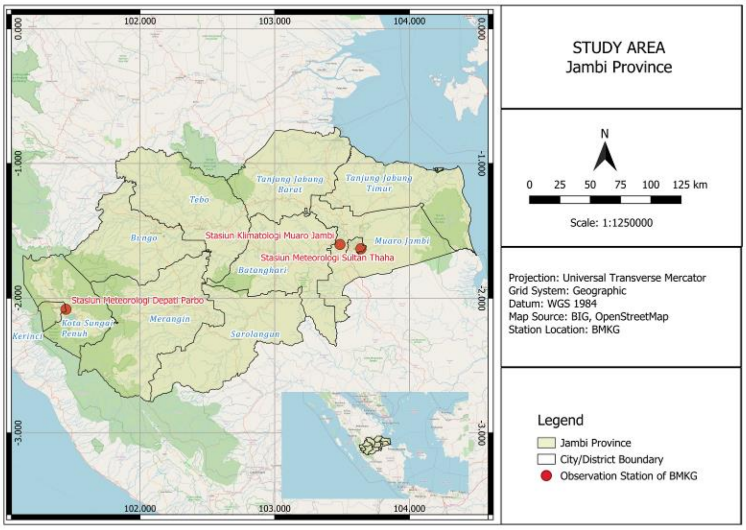

Figure 1. Jambi Province

4. Air Temperature Data

Surface air temperature (SAT) data were obtained from 3 BMKG observation stations from 2001 to 2024, located in Jambi Province, classified as Urban and Sub-Urban Areas.

Urban and Sub-Urban areas in this study were determined based on the Regulation of the Head of BPS Number 120 of 2020 concerning the Classification of Urban and Rural Villages in Indonesia in 2020—the BMKG observation stations of Jambi Province shown in **Table 1**.

Table 1. List of Meteorological Stations in Jambi Province

Station	Coordinat		Elevasi	Class
	Latitude	Longitude		
Stasiun Meteorologi Sultan Thaha Kota Jambi	01038' 01' LS	103038,496' BT	27 m	Urban
Stasiun Klimatologi Muaro Jambi	010 36' 07" LS	1030 29' 41" BT	25 m	Sub urban
Stasiun Meteorologi Depati Parbo Kerinci	02º05'28.2" LS	101º27'43.1" BT	797 m	Rural

The analysis was carried out through the following steps and research flow shown in **Figure 2**:

1. This study utilised MODIS data, which is available in clear-sky conditions. MOD11C3 LST data is only available for clear-sky conditions; in cloudy pixel conditions, LST data is not available (NaN value). To minimise missing data due to cloud cover, LST data was averaged into an annual average (X. Chen et al, 2017). The mean value and standard deviation for Jambi City and its surrounding areas were calculated according to the pixel location in the administrative shapefile data.

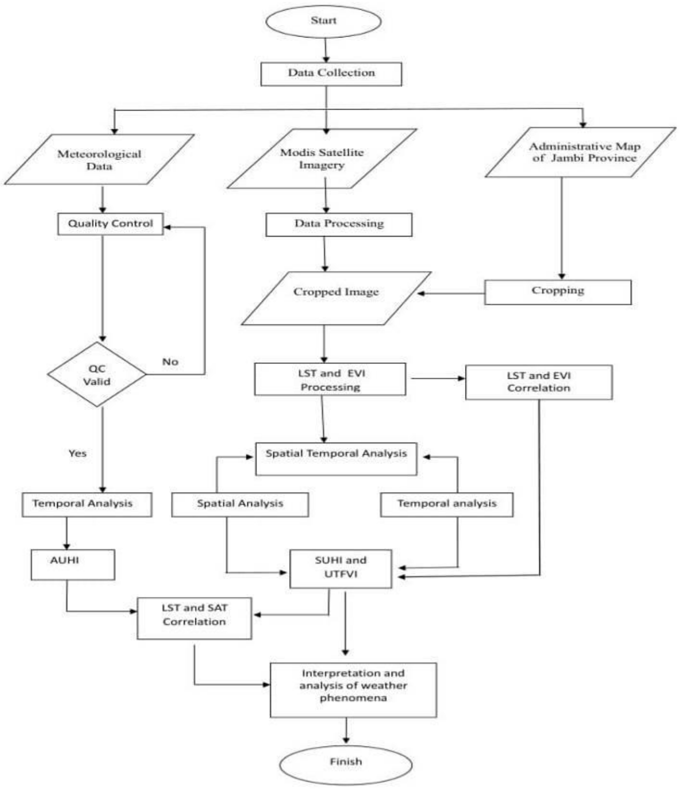

Figure 2. Research Flow

2. Judging from the time the satellite passes, LSTnight from the Aqua satellite observation (MYD) is closer to the minimum temperature value of the BMKG observation data because the minimum temperature generally occurs in the early hours of the morning (Ferdiansyah et al, 2024). LSTday is close to the maximum temperature value observed during the day
3. Temporal analysis of surface temperature was carried out by analysing LSTday, LSTnight and EVI in a seasonal composite to determine the monsoonal effect on surface temperature variations in Jambi Province. The monsoonal division follows the seasonal distribution commonly used in weather and climate analysis, namely December, January, February (DJF) which is the peak of the rainy season, March, April, May (MAM) is the transition season from the rainy season to the dry season, June, July, August (JJA) is the peak of the dry season. September, October and November (SON) is the transition from the dry season to the rainy season.
4. To describe the LST profile, a cross-section of the continuous surface temperature distribution covering urban and rural areas is made, in the form of a west-east cross-section divided into grids. Grid data is aggregated according to region in the Jambi Province shapefile.
5. SUHI intensity, calculated using the following equation (J. Zhao et al, 2020):

$$\text{SUHII} = \frac{(\text{t\_city} - \text{t\_area\_mean})}{\text{t\_area\_std}} \quad (1)$$

6. Urban Thermal Field Variance index (UTFVI), which describes how strong the impact of SUHI is on the surrounding area, is calculated using the following equation: (L. Liu et al, 2011)

$$\text{UTFVI} = \frac{(\text{t\_city} - \text{t\_area\_mean})}{\text{t} - \text{city}} \quad (2)$$

where t_city is the spatial average of LST of Jambi city, t_area_mean is the spatial average of LST of the surrounding area (Muaro Jambi Regency), and t_area_std is the spatial standard deviation of LST of the surrounding area (Muaro Jambi Regency). SUHI and UTFVI intensity measurements were analysed as time series and annual cycles using ENSO Year analysis to determine the influence of global natural phenomena such as El Nino/La Nina

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7. Validation of LST and air temperature from BMKG observation stations.
8. The correlation test was carried out using the Pearson Product-Moment correlation test method, where this test will assess the correlation coefficient, whose value ranges between -1.0 and 1 (Pratiwi & Jaelani, 2021). The correlation coefficient value is obtained using the following equation:

$$R_{xy} = \frac{n\Sigma xiyi - \Sigma xi\Sigma yi}{\sqrt{n\Sigma xi^2 - (\Sigma x_i)(\Sigma xi)^2}} \quad (3)$$

RESULTS AND DISCUSSION

1. Land Surface Temperature (LST)

a. *LST_{day}*

The average LSTday value for 24 years was the lowest at 17.31 °C in Kerinci Regency and reached a maximum value in Jambi City of 33.05 °C (**Figure 3**). This is supported by research by Sutriani (2020), which found that the average surface temperature in Jambi City from 2009 to 2019 increased by 1 - 2.96 °C. In 2009, the average surface temperature was 24.13 °C; in 2014 it rose to 27.09 °C; in 2019 it reached 28.55 °C (Sutriani, 2020).

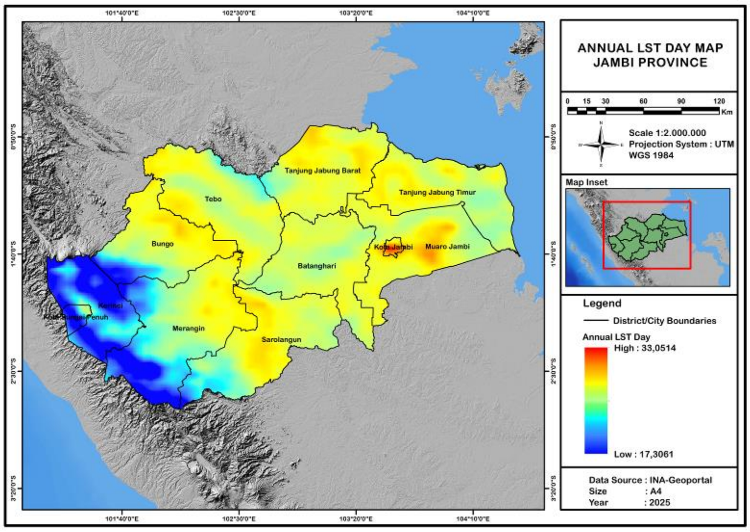

Figure 3. Average LSTday over 24 years (January 2001 to December 2024)

The seasonal LSTday average is calculated by calculating the quarterly seasonal average of DJF, MAM, JJA and SON from 2001 – 2024 (**Figure 4**).

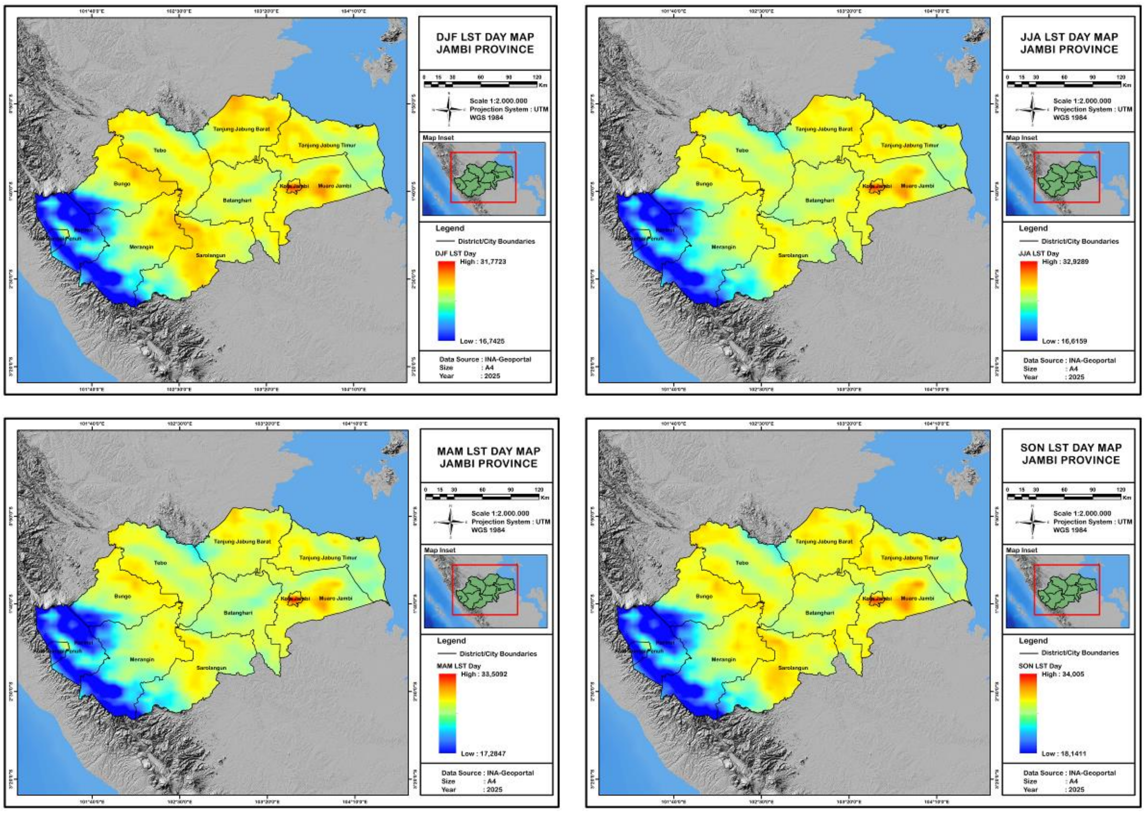

Figure 4. Average seasonal composite LSTday for 24 years of DJF, JJA, MAM, SON.

The highest spatial and temporal distribution of the 24-year seasonal LSTday average is in the September, October and November (SON) period, reaching the maximum LSTday in the eastern part of Jambi Province, precisely in Jambi City, which is 34.01 °C and the minimum LSTday in the western part of Jambi Province, Kerinci Regency, and the western part of Merangin Regency of 18.14 °C. The lowest average seasonal LSTday is in the December, January and February (DJF) period, reaching the maximum LSTday value in Jambi City of 31.77 °C and the minimum LSTday in the western part of Jambi of 16.74 °C.

The Jambi Province area, located around the equator at coordinates 1° 36'35.093" LS and 103° 36'49.115" BT, is more influenced by the apparent daily motion of the sun. The highest seasonal variation of LSTday during 24 years was in September, October and November (SON), which is the transition period from the dry to the rainy season. The lowest seasonal variation of LSTday occurred in

December, January and February (DJF), the peaks of the rainy season.

The average monthly LSTday is warmer in September than in other months. This is related to the period of maximum solar radiation because in September the sun's position is at the equator, and it is at its lowest in December because it is at the southernmost equator (**Figure 5**).

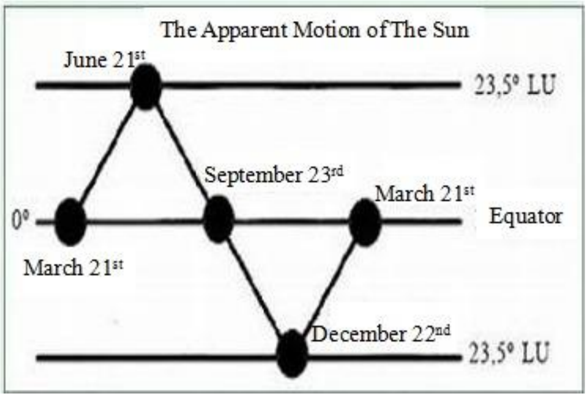

Figure 5. Apparent daily motion of the sun

b. LSTnight

The distribution pattern of nighttime surface temperatures follows the distribution pattern of daytime surface temperatures, where the lowest temperatures occur in the western region and increase towards the east of Jambi Province. The average LSTnight value for 24 years reached the lowest value in the western region of Jambi Province, namely in Kerinci Regency and the western part of Merangin Regency, 17.31 °C (**Figure 6**). The LSTnight value continued to increase and reached a maximum value in the Jambi City area of 23.44 °C.

LST night variations are also analysed spatially and temporally based on seasonal composites in the periods of December, January, February (DJF), March, April, May (MAM), June, July, August (JJA), and September, October, November (SON).

The spatial and temporal analysis of the average seasonal LSTnight for 24 years in the MAM period is higher than in other seasonal periods (**Figure 7**). In the MAM period, the average seasonal LSTnight for 24 years reached a maximum LSTnight of 24,071 °C in the east of Jambi Province, precisely in Jambi City and a minimum LSTnight in the west of Jambi Province, namely 10.75 °C in

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Kerinci Regency and the western part of Merangin Regency. The lowest average seasonal LSTnight was in the SON period, reaching a maximum average LSTnight value of 23.01 °C in the eastern part of Jambi and a minimum of 10.02 °C in the western part of Jambi Province. In the JJA period, the minimum LSTnight was 10.30 °C and the maximum was 23.63 °C. In the DJF period, the average LSTnight is a minimum of 9.64 °C and a maximum of 23.48 °C.

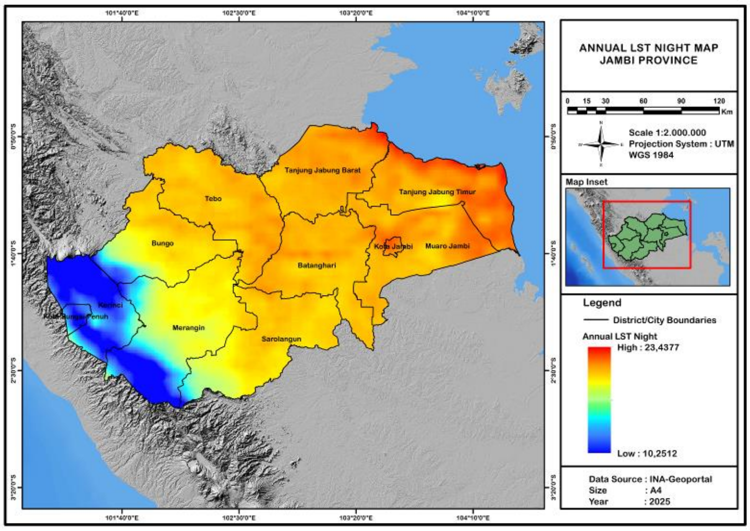

Figure 6. LST night average over 24 years

The highest temporal variation of LSTnight is in the MAM period because monsoonally, the MAM period is a transition period from the rainy to the dry season; night temperatures increase due to the influence of cloud cover, reducing air cooling at night. The lowest LSTnight occurs in the SON period, a transition period from the dry to the rainy season. In general, the temporal variation of night surface temperatures is relatively the same throughout the year, with an average LSTnight maximum at intervals of 23.20 - 24.41 °C in the eastern region of Jambi Province which borders the East Coast of Sumatra and a minimum of 8.96 - 11.03 °C in the western region of Jambi Province which is a hilly area.

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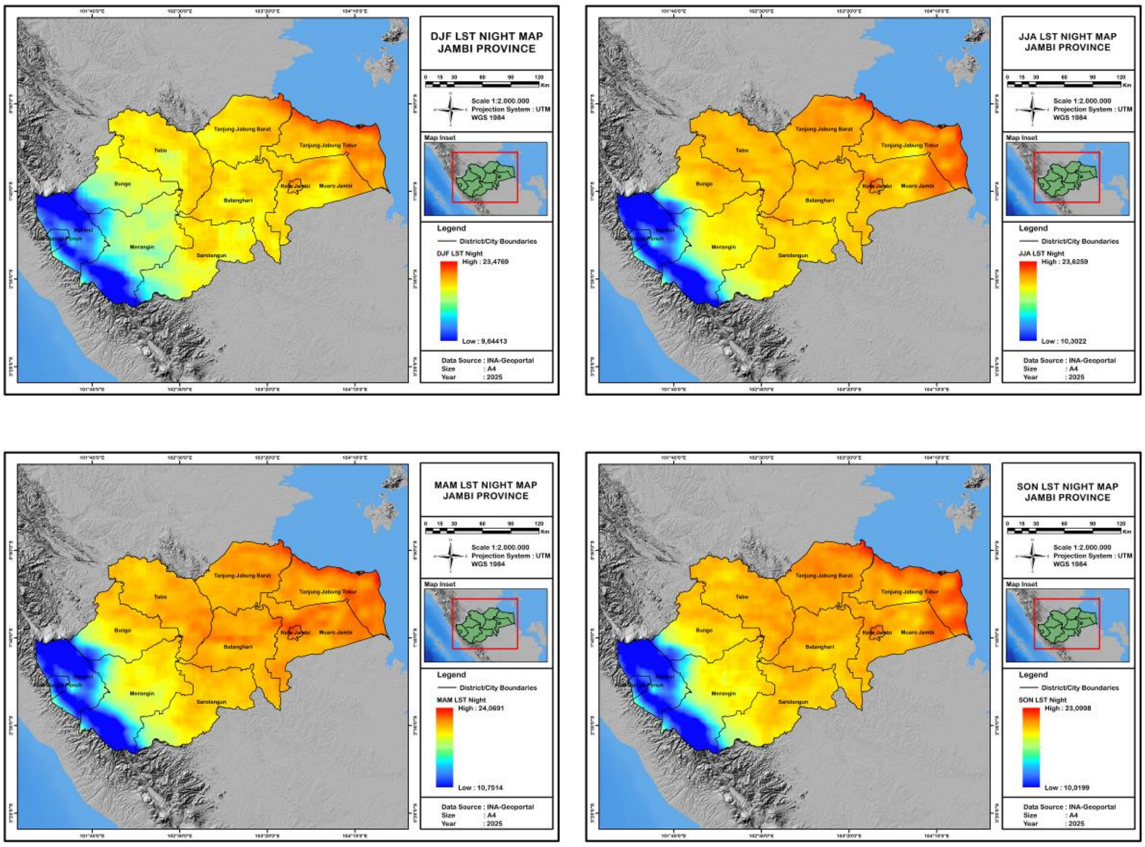

Figure 7. Average seasonal LST for 24 years in DJF, JJA, MAM, SON periods

2. Enhanced Vegetation Index (EVI)

This study used the Enhanced vegetation index (EVI) available from the MODIS satellite Terra and Aqua MOD13C2 and MYD13C2 sensors from 2001 to 2024. Enhanced vegetation index (EVI) is a vegetation index used to measure the level of greenery or density in an area (www.Earthdata.nasa.gov). EVI can act as an indicator of vegetation cover that can reduce the UHI effect; the higher the EVI value, the less the UHI effect.

Average EVI value is in the interval of 0.33 - 0.59, which is lower in the western and eastern regions than in the central region of Jambi Province. Low EVI is found in the Jambi City and the Kerinci Regency areas, which are hilly. The Jambi City EVI index of 0.33 explains that there is little vegetation in Jambi City. (**Figure 8**.)

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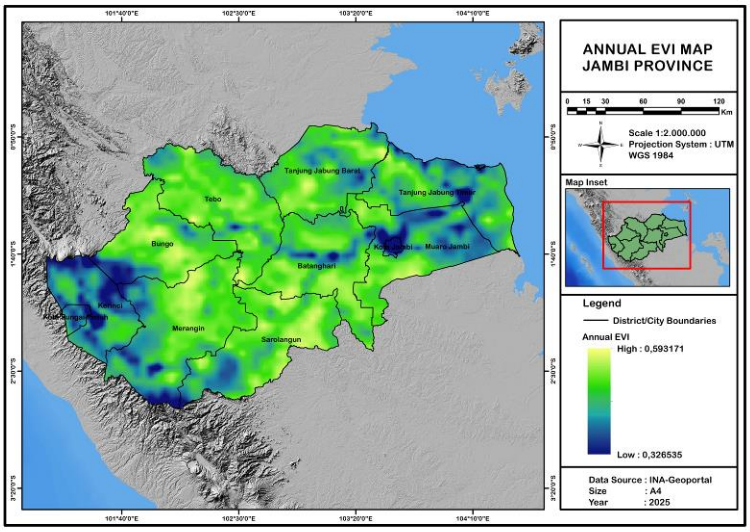

Figure 8. Average EVI index for 24 years

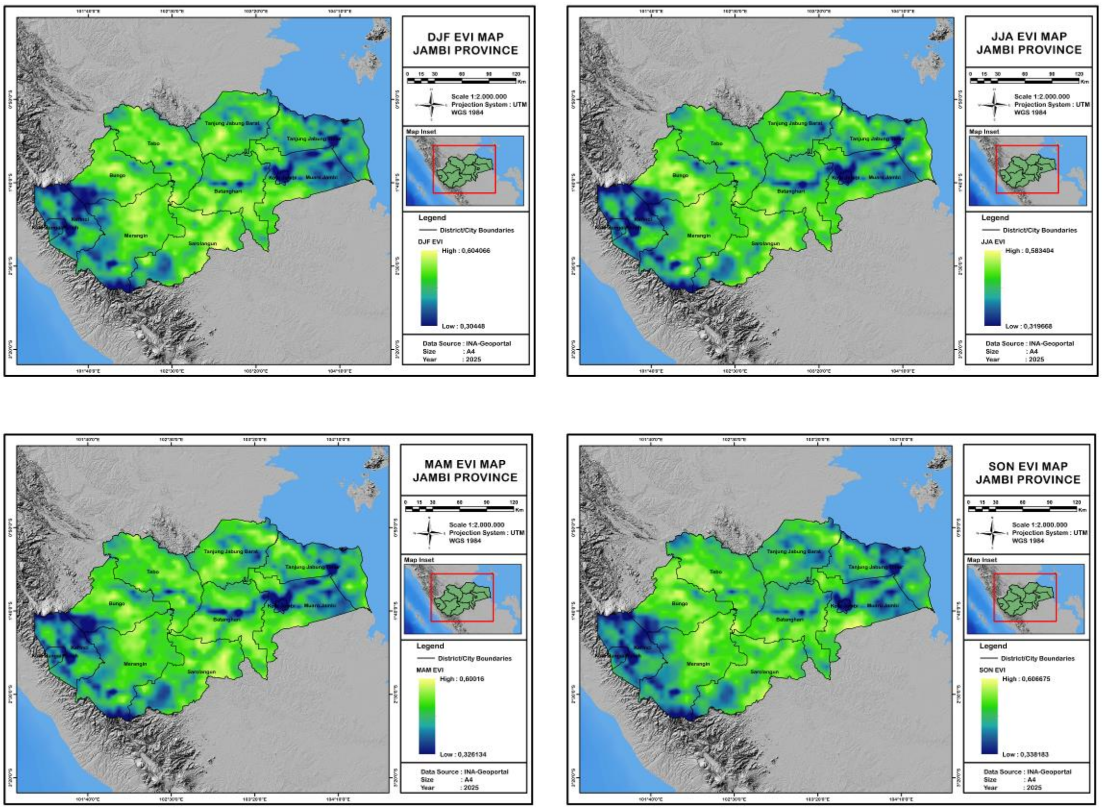

Figure 9. Average EVI index in DJF, JJA, MAM, SON periods

EVI shows a negative relationship with UHI, meaning increasing vegetation tends to reduce UHI. This happens because of the nature of plants, which can naturally absorb heat completely (Alfath & Anna, 2024). The lowest EVI value occurs in Jambi City, which results

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in a decrease in vegetation and causes an increase in surface temperature, thereby increasing UHI in the Jambi City area. The distribution of EVI values in the seasonal periods of MAM, JJA, and SON is relatively the same at intervals of 0.30-0.60 (**Figure 9**), slightly lower in the DJF period with a low EVI Index in the western region of Jambi (Kerinci Regency) and eastern Jambi, precisely in Jambi City, which is 0.30. The EVI value throughout the year is relatively the same at intervals of 0.30 - 0.60; the lowest occurs in December at intervals of 0.29 - 0.61, the highest in September at 0.34 - 0.60 and October at 0.35 - 0.62.

3. Correlation of LST and EVI

The correlation between LST and EVI is carried out to analyse the relationship between surface temperature and vegetation conditions in an area. In this study, the correlation between LST and EVI is carried out to understand the phenomenon of urban heat islands in Jambi City, where areas with low vegetation tend to have higher surface temperatures.

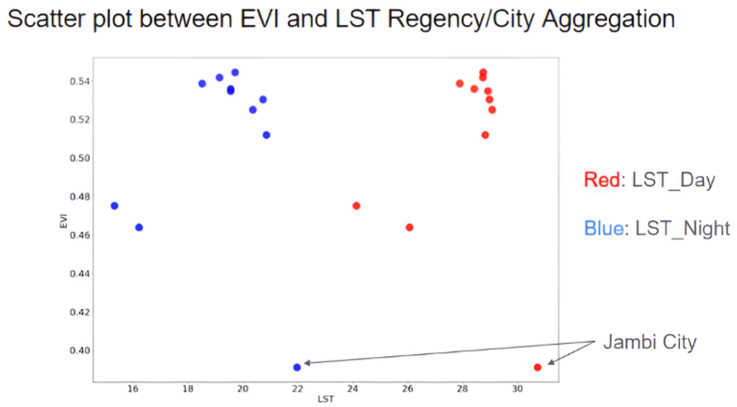
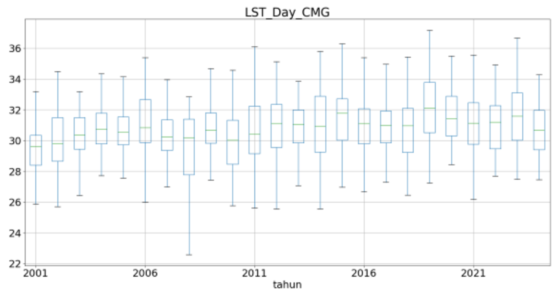
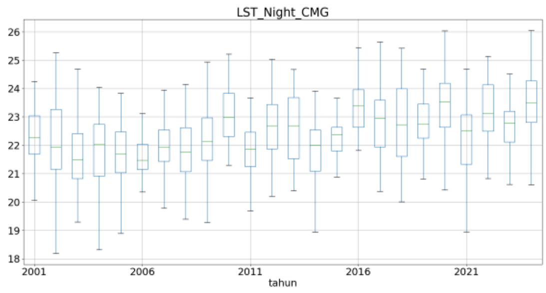


Figure 10. Scatter plot between EVI and LST Regency/City Aggregation, (Red: LSTday, Blue: LSTnight)

Figure 10 shows that Jambi City's LST is higher than other regencies/cities, and the EVI index is at its lowest value during the day and at night. In the Jambi City area, a low EVI value was detected, <0.40, which means that there is rarely vegetation in the Jambi City area. EVI can act as an indicator of vegetation cover that can reduce the UHI effect; the higher the EVI value, the lower the UHI effect.



(a)



(b)

Figure 11. Time series of average LSTday (a) and average LSTnight (b)

During the 24 years (2001-2024), the daytime LST value in Jambi City fluctuated, where the LST temperature was in the range of 26 - 36 °C, but there was an upward trend in LSTday. Likewise, the average LSTnight is shown in the figure where there is a fluctuation in the LST value in the range of 20 - 26 °C, but there is an upward trend in LSTnight (**Figure 11**).

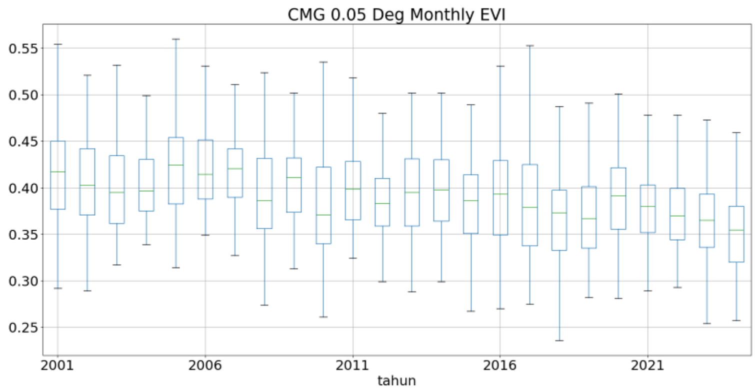


Figure 12. Time series, average EVI

The EVI value in Jambi City fluctuates, where the EVI index is 0.25 – 0.50 (**Figure 12**). However, the EVI index has a downward trend, indicating that Jambi City vegetation is becoming increasingly sparse.

From **Figure 13**. It can be seen that the EVI cross-section has a pattern that is inversely proportional to the LST cross-section. The EVI value is low in the western region of Jambi Province, increases slowly to the central region, and decreases sharply in the eastern region of Jambi, specifically in Jambi City.

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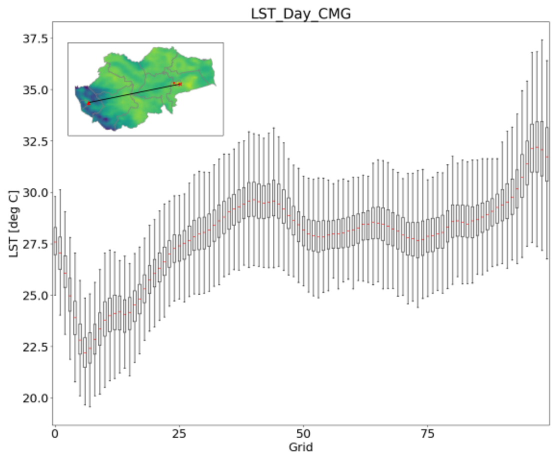
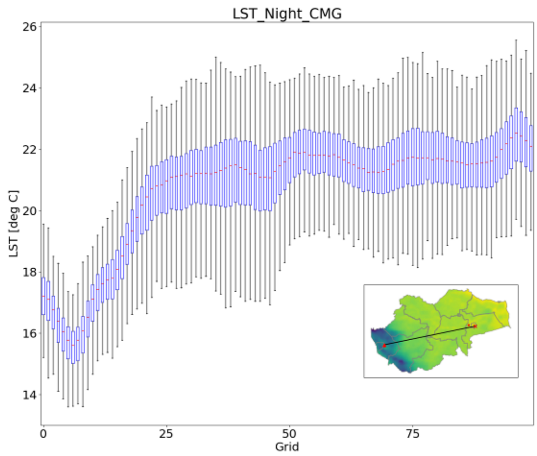
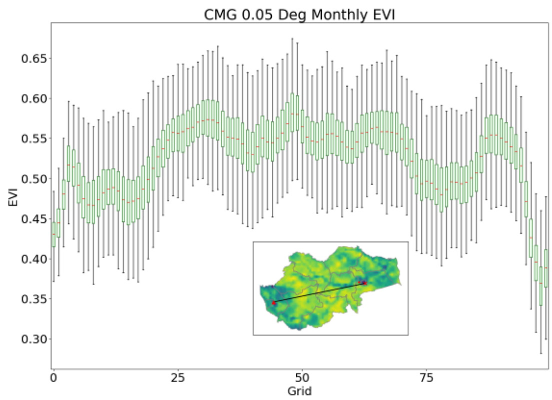


(a)



(b)



(c)

Figure 13. Cross-section of (a) LSTday, (b) LSTnight, and (c) EVI

4. SUHI and UTFVI Trends

During the 24 years from 2001 to 2024, the SUHI intensity in Jambi City had a positive value between 0.2 and 2.5 °C (**Figure 14**). The lowest occurred in 2008 and the highest in 2020. There was an increase in SUHI intensity from 2021 to 2024. The positive value of SUHI intensity indicates that the surface temperature in Jambi City is higher than that of the surrounding areas. Positive values indicate the occurrence of local phenomena in the Jambi City area, such as increased temperatures due to human activities, changes in land cover, and the use of materials that absorb heat.

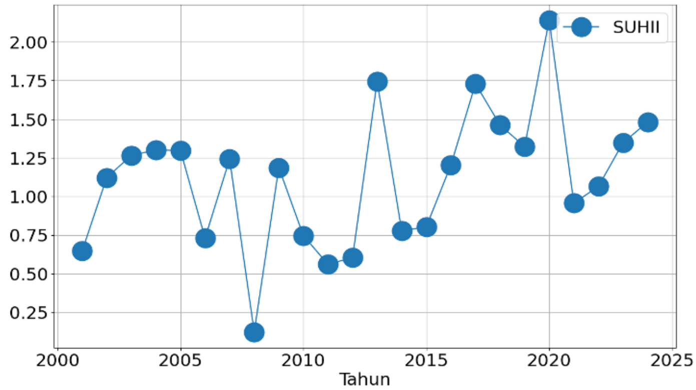


Figure 14. Time series of SUHI intensity in Jambi City from 2001-2024

The SUHI phenomenon can reduce the comfort level, so it is necessary to calculate the UTFVI value. UTFVI in Jambi City for 24 years (2001-2024) has a positive value between 001-0.07. The lowest UTFVI value occurred in 2008 and the highest in 2006 (**Figure 15**). The positive UTFVI value, and the higher it is, indicates a decrease in thermal comfort. The lower the UTFVI value, the higher the level of thermal comfort; conversely, the higher the UTFVI, the lower the thermal comfort (Hadibasyir & Firdaus, 2022).

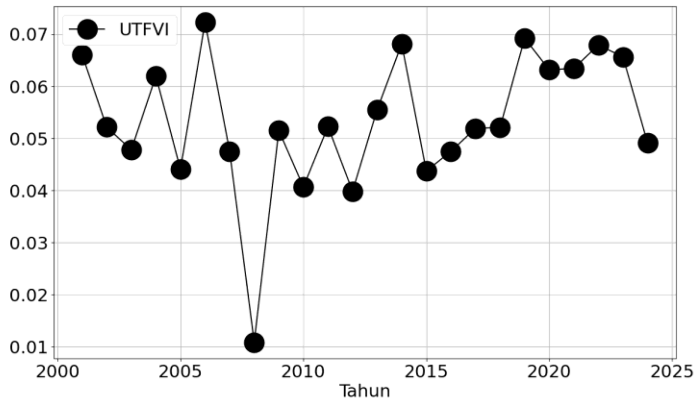


Figure 15. UTFVI time series

ENSO years and dipole mode index are used to analyse the trend of SUHI and UTFVI intensity. The lowest SUHI and UTFVI intensity occurred in 2008, a La Nina year, where, in general, in La Nina years, the air temperature tends to be lower, humidity increases, increasing the potential for the formation of rain clouds and wetter weather conditions. In this condition, the surface temperature decreases, and the SUHI intensity decreases; the Jambi City area's thermal comfort conditions improve.

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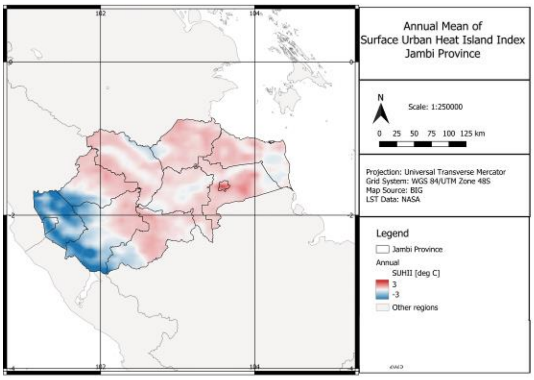
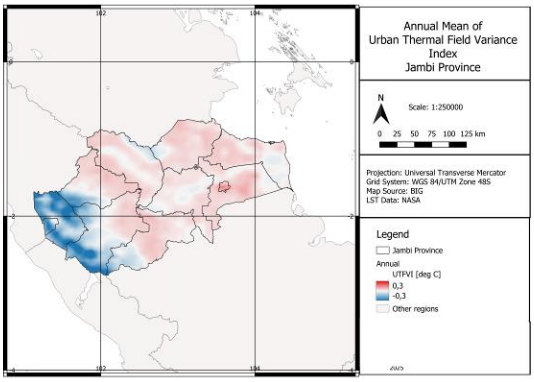
The highest SUHI intensity occurred in 2020, a Neutral year, where weather conditions tended to be drier than La Nina years. In Neutral years, rainfall and air temperature approach average or normal conditions. In the Neutral phase of 2020, the Jambi Province area generally experienced a dry season, thus increasing the SUHI intensity. The map of the average annual SUHI and average annual UTFVI in Jambi Province is shown in **Figure 16**.



(a)



(b)

Figure 16. Annual mean of SUHI (a) and Annual mean of UTFVI (b) in Jambi Province

The highest UTFVI value was in 2006 when the El Nino phenomenon occurred, which caused an increase in surface temperature and forest and land fires in Jambi Province covering an area of 3,797 ha (Fire bulletin. WWF2007). The ecological and thermal comfort levels in Jambi City worsened.

5. SAT Analysis

Surface air temperature is a picture of energy in the air or atmosphere that can be felt by the body and can be measured by an air temperature measuring device (Thermometer) with units of °C or °K (Effendy et al., 2006). Air temperature observation data conducted at BMKG observation stations in Jambi Province, namely at the Sultan Thaha Meteorological Station in Jambi City, the Muaro Jambi Regency Climatology Station and the Depati Parbo Meteorological Station in Kerinci Regency, are used to measure the atmospheric UHI, which is more influenced by turbulence and wind speed, which will have an impact on the surrounding air temperature.

In this study, temperature correction was used to reduce the impact of the height of the observation location at the Depati Parbo Kerinci Meteorological Station, which is located at 797 m above sea level. The temperature correction

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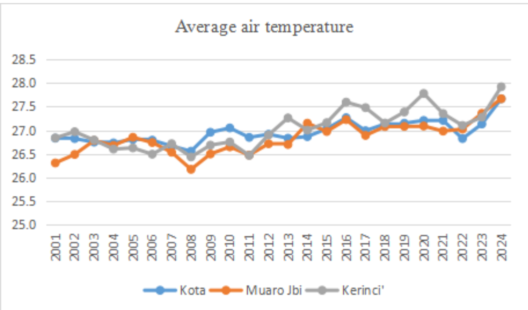
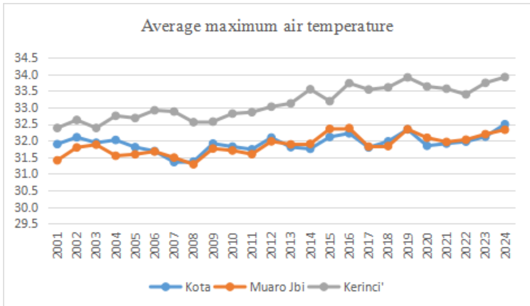
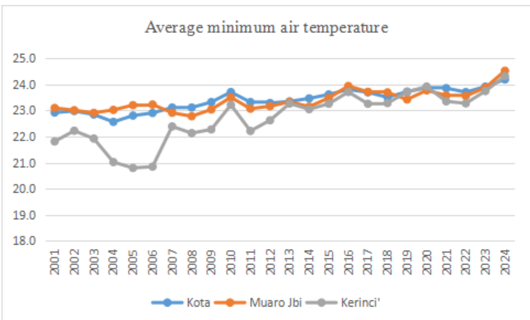
follows the concept of the rate of temperature decrease with height of 6° per 100 meters. This correction is empirical and may have great uncertainty (Wang et al., 2017). Braak (1928) stated that for every 100-meter increase in place on the earth's surface, the air temperature will drop by an average of around 0.6 °C in areas around the equator (Mohr et al., 1972). From the results of processing air temperature data for the last 24 years (2001 - 2024), there has been an increase in average air temperature, average maximum air temperature and average minimum air temperature. For the Jambi City area, there was an increase in average air temperature of 0.025 °C, Muaro Jambi Regency 0.038 °C and Kerinci Regency 0.045 °C. The highest temperature increase occurred in Kerinci Regency, especially from 2013 to 2024. Although fluctuating, it is higher than Jambi City and Muaro Jambi Regency. The highest average air temperature in the three regions occurred in 2024, namely in Jambi City at 27.7 °C, Muaro Jambi Regency at 27.7 °C and Kerinci Regency at 27.9 °C (See **Figure 17**).



(a)



(b)



(c)

Figure 17. Average air temperature (a), average maximum temperature (b), and average minimum temperature (c) in Jambi City (urban), Muaro Jambi (sub-urban), and Kerinci (rural)

From the calculation of the average maximum air temperature, there was an increase in the average maximum air temperature in Jambi City by 0.016 °C, Muaro Jambi Regency by 0.031 °C and Kerinci Regency by 0.064 °C. The average maximum air temperature increase in Kerinci Regency was higher than in Jambi City and Muaro Jambi Regency. This is influenced by the topography of Kerinci Regency, which is located in the mountains in the westernmost region of Jambi Province and local conditions at the weather observation station in Sitinjau Laut District, which is included in the Urban area (Peraturan BPS Nomor 120 Tahun 2020, 2020). The convection process that occurs in mountainous areas will trigger the formation of valley winds. During the day, warm air from the valley will rise upwards, increasing air temperature. There was an increase in the average minimum air temperature in Jambi City by 0.055 °C, Muaro Jambi Regency by 0.047 °C and Kerinci Regency by 0.118 °C.

From the overall processing of air temperature data in Jambi Province, Kerinci Regency experienced the highest increase in temperature compared to Jambi City and Muaro Jambi Regency. Based on BPS regulation number 124 of 2020 concerning the classification of Villages and Urban Areas in Indonesia, the Sitinjau Laut sub-district which is the location of the BMKG weather observation station in Kerinci Regency is included in the Urban area, the increase in the number of settlements around the weather observation station has resulted in reduced vegetation and increased air temperature.

Figure 17 shows that the average, maximum, and minimum air temperatures at each weather observation station experienced the highest increase in 2024. Based on the dipole mode index analysis (**Figure 18**), 2024 is a neutral year where the dipole mode index value is at + 0.4, generally drier weather conditions.

Figure 18. Dipole Mode Index *(www.bom.gov.au)*

6. AUHI (Atmospheric urban heat island)

This study calculated the difference in air temperature between Jambi City (urban) and Muaro Jambi Regency (suburban). The maximum air temperature difference between Jambi City and Muaro Jambi Regency was (-0.1) – 0.3 °C, the highest in November 2025 at 0.3 °C, and the lowest in May at -0.2 °C. The highest AUHI temporal variation occurred in November. This result is close to the LST calculation where the highest temporal variation occurred in the SON period. The minimum air temperature difference between the City and Muaro Jambi for the monthly period has a value that is evenly distributed every month around (-0.1) – 0.1 °C; the lowest occurred in April at -0.1 °C. Muaro Jambi Regency is a buffer zone whose territory surrounds Jambi City. This affects the distribution of population concentrations around the city's outskirts. (Bank Indonesia, 2012). The air temperature conditions in the Muaro Jambi Regency area are relatively the same as those in Jambi City.

Figure 19 shows that the nighttime AUHI of Jambi_Muaro Jambi City has a higher value than the daytime AUHI in May, June, July, August, September and October. This indicates that the nighttime AUHI between Jambi City and Muaro Jambi Regency is stronger in the dry season.

The maximum air temperature in Kerinci Regency is higher than the maximum air temperature in Jambi City. The difference in maximum air temperature between Jambi City and Kerinci Regency has a negative value between (-1.7) and (-0.5) °C, the highest occurring

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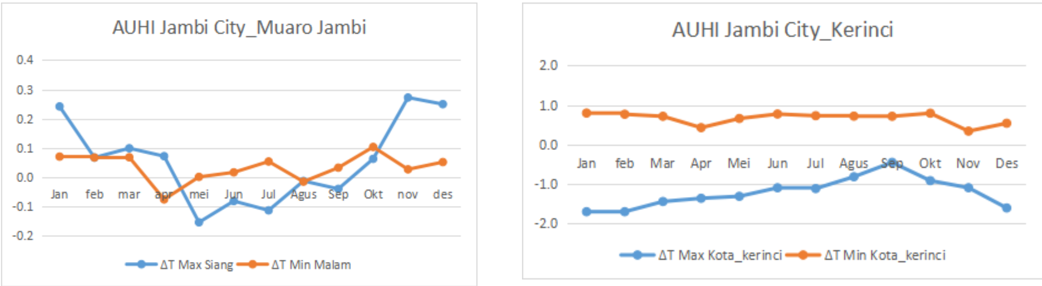
in September. The difference in minimum air temperature between Jambi City and Kerinci Regency is between 0.3 – 0.8 °C, the highest occurring in January, February, June and October, and the lowest in November. The AUHI between Jambi City and Kerinci at night is higher than the daytime AUHI.



(a) (b)

Figure 19. Maximum and minimum AUHI SAT graphs for Jambi city and Muaro Jambi (a) and Jambi and Kerinci districts (b)

The overall results show that the nighttime AUHI is higher than the daytime AUHI. This study found the highest AUHI values in January, February, June and October. Comparison between air temperature data collected from urban and rural weather stations has long been used for atmospheric UHI research (Cleugh & Oke, 1986). Generally, the atmospheric UHI at night is stronger than the UHI during the day.

The atmospheric UHI at night is influenced by the energy stored in urban materials during the day and released at night. Anthropogenic heat release, namely heat generated by human activities originating from the use of motor vehicles, buildings and industrial waste, is stronger in winter, causing the atmospheric UHI to increase over time during winter nights but decrease over time during summer nights. (Wang et al., 2017)

7. Correlation between LST and SAT

Air temperature is influenced by surface temperature because the surface temperature will be transferred to the air by convection. High surface temperatures will also have high air temperatures (Jatmiko & Hartono, 2016). This correlation aims to validate LST and air temperatures, although both parameters are incompatible for direct comparison or validation purposes

(Siswanto et al., 2023). The correlation results show a positive correlation between the two variables, where variable x is the temperature of the LST processing results and variable y is the air temperature from the BMKG observation station.

The UHI phenomenon is common in metropolitan cities and developing areas. One of the causes of UHI is the high flow of urbanisation, which results in fairly rapid urban development over time (Alwi et al., 2022).

In general, the surface and atmosphere are related, where the surface will affect the level of atmospheric temperature generated. The relationship between surface temperature and atmospheric temperature is based on its height from the ground surface, although the surface temperature is higher than the air temperature (Ngie et al., 2014; Syafitri, 2020).

The increase in the number of vehicles in Jambi City every year is very significant, where in 2022 the number of motorised vehicles was 740,206 units, in 2023 it increased to 969,222 units and in 2024 it jumped to 1,005,473 units (BPS, 2025). The increase in motorised vehicles in Jambi City contributes to increasing air pollution. Emissions from motor vehicles play a role in the local greenhouse effect, which causes air temperatures in densely populated areas to be higher than in other areas (Mongabay, 2018). The release of carbon emissions from the increasing use of motor vehicles in Jambi City has increased air temperature and surface temperature, which is one of the factors why the SUHI and UTFVI intensities are positive.

Rapid urbanisation and economic development in Jambi City have triggered new government and private sector housing development. The development of new housing, of course, will result in the conversion of land from vegetation to housing. The enhanced vegetation index of Jambi Province has decreased sharply in Jambi City, namely between 0.4 and 0.5, which shows that Jambi City has very few areas with vegetation.

The SUHI intensity in Jambi City over the past 24 years has a positive value between 0.2 and 2.5 °C. The positive value of SUHI intensity indicates that the surface temperature in Jambi City is higher than the surrounding areas. This positive SUHI value is an indicator of the urban heat island effect in Jambi City. The LST calculation shows that the highest seasonal variation of LSTday for 24 years is in September, October and November (SON) because these months are related to the period of maximum solar radiation due to the solstice. The analysis of the seasonal temporal variation of LSTnight for 24 years in the MAM period is higher compared to other seasonal periods because monsoonally, the MAM period is a transition period from the rainy season to the dry season; night temperatures increase due to the influence of cloud cover, which reduces air cooling at night.

The intensity of AUHI during the day between Jambi City and Muaro Jambi Regency is around -0.2 - 0.3, the highest in November. While the intensity of AUHI at night between Jambi City and Muaro Jambi Regency is almost evenly distributed between -0.1 and 0.1. AUHI at night between Jambi City and Muaro Jambi reaches a positive value of 0.1 in December, January and February (DJF), the peaks of the rainy season.

The calculation of AUHI between Jambi City and Kerinci Regency uses an adiabatic lapse rate of 0.6 °C/100 m (temperature decrease of 0.6 °C for every 100 meters increase in altitude). This calculation shows that the maximum temperature during the day in Kerinci Regency is higher than in Jambi City. Generally, the nighttime AUHI between Jambi City and Kerinci Regency is stronger than the daytime AUHI.

Urban areas are complex and heterogeneous; therefore, measurements from a single urban monitoring station do not provide sufficient detail for urban climate research and decision-making applications (Voogt & Oke, 2003).

CONCLUSIONS

Jambi City has a higher average LST than its surrounding areas. The highest temporal variation of daytime LST is in the SON period while the lowest nighttime LST occurs in the DJF period. The lowest EVI index <04 occurs in Jambi City; the EVI index reaches its lowest value in the JJA period. Spatial analysis of LST, SUHI and UTFVI shows the same pattern: low in the west of Jambi Province, increasing to the east and reaching a maximum in Jambi City. The SUHI intensity in Jambi City has a positive value between 0.2 and 2.5 °C. Meanwhile, the AUHI intensity between urban and suburban is around -0.2 - 0.3 °C during the day and -0.1 - 0.1 °C at night. The UTFVI index is between 0.01

and 0.07. Although the SUHI and AUHI intensities are not too large, the decreasing trend in EVI values can indicate the occurrence of UHI in Jambi City.

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