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Assessing Urban Land Surface Temperature Fluctuations Amidst the Covid-19 Pandemic: A Landsat 8 and Landsat 9 Study of Bandar Lampung City

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Abstract
Community activities before, during, and after the Covid-19 pandemic have undergone significant changes. This is due to the limitation and exemption of activities set by the government which can also result in changes in surface temperature. Physical separation from the Large-Scale Social Restrictions (PSBB) has led to a decrease in communal activities like traffic and the industrial sector, which has a policy of allowing most employees to work from home. This study intends to examine variations in Bandar Lampung surface temperature that took place in 2020, 2021, and. Identifying surface temperature using remote sensing technology, including Landsat 8 and Landsat 9 images. Both of these images have advantages with a large number of bands, especially the presence of a Thermal Infrared Sensor (TIRS) wavelength which has a sensitivity to detect temperature. Utilization of this wavelength can distinguish parts of the earth's surface that have a hotter temperature than the surrounding area. The land surface temperature (LST) approach can be used to determine the dynamics of surface temperature variations before, during, and after the Covid-19 epidemic. Image processing and analysis are done using Google Earth Engine. The results of the analysis of surface temperatures before Covid, the image recording time in 2020 has a value range of 13^{o}C - 32^{o}C, during the occurrence of Covid, the 2021 recording time has a value range of 3^{o}C - 33^{o}C, while after Covid, the 2022 recording time has a value range of 18^{o}C - 32^{o}C.

Keywords: Covid-19, Landsat 8, Landsat 9, LST

INTRODUCTION

Land Surface Temperature (LST) is one of the crucial factors in climate change, drought, urban heat islands (Mo et al., 2021) and surface physical processes (García, 2022; Qin et al., 2018). LST plays a role in the approach of hydrology, ecology, agriculture and meteorological processes on the earth's surface. LST can be used as a variable in determining the amount of the budget for Earth's surface radiation (Hulley et al., 2019). However, since the COVID-19 pandemic has reduced people's activities, this change has also caused some changes to the earth's environment (Ramdani & Setiani, n.d.). This pandemic was caused by the worldwide spread of the coronavirus disease (COVID-19), so the State of Indonesia decided to carry out PSBB (Large-Scale Social Borders) and implement Work From Home. Where the decision had a major impact on the economic sector Indonesia (Yudhia & Alam, 2022).

Bandar Lampung City is the capital city of Lampung Province and is located in the southern part of Sumatra Island. As a connecting point between the islands of Java and Sumatra, this coastal city is one of Sumatra's most important economic centers. Bandar Lampung City covers an area of 169.21 km2 and is divided into 20 sub-districts and 126 urban villages. Based on the results of the 2010 Population Census, the population of Bandar Lampung reached 879,651 people with a population density of around 42 people per hectare (Sitadevi, 2017). Bandar Lampung City is the gateway to Sumatra and has a lot of activity and high mobility. This allows changes to the surface temperature (LST), which can also change.

LST calculations have been carried out in recent decades using remote sensing data. It has been demonstrated in numerous studies that medium- to high-resolution satellite imagery is suitable for collecting LST in a variety of locations (Dang et al., 2020; Sayão et al., 2018). Several studies use Landsat imagery for LST analysis to obtain trends and analyze the effects of climate change (Athick et al., 2019). Landsat has a thermal wavelength that can represent temperature fluctuations on the surface.

LST is more closely linked to the relationship between urban heat islands, vegetation density, open land conversion, and other factors than its development and research. Research has been done utilizing NDVI (Normalized Difference Vegetation Index) and NDBI (Normalized Difference Built-up) parameters index data to examine the effects and variations in LST before and during the Covid-19 epidemic (Arrofiqoh & Setyaningrum, 2021; Mukherjee & Debnath, 2020; Zulkarnain, 2021; Ashraf et al., 2021; Hadibasyir et al., 2020a; Hafiudzan, 2021; Apicella et al., 2021). Utilizing MODIS imaging, a second investigation was carried out in Wuhan City, China, to assess the ground surface temperature before and after the appearance of Covid-19 (Hadibasyir et al., 2020b). East Java's Kediri has conducted research on variations in land surface temperature during the Covid-19 pandemic (Nando, 2021). Employing remote sensing data from Dhaka City, Bangladesh, a study was conducted to examine how the COVID-19 Lockdown affected the Vegetation Index and Urban Heat Island (Sresto et al., 2022). The period following the COVID-19 pandemic has never been researched, even though there have been numerous studies looking at temperature variations before and during the pandemic.

Based on the problems above, this study aims to analyze changes in LST in Bandar Lampung City before, during and after the occurrence of Covid 19. Changes in activities in Bandar Lampung City before, during and after the occurrence of Covid 19 need to be analyzed using the method of calculating changes in surface temperature. land / LST. This study uses Landsat 8 and Landsat 9 data to compare LST changes.
The novelty of this study lies in the use of Landsat 9, which was only launched in 2021, as the primary data source, making this study one of the first to utilize it in the context of urban surface temperature analysis. In addition, this study is likely to explore the direct impact of the pandemic on land surface temperature, taking into account changes in human activity and land use patterns during the lockdown period. The analysis methodologies used in this study may also include innovative image processing techniques or data analysis models.

RESEARCH METHODS

Research Location

The study area is in Bandar Lampung City, the administrative center of Lampung Province and one of the major cities outside Java Island. Based on the 2020 Census, Bandar Lampung would have a population of 1.166.066 people and a 197.22 km2 area. Bandar Lampung City is the second most inhabited city in Sumatra with this number of residents. Because of its position as the link between the islands of Java and Sumatra, Bandar Lampung is also known as the entrance to the island of Sumatra. More details of the research location are presented in Figure 1.

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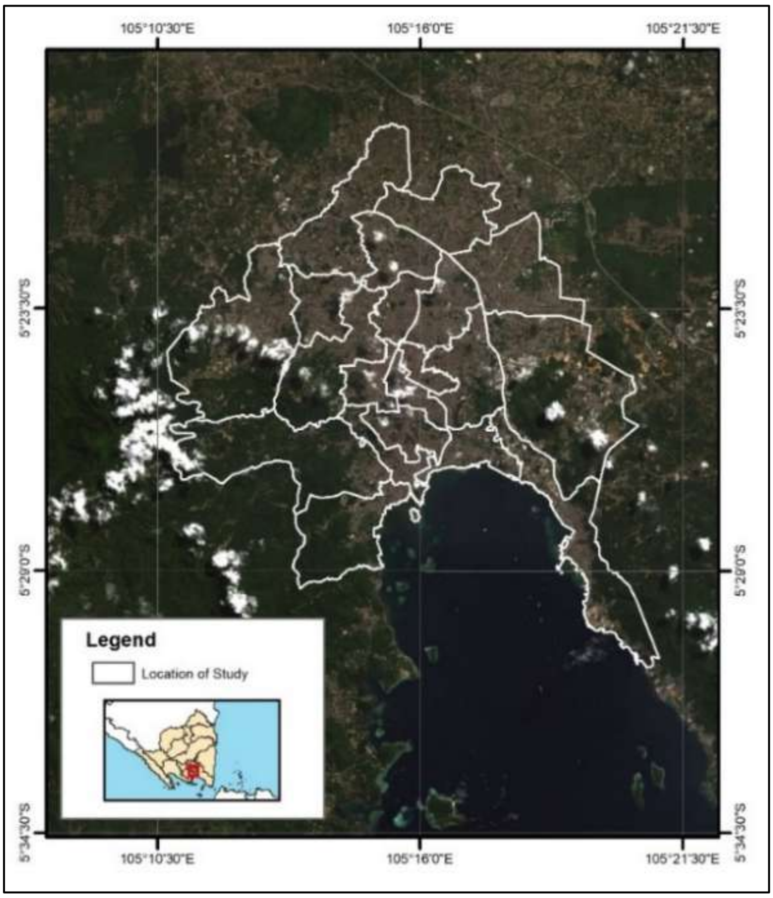

Figure 1. Research Sites

Data Collection

This research uses 2 types of images, namely Landsat 8 and Landsat 9 with different recording times. Recording before, is happening and after it is declared that covid is over. Landsat 8 and Landsat 9 image data can be downloaded at https://eartheexplorer.usgs.gov/. Image recording time is 25 December 2020, 26 November 2021 and 13 May 2022. More details on the image specifications used are described in Table 1.

Table 1. Landsat 8 and Landsat 9 Image Specifications

Band	Wavelength (µm)	Spatial Resolution (m)
Band 1- Coastal Aerosol	0.435 – 0.451 µm	30
Band 2- Blue	0.452 – 0.512 µm	30
Band 3- green	0.533 – 0.590 µm	30
Band 4- Red	0.636 – 0.673 µm	30
Band 5 Near-Infrared	0.851 – 0.879 µm	30
Band 6 SWIR-1	1.566 – 1.651 µm	30
Band 7 SWIR-2	2.107 – 2.294 µm	30
Band Panchromatic	0.503 – 0.676 µm	15
Band Cirrus	1.363 – 1.384 µm	30
Band 10 TIRS-1	10,60 -11,19µm	100
Band 11 TIRS-2	11,50 -12,51 µm	100

Methods

The methodology includes pre-processing, namely radiometric correction and geometric correction, spectral radiance extraction, brightness temperature extraction, LSE value extraction, accuracy testing, analysis of changes and mapping of land surface temperatures. More details as shown in Figure 2.

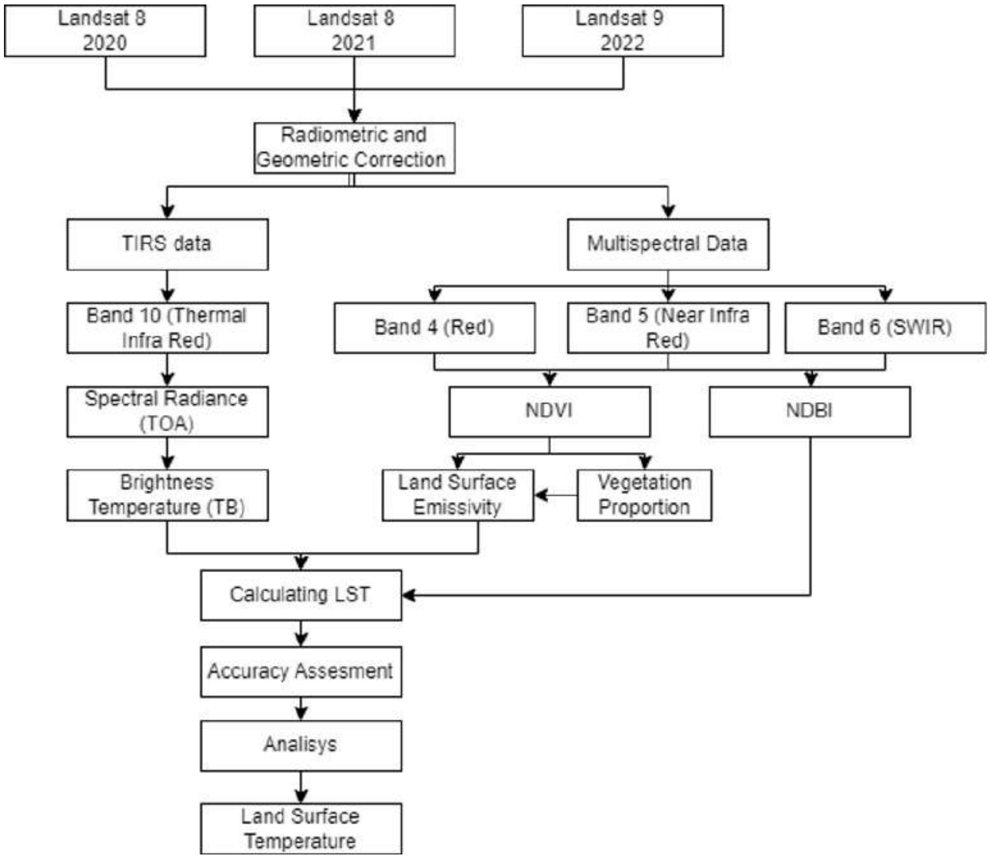

Figure 2. Research Flowchart

Before spectral extraction, a preprocessing process is carried out, namely geometric and radiometric corrections on Landsat 8 and Landsat 9 data which aims to improve the position of the image and reduce noise in the image. Calculation of the spectral radian (radiance) is carried out with the following equation:

$$L\lambda = M\mathrm{L} \times Q\mathrm{cal} + A\mathrm{L} \quad (1)$$

Where:
Lλ = spectral radian
ML = multiplication scale factor
Qcal = Standard product pixel value that has been quantized and calibrated (DN)
AL = increasing scale factor

In changing the spectral value of radians to land surface temperature (Kelvin), it is done through the following equation:

$$T = \frac{K2}{L\lambda\ (\frac{K1}{L\lambda})} \quad (2)$$

Where:
T = Temperature (in Kelvin)
Lλ = spectral radian
K1 = the metadata's thermal conversion constant for a certain band
K2 = the metadata's thermal band-specific conversion constant

Extract the Brightness Temperature Value (TB)
The following equation can be used to obtain the Brightness Temperature (TB) Value.

$$TB = \frac{K2}{\ln\left(\frac{K1}{L\lambda}+1\right)} \quad (3)$$

where K1 and K2 are constants, Lλ is the spectral radiance, and Landsat TM, K1 = 607.76, K2 = 1260.56 Landsat ETM+, K1 = 666.09, K2 = 1282.71; Landsat OIL TIRS, K1 = 774.88, K2 = 1321.07(Dang et al., 2020).

Extract of LSE Value

Because of the high correlations between NDVI and vegetation density, productivity, photosynthetic capacity, and leaf area index, it has become the most often used index (Huang et al., 2021). NDVI is formulated in the following equation:

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (4)$$

The following equation can be used to get the vegetation proportion (PV).

$$Pv = \frac{NDVI-NDVImin}{NDVImax-NDVImin} \quad (5)$$

The normalized difference default index (NDBI) in the following equation is used to extract the built-up area (Guha et al., 2018). The NDBI equation can be formulated as follows:

$$NDBI = \frac{SWIR-NIR}{SWIR+NIR} \quad (6)$$

Land surface emissivity

$$\varepsilon\lambda = \varepsilon v\lambda Pv + \varepsilon s\lambda(1 - Pv) + C\lambda \quad (7)$$

Where εv and εs are soil and vegetation emissivities, respectively, and are surface roughness (C = 0 for homogeneous and flat surfaces).

The equation can be used to measure emission and spectral reflectance and derive an empirical link between LSE and NDVI.

$$\varepsilon = 1.0094 + 0.047\ln(NDVI) \quad (8)$$

LST calculation

Land Surface Temperature (LST) calculation is the process of estimating the Earth's surface temperature from Brightness Temperature (BT) and Land Surface Emissivity (LSE) measurements. BT is the temperature of thermal radiation measured by satellite sensors, while LSE is the ability of the Earth's surface to emit thermal radiation. The LST calculation based on the results of BT and LSE is formulated as follows (Sahani et al., 2021).

$$LST = \frac{BT}{[1+(\lambda*\frac{BT}{\rho}*\ln\varepsilon_\lambda)]} \quad (9)$$

LST Change Analysis

LST estimation results can be compared between two data in different recording periods. The estimated LST from Landsat 8 imagery at the recording time in 2020 and 2021 are compared with the LST estimated from the Landsat 9 image at the recording time in 2022.

RESULTS AND DISCUSSION

Spatial distribution NDVI and NDBI

The results of the analysis of Landsat 8 and Landsat 9 using the NDVI and NDBI methods in Bandar Lampung City show that there are differences between conditions before, during and after Covid 19. NDVI and NDVI are parameters for determining LST (Hafiudzan, 2021). The comparison of NDVI and NDBI index values is described in Figure 3.

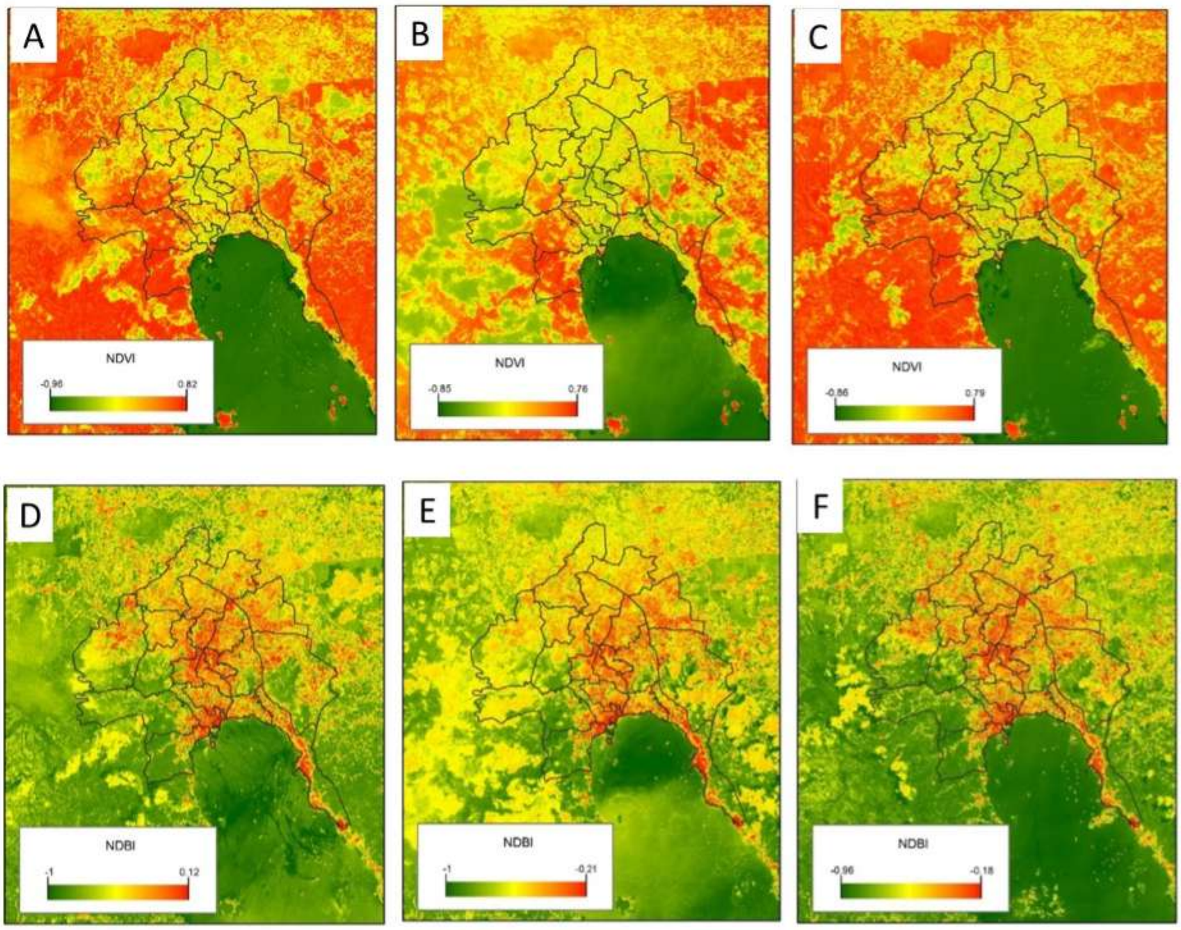

Figure 3. (a) NDVI Index Value before Covid (25 December 2020) (b) NDVI Index Value During Covid (26 November 2021) (c) Post-Covid NDVI Index Value (13 May 2022) (d) NDBI Index Value before Covid (25 December 2020) (e) NDBI Index Value During Covid (26 November 2020) 2021) (f) Post-Covid NDBI Index Value (13 May 2022)

The data provides information on the Normalized Difference Vegetation Index (NDVI) for three different years - 2020, 2021 and 2022 - and its relationship with land surface temperature (LST).

In 2020, the NDVI Index values ranged from 0.01 to 0.72, showing the variation of vegetation in the region. The higher the NDVI value, the higher the greenness and healthiness of the vegetation in the observed area. 2021 showed a slight decrease in NDVI values, ranging from 0.02 to 0.7. However, the area still showed diverse levels of vegetation. Furthermore, in 2022, the NDVI values ranged from 0 to 0.68, indicating a more significant change in the vegetation condition of the area. The relationship between LST and NDVI values can be seen in Figure 3.2. In 2020, the relationship can be explained using the straight line equation $y = -0.0516x + 1.6693$, with an R^2 value of 0.5187. The R^2 value indicates the degree of fit between the observed data and the line equation model. The higher the R^2 value approaches 1, the better the line equation model can explain the relationship between LST and NDVI. In 2020, the R^2 value of 0.5187 indicates that about 51.87% of the variation in NDVI can be explained by the variation in LST. However, there are still other factors affecting NDVI besides LST.

In 2021, the relationship between LST and NDVI has the equation $y = -0.002x + 0.3984$, with an R^2 value of 0.43. The lower R^2 value (0.43) indicates that the line equation model is less able to explain the relationship between LST and NDVI in 2021. This indicates that there are other factors that are more dominant in influencing the variation of NDVI in that year. Then, in 2022, the relationship between LST and NDVI has the equation y = -0.1048x + 3.219, with an R^2 value of 0.7354. The higher R^2 value (0.7354) indicates that the line equation model better explains the relationship between LST and NDVI in 2022. This indicates that LST may be one of the more influential factors on the variation of NDVI in that year. These data provide insight into the complex relationship between the Earth's surface temperature and vegetation indices in the region observed over three different years. The year-to-year variability of NDVI values may be influenced by various factors, including seasonal changes, land use changes and climate fluctuations. Further studies are needed to understand the factors affecting the relationship between LST and NDVI and their impact on the environment and human life in the region.

The year 2020 shows a correlation above 50%, which means that there is a strong relationship between LST and vegetation density, but in 2022 the correlation is only 43% because most of the temperature drops are significant even though they have low vegetation density. Meanwhile, in 2022, it shows a correlation of 73%, meaning that this relationship is very strong. The NDBI index value in 2020 has a value range of – 0.82 – -0.5, in 2021 it has a value range of -0.82 – -0.53, while in 2022 it has a value range of -0.83 – -0.5. The correlation between the LST value and NDBI in 2020 y = 0.0023x - 0.7307 with a value of R^2 = 0.491, in 2021 the equation y = 0.015x - 1.0666 with a value of R^2 = 0.234 while in 2022 the equation y = 0.0407x is obtained - 1.8189 R^2 = 0.7033.

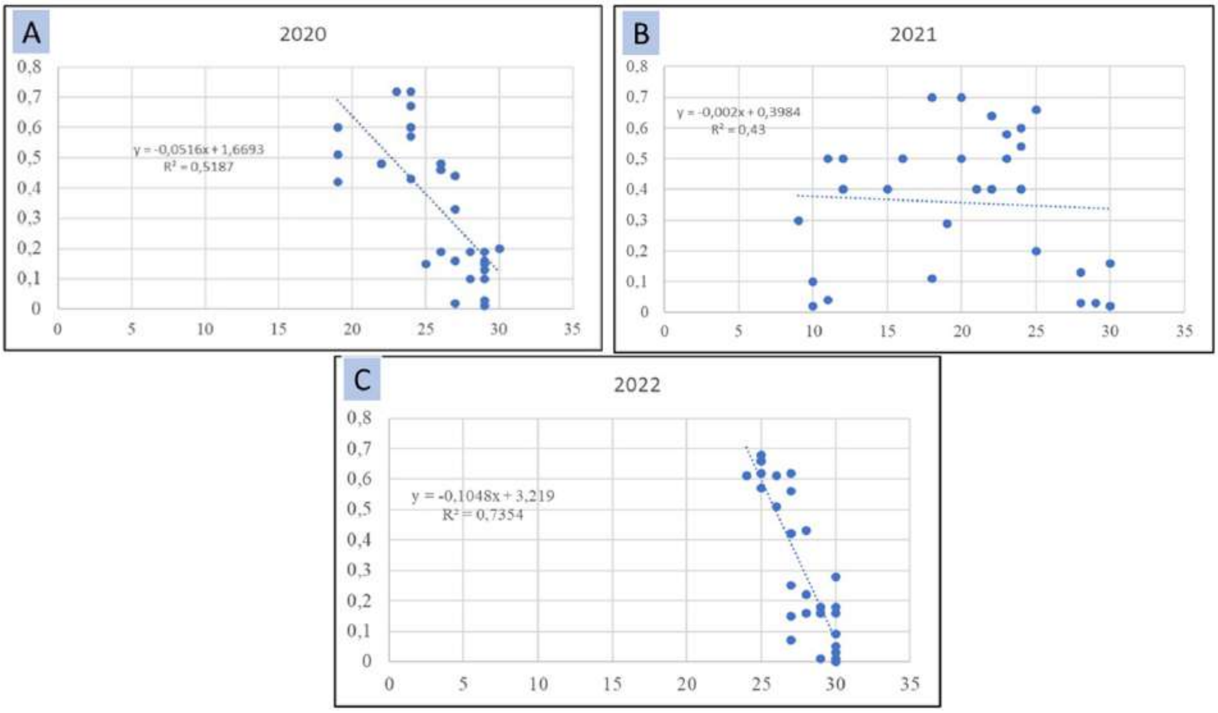

Figure 4. (a) Correlation of LST value and NDVI index before Covid (25 December 2020) (b) Correlation of LST value and NDVI index during Covid (26 November 2021) (c) Correlation of LST value and NDVI index Post Covid (13 May 2022)

Based on this correlation, it shows that in 2020 there is a 49% relationship between built-up land and surface temperature. However, in 2020 the relationship decreased by only 23%, this is possible because the activities that occur in the built area also decreased. But a significant increase in 2022 after Covid 19 there is a very strong relationship of 70%.

In constructed areas, which often have higher temperatures than non-built areas due to ground surface factors, there has been a change in land surface temperature for 9 months, according to the analysis of land surface temperature (LST) both before and during the Covid-19 epidemic. both the area itself and the anthropogenic activities performed there (Haris Nando, 2021). When compared to before the pandemic, ground surface temperatures tend to drop. The Covid-19 pandemic-related restrictions on outdoor activities in the Yogyakarta urban agglomeration are getting much better as the weather. But as human activity returns to normal after the new normal, the temperature remains the same or even rises slightly from before the epidemic (Arrofiqoh & Setyaningrum, 2021).

Spatial distribution LST

Based on Figure 3 the results of the analysis of surface temperatures before the presence of covid when the image recording on December 25, 2020 has a value range of 13°C - 32°C, during the occurrence of Covid the recording time on November 26, 2021 has a value range of 3°C - 33°C while after Covid with a recording time on May 13, 2022 has a value range of 18°C – 32°C. For each recording time, there is a disparity between the minimum and maximum LST values. LST's lowest value declines in 2021, but its maximum value is still higher than it was under the previous two conditions. A significant increase occurred after Covid 19 in 2022. The distribution of LST in 2020 before the onset of covid 19 was quite evenly distributed in each sub-district, but in 2021 there were a decline in Rajabasa, Kemiling, Tanjung Glad, Labuhan Ratu, Langkapura, and Subdistricts. West Betung Bay. Meanwhile, the Districts of Panjang, Bumi Waras, Way Halim, Enggal and Teluk Betung Utara still have a relatively high LST. This can be due to the ongoing community activities in this area and the dense population is also a factor. After the end of the Covid-19 pandemic, the sub-districts of Tanjung Senang, Rajabasa, Kedaton, Way Halim, and Tanjung Karang Pusat experienced a significant increase in LST. This indicates that community activities have become more active in this area. A more detailed comparison between conditions before, during and after Covid 19 is presented visually in Figure 5.

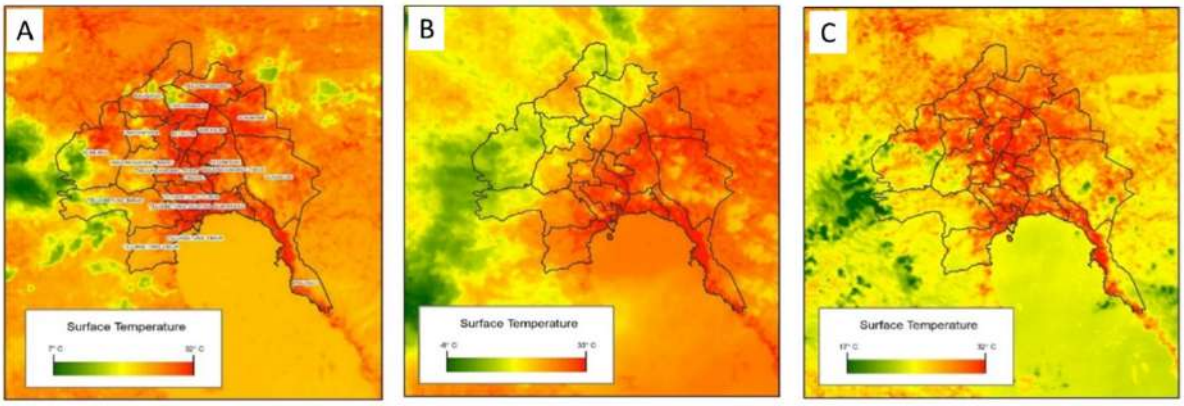

Figure 5. (a) Before Covid 19 (25 December 2020) (b) During Covid 19 (26 November 2021) (c) After Covid 19 (13 May 2022)

The analysis of LST changes before, during and after Covid 19 is seen based on the distribution of sub-districts in Bandar Lampung City. In 2020, Kemiling District has a minimum temperature of 13oC and a maximum temperature of 32oC, in 2021 the minimum temperature will also be in Kemiling District and a maximum

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temperature of 33oC in Bumi sane and Panjang districts. In 2022, the minimum temperature of 18oC is found in the Teluk Betung Barat sub-district while the maximum temperature is found in several sub-districts, namely Bumiwaras, Enggal, Kemiling, Panjang, Tanjung Karang Pusat, Tanjung Karang Timur, Tanjung Karang Barat, and Way Halim. More details on the distribution of LST can be seen in Table 2.

Table 2. Distribution of LST in Each District

Name	2020			2021			2021		
	avg	min	max	avg	min	max	avg	min	max
Bumiwaras	27,93	24	31	27,07	18	33	28,6	25	32
Enggal	27,769	25	30	26,58	19	31	28,85	23	32
Kedamaian	27,053	24	30	26,37	18	31	27,98	25	31
Kedaton	28,46	25	30	19,16	13	25	29,52	25	31
Kemiling	23,1	13	32	9,41	3	17	26,26	20	32
Labuhan Ratu	25,86	17	30	13,04	5	21	28,72	23	31
Langkapura	24,69	18	29	12,35	7	19	28,34	24	31
Panjang	26,47	22	31	26,44	18	33	27,44	23	32
Rajabasa	25,69	17	30	15,46	7	24	28,11	25	31
Sukabumi	25,82	21	30	24,67	18	31	26,72	20	31
Sukarame	27,37	20	30	25,36	16	30	28,5	26	31
Tanjung Karang Barat	25,16	20	30	17,39	9	26	27,04	21	32
Tanjung Karang Pusat	27,54	24	30	22,39	16	28	28,6	24	32
Tanjung Karang Timur	28,46	26	30	24,16	18	30	29,71	26	32
Tanjung Senang	26,71	19	31	14,11	7	22	28,54	26	31
Teluk Betung Barat	22,73	14	30	17,51	5	29	25,65	18	31
Teluk Betung Selatan	27,57	24	30	25,3	18	31	28,31	25	31
Teluk Betung Timur	25,05	22	30	23,94	14	30	26,28	24	31
Teluk Betung Utara	28,21	26	31	26,4	19	30	28,78	24	31
Way Halim	28,41	25	31	23,54	13	29	29,22	23	32

Source: Analysis Results (2022)

LST Change Analysis

The data listed in the table shows the average temperature (avg), minimum temperature (min) and maximum temperature (max) for three different years, namely 2020, 2021 and 2022. In 2020, the average temperature reached 26.39 degrees Celsius, with the lowest minimum temperature reaching 13 degrees Celsius and the highest maximum temperature reaching 32 degrees Celsius. Furthermore, in 2021, there was a decrease in the average temperature to 21.03 degrees Celsius, with the minimum temperature reaching 3 degrees Celsius, being the lowest temperature in three years, and the maximum temperature reaching 33 degrees Celsius, being the highest temperature in three years. However, in 2022, there was an increase in the average temperature to 28.06 degrees Celsius, with the minimum temperature reaching 18 degrees Celsius and the maximum temperature remaining at 32 degrees Celsius. Analysis of this data shows significant fluctuations in temperature from year to year. A decrease in average temperature in 2021, followed by an increase in 2022, indicates climate variations that may affect weather conditions in the region. Very low minimum temperatures in 2021 indicate the potential for extreme cold weather periods, while high maximum temperatures in 2021 and 2022 signal the possibility of more intense hot periods. In general, the LST of Bandar Lampung City is averaged, as presented in Table 3.

In more detail, the LST changes are described in the graph as shown in Figure 6.

Table 3. Changes In LST Value 2020, 2021 and 2022

Year	avg	min	max
2020	26,39	13	32
2021	21,03	3	33
2022	28,06	18	32

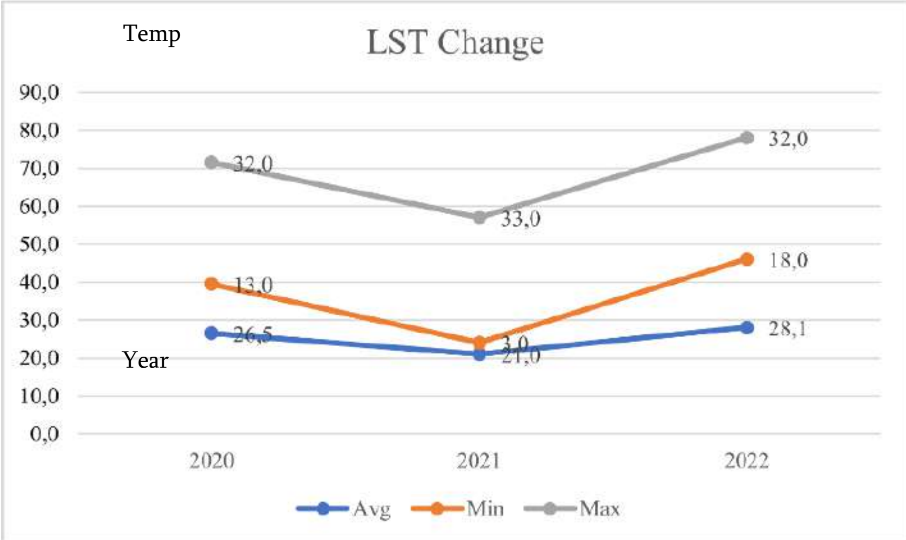

Figure 6. LST Changes in Bandar Lampung City

In 2020, the average temperature reached 26.39 degrees Celsius, with the lowest minimum temperature reaching 13 degrees Celsius and the highest maximum temperature reaching 32 degrees Celsius. In 2021, the average temperature decreased to 21.03 degrees Celsius, with the lowest minimum temperature reaching only 3 degrees Celsius and the highest maximum temperature reaching 33 degrees Celsius. However, in 2022, the average temperature increased to 28.06 degrees Celsius, with the minimum temperature reaching 18 degrees Celsius and the maximum temperature remaining at 32 degrees Celsius. This data provides an overview of the temperature variations in the region over the past three years. The significant changes in temperature from year to year indicate the existence of weather fluctuations that may impact the climate and environmental patterns in the region. Further analysis may be required to understand the factors influencing these temperature fluctuations and their implications for the environment and human life.

Using Landsat 8 OLI data and remote sensing methods, the difference in the average LST before, during, and after the COVID-19 lockdown was evaluated in comparison to previous studies, and the average for the last four years for the same date had the same trend as the LST in 2020 (Taoufik et al., 2021). The state of the vegetation and the land cover is closely related to LST. By calculating the magnitude of the correlation and the magnitude of the surface temperature at each density, it is possible to calculate the link between density and surface temperature. Then the assumption is made that the more vegetation the land surface temperature will be lower, and if there is little vegetation then the land surface temperature will be high. Surfaces in urban areas have a relationship, namely the more vegetation cover or with dense vegetation cover, the lower LST will be while the less vegetation cover, the hotter LST will be towards urban (urban). Determination of the land surface temperature by looking at the changes in vegetation cover seen from the density of vegetation using the vegetation index value. Vegetation can be an indicator of temperature dynamics. Open land and built-up regions exhibit comparable behavior and have higher values than Green Vegetation and Aquatic areas by 2 to 4°C, with the highest difference in mean LST between open land and green vegetation (Nando, 2021; Dang et al. 2020).

CONCLUSION

The results of the analysis of surface temperatures before Covid, the image recording time in 2020 has a value range of 13°C - 32°C, during the occurrence of Covid, the 2021 recording time has a value range of 3°C - 33°C, while after Covid, the 2022 recording time has a value range of 18°C - 32°C. There is a difference between the minimum and maximum LST values for each recording time. There was a decrease in the minimum LST value in 2021 but the maximum value was the highest compared to the other 2 conditions and a significant increase occurred after Covid 19 in 2022. There is a substantial association between LST and vegetation density in 2020, as indicated by the correlation between LST and NDVI, which is above 50%, but in 2022 the correlation is only 43% because most of the significant temperature decreases even though they have low vegetation density. Meanwhile, in 2022, it shows a correlation of 73%, meaning that this relationship is very strong. The correlation between LST and NDBI shows that in 2020 there will be a 49% relationship between built-up land and surface temperature. However, in 2020 the relationship decreased by only 23%, this is possible because the activities that occur in the built area also decreased. But a significant increase in 2022 after Covid 19 there is a very strong relationship of 70%. Both before and during the Covid-19 pandemic, an analysis of land surface temperature (LST) revealed a change in land surface temperature. By examining the changes in vegetation cover as visible from the density of vegetation using the vegetation index value, one can determine the land surface temperature.

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