

Identification of Land Surface Temperature (LST) using Multitemporal Sentinel 3 Images from 2019-2023 Case Study: Padang City Area, West Sumatra

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ARTICLE INFO

Keywords: Land Surface Temperature (LST); Sentinel 3, Multitemporal, NDVI

Received: April 15, 2024

Accepted: Mei 28, 2024

Published: June 1, 2024

ABSTRACT

Land Surface Temperature (LST) is widely utilized in current studies, particularly as an initial survey tool to assess geothermal activity in locations suspected to have geothermal sources. The research method involves geometric correction of Sentinel-3 imagery and conversion of temperature units from Fahrenheit (F) to Celsius (C) to ensure accuracy in temperature measurement. Image data processing from Sentinel-3, including thermal band analysis, is carried out to generate land surface temperature values. The field-measured temperatures are then compared to the land surface temperature data obtained through processing. The temperatures in the location, ranging from 23°C to 35°C, fall within the minimum geothermal temperature range, indicating potential geothermal activity. However, the LST values from the image data exhibit some differences compared to the on-site measurements. These discrepancies are categorized into classes I (23.7 – 24°C), II (24 – 24.3°C), and III (24.3 – 24.8°C), marked by red areas in the LST values. These discrepancies are attributed to various factors during image recording and processing, such as atmospheric interference and sensor calibration.

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Introduction

Increasing population leads to a rise in temperature because a growing population reduces vegetation cover. Lands are often converted into urban areas, which diminishes the region's oxygen-producing capacity, as trees produce oxygen through photosynthesis by absorbing carbon dioxide from air pollution. Consequently, the temperature rises. Urbanization, along with the proliferation of industries and vehicles in densely populated areas, contributes to higher pollution levels. This pollution increases temperature while reducing the number of vegetation, which are oxygen producers and temperature regulators, due to land conversion.

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Padang, a city with a relatively dense population, serves as the center of West Sumatra Province. The population growth in Padang over the last decade has not been significantly high, but it has been increasing, albeit not substantially from year to year. According to the Central Bureau of Statistics (BPS) of Padang City, the population in Padang is 902,413 people, with a population growth rate of 1.52% from 2010-2015 and 1.44% from 2014 to 2015. However, the population in Padang decreased from 950,871 people in 2019 to 909,040 in 2020. This coincides with a declining population growth rate in Padang, which dropped from 1.47% in 2019 to 0.84% in 2020. Population growth is a factor that affects the increase in surface temperature.

Padang is an economic center where economic activities significantly contribute to urbanization. People tend to migrate to cities in search of employment opportunities, which contributes to urbanization. Land Surface Temperature (LST) is influenced by urbanization; the more densely populated an area is, the higher its surface temperature. The vegetation density in Padang has decreased by 30,741.86 hectares in the last 20 years. This reduction in vegetation has led to an increase in the surface temperature of Padang.

Land Surface Temperature (LST) is the average temperature of the Earth's surface as recorded by satellite images at a specific time. Variations in temperature can influence climate elements. Changes and increases in temperature can be caused by both direct and indirect human activities. LST can also be defined as the average surface temperature depicted in a pixel with various types of different surfaces. The value of LST is influenced by the wavelength of thermal infrared radiation. However, each wavelength is sensitive to changes in temperature that affect the reflectance values of objects. To obtain LST information, the identification process of land surface temperature is carried out using the thermal wavelength available in satellite images. The Earth's surface can emit energy either partially or entirely if the temperature is above absolute zero (0 K, -273.15°C).

The surface temperature of Padang in 2007 was 30.25°C, increasing to 33.80°C in 2009, then rising to 34.35°C in 2013, and further increasing to 34.67°C in 2019. Over the past 15 years, the temperature in Padang has increased by 4.42°C (Irza Annesi Ulfa and Triyatno). This study examines temperature changes by identifying Land Surface Temperature (LST) using multi-temporal Sentinel-3 satellite imagery through remote sensing.

Methodology

The city of Padang, the capital of the province of Western Sumatra, Indonesia, is located at geographical coordinates approximately 0°57' S and 100°21' E. With an area of about 694.96 km², the city exhibits significant topographic variation, ranging from 0 meters above sea level in coastal areas to about 1,853 meters above sea level in hilly and mountainous areas. Padang is also known for its diverse geographical features, such as the west coast of Sumatra, hills, and valleys through which several major rivers flow, including the Arau River and the Kuranji River.

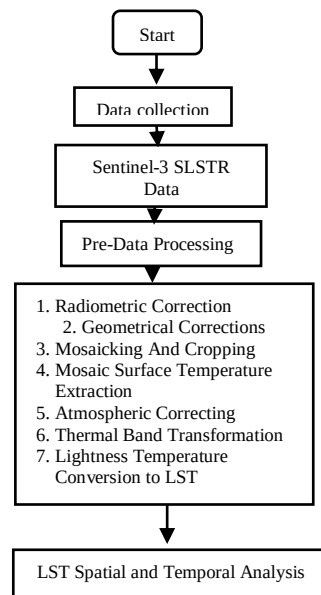
Padang has a tropical monsoon climate, with an average annual rainfall between 3,000 and 4,000 mm and an average temperature ranging from 24°C to 32°C throughout the year. The city experiences two major seasons: the rainy season and the dry monsoon season, with varying intensity of rainfall throughout the year.

The data used in this study include satellite images of the Sentinel-3 SLSTR, downloaded from the Copernicus Open Access Hub. These images have a 1 km spatial resolution for the thermal band and a revisit time of every 2-3 days. The thermal bands used are SLSTR TIR1 (10.85 μm) and TIR2 (12.00 μm), covering the period from 2019 to 2023. The data processing

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was conducted using SNAP software. The research methodology is summarized in the research flowchart (Figure 1).

Figure 1. Research Flowchart



Result

The Land Surface Temperature (LST) results are represented through color gradation: orange indicates elevated temperatures associated with low human activity, while blue signifies areas with no human activity or surfaces covered with vegetation. The maximum temperature in Padang City is observed in the coastal areas, predominantly to the west of the city. Overall, surface temperatures in most areas of Padang City are relatively high. Lower temperatures are primarily found in areas farther from the coast, typically within forested regions.

Discussion

The research findings on Land Surface Temperature (LST) in Padang City are detailed below.

Figure 2. Land Surface Temperature Map of Padang City in the year 2019

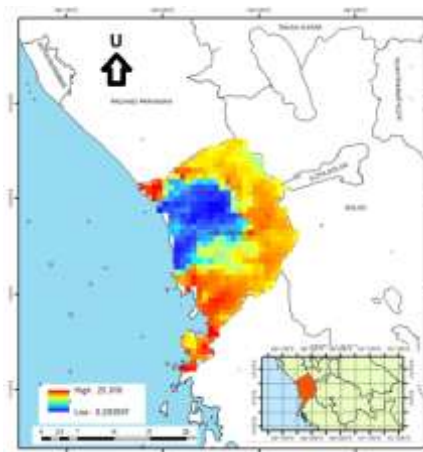


Figure 2 depicts the map of land surface temperature distribution in Padang City, extracted from Sentinel-3 imagery in 2019. The temperature distribution pattern varies significantly, with the maximum surface temperature in Padang City in 2019 reaching

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33.296°C and a minimum of 5.854°C. The red color represents areas in Padang City with the highest temperatures, which are located near the coast.

Figure 3. Land Surface Temperature Map of Padang City in 2020

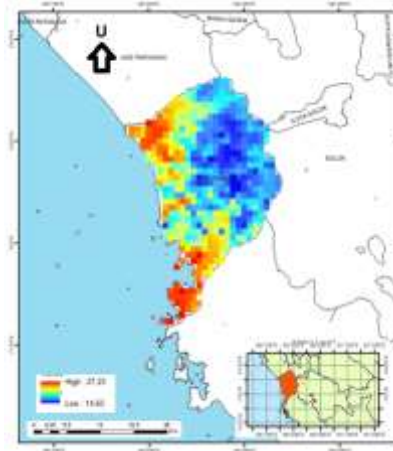


Figure 3 displays the map of land surface temperature distribution in Padang City, extracted from Sentinel-3 imagery in 2020. Compared to 2019, the temperature distribution pattern in 2020 shows a minimum of 15.102°C and a maximum of 32.09°C. The maximum temperature is located in the coastal areas, while the minimum temperature is found at the outskirts of Padang City. The temperature in Padang City in 2020 is significantly lower compared to the surface temperature in the years 2021, 2022, and 2023. This decrease is attributed to the COVID-19 pandemic, which restricted outdoor activities. This led to a reduction in air pollution caused by traffic activities, resulting in lower surface temperatures. The population of Padang City, including many newcomers such as students and workers, had their activities moved online or temporarily suspended during the COVID-19 period, causing Padang City to become relatively quiet. This had an impact on the surface temperature of Padang City. The maximum surface temperature in Padang City in 2020 was 27.230°C with a minimum temperature of 14.63°C. The areas with higher temperatures are located to the west of Padang City, near the coast.

Figure 4: Land Surface Temperature Identification Map of Padang City in 2021

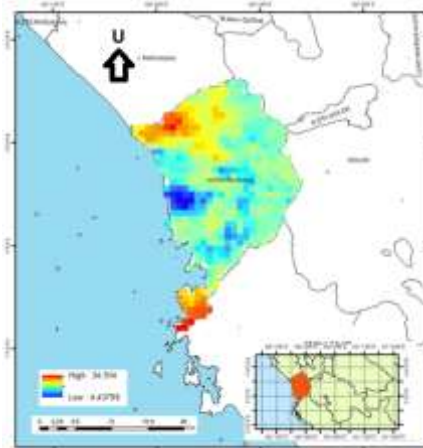


Figure 4 displays the map of land surface temperature distribution in Padang City, extracted from Sentinel-3 imagery in 2021. The temperature distribution pattern varies, with the maximum surface temperature in Padang City in 2021 recorded at 35.58°C and a minimum of 7.64°C. The areas with maximum temperatures are located near the coast, although not as many as in 2022 and 2023. A temperature of 35.58°C is categorized as quite hot, making Padang City experience high temperatures during both day and night.

Figure 5: Land Surface Temperatures Identification Map of Padang City in 2022.

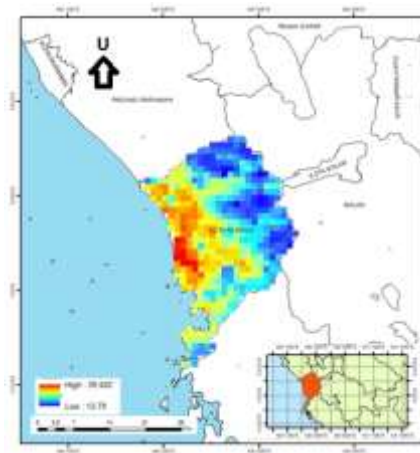


Figure 5 shows the distribution map of land surface temperatures in Kota Padang based on the extraction of Sentinel 3 satellite imagery from 2022. The temperature distribution pattern varies, with the maximum surface temperature of Kota Padang in 2022 reaching 39.622°C, and the minimum temperature being 12.79°C. The minimum temperature in Kota Padang in 2022 is higher compared to the minimum temperature in 2023, and there are more areas with minimum temperatures in 2022, especially in the outskirts of Kota Padang, far from the coast. Meanwhile, the maximum temperature is located in the coastal areas, which constitute the center of Kota Padang. The temperature fluctuations may have various causes, including seasonal changes, human activities, or other natural factors. Further analysis may be necessary to understand the reasons behind these temperature variations and their impacts on the environment and the local population.

Figure 6: Land Surface Temperature Identification Map of Padang City in 2023

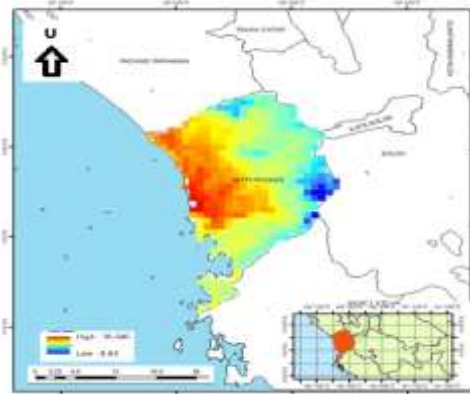


Figure 6 illustrates the map depicting the distribution of land surface temperatures in Kota Padang, obtained through the extraction of Sentinel 3 satellite imagery from 2023. The temperature distribution pattern exhibits significant variation, with the lowest recorded temperature at 6.63°C and the highest at 36.646°C. The relatively high temperatures contribute to Kota Padang experiencing warmth both during the day and night. The maximum temperature in Kota Padang is predominantly observed in areas close to the coast, specifically the western region of the city. Generally, surface temperatures in various parts of Kota Padang tend to be high, with only a few areas showing lower temperatures, particularly those situated farther from the coastline.

The density of vegetation significantly influences land surface temperatures, displaying an inverse relationship. Areas with dense vegetation typically have lower temperatures, while regions with sparse vegetation exhibit higher temperatures. Dense vegetation is commonly

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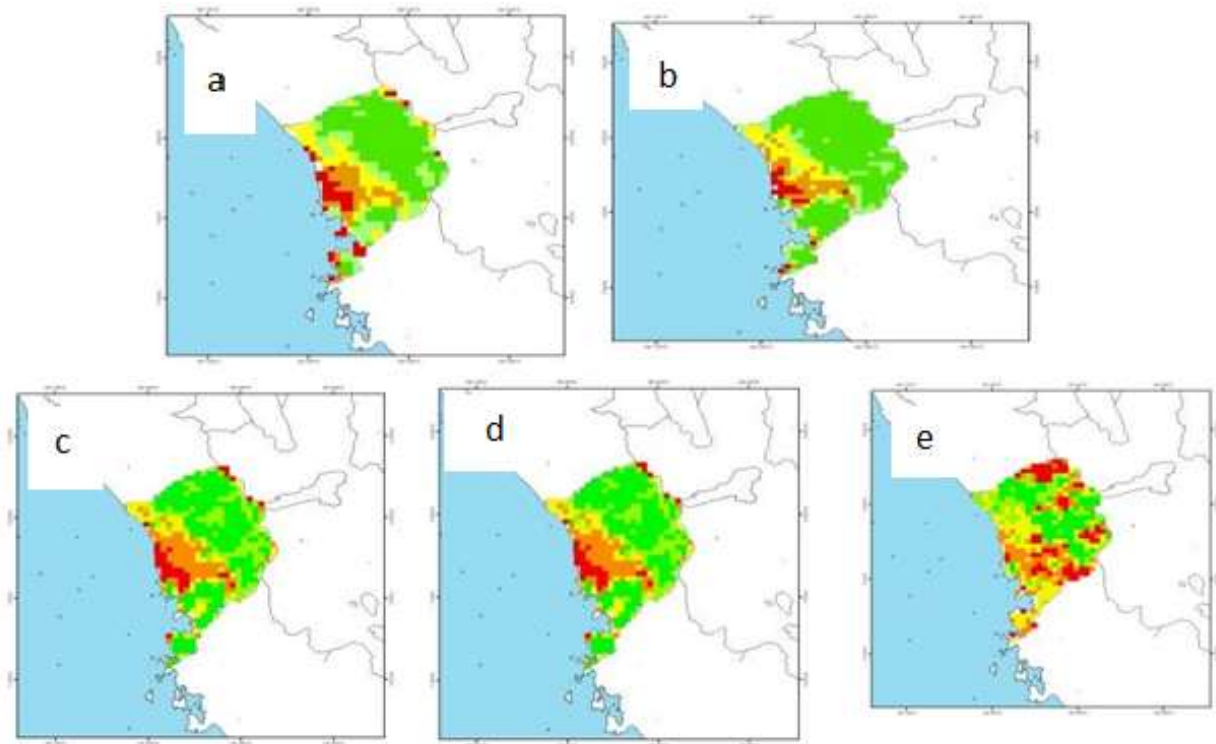
found in hilly or forested areas, while areas with sparse vegetation are associated with urban zones, where vegetation is less prevalent. In Kota Padang, areas with dense vegetation primarily represent forested regions. However, in 2023, the density of vegetation began to decline due to human activities, such as land transformation from forests to urban settlements. This transformation has led to an increase in land surface temperatures within previously forested areas. In contrast, densely populated urban areas experience higher temperatures, primarily because of the reduced vegetation density, which consequently results in elevated land surface temperatures.

Table 1. Multitemporal LST

<i>Year</i>	<i>Minimum LST</i>	<i>Maximum LST</i>
2019	5.854	33.296
2020	15.102	32.090
2021	7.636	35.582
2022	12.790	39.622
2023	6.630	36.646

NDVI Map of Kota Padang Over the Last 5 Years

Figure 7. (a). NDVI in 2019, (b) NDVI in 2020, (c) NDVI in 2021, (d) NDVI in 2022, (e) NDVI in 2023



Dense vegetation tends to absorb more solar energy through the process of photosynthesis. This results in a decrease in surface temperature in areas covered by vegetation because most of the energy is converted into chemical energy within the plants and is not radiated back as heat. Vegetation also provides shade, which helps reduce direct heating by sunlight. As a result, temperatures under vegetation or in areas with plant growth are usually lower than in open areas.

Research has shown a strong correlation between vegetation density and surface temperature. Dense vegetation has a greater capacity to lower surface temperatures compared to areas with minimal vegetation. For instance, a study conducted by Smith et al. (2018) found

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that regions with high forest density exhibited lower surface temperatures compared to deforested areas. The results of this research are consistent with other findings that suggest dense vegetation helps mitigate surface temperature warming (Brown & De Beurs, 2008).

Furthermore, research by Johnson et al. (2019) indicates that urban areas dominated by buildings and concrete land cover tend to have higher surface temperatures than areas with more vegetation. This highlights the significant role of vegetation in maintaining lower surface temperatures in urban environments.

Conclusion

Using Sentinel-3 multispectral imagery, the following conclusions about Land Surface Temperature (LST) in Kota Padang over the past 5 years can be drawn:

1. The LST in Kota Padang from 2019 to 2023 shows significant variation. The highest temperature was recorded in 2022, reaching 39.622°C, primarily observed in areas with open land, factories, and dense settlements. This temperature variation is influenced by the soil's heat-absorbing properties and human activities such as industrial operations and urban development. The high temperatures can also be attributed to emissions and air pollution generated by human activities in these areas.
2. Changes in land surface temperatures in Kota Padang are significantly influenced by climate and weather conditions. Prolonged drought conditions in 2022 contributed to the elevated land surface temperatures. In contrast, the land surface temperature in 2020 remained relatively normal due to the absence of extreme drought conditions.
3. Temperature differences can be classified into various categories: low to very low temperatures in areas with dense vegetation, and moderate temperatures in open water bodies such as deep seas, shallow seas, rivers, lakes, and ponds. Cloud-covered areas also exhibit moderate temperatures.

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