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The Dynamics of Land Surface Temperature Changes in Padang City: A Temporal Study from 2016 to 2024

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ABSTRACT

Population growth and economic development in Padang City have led to increased land use, impacting changes in land surface temperature. This study aims to analyze the spatial distribution of land surface temperature in Padang City using a quantitative descriptive method. The data utilized consists of Landsat 8 satellite imagery from 2016 to 2024 with a two-year interval. Surface temperature values were derived from processing the thermal bands of satellite imagery and identified through an overlay with the administrative boundaries of Padang City.The results indicate that built-up areas tend to have higher surface temperatures compared to regions with dense vegetation cover. Nearly the entire western part of Padang City has experienced a significant temperature increase, particularly in highly populated areas such as Padang Barat, Padang Timur, and Padang Utara. Meanwhile, lower-temperature regions are still found in the eastern part, particularly in Pauh District and its surroundings, which still retain substantial green land cover. These findings suggest the presence of an Urban Heat Island (UHI) effect due to reduced vegetation and an increase in built-up areas.

Keywords: Temporal Change, Land Surface Temperature, NDVI, Urban Heat Island, Landsat 8

1. Introduction

Padang City is the capital of West Sumatra. The city is rapidly developing due to its population activities and services. The population growth rate continues to increase and will not stop, whether consciously recognized or not. Based on data from BPS, the 2010/2020 Population Census (SP), and the 2015 Intercensal Survey (SUPAS), the population of West Sumatra Province has shown a significant upward trend from 2010 to 2021 [1].

Land use has increased significantly, particularly in residential and industrial areas, in 2020. By 2021, land use had further expanded to include residential land, industrial zones, corporate land, service areas, farmland, vacant land, and urban land. Conversely, the use of irrigated rice fields declined in 2020, followed by a reduction in river areas in 2021. Previous researchers have conducted various studies related to land use and land cover change.In numerous studies on climate change and environmental analysis at local, regional, and global scales, Land Surface Temperature (LST) and albedo have been identified as the two most significant variables. LST is a crucial parameter in surface processes as it reflects climate change and regulates terrestrial outgoing radiation, as well as the exchange of latent and sensible heat fluxes between the surface and the atmosphere [4]. Since artificial surfaces absorb and release heat, leading to the formation of the Urban Heat Island (UHI) phenomenon, changes in urban land cover that replace natural surfaces with built-up areas are one of the key factors contributing to the increase in Land Surface Temperature (LST) in urban environments. UHI refers to the temperature difference between urban and rural areas, where cities tend to be warmer than surrounding rural regions [6]. The Mono-Window Brightness Temperature (MWBT) algorithm can be used to identify land surface temperature values. This algorithm utilizes brightness temperature data from thermal bands to estimate land surface temperature while considering atmospheric transmission and surface emissivity factors. An enhanced version of the mono-window algorithm is a further development of the original algorithm, which was initially designed for Landsat TM data. This improved algorithm is more robust and well-suited for Landsat 8 TIRS Band 10, which has a different spectral response function compared to Landsat TM. Additionally, it is better adapted to varying atmospheric conditions and higher surface emissivity, making it more effective for land surface temperature estimation [7, 8]. In summary, the mono-window algorithm offers numerous advantages, including practicality, broad applicability, low sensitivity to emissive errors, resilience to atmospheric conditions, and higher accuracy. These benefits make it a popular choice among researchers and practitioners, serving as a valuable tool for Land Surface Temperature (LST) retrieval. One of the key advantages of the mono-window algorithm is its ability to simplify the atmospheric correction process. It requires only three essential parameters: land surface emissivity, atmospheric transmission, and effective mean atmospheric temperature. This simplification makes the algorithm more efficient and easier to implement compared to other methods that require a larger number of parameters. Additionally, the algorithm is less sensitive to atmospheric errors and demonstrates strong resilience to varying atmospheric conditions, making it particularly effective in environments with high temperature and humidity [9 - 13].

Based on the above statement, it can be concluded that the high intensity of land use and the decreasing availability of land in Padang City have significantly impacted various environmental and urban spatial planning aspects. Changes in land use influence the distribution of land surface temperature (LST), contributing to variations in urban thermal conditions. Therefore, further research is necessary to analyze the effects of land use changes on the distribution of land surface temperature and their implications for urban sustainability [14, 15].

2. Research Methodology

This study examines the impact of land cover changes on the distribution of land surface temperature in Padang City and its surrounding areas. A quantitative descriptive approach is applied in this research. The Mono-Window Brightness Temperature algorithm is utilized to extract land surface temperature values from thermal infrared channels. The results of this analysis are then integrated with a land cover map obtained through the supervised classification method to evaluate the effects of land cover changes on temperature distribution. This study produces a spatial distribution map of land surface temperature as the primary output, which can be used for further analysis.

This study was conducted in Padang City, which is geographically located between 00° 44’ 00” and 1° 08’ 35’’ North Latitude and 100° 05’ 55’’ and 100° 34’ 09’’ East Longitude. Administratively, Padang City consists of 11 districts and 104 sub-districts, including Padang Barat, Padang Selatan, and Padang Timur.

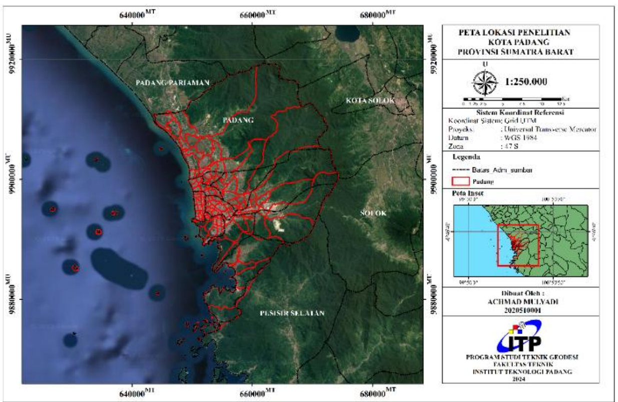


Figure 1. Research Location

The first stage involves conducting a literature review to gather relevant theories that serve as the foundation for this research. Subsequently, the required data for this study is collected, including Landsat 8 satellite imagery from the years 2016, 2018, 2020, 2022, and 2024, as well as the administrative boundaries of Padang City. Once the data is acquired, the next step is Radiometric Calibration, which is used to minimize atmospheric disturbances during the image acquisition process. The corrected satellite imagery is then cropped according to the administrative boundaries of Padang City and further processed using the Mono-Window Brightness Temperature algorithm following the equations outlined in Equation (1), Equation (2), and Equation (3).

$$L_\lambda = L_{min\,(\lambda)} + \left\{L_{max\,(\lambda)} - L_{min(\lambda)}/Q_{max\,(\lambda)}\right\} x\, Q_{DN} \quad \textbf{(1)}$$

Where *Lλ* is Spectral Radiance, *Lmax(λ)* is Maximum Spectral Radiance, *Lmin(λ)* is Minimum Spectral Radiance, and *Qmax(λ)* is Maximum Value Digital Number. Then, conversion of spectral radiance to kelvin:

$$Tb = \frac{K_2}{In(\frac{K_1}{L_\lambda}+1)} \quad \textbf{(2)}$$

Where *Tb* is Temperature Brightness Satellite (K), K_1 is Spectral Radiance Calibration Constant, K_2 is Spectral Temperature Calibration Constant, and Lλ is Spectral Radiance. Conversion of Temperature from Kelvin to Celsius:

$$T_{Celcius} = T_{Kelvin} - 273 \quad \textbf{(3)}$$

3. Result and Discussion

From the processed Land Surface Temperature (LST) data, a spatial distribution map of Padang City's surface temperature for the years 2016, 2018, 2020, 2022, and 2024 was generated. The resulting maps can be seen in Figure 2 below.

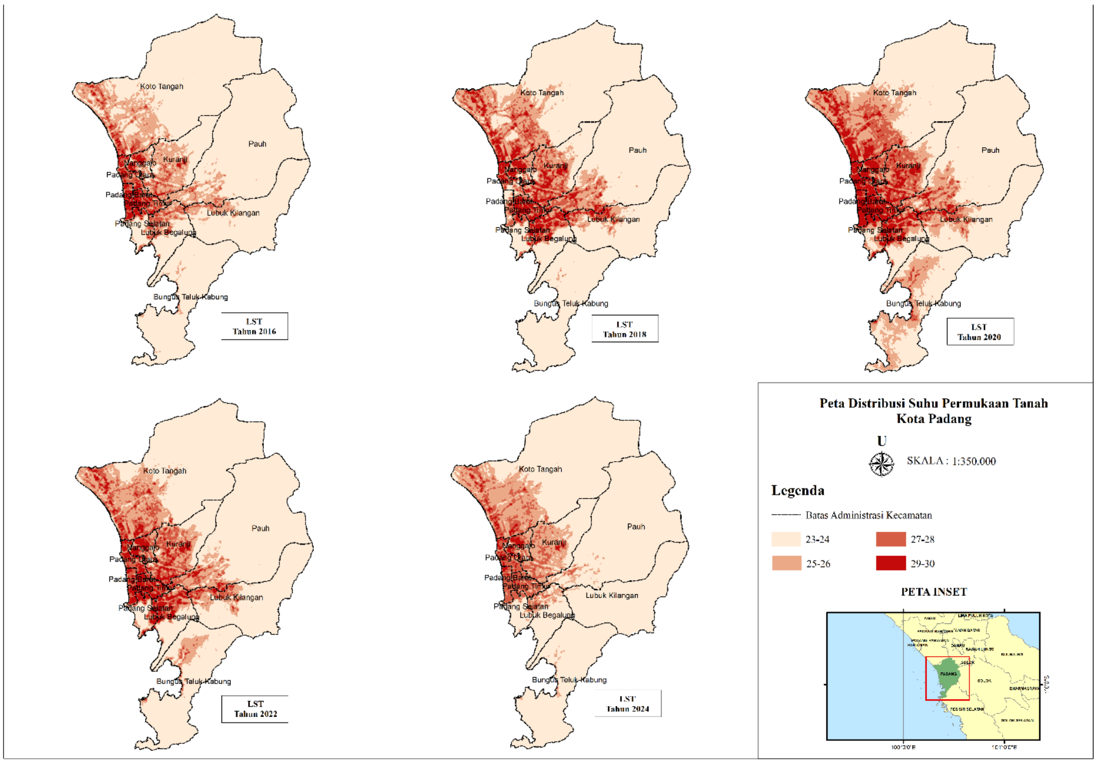
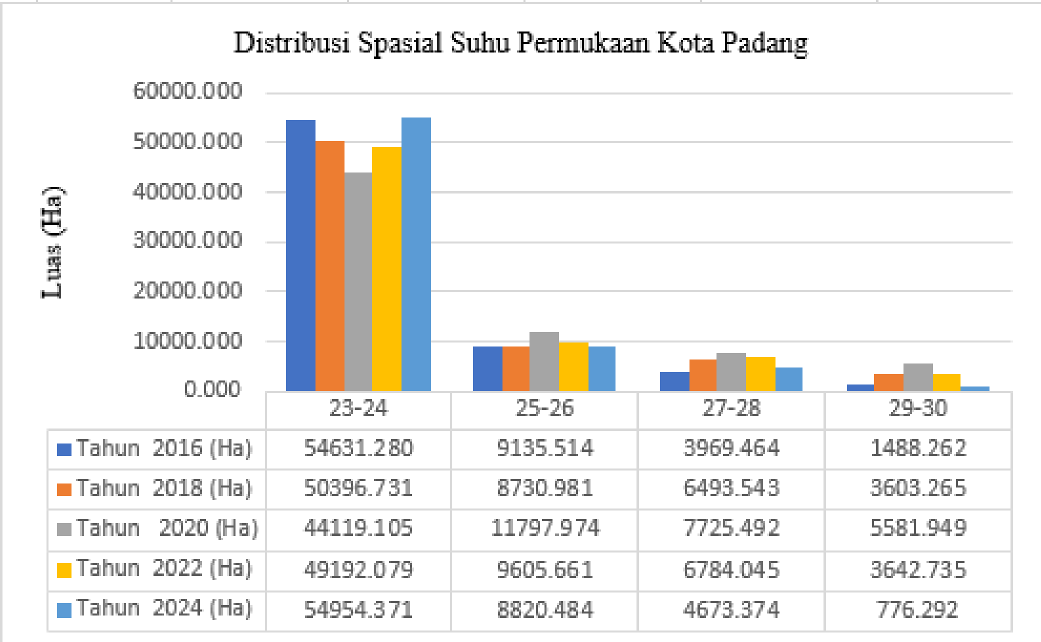


Figure 2. Land Surface Temperature Distribution Map in Padang City (2016 – 2024)

Based on the land surface temperature distribution map of Padang City from 2016 to 2024, there is a noticeable trend of increasing temperatures, particularly in urban and surrounding areas. The red areas, which indicate high temperatures (27–30°C), have expanded over time, especially in the city center and densely populated regions. Meanwhile, areas with lower temperatures (23–24°C) have gradually decreased, suggesting that urbanization and land cover changes contribute to the rise in surface temperature. From 2016 to 2020, the increase in temperature was particularly significant in the northern part and central area of Padang City, likely due to increased construction activities and a reduction in vegetation cover. In 2022 and 2024, the distribution of high-temperature zones continued to expand, further indicating the dominance of the urban heat island (UHI) effect. Areas with high temperature concentrations are found in regions with high building density, leading to increased heat emissions.

This temperature distribution pattern also correlates with infrastructure development and the reduction of green spaces. Therefore, these findings highlight the importance of sustainable spatial planning to mitigate the impact of rising surface temperatures in Padang City. The spatial distribution of land surface temperature in Padang City can be observed through the graph in Figure 3 below.



	23-24	25-26	27-28	29-30
Tahun 2016 (Ha)	54631.280	9135.514	3969.464	1488.262
Tahun 2018 (Ha)	50396.731	8730.981	6493.543	3603.265
Tahun 2020 (Ha)	44119.105	11797.974	7725.492	5581.949
Tahun 2022 (Ha)	49192.079	9605.661	6784.045	3642.735
Tahun 2024 (Ha)	54954.371	8820.484	4673.374	776.292

Figure 1 Graph of Spatial Distribution of Land Surface Temperature in Padang City

In that figure, fluctuations in the area of each temperature category can be observed. The low-temperature category (23–24°C) exhibits a relatively stable pattern, covering the largest land area compared to other categories, ranging between 50,000 to 55,000 hectares. Although there was a slight decline in 2020, the area of this category increased again in 2024, indicating that lower temperatures still dominate. This trend aligns with research conducted by Dimas Indo Saputro (2021) in Denpasar, Bali, and Omeria Waruwu (2022) in Medan City, where both studies found that prior to the COVID-19 pandemic, land surface temperatures in the study areas were relatively high. However, during and after the pandemic, there was a notable decrease in temperature. This phenomenon occurred as Indonesia, along with the rest of the world, implemented Large-Scale Social Restrictions (PSBB) in 2020 to limit physical interactions by restricting activities such as work, school, and public gatherings. The reduction in human activities contributed to a decline in land surface temperatures, which had previously been increasing. The medium-temperature category (25–26°C) shows a fluctuating trend. In 2016, the land area in this category was 9,135 hectares, decreasing in 2018 but rising again in 2020 to 11,797 hectares before declining once more in 2024 to 8,820 hectares. This fluctuation suggests that temperature distribution is influenced by land cover changes and climatic variations. Higher temperature categories (27–

28°C and 29–30°C) show a steady increase until 2020, with the area of land in the 27–28°C range expanding from 3,969 hectares in 2016 to 7,725 hectares in 2020. The highest temperature category (29–30°C) also saw a significant rise, increasing from 1,488 hectares in 2016 to 5,581 hectares in 2020, before sharply declining to 776 hectares in 2024.

Overall, these findings indicate that Padang City experienced an increase in land surface temperature over certain periods, likely due to vegetation loss and intensified urban development. However, the decline in high-temperature areas in 2024 may suggest the presence of mitigation efforts or other environmental factors influencing land surface temperature.

4. Conclusion

Based on the analysis conducted using the Mono-Window Brightness Temperature (MWBT) algorithm, it was found that the distribution of land surface temperature in Padang City underwent significant changes between 2016 and 2024. Built-up areas tend to have higher surface temperatures compared to regions with dense vegetation cover. Almost the entire western part of Padang City experienced a significant temperature increase, particularly in high-density urban areas such as Padang Barat, Padang Timur, and Padang Utara. Meanwhile, lower-temperature regions are still found in the eastern part of the city, particularly in Pauh District and its surroundings, where green land cover remains relatively abundant. This indicates that land-use changes, especially the expansion of built-up areas, have contributed to the rise in land surface temperature over time.

Bibliography

[1] F. Fajrin, A. Almegi, A. Bakari, R. Ramadhan, and Y. Antomi, "Enviromental Monitoring of Land Subsidence in The Coastal Area of Padang City Using Sentinel 1 Sar Dataset," *Sumatra J. Disaster, Geogr. Geogr. Educ.*, 5(1), p. 30–34, 2021. https://doi.org/10.24036/sjdgge.v5i1.359

[2] B. P. Statistik, "Kota Padang dalam Angka," 2024.

[3] N wulandari, "gambaran umum kota Padang," vol. 01, pp. 1–23, 2016.

[4] E. Igun and M. Williams, "Impact of urban land cover change on land surface temperature," *Glob. J. Environ. Sci. Manag.*, 4(1), p. 47–58, 2018. https://doi.org/10.22034/gjesm.2018.04.01.005

[5] F. Divia, I. Armi, S. Fikri, and D. Arini, "Analisis Perbandingan Suhu Permukaan Di Kota Padang Dan Kota Pekanbaru Menggunakan Citra Landsat," *MAROSTEK J. Tek. Komputer, Agroteknologi dan Sains*, 2(1), p. 47–55, 2023.

[6] Yastisio, G. R., Arini, D., & Bramanto, B. Quality Control Analysis of UAV Digital Terrain Model with GNSS Geodetic Terrain Model. *SEAJAET*. 1(3), p 82-92. 2024. https://doi.org/10.62447/seajaet.v1i3.36

[7] Alston, E. J, Sokolik, I. N, & Doddridge, B.G. Investigation into the use of satellite data in aiding characterization of particulate air quality in the Atlanta, Georgia metropolitan area. *J Air Waste Manage Assoc*, 61(2), p 211–225, 2011. https://doi.org/10.3155/1047-3289.61.2.211

[8] S. Odunuga and G. Badru, "Landcover Change, Land Surface Temperature, Surface Albedo and Topography in the Plateau Region of North-Central Nigeria," *Land*, vol. 4, no. 2, pp. 300–324, 2015, https://doi.org/10.3390/land4020300

[9] Z. Qin, A. Karnieli, and P. Berliner, "A mono-window algorithm for retrieving land surface temperature from Landsat TM data and its application to the Israel-Egypt border region," *Int. J. Remote Sens.*, vol. 22, no. 18, pp. 3719–3746, 2001, https://doi.org/10.1080/01431160010006971

[10] F. Wang, Z. Qin, C. Song, L. Tu, A. Karnieli, and S. Zhao, "An improved mono-window algorithm for land surface temperature retrieval from landsat 8 thermal infrared sensor data," *Remote Sens.*, 7(4), p. 4268–4289, 2015, https://doi.org/10.3390/rs70404268

[11] Arini D., Guvil Q., Wahidah N. Land Cover Identification Using Pleiades Satellite Imagery by Comparison of NDVI and BI Methode in Jatinangor-West Java. *IOP Conference Series: Earth and Environmental Science*, 500(1):012007. 2020. https://doi.org/10.1088/1755-1315/500/1/012007

[12] Driptufany D. M. Early Detection of the Distribution of Heat Stress Hazard for Sustainable Land Use Planning in Padang City. *IOP Conference Series: Earth and Environmental Science*, 709(1):012059. 2021. https://doi.org/10.1088/1755-1315/708/1/012059

[13] Arini D., Sari S. M., & Driptufany D. M. Pemanfaatan Citra Landsat 8 untuk Mendeteksi Tingkat Kesehatan Tanaman Kelapa Sawit Menggunakan Metode Normalized Difference Vegetation Index (NDVI) di Kabupaten Bengkalis. *EL-JUGHRAFIYAH*, 2(2), p 50-60. 2022.

[14] Sudirman, M. L. Kondolayuk, and I. M. E. Sriwahyuningrum, Ayunda, Cahaya, “Metodologi penelitian 1,” *Media Sains Indones.*, no. July, pp. 166–178, 2023.

[15] S. A. Al Mukmin, A. P. Wijaya, and A. Sukmono, “Analisis Pengaruh Perubahan Tutupan Lahan Terhadap Distribusi Suhu Permukaan dan Keterkaitannya Dengan Fenomena Urban Heat Island,” *J. Geod. Undip*, 5(1), p. 224–233, 2016.