

Terbit online pada laman web jurnal : <https://jes-tm.org/index.php/jestm/index>

# Journal of Engineering Science and Technology Management

| ISSN (Online) 2828 -7886 |



Article

## Identification of Urban Heat Island (UHI) in Bangkinang City Using Remote Sensing and Geographic Information System Techniques

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### ARTICLE INFORMATION

Volume 4 Issue 2

Received: 09 August 2024

Accepted: 26 September 2024

Publish Online: 30 September 2024

Online: at <https://JESTM.org/>

### Keywords

Urban Heat Island (UHI)

Land Surface Temperature (LST)

Citra Landsat

### ABSTRACT

Bangkinang is the capital of the district of Kampar, has an area of 177.2 km<sup>2</sup> with a population of 39,793 people. The city has a tropical climate and is located on the phenomenal line, causing temperatures to tend to warm. In addition to the increasing human population, the heat of a city is also caused by vehicles and the intrusion of industrial waste, which has an effect on the temperature of the surface that becomes hot. UV rays that reflect on the surface of the soil are not delivered well into the atmosphere making the surface absorb heat so that urban temperatures become warmer than the surrounding area. In addition, the population population as well as the lack of vegetation density make a city affected by the UHI effect. In this study will identify the surface temperature in 2021, 2022, and 2023 using Landsat Images 7 ETM+ and 8 OLI/TIRS. The first is the calculation of the Land Surface Temperature (LST) using the Single-Chanel Algorithm method. The results are the land surface temperature values in Bangkinang City with average temperatures for the years 2021, 2022, and 2023 in sequence of 27.755°C; 26.644°C, and 27.130°C where the results of the Pearson Product Moment correlation test between the Land surface temperature ( LST) and the field temperature obtained from the BPS (Central Statistical Unit), the result is a correlations coefficient value (Rxy) of 0.226; that means that there is sufficient correlation. Finally, from the Urban Heat Island (UHI) Threshold Method map, the size of the area affected by the UHI has always been declining from 2021, 2022, and 2023.

## 1. Introduction

Bangkinang is the capital city of Kampar Regency, covering an area of 177.2 km<sup>2</sup> with a population of 39,793 people. The city has a tropical climate and lies directly on the equator, making it a region with high heat intensity. The global issue of climate change is one of the most critical environmental challenges faced today. The increase in greenhouse gas emissions resulting from various human activities, including transportation, industry, and construction, has led to a rise in surface temperature (Adeswastoto, 2024). Ultraviolet radiation reflected from the ground is not well dispersed into the atmosphere, causing the land surface to absorb heat and making urban temperatures higher than those in surrounding rural areas. Other contributing factors include high population density and low vegetation coverage.

Continuous urban expansion and rapid land-use change have caused an increase in surface temperature. This situation has become increasingly serious, affecting sustainable urban development and reducing the quality of life in cities (Sumaryana et al., 2022). The Urban Heat Island (UHI) phenomenon indicates that temperatures in urban areas are 3 to 10°C higher than in rural areas. In Bangkinang, temperatures range from 23°C to 32°C, rarely dropping below 22°C or exceeding 34°C. The hot season lasts about three to four months, from March to July, with high average temperatures ranging from 24°C to 32°C.

The UHI effect is influenced by anthropogenic activities—human actions that impact the environment—such as pollution caused by industrial, mining, and agricultural waste (Radjasa, 2019). UHI is closely related to the lack of green open spaces (RTH), population growth, urban expansion, and vehicle density. UHI also contributes significantly to long-term global warming. The reduction of green spaces disrupts the rainfall cycle and increases soil erosion. UHI leads to the formation of hot spots in urban areas due to dense infrastructure, impervious surfaces, and limited vegetation cover. These hot spots become worse during extreme heat events that are increasingly frequent as a result of human activities in cities (Sidiqi, 2021).

Urban environmental problems, including UHI, are largely caused by poor spatial planning. Prioritizing economic and urban growth without considering ecological balance endangers future sustainability. Converting grasslands into built-up areas increases surface temperatures in urban regions (Wibisono et al., 2023). The rising temperatures in Bangkinang's residential areas have a significant impact. Although the city is often covered by clouds, it still experiences warm to hot conditions. Geographic Information System (GIS) technology serves as an effective spatial information tool for

rapid mapping and data communication (Bahri et al., 2012).

In this study, the digital values of Landsat 7 ETM+ and Landsat 8 OLI/TIRS satellite imagery were converted to tropical ranges to obtain Land Surface Temperature (LST). The process was carried out using ArcGIS software to generate UHI distribution maps. Temporal variations in LST and UHI were observed throughout the study period. The findings are intended to provide information and recommendations for future urban planning and environmental protection. The study was conducted in Bangkinang City, the capital of Kampar Regency.

## 2. Literature Review

Research by Pratiwi & Jaelani (2021) aimed to analyze the changes in the distribution of Urban Heat Island (UHI) in Surabaya City in the years 2002, 2014, and 2019 using Landsat 7 (ETM+) and Landsat 8 (OLI/TIRS) imagery. Using the Single-Channel Algorithm method, UHI distribution analysis was then carried out using the Threshold Method and Hot Spot Analysis. The results showed that the average Land Surface Temperature (LST) in Surabaya City for 2002, 2014, and 2019 were 29.094°C, 26.889°C, and 27.130°C respectively. The Pearson Product Moment correlation test between LST and field temperature obtained from weather stations produced a correlation coefficient (Rxy) of 0.449, indicating a moderate correlation. Finally, based on the Threshold Method UHI maps, the area affected by UHI consistently decreased from 2002 to 2019, with reductions of 0.70 km<sup>2</sup> and 7.995 km<sup>2</sup>, respectively. Similarly, based on the \*Hot Spot Analysis (Getis-Ord Gi)\*\*<sup>2</sup>, the UHI-affected area also decreased, with reductions of 2.027 km<sup>2</sup> and 31.168 km<sup>2</sup>.

Research by Marsiska (2019) aimed to estimate the reduction of urban Land Surface Temperature (LST) through temporal analysis using Landsat imagery, and to detect and map the presence of UHI as the hottest areas compared to their surroundings, which directly affect urban environments and human life due to temperature rise. The study also emphasized the importance of policy recommendations for controlling and mitigating the negative impacts of UHI in urban spatial planning. The findings indicated that UHI is expected to continue increasing along with urbanization growth in the future. Therefore, strategies to control and reduce UHI impacts should be considered in city spatial planning.

Research by Urufi & Ahmad (2021) stated that temperature changes in Bandung City have become increasingly noticeable and have directly affected daily community activities. This study sought to explore the relationship between rising temperatures in Bandung City and factors such as the number of motor vehicles, public attitudes, and the area of

existing green open space (RTH). The results showed that the five studied variables influenced the dependent variable (surface temperature per district in Bandung) by 32.3%, based on an adjusted R-squared value of 0.323.

Research by Studi et al. (2022) aimed to determine the relationship between vegetation density and surface temperature using the SAVI vegetation index and LST, which contribute to the occurrence of UHI phenomena. The study found that the average temperature increased by 9.6°C from 1996 to 2018. In 1996, Bandung's temperature predominantly ranged between 16–20°C, while in 2018, temperatures in the city center ranged between 26–30°C. Based on LST estimation, UHI phenomena were confirmed to have occurred in Bandung. The correlation between SAVI and LST was found to be negative, meaning that denser vegetation corresponds to lower surface temperatures.

Research by Momentum et al. (2017) aimed to identify the spatial pattern of land surface temperature in Padang City using medium-resolution Landsat 7 ETM+ and Landsat 8 OLI/TIR imagery. The study found that the UHI areas in Padang City had surface temperatures above +30°C. The UHI exhibited a random spatial pattern (from west to east), with varying extents each year: 17.07 ha in 2007, increasing to 3,995.87 ha in 2013, and decreasing again to 859.79 ha in 2016. UHI areas tended to occur in built-up (urban) zones. One of the main factors influencing surface temperature was the Normalized Difference Vegetation Index (NDVI); statistically, surface temperature showed a strong inverse relationship with NDVI—lower NDVI values correspond to higher land surface temperatures.

Research by Nofrizal & Hanif (2018) indicated that remote sensing technology, especially Landsat imagery, can be used to rapidly obtain information about land cover types and surface temperature distribution in Solok City. The study aimed to identify the UHI phenomenon and examine the relationship between land surface temperature and land use in Solok City. Using the Land Surface Temperature algorithm, the study revealed that Solok City has varied temperatures, with the highest surface temperature reaching 36°C and the lowest around 20°C.

Research by Tadriz et al. (2020) highlighted the importance of studying UHI phenomena to understand changes in Urban Heat Island distribution in Bekasi Regency over a 10-year period. The objective was to provide insights into the extent of UHI change between 2008 and 2018.

Based on these previous studies, the researcher is interested in conducting a new study titled "Identification of Urban Heat Island (UHI) in Bangkinang City Using Remote Sensing and Geographic Information System (GIS) Techniques."

The purpose of this research is to analyze the changes in UHI in Bangkinang City over the years 2021, 2022, and 2023, and to examine whether these changes are related to land use (land cover) changes. Moreover, this study aims to provide practical benefits for both the public and the government—serving as a reference for developing green open spaces or implementing mass planting programs in residential areas. The methodology of this study is based on the approaches used in previous research, employing various online data sources such as USGS and BIG to collect Landsat imagery, and using smartphones to measure on-site temperature and identify affected land areas on the UHI map. The novelty of this study lies in its research location, which focuses specifically on Bangkinang City.

### **3. Research Methodology**

#### **3.1 Location**

This research was conducted in Bangkinang City, the capital of Kampar Regency, which is geographically located at coordinates 0°20'29" N and 101°01'46.5" E. The detailed location of the study area is illustrated in the corresponding map below.

#### **3.2 Research Design**

*This study employs a descriptive quantitative approach, which is a numerical method applied to the analysis of Landsat satellite imagery data, supported by Geographic Information System (GIS) techniques using ArcGIS and remote sensing methods. In addition, field observations were conducted directly at the study site.*

#### **3.3 Research Stages**

*The research methodology is divided into two stages: the implementation stage and the data processing stage. The implementation stage describes the overall process of the study, starting from problem identification to report preparation. Meanwhile, the data processing stage explains in detail the procedures involved in data analysis.*

## **4. Results and Discussion**

### **4.1 Result Land Surface Temperature (LST)**

*The processing of Landsat 7 ETM+ and Landsat 8 OLI/TIRS imagery using the Single Channel Algorithm (SCA) produced a Land Surface Temperature (LST) distribution map of Bangkinang City on June 3, 2021, with a minimum LST value of 17.172°C, a maximum of 29.933°C, an average of 27.755°C, and a standard deviation of 4.829°C.*

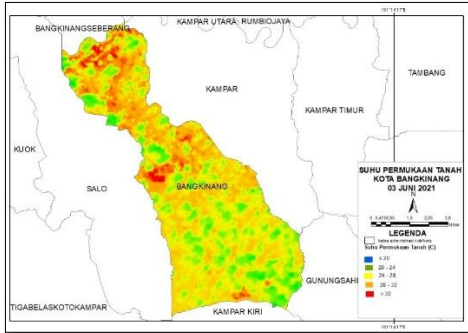


Fig. 1 Land Surface Temperature in Bangkinang City on June 3, 2021

The figure below presents the LST processing result for the satellite image dated April 15, 2022. The analysis produced a minimum LST value of 21.913°C, a maximum of 27.374°C, an average of 24.644°C, and a standard deviation of 2.731°C.

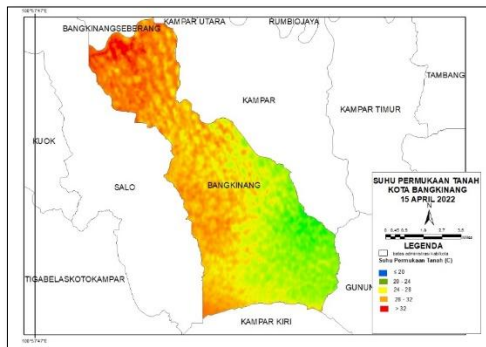


Fig. 2 Land Surface Temperature in Bangkinang City on April 15, 2022

The figure below shows the LST processing result for the satellite image dated June 11, 2019. The analysis yielded a minimum LST value of 20.804°C, a maximum of 26.390°C, an average of 27.130°C, and a standard deviation of 6.326°C.

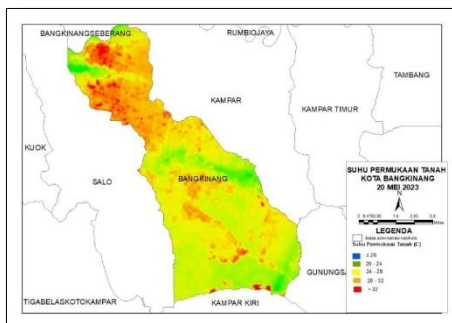


Fig. 3 Land Surface Temperature in Bangkinang City on May 20, 2023

#### 4.2 Results of land cover analysis

Land cover was identified through image classification using the Supervised Classification method with Maximum Likelihood, resulting in a land cover map of Bangkinang City categorized into three land cover classes: vegetation, built-up areas,

and water bodies. This map comprehensively illustrates the land conditions based on satellite imagery from 2021, 2022, and 2023, as presented below:

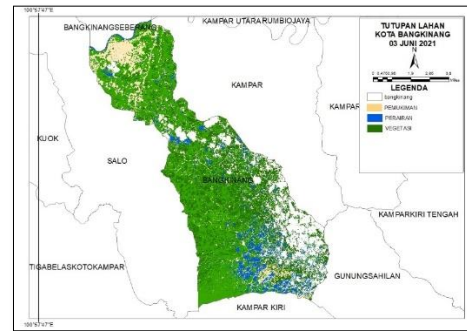


Fig. 4 Land Cover of Bangkinang City on June 3, 2021

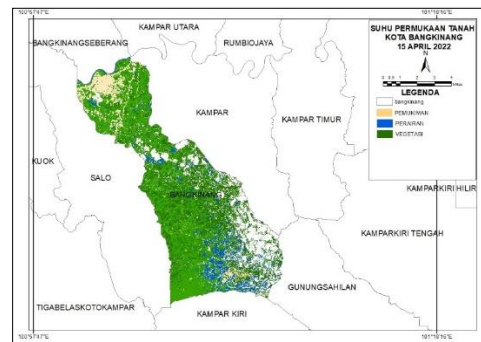


Fig. 5 Land Cover of Bangkinang City on April 15, 2022

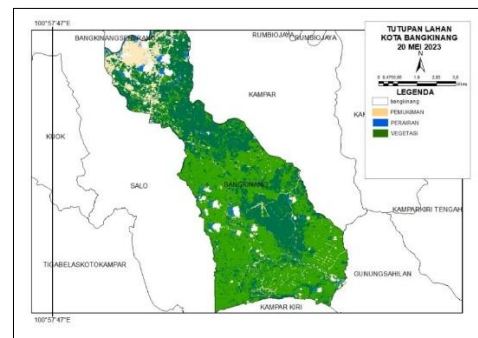


Fig. 6 Land Cover of Bangkinang City on May 20, 2023

The accuracy assessment of the classified land cover was conducted for the 2023 land cover using the confusion matrix method, with the requirement that the Overall Accuracy value be  $\geq 80\%$ .

CLASSIFICATION	VEGETATION	BUILT-UP LAND	WATER BODY	TOTAL	UA
VEGETATION	72	8	20	100	72%
BUILT-UP LAND	7	65	7	79	82%
WATER BODY	16	8	50	74	68%
TOTAL	95	81	77	253	
PA	76%	89%	65%		88%

*Kappa Accuracy* : 73,3%  
*Overall Accuracy/OA* : 88%  
*UA* : *User's Accuracy*  
*PA* : *Producer's Accuracy*

The overall accuracy obtained for the land cover classification results was 88%, with a Kappa Accuracy of 73.3%. These results indicate that the classification meets the established criteria, as the Overall Accuracy exceeds the  $\geq 80\%$  threshold. Based on the Kappa Accuracy value, the achieved accuracy level can be categorized as moderate.

The output of the land cover processing shows that the development of Bangkinang City is concentrated in the western area, as illustrated in all three maps where built-up land classes are predominantly located in the west, while vegetation and water body classes are mainly found in the southern part of Bangkinang City.

### 4.3 UHI Threshold Method

First, the calculation of the UHI threshold was carried out using the previously derived LST values, based on the established equation. In the UHI map generated using the threshold method, areas unaffected by UHI are represented by zero or negative values ( $\leq 0$ ), while affected areas show positive values ( $> 0$ ). The areas influenced by UHI were then classified into three categories according to the magnitude of the UHI value: UHI class 1 (0–2°C), UHI class 2 (2–4°C), and UHI class 3 ( $> 4$ °C). The higher the UHI value, the hotter the area and the greater the impact of the UHI phenomenon.

Table. 2 UHI Values in 2021, 2022, and 2023

Tahun	Ambang Batas (°C)	Nilai Uhi Maksimum (°C)
2021	29,899	2,144
2022	26,574	1,93
2023	28,597	1,467

In the table above, it can be observed that the UHI threshold values vary across the years. This variation occurs because the UHI threshold values correspond to the temperature changes recorded in the processed imagery; therefore, threshold values

derived from images taken at different times will show differences.

The following are the results of the UHI distribution maps in Bangkinang City for the years 2021, 2022, and 2023, generated using the Threshold Method:

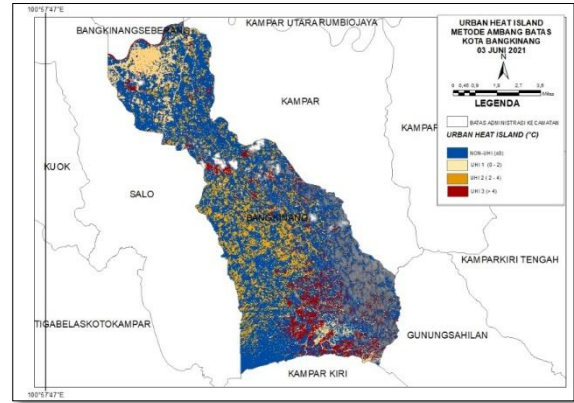


Fig. 7 Threshold Method – June 3, 2021

The figure above represents the Threshold Method applied to the imagery dated June 3, 2021. The results indicate a maximum UHI value of 2.144°C. The UHI threshold value derived from the 2021 LST data is 29.899°C, indicating that areas with temperatures higher than 29.899°C are affected by UHI. Based on the 2021 imagery processing results, no areas were classified as UHI Class 3 ( $> 4$ °C), since the maximum UHI value obtained was 2.144°C.

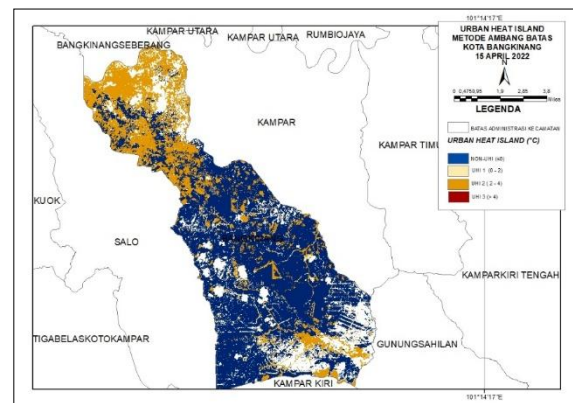
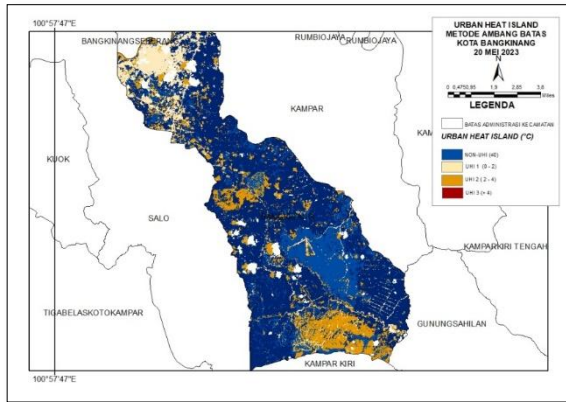


Fig. 8 Threshold Method – April 15, 2022

The figure above represents the Threshold Method applied to the imagery dated April 15, 2022. The results show a maximum UHI value of 1.930°C. The UHI threshold value derived from the 2022 LST data is 26.574°C, indicating that areas with temperatures higher than 26.574°C are affected by UHI. In the 2022 imagery processing results, no areas were classified as the highest UHI class, UHI Class 3 ( $> 4$ °C), since the maximum UHI value obtained was 1.930°C.

**Table. 1 Confusion Matrix for Land Cover Accuracy Assessment**

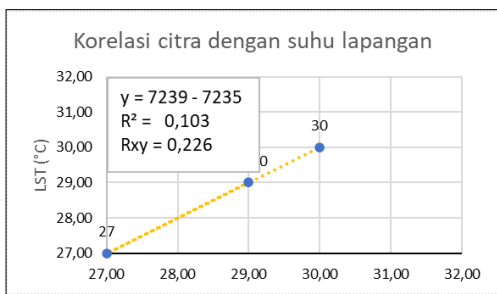


**Fig. 9 Threshold Method – May 20, 2023**

The figure above presents the results of the threshold method applied to the imagery dated May 20, 2023. Based on the analysis, the maximum UHI value obtained was 1.467°C. The UHI threshold value derived from the 2023 LST temperature was 28.597°C, indicating that areas with temperatures higher than 28.597°C are classified as affected by the UHI phenomenon. Furthermore, the 2023 imagery analysis revealed no areas within the highest UHI intensity class (UHI 3, >4°C), as the maximum UHI value recorded was only 1.467°C.

**4.2 Correlation Test between LST and BPS Data**

After obtaining the LST-processed temperature results, a correlation test was conducted using field temperature data obtained from BPS. This correlation test employed the Pearson Product-Moment method, as shown in Equation 2.19. The calculation for the Pearson Product-Moment correlation test is as follows:



**Fig. 10 Correlation between Satellite Imagery and Field Temperature**

The graph above shows a positive correlation with an  $R^2$  value of 0.103 and a correlation coefficient of 0.226. Thus, the relationship between the two variables is positive, indicating that the higher the field temperature, the higher the LST value. To assess the strength of this correlation, reference can be made to the correlation strength interval table, where a value of 0.226 indicates a very weak relationship between the temperature data obtained from BPS and the LST results. Although the

correlation is very weak, it does not significantly affect the UHI phenomenon, as the high temperature in Bangkinang City is influenced by other factors such as local climate, geographical location, or intensive human activities (e.g., heavy industry or dense traffic). These high temperatures can impact surrounding areas affected by UHI, as heat diffusion from hotter regions can spread to adjacent areas through conduction and convection, potentially worsening the UHI effect in already impacted zones.

**5. Conclusion**

From this study, the LST (Land Surface Temperature) calculation using the SCA (Single Channel Algorithm) method was successfully conducted. The highest surface temperature in Bangkinang City was recorded at 27.755°C on June 3, 2021, 24.644°C on April 15, 2022, and 27.130°C on May 20, 2023. The three processed satellite images show a similar temperature distribution pattern, where lower temperatures are found on the outskirts of the city, while temperatures tend to increase toward the city center.

The correlation test between the LST derived from satellite image processing and field temperature data obtained from BPS (Statistics Indonesia) resulted in a correlation coefficient ( $R_{xy}$ ) of 0.226, indicating a very weak correlation. This weak correlation suggests that the UHI phenomenon is not significantly influenced by this relationship, as high temperatures in Bangkinang City are likely caused by other factors such as local climate conditions, geographical location, or intensive human activities (e.g., heavy industry or dense traffic).

Based on the UHI map produced using the threshold method, the area affected by UHI shows a decreasing trend over the years 2021, 2022, and 2023. The decrease in the affected area was recorded at 0.760 km<sup>2</sup> and 7.995 km<sup>2</sup>, respectively.

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