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Study of Temporal Dynamics of Urban Heat Island Surface in Padang West Sumatra, Indonesia

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ABSTRACT

Padang as the capital of the province, is a strategic area and also the center of the economy. Annual population growth affects changes in land use from vegetated land to built-up areas. An increase in barren land will trigger an increase in temperature. SUHI is a temperature phenomenon that occurs on the surface resulting from the increase in temperature. SUHI can be observed through surface temperature data or Land Surface Temperature. This study aims to identify changes in land surface temperature that are affected by changes in land use in the form of building density conditions. In analyzing this using Landsat 7 ETM+ imagery in 2001, 2006, 2011, 2016, and 2020. The building density measurement method LST transformations to measure surface temperature and helps the Surface Urban Heat Island phenomenon. The results of the analysis showed that there was an increase in the building density of the city of Padang over a period of 20 years. This phenomenon affects the surface temperature, indicating that the surface temperature has increased by around 0.47°C. The highest temperature from 2001-2020 occurred in 2016, with the highest temperature of 36°C.

INTRODUCTION

The city, in its place, fulfills its function as a center of human activity, which, compared to its surroundings, develops significantly across various sub-regions in urban areas (Mathewson 2018). Rapid development in urban areas, especially in fast-growing cities, tends to ignore the environmental and social aspects of urban life (Girardet 2008, Lehmann 2010). Various impacts influence the quality of life, which can be observed from physical development as a potential resource. The interaction between villages and cities is very important. The increasing physical development of cities, along with population growth and urban activities, leads to a decrease in vegetated areas, higher pollutant emissions, and the need to comprehensively implement energy-saving and emission-reduction policies. Public activities in urban areas cause changes in the physical appearance of the city, resulting in temperature differences between the central region and its surroundings. Urban growth is most rapid in the developing world, where cities gain an average of five million residents every month in a year (Meenakshi 2012). Thus, “urban sickness” begins to appear, and “urban heat island effect” is one of it. The main cause of “urban heat island” is modification of the land surface by urban development which uses materials which effectively retain heat (Yang 2013).

Solar radiation received from the earth’s surface is absorbed and reflected directly. Hence, the temperature of the urban environment is higher than in rural areas (Effendy 2007). Urban Heat Islands are metropolitan areas that are hotter than surrounding rural areas. It is a feature of hot urban areas compared to surrounding non-urban areas. In general, UHI means an increase in air temperature, but it can also mean the relative heat of the surface and the material above it (Hermawan 2015).

As society develops and urbanization accelerates as a result of development, urban heat islands have grown and negatively impacted air quality conditions, the environment, and energy use, as well as future climate change. An increase in built-up land characterizes a high level of urbanization (Putra et al. 2018). The phenomenon of UHI in urban areas can be divided into types of UHI, namely Surface Urban Heat Island and Atmospheric Urban Heat Island, which have different characteristics in measurement methods, effects, and detection methods (Root 2013).

City Field, the capital of West Sumatra province, is the largest city on Sumatra Island. Its central location and robust economy make it easily accessible and a focal point for community activities and work, leading to population growth. The population of Padang City in the years 2001, 2006, 2011, 2016, and 2020 was 743220, 819740, 844316, 902413, and 909040 individuals respectively (BPS City Padang 2001, 2006, 2011, 2016, 2020).

The increase in population in urban areas is the result of the rate of rural-urban migration, which will create new problems in cities. Along with population growth, the need for housing and infrastructure in the city will also increase (Mariya & Novio 2019). The developments that have occurred have led to an increase in the area of construction land. This affects ecosystem function, biodiversity, and climate (Oktavianingrum et al. 2020). Transitioning from the background behind birth to the problem, two key aspects emerge: 1) Obtaining density area information: Land development in City Padang from 2001 to 2020, and 2) Understanding the consequences: Intensity of the Surface Urban Heat Island resulting from changes in density of developed land.

MATERIALS AND METHODS

Temperature surfaces can counted by subtracting temperature brightness and counting emissivity surface temperature surface data was obtained using Landsat thermal imagery and extracted using the Mono-window method. The processing algorithm for temperature data involves four stages, namely:

a. Changing digital numbers become radiation for channel thermal (band 6) Landsat 7 ETM.

$$L\lambda = \frac{(\text{Lmax} - \text{Lmin})}{(Qcalmax - Qcalmin)}\,(Qcal - Qcal\,\text{min}) + Lmin$$

Information :

Lλ = Spectral radian at the sensorin (W/m ^{2} .srad . µm)

L max = spectral radiance scaled against Qcal Max(W/ m2 – .srad . µm)

L min = spectral radiance, Which is scaled against Qcal Min(W/ m2 – .srad . µm)

QCAL Min = calibrated value minimum, related withLmin

QCAL Max = pixel value calibrated maximum, with respect to L Max = 255

Qcal = Satellite image pixel value (DN/Digits number)

b. Conversion radiance corrected atmospheric to brightness temperature.

The equation used for the calculation of temperature value :

$$Tb = \frac{K2}{In\,(\frac{K1}{L\,\lambda} + 1)}$$

Information :

TB = Brightness temperature satellite(K)

K1 = Calibration constant spectral radiance

K2 = calibration constant absolute temperature (K)

Lλ = Radian Spectral

c. Surface temperature conversion from Kelvin to Celsius.

C = T-273

Description :

C is degrees Celsius, and T is degrees Kelvin

RESULTS AND DISCUSSION

Analysis of Land Surface Temperature

Processing method temperature Lansat 7ETM+ only uses one band as surface temperature input (Nugraha et al. 2019).

The analysis of the Land Surface Temperature (LST) results shows that the minimum and maximum LST values are located in the city of Padang. The highest LST value, reaching +36°C, was recorded in the year 2016, while the lowest temperature, +8°C, occurred in 2011. This discrepancy impacted the imagery of the research area, with some regions being covered by clouds. Cloud cover poses a challenge in image management, ultimately influencing the accuracy of the classification results. As stated by Sinabutar et al. (2020), clouds obscure areas beneath them, making it difficult to obtain information from those regions and potentially leading to errors in interpretation.

The results of the study on image processing of Landsat 7ETM+ for the years 2001 to 2020 indicate fluctuations in temperature. In 2001, the lowest temperature was recorded at 10°C and the highest at 32°C. Similarly, in 2006, temperatures ranged from 14°C to 32°C. In 2011, temperatures ranged from 8°C to 33°C, while in 2016, temperatures varied from 14°C to 36°C. In 2020, temperatures ranged from 14°C to 32°C.

These findings align with the research conducted by Shrinidi in 2011, which highlighted the variability of temperatures within cities. Despite Bangalore having a moderate overall temperature, the temperature within the city varies significantly across different geographical locations and land cover types.

The regional analysis of surface temperature processing consistently reveals a pattern wherein lower temperatures are observed on the outskirts of the city while higher temperatures prevail towards the center. This pattern is attributed to the high density of building construction. Specifically, in the case of Padang City, the western part serves as the city center, while the eastern and southern regions are characterized by vegetation.

Distribution SUHI

In the study, the City of Padang is divided into two regions: the western part, classified as urban areas and serving as the city center, and the eastern part, designated as suburban areas. The surface temperature within the city center exhibits warmer conditions compared to the rural areas in the adjacent eastern region of the City of Padang. High surface temperatures are predominant in the central region of the city, whereas lower temperatures prevail in the suburbs. This observation corresponds to the concept of the Urban Heat Island (UHI), wherein urban areas experience higher temperatures than their rural counterparts. Additionally, the temperature gradient indicates that temperatures decrease as the distance from the city center increases (Fawzi 2017).

Analysis SUHI was done to assess the impact of changes in land cover and temperature surface caused by urbanization. SUHI, which is influenced by density building. Enough tall causes enhancementemissivity surface And impacts on enhancement mark LST. Intensity SUHI can be measured with a measure difference mark LST.

On the map distribution UHI (Urban Heat Island) method Threshold, areas that are not exposed to UHI are presented with marks from 0 to negative (≤ 0), whereas areas affected by UHI are classified into 3 classes based on The UHI values are UHI class 1 (UHI range 0-2°C), UHI class 2 (UHI range 2-4°C) and UHI class 3 (UHI above 4°C) . the more tall UHI value, the more big the influence of UHI (Jaelani 2020).

By spatial analysis distribution, SUHI City Padang can seen in Figs.1 to 5.

Based on the calculation of the results, 2001 refers to the threshold value limit SUHI (23.39°C), so the obtained mark SUHI highest is 8.78°C and lowest -12.9°C. Viewed from wide. The scope of the area where the phenomenon occurs SUHI in City Padang year 2001, reach 18940 Ha. Meanwhile, 50778 ha is Non-SUHI Because the LST is still on the verge of limit.

Based on the calculation of the results, 2006 refers to the threshold value limit SUHI (23.39°C), so the obtained mark SUHI highest is 8.89°C and lowest -8.91°C. In 2006, the coverage area exhibiting the Urban Heat Island (UHI)

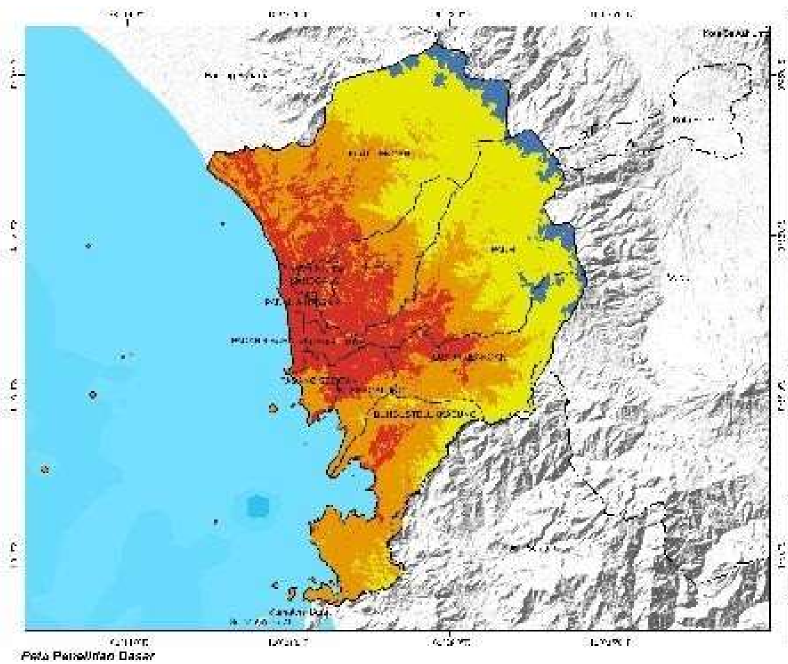

Fig. 1: Map Intensity SUHI Year 2001.

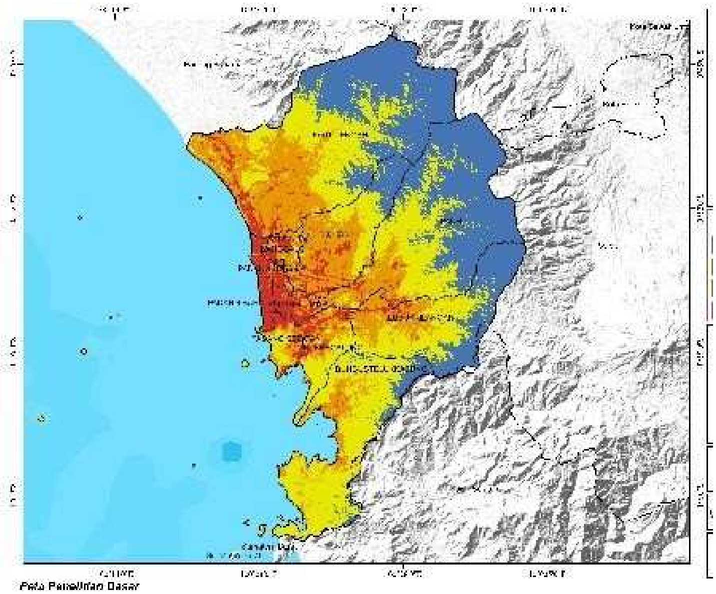

Fig. 2: Map intensity SUHI Year 2006.

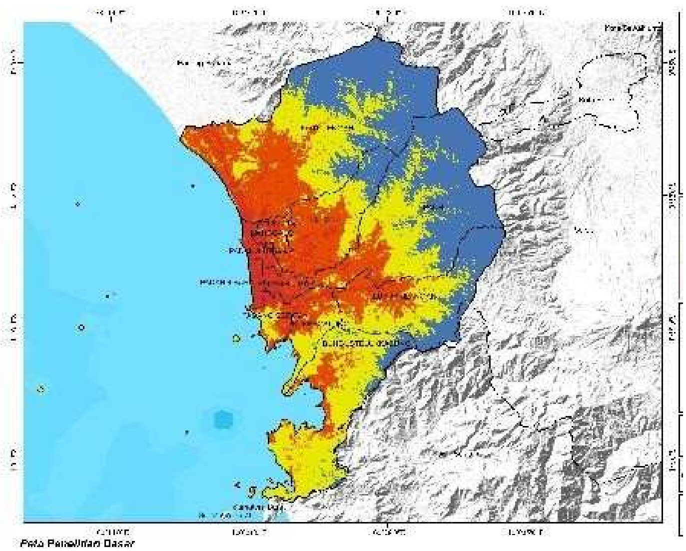

Fig. 3: Map intensity SUHI Year 2011.

phenomenon in the City of Padang reached 21124 Ha, while non-UHI areas covered an extensive area of 48594 ha.

Based on the calculation of the results, 2011 refers to the threshold value limit SUHI (23.51°C), so the obtained mark SUHI is highest at 9.55°C and lowest at -15.41°C. Regarding the coverage area where the SUHI phenomenon occurred in Padang city in 2011, it reached 20019 ha, while 49,687 ha were classified as Non-SUHI areas.

Based on the calculation of the results, 2016 refers to the threshold value limit SUHI (25.95°C), so obtained at 10.89°C And Lowest -11.02°C. Phenomenon SUHI in the city Field year 2016, reached 17960 ha whereas 51759 Ha is Non-SUHI.

Based on the calculated results, in 2020, the threshold value for the SUHI phenomenon (24.46°C) was determined. Consequently, the recorded highest SUHI value was 8.19°C, while the lowest was -10.08°C. Considering the extent of the SUHI phenomenon in the city of Padang in 2020, it covered an area of 18770 ha, whereas 5,098 ha were classified as non-SUHI areas since the Land Surface Temperature (LST) value remained within the threshold limit.

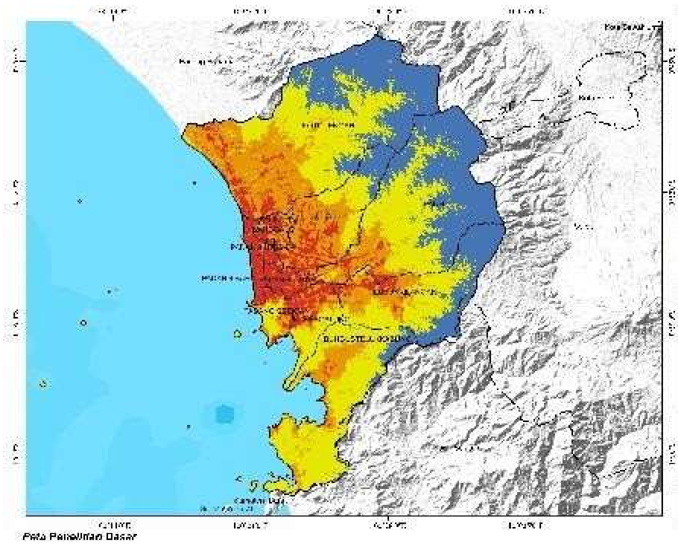

Fig. 4: Map Intensity SUHI Year 2016.

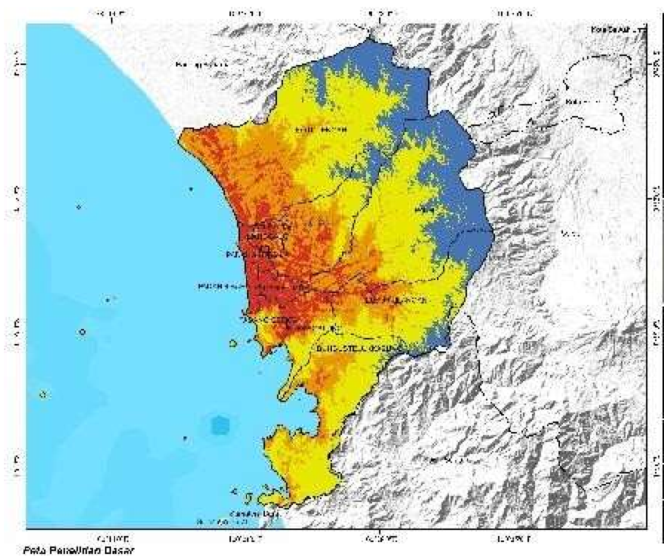

Fig. 5: Map intensity SUHI Year 2020.

The spatial distribution of the urban heat island effect, particularly evident in the center of Padang city with its high and very high temperatures, significantly impacts vegetation density. This distribution is highlighted by the majority of Padang city being characterized by low vegetation density. These observations align with the findings of Wulandari & Sudibyakto (2017), who attributed the UHI phenomenon in urban areas to extensive built-up land and a lack of urban vegetation or forests. Climate change, as emphasized by Prasad and Chakravorty (2015), is an ongoing process with far-reaching implications. Understanding the overall effects of climate change is crucial for accurate diagnosis and subsequent mitigation efforts. It's imperative to recognize the sensitivity of the climate, which can be adversely affected either by natural phenomena or human interventions. According to Prasad & Chakravorty (2015) and previous studies, climate change is most sensitive to anthropogenic influences, which can directly or indirectly lead to environmental disruptions such as floods, droughts, salinity issues, high temperatures, and more. Additionally, these influences can result in shifts in cropping seasons, alterations in growth and yield patterns, changes in pest and disease dynamics, and modifications in the behavior of pollinating insects.

CONCLUSION

Based on processing data, the study obtained results indicating a change in the density of the buildingacross wider areas. Building density experienced an increase from the year 2001-2020. In 2001, the density of high-rise buildings had an area of 1219 ha. In the year 2020, the density of the building experienced an increase of 2,718 ha to 14152 ha.

The phenomenon of Surface Urban Heat Island (SUHI) in Padang City from 2001 to 2020 exhibits a spatial pattern that remains relatively consistent with urban development. High SUHI areas tend to be concentrated in the central part of the city.

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