ANALYSIS OF CHANGES IN URBAN HEAT ISLANDS IN GORONTALO CITY USING THE LANDSAT TM8 IMAGERY

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Abstract

An urban heat island is a condition where an area has a warmer temperature than the surrounding area in an urban area. Several articles indicate that the occurrence of urban heat islands is due to a decrease in the amount of vegetation and an increase in the number of built-up areas. This study aims to analyze changes in urban heat islands **in Gorontalo City for five years** based on urban spatial patterns. The research was conducted in the city of Gorontalo using Landsat TM8 imagery to measure the surface temperature at the study location. The method used is spatial analysis through Geographical Information Systems. The results showed that the highest surface temperature was in residential areas and the lowest was in the Green Open Space area.

Keywords

Urban; temperature; Landsat imagery

I. INTRODUCTION

Changes in urban heat islands will have an impact on climate change that will trigger disasters and urban problems, including floods, drought, increased temperatures, and even causes various diseases. Increasing temperature in urban areas causes problems, including reducing the comfort of city residents, causing health problems, increasing energy consumption such as the use of air conditioning, and disturbing the balance of the ecosystem.

An urban heat island is a condition where an area has a warmer temperature than the surrounding area in an urban area. Several studies on urban heat islands show that there is a change in Land Surface Temperature (LST) over a while. The results of research [1] showed that there was an increase in temperature in the area of Nanchang City, China by 1.6 °C between 2000 and 2013. Meanwhile, [2] found that the surface air temperature in Sofia City was 1.6 - 2.4°C higher than in the suburbs in the morning, the temperature difference decreased to 0.5°C in the afternoon.

One of the causes of heat islands in cities is the number of buildings, dense urban structures, and a lack of vegetation [3]. Besides, according to [4]) the factors causing urban heat islands are different in each layer, namely in the ground (below the surface); surface (measured using remote sensing); in air volume between buildings (urban canopy layer); and on top of buildings (within the urban boundary layer).

The area of urban heat islands (UHI) varies greatly depending on the physical, geographic, and climatological characteristics of a city (Anderson et al., 2018). Meanwhile, soil surface temperature is strongly influenced by socio-ecological variables such as vegetation index, built-up area index, water index, population density, and fossil fuel CO2 emissions [1].

According to BMKG data (2020), daily temperatures in the Gorontalo and surrounding areas range between 24°C at night and 31° – 33°C during the day. Furthermore, the results of the study show that the highest surface temperature of Gorontalo City is in the downtown area which ranges from 31-32°C, and the temperature in the Pulubala residential area, Kota Tengah District is between 31-33°C [5].

Research on urban heat islands that has been carried out previously carried out an analysis of temperature changes shown in the form of degrees of temperature differences. This research is designed to see the changes in the distribution of the urban heatisland area in Gorontalo City in a period of 5 years.

II. METHODS

A. *Study Area*

The research was conducted in the city of Gorontalo, which is the capital of Gorontalo Province (Figure 1). The reason for choosing the location was because this area was the region with the fastest development growth in Gorontalo Province. This region has an archipelago tropical climate with a fairly high surface temperature.

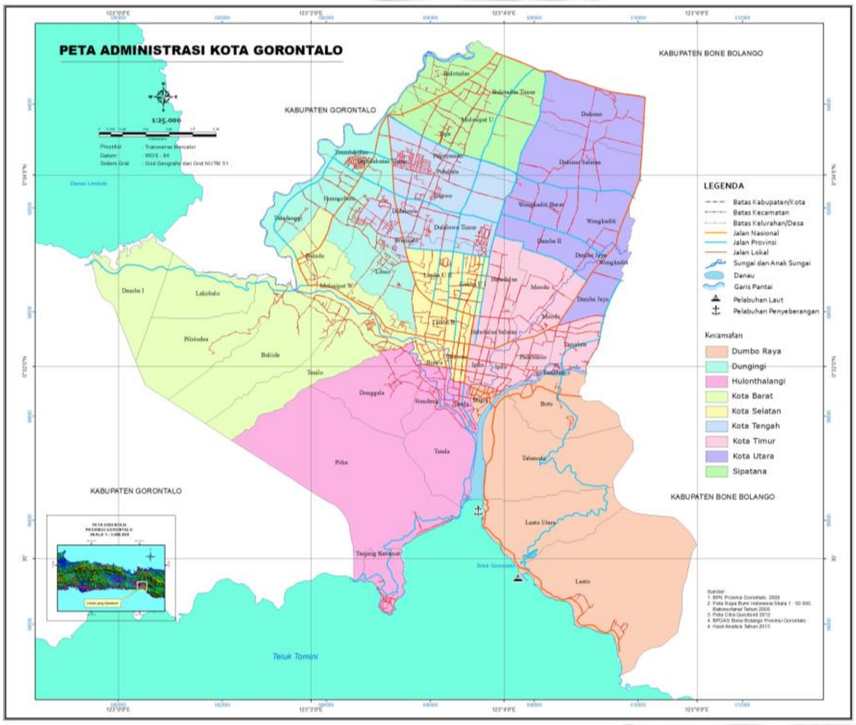

Fig. 1.Gorontalo City area (Study Area)

B. *Data Descriptions and Pre-Processing*

In this study, we used Landsat images acquired on 29 August 2020 (Landsat 8 OLI/TIRS). For the Landsat-8 OLI/TIRS data, the multispectral bands (bands 1–7 and 9) also have a 30 m spatial resolution. Its panchromatic band (band 8) has a 15 m spatial resolution, while its thermal bands (band 10 and 11) have 100 m spatial resolution, which has also been resampled to 30 m by the USGS (https://landsat.usgs.gov). During the selection of image data, cloud-free images (<10%) were considered.

In this study, we used preprocessed datasets downloaded from http://earthexplorer.usgs.gov. All the images used had undergone standard terrain and atmospheric correction (Level 1T) processing (https://landsat.usgs.gov). They have been geo-referenced to the WGS84/UTM 51 N projection system. The digital number (DN) values of the multispectral bands have been converted into surface reflectance values, while those of the thermal bands have been converted into at-satellite brightness temperature expressed in degrees Kelvin and further converted to degrees Celcius.

C. Land Surface Temperatur (LST) Analysis

Land Surface Temperature Measurement is carried out through interpretation of Landsat TM8 images. Radiometric correction on Bands 10 and 11 Landsat 8 TM OLI / TIRS is carried out by changing the DN value to radiance by looking at information on the date, month, year of image recording, and sun elevation. After that, the spectral radiance to surface temperature (°K) calibration process was carried out using equation (1) to obtain the Kelvin temperature degree value (Landsat 8 Handbook).

$$T = K2/(\ln(K1/L_\lambda+1)) \quad \text{..........} \quad (1)$$

Where :
T = Kelvin Temperature (°K)
K2 = calibration constant 2
K1 = calibration constant 1
L_λ = spektral radiance in watts/(meter squared * ster * µm)

Based on the method used by [5], the preprocessed thermal bands according to containing at-satellite brightness temperatures expressed in degrees, Kelvin. To retrieve the LST values, we first derived the land surface emissivity (ε) values Equation (2)

$$\varepsilon = m\,PV + n \quad \text{..........} \quad (2)$$

where m = (ε − ε) − (1 − εσ) Fεv and n = εs + (1 − εs) Fεv, where εs and εv are the soil emissivity and
vegetation emissivity, respectively. In this study, we used the result of ε for m = 0.004 and n = 0.986.

PV is the proportion of vegetation extracted from the NDVI Equation (3).

$$PV = ((NDVI - NDVImin)/(NDVImax - NDVImin))^2 \quad \text{..........} \quad (3)$$

where NDVI is the normalized difference vegetation index derived in Equation (5) (see Section 2.4).

The NDVImin and NDVImax are the minimum and maximum values of the NDVI, respectively.
The emissivity-corrected LST values were then retrieved using Equation (4).

$$LST\ (^\circ C) = TB/1 + (\lambda \times TB/\rho)\ln\varepsilon \quad \text{..........} \quad (4)$$

where TB = Landsat TM Band 6 at-satellite brightness temperature; λ = wavelength of emitted radiance (λ = 11.5 µm for Landsat TM Band 6, λ = 10.8 µm for Landsat TIRS Band 10) [3]; ρ = h × c/σ (1.438 × 10 – 2 mK), σ = Boltzmann constant (1.38 × 10 − 23 J/K), h = Planck's constant (6.626 × 10 − 34 Js),
c = velocity of light (2.998 × 108 m/s), ε is the land surface emissivity. We later converted the retrieved
LST values from degrees Kelvin to degrees Celsius (◦C).

The NDVI values range from −1 to 1, with positive values representing vegetated areas and negative values representing non-vegetated areas.

$$NDVI = (NIR - RED)/(NIR + RED) \quad \text{..........} \quad (4)$$

where NIR = band 4 (for Landsat TM—wavelength 0.76–0.90 µm); band 5 (for Landsat OLI—wavelength 0.85–0.88 µm); RED = band 3 (for Landsat TM—wavelength 0.63–0.69 µm); and band 4 (for Landsat OLI—wavelength 0.64–0.67 µm).

Result And Discussion

The results of research through an interpretation of Landsat TM 8 images to measure the distribution of surface temperature are grouped into 5 classes, including very low (less than 23°C); low (23-25°C); Medium (25 - 27°C); High (27 - 29°C) and Very High (> 30°C) (Figure 2). Measurement of the surface temperature using 2 images with different recording times, namely September 2015 and September 2020.

The results of the analysis show that in 2020 the areas with the highest land surface temperature (LST) are in the Kota Selatan district, Kota Tengah, Kota Timur, Dungingi, and parts of Sipatana and Hulonthalangi areas. Meanwhile, temperature drops occurred in Kota Barat Districts. In contrast to 2015, the highest surface temperature was found only in Dungingi and parts of Sipatana, while Kota Tengah, Kota Utara, Kota Barat, Hulonthalangi, and Dumbo Raya were dominated by low to very low-temperature classes.

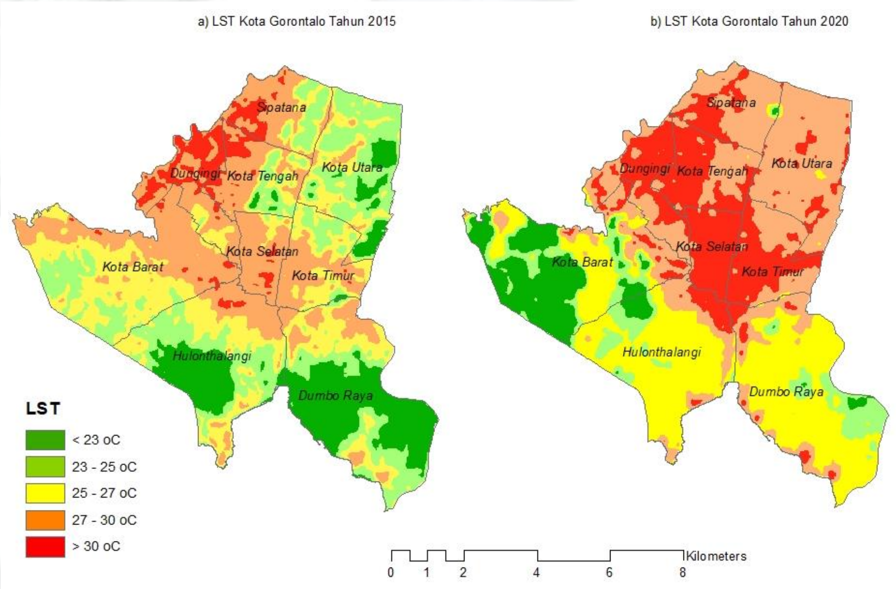

Fig. 2. Land Surface Temperature (LST) maps of Gorontalo City area in (a) 2015 and (b) 2020

The distribution of surface temperatures over the 5 years from 2015 to 2020 shows an increase in areas with a very high-temperature class of 16.37 percent and a high-temperature class of 2.49 percent. Meanwhile, the decrease in areas with the low-temperature class was 14.77 percent and the very low-temperature class was 6.79 percent.

Based on the results of this analysis, it can be seen that there has been an increase in surface temperature in the City of Gorontalo within 5 years, especially in the sub-districts located in the city center. This has led to the increasing of the urban hot island area in Gorontalo City.

TABLE I. AREA-BASED ON SURFACE TEMPERATURE CLASSIFICATION IN GORONTALO CITY

LST Class	The 2015 Year		The 2020 Year	
	Area (hectare)	Percentage	Area (hectare)	Percentage
Less 23° (very low)	1.115,64	15,79	635,85	9,00
23° - 25° (low)	1.610,55	22,79	566,55	8,02
25° - 27° (medium)	1.864,53	26,39	2.055,60	29,09

27° - 30° (high)	2.109,33	29,85	2.285,46	32,34
More 30° (very high)	365,94	5,18	1.522,53	21,55
	7.065,99	**100,00**	**7.065,99**	**100,00**

III. CONCLUSION

Changes in urban heat islands in Gorontalo City have increased in a period of 5 years from 2015 to 2020 through measurements using Landsat TM8 radiometric thermal band correction images. The urban heat island is located in a sub-district that is in the city center, while the area with a low surface temperature is in a hilly area where land use is dominated by trees and shrubs which are water catchment areas

Acknowledgment *(HEADING 5)*

This article is part of the research for a doctoral dissertation at the Hasanuddin University Architecture Study Program.

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