Measuring And Mitigating Urban Heat Island In Yogyakarta City Using Remote Sensing

Vina Nurul Husna, Nurul Ihsan Fawzi, Irza Arnita Nur

Abstract: Increased temperature in urban areas is one of the impacts of urbanization. Urban Heat Island (UHI) is one impact resulting from that increased temperature. Through UHI measurements, the influence of urban development on the increase of temperature can be measured. The aim of this paper to calculate of UHI intensity and distribution using remote sensing and its mitigate UHI. Study area in the city of Yogyakarta, Special Region of Yogyakarta. Remote sensing data was used is Landsat 8 acquired at June 24, 2013, path/row 120/65. The land surface temperature extraction method using inversion of Planck Law with emissivity and atmospheric correction using radiative transfer equation. The result we obtained intensity of UHI that occurred in the city of Yogyakarta is ±2.5oC. We found that Malioboro and its surrounding areas are potentially become UHI, therefore mitigation efforts are required. To reduce UHI impact to people and tourist, we must increase distribution of vegetation or using green roof.

Index Terms: urban heat island, remote sensing, Yogyakarta City.

1 INTRODUCTION

In 1950, only 30% of the human population in the world in the world was in the city, rising to 54.5% by 2016 [1]. Increasing city's population can give negative impacts to environment, especially CO2 production, modification of physical and chemical properties of the atmosphere, and influence on local weather and climate change [2]–[4]. One of the effects is the increase in temperature in urban areas known as urban heat island. Urban heat island (UHI) is part of heat island which occurring in urban areas, caused by higher temperature than the surrounding [5]. The basic concept of UHI is the interaction thermal energy from the sun to object in Earth's surface giving different thermal energy between rural and city [6]. The built areas in city has a high thermal conductivity thereby saving more thermal energy than rural areas. We can measure UHI with two method, using weather station data or in situ survey and using remote sensing technique. On a regional scale, in situ measurements have disadvantages in terms of time, cost, and there are accuracy problems in spatial data interpolation. The efficient one is using remote sensing technique in regional analysis with availability of data, consistency, recurrence of recording, and ability to measure condition of the earth with good degree [7]. The use of remote sensing methods becomes an unavoidable requirement in the future, especially related to the efficiency and effectiveness of urban analysis [8], [9]. The current research about UHI has explained about intensity of UHI, but often without spatial distribution of UHI itself, and vice versa [10]–[15]. In this paper we try to try to explore to extract UHI intensity and distribution using remote sensing technique.

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2 STUDY AREA DESCRIPTION

2.1 General Condition

We measure UHI using remote sending in Yogyakarta city (7 ° 48'5 "LU, 110 ° 21'52" BT), Fig 1 shows the location of study area. This city chosen because it is a medium-sized city and densely population. Based on census data 2010, the population of Yogyakarta City is 388.088 people. The role of the city become city of students and city of tourism accelerates the city development. In 2011 – 2015, the average population density is 12,699 inhabitants / km2 [16].

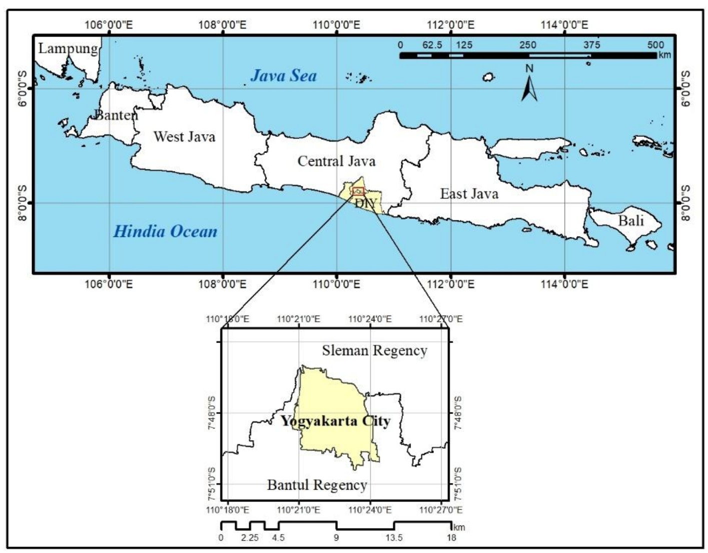

Fig. 1 *Study area in Yogyakarta City.*

2.2 Data Collection

We have collected the data in the field such as average temperature in built-up area and average temperature in bare land. Field survey have been conducted on June 2013, according with Landsat image data acquisition.

3 RESEARCH PROCEDURE

3.1 Remote Sensing Data and Processing

We used Landsat 8 path/row 120/65 with acquired date on June 24, 2013. The images was converted into TOA spectral radiance using the radiance rescaling factors provided in the metadata file [17]. The converted images then corrected emissivity and converted into at sensor radiances using this equation [18].

L_(sensor,λ)= (L_λ- L_atm^↑)/(ε τ)- (1- ε)/ε L_atm^↓

Where:

L_(sensor,λ) = TOA spectral radiance (W/m2.sr.µm)
ε_(λ) = emissivity
L_atm^↓ = down-welling atmospheric radiation (W/m2.sr.µm)
L_atm^↑ = up-welling atmospheric radiation (W/m2.sr.µm)
τ_(λ) = Atmospheric transmittance

L_(sensor,λ) then converted into brightness temperature (T_rad) using the thermal constants provided in the metadata file (T_rad) using this equation [17]:

T_rad "= " "K" _"2" /"ln" □("K1" /"L" _"sensor,λ" "+ 1")

Where:

Trad = At-satellite brightness temperature (K)
Lλ-e = TOA spectral radiance (W/m2.sr.µm)
K1 = Band-specific thermal conversion constant from the metadata
K2 = Band-specific thermal conversion constant from the metadata

3.2 Urban Heat Island Calculation

To obtain UHI intensity and distribution, we used threshold method [19]. The equation for non-UHI area is:

$$T > \mu + 0{,}5\ \alpha$$

and for UHI area is:

$$0 < T \leq \mu + 0{,}5\ \alpha$$

Where µ and α is the average pixel value from images and its deviation, respectively. In addition, thermal analysis considering influenced by pixel value next to it. If the pixel have a higher value than surrounding, it will affect the value of pixel next to it, and vice versa. To solve this consideration, we used neighbourhood pixel analysis with filtering applied. So, for the equation we used in this research is:

$$UHI = T_{mean} - (\mu + 0{,}5\ \alpha)$$

Where Tmean is average temperature on pixel from filtering process. Calculation of UHI intensity using this threshold method approach, based on medication from [20], [21]. Therefore UHI intensify can be calculate using this equation.

$$\Delta T_{max\text{-}\mu} = T_{max} - T_{\mu}$$

Where Tmax is maximum temperature from images, and Tµ is threshold value temperature for UHI..

4 Results and Discussion

We found the value µ = 33,82 oC and α = 1,19^{o}C, the temperature threshold is 34,41^{o}C. UHI intensity ∆Tmax-µ is 2,5^{o}C. Fig 2 shows the urban heat island with different range of temperature. The core of UHI distribution in Malioboro Street and its surrounding. This street located in centre of Yogyakarta City with surrounded with many hotels, restaurants, shop, sidewalks and square, with no vegetating in this area [22]. Therefore need mitigating of UHI using urban vegetation which had considerable effect on the temperature in the city [21], [23]. It can be said that the availability of vegetation becomes the determinant factor in increasing or decreasing the surface temperature in urban areas that affect the intensity of UHI [24]. In relation to UHI, vegetation coverage will make the urban temperatures lower and able to counteract the effects of UHI [9]. The presence of vegetation can reduce the average air temperature by 2^{o}C [23] to 4 °C [25]. In major cities in Asia, such as Singapore, Kuala Lumpur and Hongkong, UHI's impact reduction efforts have been widely implemented, such as the use of green roofs that proved to be effective in overcoming UHI problems [26], [27].

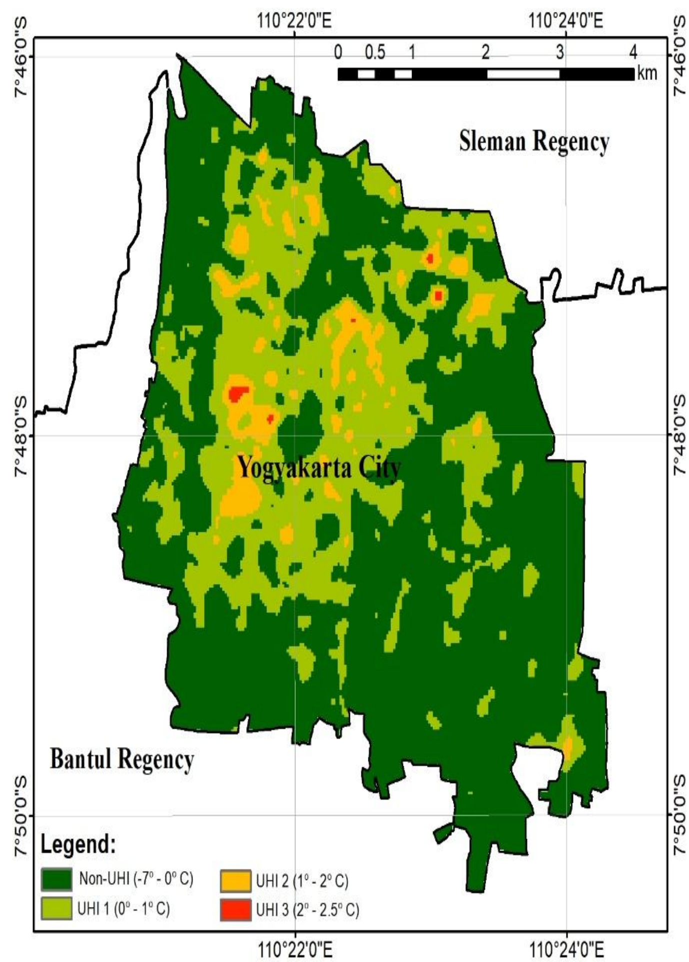

Fig. 2 *UHI distribution map in Yogyakarta City. Green colour is no-UHI areas, and yellow to red colour is UHI area.*

5 Conclusion

Remote sensing is effective for analysis UHI because give us the intensity and distribution of UHI. The result we obtained intensity of UHI that occurred in the city of Yogyakarta is ±2.5°C. We found that Malioboro and its surrounding areas are potentially become UHI, therefore mitigation efforts are required. To reduce UHI impact to people and tourist, we must increase distribution of vegetation or using green roof.

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