ANALYSIS OF URBAN HEAT ISLAND PHENOMENON IN PEKANBARU CITY 2013-2018 PERIOD

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ABSTRACT

Pekanbaru City is the capital of Riau Province with a variety of very rapid development activities along with the increasing number of city residents, resulting in reduced vegetative land. This is the cause of the increase in surface temperature in Pekanbaru City, especially in the city center, which can accelerate the Urban Heat Island (UHI) phenomenon. The purpose of this study was to determine the distribution of surface temperature and identify the UHI phenomenon in Pekanbaru City. The research method is to identify the distribution of surface temperatures in the research period 2013-2018. Extraction of surface temperature comes from Landsat 8 imagery. The UHI phenomenon is seen from the temperature difference between the downtown area represented by Sukajadi Village and suburban areas, namely Kulim Village, Tebing Tinggi Okura, Muara Fajar, and Tuah Karya. The results showed that Pekanbaru City experienced the UHI phenomenon during the study period, because the temperature was already more than 30℃ and there was a temperature difference between the city center and the outskirts of the city that exceeded 3℃.

Keywords: Land Surface Temperature, Urban Heat Island, Pekanbaru City

1. Introduction

A phenomenon that occurs due to significant changes in urban land cover is often called Urban Heat Island (UHI) [1]. UHI can be estimated by increasing atmospheric and land surface temperatures in urban areas compared to surrounding areas [2]. Generally, UHI is caused by urbanization patterns that occur in large cities, the need for city infrastructure causes cities to strive to continue to develop. This high level of development activity causes high heat absorption from building coatings, causing the city climate to become very hot, which will change ground surface conditions and energy exchange between the city and the atmosphere [3].

The status of Pekanbaru City, as the capital of Riau province, has a fairly high population in Indonesia with a population of 1.091.088 people in 2019. The population tends to increase every year with a percentage increase of 2.86% [4]. This shows that Pekanbaru City is a city with rapid development. Crowded city conditions can affect the quality of the surrounding air. Dense urban areas generally have higher temperatures because many of the residents' activities produce heat. In addition, there are greenhouse gases (GHG) in the atmosphere that trap heat beneath it so that temperatures become hotter in the city [5]. Temperature data for the Pekanbaru City area measured by the Sultan Syarif Qasim II Meteorological Station shows an increase in air temperature from 2013-2017. In 2013 the average maximum temperature reached 33.15°C, while in 2017 the average maximum temperature increased to 34.9°C. In connection with the UHI phenomenon, an area is said to have indications of a UHI phenomenon if the temperature of an area is above 30°C [6]. UHI is an event where the difference in air temperature in urban areas compared to rural areas reaches 3-10ºC [7], whereas according to the US EPA, temperatures in cities are 1-3°C hotter than their surroundings during the day and can reach 12°C during the night [8]. The rapid development of development in the Pekanbaru City area has an impact on vegetation land continuing to decrease, causing carbon absorption to become lower resulting in an increase in land surface temperatures [9]. This increase in temperature can be neutralized by vegetation cover because plants evaporate and transpire thereby releasing water into the air, which can reduce the surrounding air temperature [8].

Direct temperature measurements in the city and around the city can show the temperature differences that occur. The rapid development of technology means that UHI can be determined using remote sensing by obtaining surface temperature data at the research site [10]. The advantages of remote sensing include the availability of data with good resolution and can be carried out continuously [11]. Apart from that, remote sensing allows data on objects on a wider surface of the earth, without having to be in direct contact with the target object (direct observation) [12].

The study of UHI has developed in several countries because it has caused various impacts, especially the increase in energy requirements for buildings in urban areas to reduce the effects of UHI [13]. In Tangerang City, Indonesia, research by Setyaningrum et al shows that there is a strong relationship between dense areas with tall buildings and the UHI phenomenon [14]. Pekanbaru City itself shows a very fast population growth rate which is followed by the addition of built-up land such as residential and industrial areas which can trigger the UHI phenomenon in the Pekanbaru City area, so an identification study is needed. Based on the research above, it is known that Landsat imagery can be used to identify UHI phenomena based on surface temperature, then temperature data from the SSKIIMS weather station is used as comparative data with the image surface temperature. The aim of this research is to analyze the UHI phenomenon in Pekanbaru City based on the distribution of surface temperature values.

2. Research Methods

Research sites. The Pekanbaru City research location is located between 101º 14' - 101º 34' East Longitude and 0º 25' - 0º 45' North Latitude. Pekanbaru City consists of 12 sub-districts and 58 sub-districts/villages and has an area of 638.38 km^2 [4]. The research data used comes from image data from Landsat 8 path 127 and row 60, on year 2013 – 2018.

Data processing. This research used Landsat 8 band 10 and 11 (TIR) image data on the page https://earthexplorer.usgs.gov/, climate temperature data and administrative map data for Pekanbaru City, then processed with ArcGis 10.3 geographical information system software. From these two image bands, surface temperatures in the Pekanbaru City area will be obtained. In the image data formulation process, the data processing is carried out on the raster calculator tool for the extracted image bands.

Brightness Temperature (BT) Calculation. The BT value calculation uses the constant values available in the metadata, consisting of constant 1 and constant 2. This is done on each band (10 and 11) in turn. The value 273.15 is a conversion value from degrees Kelvin to degrees Celsius. The following is the equation for BT calculations [15]:

$$BT = \frac{K2}{\ln\left(\frac{K1}{L\lambda}\right)+1} - 273.15 \quad \text{..... (1)}$$

description:
BT = Brightness Temperature (^{0}C)
K1 = Band-specific thermal convertion constant from the metadata (K1_constant_band_x, where x is the band number, 10 or 11)
K2 = Band-specific thermal convertion constant from the metadata (K2_constant_band_x, where x is the band number, 10 or 11)
Lλ = Spectral radiance (W/(m^2*sr*μm))
273.15= Kelvin conversion to Celcius

The BT values obtained from bands 10 and 11 are averaged in the spatial analysis tool in the statistics cell.

Ls (Land Surface Temperature) Calculation. The steps to obtain the Ls value are by calculating the Ls bands 10 and 11 which have been averaged using the formula [15]:

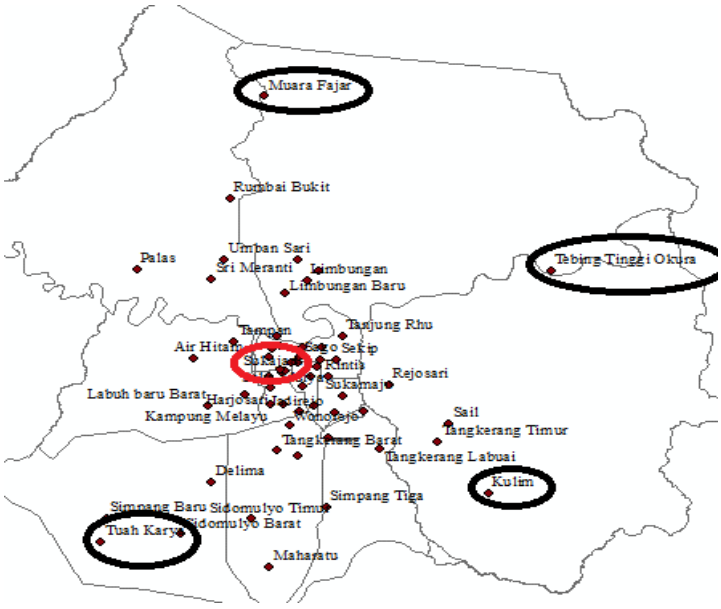
$$Ls = \frac{BT}{\{1+[\left(\frac{\lambda BT}{\rho}\right)ln\varepsilon]\}} \quad \text{..... (2)}$$

description:
Ls = *Land Surface Temperature* (^{0}C)
ρ = Constanta, 1.438

UHI phenomenon in Pekanbaru City. The results of Landsat 8 image data processing using geographic information system software in the form of surface temperature distribution map data in Pekanbaru City. The process of analyzing the UHI phenomenon is carried out by determining the city center location point as the city center temperature, then determining the outer location point of the Pekanbaru City area which is used as the temperature of the city edge. The location used as the city center temperature is Sukajadi Subdistrict, while the locations used as suburban temperatures are four locations in each corner of the Pekanbaru City area, namely Muara Fajar Subdistrict, Tebing Tinggi Okura Subdistrict, Rumbai Pesisir Subdistrict, and Kulim Subdistrict (figure 1, Table 1).

Table 1. Location of the city center and outermost points

Subdistrict	Location	Coordinate	Elevation (m)
Sukajadi	City center	N 0º 31’ 40.40”	11
		E 101º 26’ 16.98”	
Muara Fajar	Outer point	N 0º 38’ 44.76”	66
		E 101º 25’ 57.12”	
Tebing Tinggi Okura	Outer point	N 0º 34’ 16.39”	8
		E 101º 32’ 19.95”	
Kulim	Outer point	N 0º 29’ 14.27”	34
		E 101º 22’ 19.75”	
Tuah Karya	Outer point	N 0º 27’ 16.03”	26
		E 101º 32’ 19.39”	



Information:
Red Circle: City center location represented by Sukajadi sub-district
Black Circle: Suburban location

Figure 1. Location of UHI Intensity Determination Point

The temperature data obtained for the city center and suburbs was subtracted, where the temperature of the city center was subtracted from the temperature of the suburbs, so that the UHI intensity value was obtained as an analysis to determine whether an area was affected by the UHI phenomenon or not affected by the UHI phenomenon.

A comparison between the temperature produced by the image and the temperature from SSKII MS was carried out to see what the difference was between the temperature produced by the geographic information system software modeling with Landsat 8 image data compared to the temperature produced from SSKII MS, which is in Maharatu Village, Pekanbaru City.

3. Results and Discussion

Land Surface Temperature Distribution Analysis
In the process of processing surface temperature data using Landsat images, the 8 bands used are bands 10 and 11 (thermal). The surface temperature distribution map data modeling in Pekanbaru City was carried out by determining the temperature range using an assumptive method which was created by adapting the results of this research. Table 2 is the temperature class category based on the temperature range obtained.

When modeling surface temperature distribution maps using Landsat 8 images, the image data usually experiences atmospheric disturbances [16]. Almost all Landsat 8 image data experiences this interference, but in the research process efforts are made to find quality image data with the least amount of atmospheric interference, so that in the study process accurate data is obtained.

In the process of modeling surface temperature distribution, atmospheric disturbance in the form of cloud cover has a very low value, depending on how concentrated the atmospheric disturbance is in the image data. Based on modeling results using geographic information system software from Landsat 8 images, the surface temperature distribution in Pekanbaru City was obtained from 2013-2018, with the surface temperature distribution obtained being fluctuating. The data collection is carried out on different days each year, and 1 day for each year. Figure 2(a) to image 2(f) are maps of the surface temperatures based on Landsat 8 image data processing from 2013 to 2018.

Table 2. Temperature Categories Based on Temperature Range

No	Temperature Range	Temperature Categories	Coloring
1	≤ 20°C	Atmospheric disturbances	Grey
2	20-30°C	Low	Light Blue
3	30-33°C	Medium	Yellow
4	33-35°C	High	Pink
5	35-38°C	Very High	Blue
6	≥38°C	Extreme	Red

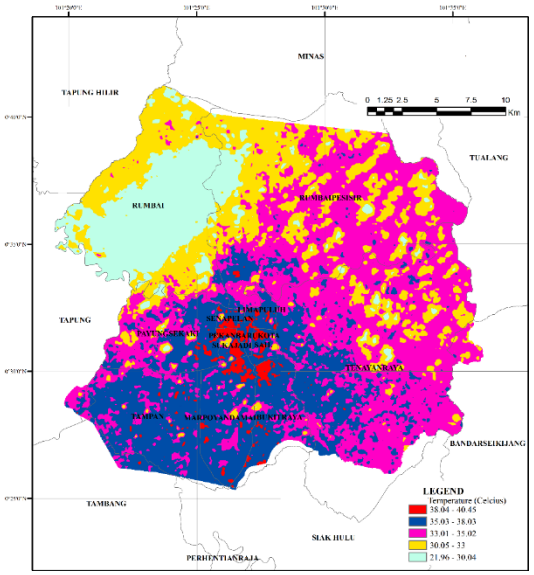


Fig 2. (a)

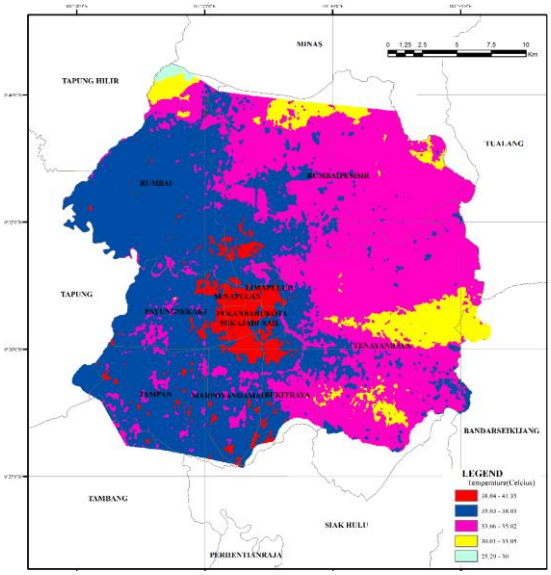


Fig 2. (b)

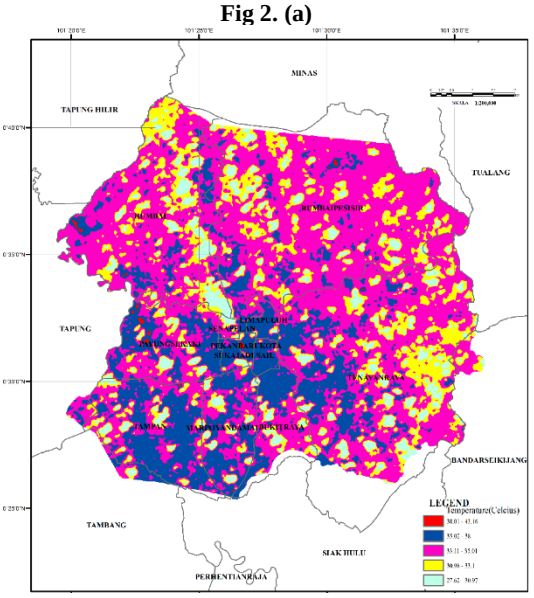


Fig 2. (c)

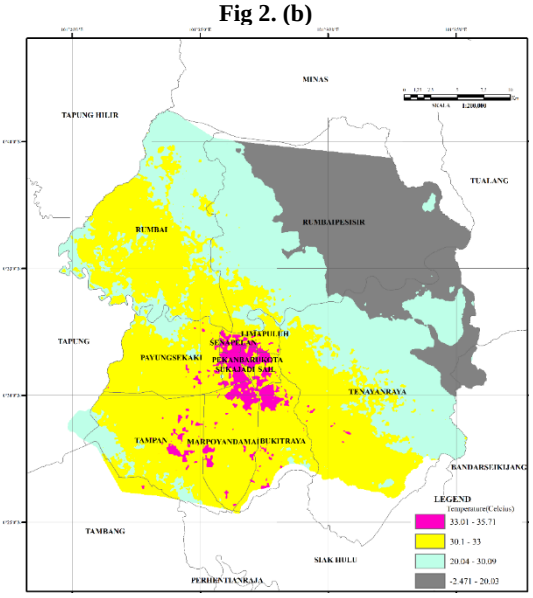


Fig. 2 (d)

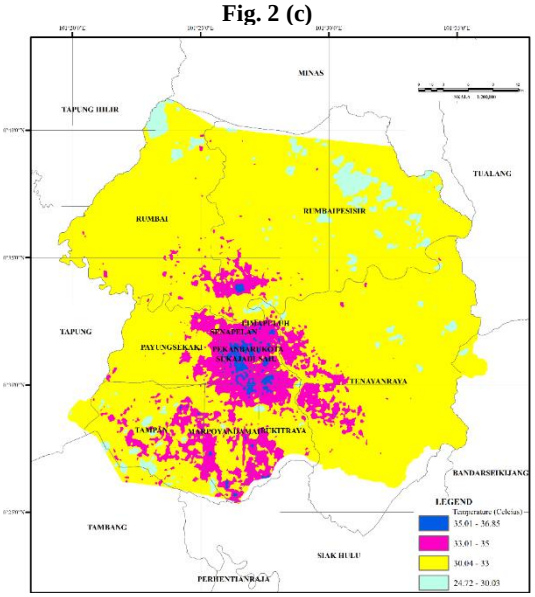


Fig 2 (e)

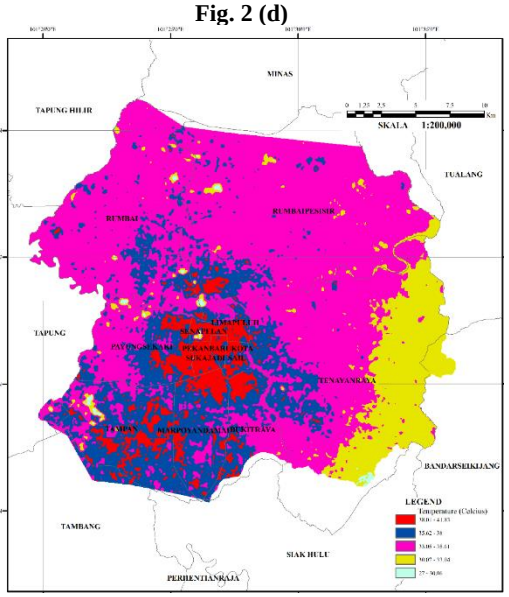


Fig. 2 (f)

Figure 2. Map of the ground surface temperatures in Pekanbaru City year (a) 2013, (b) 2014, (c) 2015, (d) 2016, (e) 2017, and (f) 2018

The highest recorded temperatures are the 2014 and 2018 image maps, this is because these two images have the least amount of atmospheric interference so that a high average surface temperature is obtained. Other years' image maps have the lowest average surface temperatures because they have very extensive atmospheric disturbances, the majority of which are in the Rumbai Pesisir District. From Figure 2, it can be seen that there is an increase in the number of areas that have the highest average ground surface temperature, which is indicated by the increase in red areas that occur in the city center and the southern part of Pekanbaru. Research by Yao et al (2020) said that the increase in surface temperature is influenced by land cover [1]. In areas that have a lot of vegetation, the surface temperature value will be lower. To do this, Arifah and Susetyo (2018) suggest optimizing greening using the green building concept in built-up areas, improving green open spaces (RTH) and adding greenery to green belts [15].

Percentage of Surface Temperature Exposure Area Based on Class in Pekanbaru City from 2013-2018. The results of Landsat 8 image data processing in the geographic information system software in Figure 2 show the percentage of areas experiencing surface temperatures based on each class from 2013-2018. Based on Table 3, it is known that from 2013-2015 the majority of temperatures covering the Pekanbaru City area were high category temperatures (33-35ºC) with a percentage in 2013 of 39.06%, in 2014 of 44.7%, and in 2015 it was 55.11%. In 2016-2017 the majority of temperatures were in the moderate level temperature category (30-33ºC) with a percentage in 2016 of 43.11%, while in 2017 it reached 83.25%. The latest 2018 image data shows that the majority of high category temperatures have again covered the Pekanbaru City area with an exposure percentage reaching 60.8%.

Relative extreme temperatures always appear in every image, but in a percentage that is not too large. In 2013, extreme temperatures were 1.75%, in 2014 it was 4.69%, in 2015 it was 0.16%. In the 2016 and 2017 images, extreme temperature categories did not appear based on Landsat 8 image recordings, but in 2018 extreme temperatures appeared again with a higher percentage than before, namely 6.73%. Based on the images that are considered the most accurate with the least amount of atmospheric disturbance, the 2014 and 2018 images were selected as references to see trends in surface temperature changes. It was found that the area of change in extreme temperature exposure between the 2014 and 2018 images was an increase in the area of surface temperature exposure in the extreme category of 2.04% or an area of 13.02 km^2.

UHI Intensity Analysis. Oke's research [17] explains that Urban Heat Island (UHI) is the difference in temperature between city areas and suburban areas. In this regard, to determine the intensity of the UHI, you can find out the difference between the temperature of the city center and the temperature of the city/rural suburbs. The temperature in suburban areas was chosen based on the outermost position of other sub-districts in Pekanbaru City which was used as a reference for determining UHI intensity.

Based on the data above, it can be seen that the maximum surface temperature of Pekanbaru City from 2013-2018 has always been above 30ºC. The average UHI intensity from 2013-2018 was always above 3ºC, except for the image on 2015 with a UHI intensity value of -0.035. This is because there is a lot of atmospheric disturbance in this image, so that in the identification process in areas that have atmospheric disturbance the surface temperature tends to be below the standard temperature for the Pekanbaru City area which is very low. Pekanbaru City can be said to have experienced the UHI phenomenon since 2013. This result is in line with research by Wibowo and Rustanto [6], Naf and Herawati [7], Sencaki [9], Jeevalakshmi, et al. [18], Hu, et al. [19], Peng, et al. [20], where in studies there were temperature differences reaching 3-10ºC between the city center and the outskirts of the city.

Table 3. Percentage of Area Based on Temperature Class in Pekanbaru City 2013-2018

Year	Unit	Temperature Categories						
		Atmospheric disturbances (<20 ºC)	Low (20-30 ºC)	Medium (30-33 ºC)	High (33-35 ºC)	Very High (35-38 ºC)	Extreme (>38 ºC)	Total
2013	Area (km^2)	-	81.76	139.38	249.33	156.76	11.16	638.38
	Percentage (%)	0	12,81	21,83	39,06	24,56	1,75	100
2014	Area (km^2)	-	1.99	43.51	285.33	277.64	29.97	638.38
	Percentage (%)	0	0,31	6,82	44,70	43,49	4,69	100
2015	Area (km^2)	-	46.88	107.98	351.81	130.67	1.04	638.38
	Percentage (%)	0	7,34	16,91	55,11	20,47	0,16	100
2016	Area (km^2)	138.25	207.33	275.21	17.59	-	-	638.38
	Percentage (%)	21,66	32,48	43,11	2,76	0	0	100
2017	Area (km^2)	-	26.59	531.48	74.89	5.42	-	638.38
	Percentage (%)	0	4,16	83,25	11,73	0,85	0	100
2018	Area (km^2)	-	2.009	76.27	388.15	129.006	42.95	638.38
	Percentage (%)	0	0,31	11,95	60,80	20,21	6,73	100

Table 4. UHI Intensity in Pekanbaru City

Image Recording Date	City Center Temperature	Outskirts of the city Temperature	UHI Intensity
11th July 2013	Sukajadi (40,45ºC)	Muara Fajar (30,85ºC)	9,6ºC
		Tebing Tinggi Okura (34,98ºC)	5,47ºC
		Kulim (36,78ºC)	3,67ºC
		Tuah Karya (34,22ºC)	6,23ºC
		Average UHI intensity	**6,24ºC**
12th June 2014	Sukajadi (40,00ºC)	Muara Fajar (35,59ºC)	4,41ºC
		Tebing Tinggi Okura (34,80ºC)	5,2ºC
		Kulim (35,26ºC)	4,47ºC
		Tuah Karya (34,86ºC)	5,14ºC
		Average UHI intensity	**4,80ºC**
2nd August 2015	Sukajadi (34,71ºC)	Muara Fajar (33,96ºC)	0,75ºC
		Tebing Tinggi Okura (34,08ºC)	0,63ºC
		Kulim (36,47ºC)	-1.76ºC
		Tuah Karya (34,47ºC)	0,24ºC
		Average UHI intensity	**-0,035ºC**
14th April 2016	Sukajadi (34,50ºC)	Muara Fajar (26,23ºC)	8,27ºC
		Tebing Tinggi Okura (18,00ºC)	16,5ºC
		Kulim (32,58ºC)	1,92ºC
		Tuah Karya (28,82ºC)	5,68ºC
		Average UHI intensity	**8,09ºC**
23rd August 2017	Sukajadi (34,99ºC)	Muara Fajar (31,99ºC)	3ºC
		Tebing Tinggi Okura (31,83ºC)	3,16ºC
		Kulim (33,41ºC)	1,58ºC
		Tuah Karya (30,23ºC)	4,76ºC
		Average UHI intensity	**3,12ºC**
26th August 2018	Sukajadi (39,97ºC)	Muara Fajar (35,44ºC)	4,53ºC
		Tebing Tinggi Okura (34,63ºC)	5,34ºC
		Kulim (36,61ºC)	3,36ºC
		Tuah Karya (36,08ºC)	3,89ºC
		Average UHI intensity	**4,28ºC**

Table 5. Comparison of Maximum Surface Temperature of Landsat 8 Imagery and Maximum Temperature of Sultan Syarif Kasim II Pekanbaru Meteorological Station

No	Image Data	Image Temperature	SSKII MS Temperature*	Temperature Difference
1	11th Juli 2013	35,93ºC	34,4ºC	1,53ºC
2	12th Juni 2014	36,57ºC	34,2ºC	2,37ºC
3	2nd Agustus 2015	35,87ºC	34,5ºC	1,37ºC
4	14th April 2016	31,59ºC	35,3ºC	-3,71ºC
5	23rd Agustus 2017	33,03ºC	33,4ºC	-0,37ºC
6	26th Agustus 2018	36,60ºC	34,6ºC	2ºC

*source : [21]

Comparison of Landsat 8 Image Land Surface Temperature and Climate Temperature at Sultan Syarif Kasim II Meteorological Station (SSKII MS), Pekanbaru City. The image maximum surface temperature data with the SSKIIMS maximum temperature was compared in Maharatu Village because the Sultan Syarif Kasim II Meteorological Station is in that area. From the data in table 5, it is known that the difference between the highest image temperature and the SSKIIMS temperature during the research period was 2.37ºC. The difference between image temperature and SSKIIMS temperature is because image temperature is land surface temperature data where the radiation from each type of surface provides a temperature hue captured by satellites resulting in the appearance of temperature recorded by a thermal sensor or called Brightness Temperature, while SSKIIMS temperature is climate temperature data. Furthermore, the thing that influences the difference between image temperature and SSKIIMS is that the image temperature has atmospheric disturbances which are difficult to avoid, so that in the process of identifying areas where there is atmospheric disturbance the temperature is abnormal (classified as low). Data from SSKIIMS shows that climate temperature measurements were carried out at an elevation of 39 meters above sea level in the Pekanbaru City area, while the temperature values from the image are values resulting from each type of surface in the Pekanbaru City area from various height variations (12-75 meters above sea level). Wibowo and Rustanto's research [6] compared surface temperatures using Landsat 5 and 8 images with SSKIIMS temperatures in Bandung City, where the difference between image temperatures and SSKIIMS temperatures was found to be 4-6ºC. From Jeevalakshmi's research data [18], he compared surface temperature images using

Landsat 8 images with a weather station in Andrha Pradesh, India, where the difference between the image temperature and the temperature recorded at the weather station was found to be ±3ºC.

4. Conclusion

Based on research analyzing the urban heat island phenomenon based on land cover in Pekanbaru City, the following conclusions can be drawn:

1. The majority of temperatures covering the Pekanbaru City area in 2013-2015 were high category temperatures (33-35ºC) with a percentage in 2013 of 39.06%, in 2014 of 44.7%, and in 2015 of 55.11 %. In 2016-2017, the majority of temperatures were dominated by moderate levels (30-33ºC) with the percentage in 2016 being 43.11%, while in 2017 it reached 83.25%. The latest 2018 image data shows that the majority of high category temperatures again dominate the Pekanbaru City area with an exposure percentage reaching 60.8%.
2. Pekanbaru City Land surface temperature data from 2013-2018 shows temperatures above 30ºC. The intensity of the UHI in 2013-2018 with the exception of 2015 shows that the temperature difference between the city center and the outskirts of the city is more than 3ºC, so it is concluded that the city of Pekanbaru experienced the UHI phenomenon during the research period.

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