The Social Restrictions Impact on Urban Heat Island Phenomena (Case Study: Cities in Java Island)

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Abstract. The Coronavirus Disease 2019 (Covid-19) pandemic has hit Indonesia since March 14, 2020. The rapid spread of the virus has caused the central and regional governments to implement community activity policies. Some terms and methods used by local governments such as PSBB (the Large-Scale Social Restrictions) are applied in Special Capital Region of Jakarta and Surabaya City, in Semarang City has PKM (Restrictions on Community Activities). This study aims to analyze the impact of the social restrictions on Urban Heat Island (UHI) in the Java Island big city. This research was conducted in big cities on Java Island that apply social restrictions, namely Special Capital Region of Jakarta, Bandung, Semarang, Yogyakarta, Surakarta, Surabaya, and Malang. The data used are Landsat 8 satellite imagery in 2019 and 2020. The method used is to compare the magnitude of the Land Surface Temperature (LST) and UHI before and after social restrictions. The results of the analysis explain that there is a decrease in LST and changes in UHI in the cities of Special Capital Region of Jakarta, Bandung, Semarang, Surakarta, and Yogyakarta. However, in Surabaya and Malang, there was an increase in LST. This study concludes that the implementation of social restrictions affects changes in UHI and decreases LST.

Keywords: Covid-19, Land Surface Temperature, Social Restriction

1. Introduction

The COVID-19 pandemic has hit the world since early 2020 and Indonesia has been affected by the pandemic since March 2020. Data compiled by the Center for Systems Science and Engineering (CSSE) states that as of April 1, 2021, there have been 129,174,928 positive cases in 192 countries worldwide and 2,820,503 people died from infection with this virus [1]. In Indonesia, as of April 1, 2021, there were 1,517,854 confirmed positive cases and 41,054 people died due to COVID-19 [2].

The transmission of COVID-19 between humans occurs through droplets from infected humans [3]. The spread of COVID-19 is mostly done from person to person through human mobility. The rapid spread of the virus has caused the central and regional governments to implement policies to limit community activities in several areas in Indonesia. The area that first implemented the PSBB in Indonesia was Special Capital Region of Jakarta, on April 10, 2020. This was followed by Surabaya, Surakarta, Yogyakarta and Semarang. Special Capital Region of Jakarta became the initial epicenter of the spread of COVID-19 in Indonesia. PSBB in Indonesia is a modification of the lockdown policies implemented by various countries that are also trying to control the spread of COVID-19 [4]. The basic rules used in the PSBB are Government Regulation Number 21 of 2020 concerning Large-Scale Social Restrictions and Presidential Decree Number 11 of 2020 concerning the Determination of Public Health Emergency Corona Virus Disease 2019 (COVID-19).
Special Capital Region of Jakarta and Surabaya City are two examples of many regions that have implemented PSBB policies to control the spread of Covid-19. The two regions are also considered to have an equal role in the regional economic system, geographical character, and the character of trade and service activities on a national scale. Special Capital Region of Jakarta has implemented the PSBB policy in several stages while the City of Surabaya has implemented the Restriction policy in the form of the Surabaya Raya PSBB from April 28, 2020. When the local transmission of COVID-19 in the Surabaya Raya area is felt to be under control. In February 2021 the City of Special Capital Region of Jakarta and Surabaya Implemented a social restrictions policy in the form of the Implementation of Micro-Community Activity Restrictions (PPKM).

The policy of restricting society has an impact on movement, use of transportation, and industrial processes. These activities will produce anthropogenic heat sources [5]. The high community activity in urban areas will have an impact on land cover changes and increased anthropogenic heat [6,7]. On the island of Java, the growth of main cities is very fast, as happened in Jabodetabek and Surabaya Raya [8], so that the surface temperature in big cities in Java has increased [9].

During the COVID-19 pandemic, there were quite massive restrictions on activities and community movements. In some countries, lockdown is imposed, but in Indonesia, the policy is different, namely only social restrictions. Several studies such as [10–15] explain that there was a decrease in surface temperature during the implementation of the social restrictions/lockdown. Urban heat island (UHI) is a common phenomenon with urban development and the conversion of urban land cover functions [7,16–22], marked by a striking temperature difference between urban areas and the surrounding area [6]. Therefore, this study was conducted to identify how big the impact of PSBB on Urban Heat Island changes in big cities in Indonesia which in this study was conducted on the island of Java as the location of the case study.

2. Data and Methods

2.1 Study Area

The study areas are the big city in Java Island, namely: Jakarta, Bandung, Semarang, Surakarta, Yogyakarta, Surabaya and Malang (see Figure 1). These cities have imposed the social restrictions (PSBB) to prevent the transmission of the COVID-19 virus.

![Figure 1. The Study Area](image-url)
2.2 Materials and Methods

This study uses Landsat 8 Level 1 Collection satellite imagery data provided by USGS. Landsat 8 satellite can capture a 12-bit image that consists of 8 multispectral bands (OLI sensor) with 30m spatial resolution, one panchromatic band with 15m resolution, and 2 thermal (TIRS) bands with 100m resolution. The satellite will capture the same scene within 16 days period. To conduct the study, 2 images of each city will be used and analyzed, one from the pre-outbreak period in 2019 and the other is during the enforcement of the social restrictions in 2020. Table 1 below shows the capture date of each image used in the study.

| City                      | 2019 image capture date | 2020 image capture date |
|---------------------------|-------------------------|-------------------------|
| Special Capital Region of Jakarta | July 25, 2019          | April 22, 2020           |
| Bandung                   | May 22, 2019            | May 24, 2020             |
| Semarang                  | May 24, 2019            | May 10, 2020             |
| Solo                      | May 17, 2019            | June 4, 2020             |
| Yogyakarta                | May 8, 2019             | May 10, 2020             |
| Surabaya                  | June 11, 2019           | June 13, 2019            |
| Malang                    | May 26, 2019            | June 13, 2020            |

The method to calculate and determine UHI intensity according to Alves & Lopes (2017) and Kindap et al (2012) is specified as below.

\[
\Delta T_{\mu-r} = T_{\mu} - T_r
\]

\[
\Delta T_{\mu-r} = \text{UHI intensity}
\]

\[
T_{\mu} = \text{LST of the measured city}
\]

\[
T_r = \text{LST around the measured city (} T_{\mu} \text{)}
\]

The calculation above is then being derived to extract and identify areas impacted with UHI by [25] into another formula below.

\[
UHI = \mu + \frac{1}{2} \alpha
\]

\[
\mu \text{ stands for the average LST of the area and } \alpha \text{ stands for the standard deviation of the LST. This formula is used as a criterion to specify how high the intensity of UHI is in that specific area.}
\]

3. Results and Discussion

UHI analysis begins with an analysis of NDVI (Normalized Difference Vegetation Index) and then surface temperature (LST) analysis. This article describes the results of LST and UHI analysis.

3.1 LST and UHI in Special Capital Region of Jakarta

The results of the LST analysis in Special Capital Region of Jakarta before and during the implementation of social restrictions are explained in Figure 2 and Table 2. The LST calculation of each city was obtained by processing Landsat-8 images that were captured before the Covid-19 outbreak in 2019 and after the social restrictions were enforced in 2020.
Figure 2. LST difference before and during social restrictions in Special Capital Region of Jakarta

Table 2. Temperature parameter comparison in Special Capital Region of Jakarta, before and during the pandemic (in °C)

| Parameter          | 2019   | 2020   | Difference (Δ) |
|--------------------|--------|--------|----------------|
| Minimum LST        | 25.11  | 23.38  | -1.73          |
| Maximum LST        | 37.95  | 33.76  | -4.19          |
| Average LST        | 31.31  | 28.39  | -2.92          |
| Standard deviation | 1.42   | 1.38   | -0.04          |
| UHI threshold      | 32.02  | 29.08  | -2.94          |

Figure 3. Land surface temperature distribution in Special Capital Region of Jakarta

Figure 3 indicated that the temperature of Jakarta was decreasing when the Covid-19 outbreak happens. The average temperature decreased by 2.92°C in 2020, and as the temperature decreased, the UHI threshold of Jakarta also decreased from 32.02°C to 29.08°C. The temperature distribution also changed, indicated with more areas having lower temperatures in 2020. Therefore, during the
implementation of the social restrictions, Special Capital Region of Jakarta experienced a decrease in LST with a UHI threshold of -2.94 °C.

3.2 LST and UHI in Bandung

The processing of LST and UHI in Bandung before and during social restrictions is explained in Figure 4 dan Table 3.

![LST map of Bandung before Covid-19 outbreak, 2019](image1) ![LST map of Bandung during Covid-19 outbreak, 2020](image2)

**Figure 4. LST difference before and during social restrictions in Bandung**

Figure 4. LST difference before and during social restrictions in Bandung describes the decline in LST in Bandung. The average decrease LST in Bandung is 1.58 °C (Table 3. Temperature parameter comparison in Bandung, before and during the pandemic (in °C).

**Table 3. Temperature parameter comparison in Bandung, before and during the pandemic (in °C)**

|                  | 2019  | 2020  | Difference (Δ) |
|------------------|-------|-------|----------------|
| Minimum LST      | 20.13 | 19.884| -0.25          |
| Maximum LST      | 33.99 | 32.756| -1.23          |
| Average LST      | 28.40 | 26.82 | -1.58          |
| Standard deviation | 1.59  | 1.53  | -0.06          |
| UHI threshold    | 29.19 | 27.59 | -1.61          |
Figure 5. Land surface temperature distribution in Bandung

Figure 5 indicated that the temperature of Bandung was decreasing when the Covid-19 outbreak happens. The average temperature decreased by 1.58°C in 2020, and as the temperature decreased, the UHI threshold of Bandung also decreased from 29.19°C to 27.59°C. The temperature distribution also changed, indicated with more areas having lower temperatures in 2020.

3.3 LST and UHI in Semarang

The LST changes UHI in Semarang during social restrictions occurred quite significantly (-3.68 °C). The LST changes in LST in Semarang are explained in Figure 6 and Table 4.

![LST map of Semarang before Covid-19 outbreak, 2019](image1)

![LST map of Semarang during Covid-19 outbreak, 2020](image2)

Figure 6. LST difference before and during social restrictions in Semarang

|                         | 2019   | 2020   | Difference (Δ) |
|-------------------------|--------|--------|----------------|
| Minimum LST             | 15.46  | 16.31  | 0.85           |
| Maximum LST             | 36.25  | 32.27  | -3.97          |
| Average LST             | 26.31  | 22.63  | -3.68          |
| Standard deviation      | 2.37   | 1.34   | -1.02          |
| UHI threshold           | 27.49  | 23.30  | -4.19          |
Figure 7. Land surface temperature distribution in Semarang

Figure 7 indicated that the temperature of Semarang was decreasing when the Covid-19 outbreak happens. The average temperature decreased by 3.68°C in 2020, and as the temperature decreased, the UHI threshold of Semarang also decreased from 27.49°C to 23.3°C. The temperature distribution also changed, indicated with most of the city area having lower temperature in 2020.

3.4 LST and UHI in Surakarta

The analysis and processing of LST and UHI in Surakarta are described in Figure 8. There is a change in LST in Surakarta during social restrictions (Table 5).

Figure 8. LST difference before and during social restrictions in Surakarta

Table 5. Temperature parameter comparison in Surakarta, before and during the pandemic (in °C)

| Parameter          | 2019   | 2020   | Difference (Δ) |
|--------------------|--------|--------|----------------|
| Minimum LST        | 22.46  | 23.55  | 1.09           |
| Maximum LST        | 33.40  | 30.46  | -2.94          |
| Average LST        | 30.32  | 27.64  | -2.68          |
| Standard deviation | 1.14   | 0.94   | -0.20          |
| UHI threshold      | 30.89  | 28.11  | -2.78          |
Figure 9 indicated that the temperature of Surakarta was decreasing when the Covid-19 outbreak happens. The average temperature decreased by 2.68°C in 2020, and as the temperature decreased, the UHI threshold of Surakarta also decreased from 30.89°C to 28.11°C. The temperature distribution also changed, indicated with more areas having lower temperatures in 2020.

3.5 LST and UHI in Yogyakarta

The results of the analysis and processing of LST and UHI in Yogyakarta show that there is a decrease and change in UHI (Table 6). The differences in LST in Yogyakarta before and during social restrictions are explained in Figure 10.
LST map of Yogyakarta before Covid-19 outbreak, 2019  
LST map of Yogyakarta during Covid-19 outbreak, 2020

**Figure 10.** LST difference before and during social restrictions in Yogyakarta

**Table 6.** Temperature parameter comparison in Yogyakarta, before and during the pandemic (in °C)

| Parameter          | 2019     | 2020     | Difference (Δ) |
|--------------------|----------|----------|----------------|
| Minimum LST        | 23.83    | 21.97    | -1.86          |
| Maximum LST        | 30.95    | 27.39    | -3.56          |
| Average LST        | 27.48    | 24.16    | -3.32          |
| Standard deviation | 0.81     | 0.55     | -0.26          |
| UHI threshold      | 27.89    | 24.44    | -3.45          |

**Figure 11.** Land surface temperature distribution in Yogyakarta
Figure 11 indicated that the temperature of Yogyakarta was decreasing when the Covid-19 outbreak happens. The average temperature decreased by 3.32°C in 2020, and as the temperature decreased, the UHI threshold of Yogyakarta also decreased from 27.89°C to 24.44°C. The temperature distribution also changed, indicated with more areas having lower temperatures in 2020.

### 3.6 LST and UHI in Surabaya

Surabaya is one of 2 cities in this study to have a temperature increase during the outbreak. Unlike other cities, LST and UHI in Surabaya have increased before and during social restrictions (Figure 12 dan Table 7).

**Figure 12. LST difference before and during social restrictions in Surabaya**

**Table 7. Temperature parameter comparison in Surabaya, before and during the pandemic (in °C)**

|                  | 2019     | 2020     | Difference (Δ) |
|------------------|----------|----------|----------------|
| Minimum LST      | 21.10    | 21.43    | 0.33           |
| Maximum LST      | 31.76    | 35.05    | 3.29           |
| Average LST      | 27.00    | 28.92    | 1.92           |
| Standard deviation| 1.69    | 1.86    | 0.17           |
| UHI threshold    | 27.85    | 29.85    | 2.01           |

**Figure 13. Land surface temperature distribution in Surabaya**
Figure 13 indicated that the average temperature of Surabaya increased by 1.92°C in 2020. As the temperature increased, the UHI threshold of Surabaya also increased by 2°C, from 27.85°C to 29.85°C. The temperature distribution also changed, indicated with more areas having higher temperatures in 2020.

3.7 LST and UHI in Malang

Like the city of Surabaya, the city of Malang during the social restrictions also experienced an increase in LST and changes in UHI (Table 8). It can be seen in Figure 14 that the distribution of zones with red color temperature > 32 °C is getting wider.

![LST map of Malang before Covid-19 outbreak, 2019](image1)

![LST map of Malang during Covid-19 outbreak, 2020](image2)

**Figure 14.** LST difference before and during social restrictions in Malang

| Table 8. Temperature parameter comparison in Malang, before and during the pandemic (in °C) |
|---|---|---|
| Minimum LST | 19.80 | 20.33 | 0.53 |
| Maximum LST | 30.61 | 32.78 | 2.17 |
| Average LST | 26.03 | 27.04 | 1.01 |
| Standard deviation | 2.07 | 2.12 | 0.05 |
| UHI threshold | 27.07 | 28.10 | 1.03 |
Figure 15 indicated that the average temperature in Malang increased by 1.01˚C in 2020. As the temperature increased, the UHI threshold of Malang also slightly increased from 27.07˚C to 28.1˚C. The temperature distribution in Malang also changed, indicated with more areas having higher temperatures in 2020.

4. Conclusion

The results of the analysis of LST and UHI in big cities in Java before and during social restrictions show that there is a change in the decline in LST and changes in UHI. So, there is an effect of the enactment of social restrictions on the decline in LST and changes in UHI. This further strengthens the findings of previous studies [5,9,14,26] that LST and UHI are also influenced by community activities in the form of movement and transportation. During the social restrictions, people's movements were severely restricted, so the number of movements and use of transportation decreased significantly.

There are other cases, namely the increase in LST and UHI in the cities of Surabaya and Malang during the social restrictions. The findings of this case need further research on why the increase in LST occurred. However, this study still concludes that the social restrictions imposed can reduce the value of LST and UHI changes.

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