Jakarta and Surabaya land surface temperature before and during the Covid-19 pandemic

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Abstract. The first incidence of the novel coronavirus or Covid-19 was reported in late 2019, and in the following year, the disease was declared a global pandemic. In Indonesia, the first case was reported in early March, 2020, and ever since, the government has appealed to the public to reduce outdoor activities in order to curtail the spread of the virus. Consequently, many companies and institutions implemented the 'Work from Home' (WFH) policy. At the end of April, the provincial government of Jakarta issued large-scale social restrictions, locally called PSBB. These restrictions were later implemented in other cities such as Surabaya. Jakarta was the epicentre of the spread of the virus in Indonesia, followed by Surabaya, the second largest city in the country. Therefore, this study aimed to analyze the Thermal Humidity Index (THI) of both cities, before and during the pandemic. Data were obtained from the MODIS Terra Land Surface Temperature and Emissivity 8-Day Global 1km, from the 1st to 14th May, 2019 (before the pandemic), and during the same period the following year (during the pandemic). Furthermore, data analysis was carried out using Google Earth Engine (GEE), a cloud-based platform for geo-spatial data analysis. The hypothesis in this study was that the social restriction policy caused a difference in the THI before and during the pandemic. Therefore, this hypothesis was proven by the results, as the policy caused a decrease in the THI during the pandemic.
Key Words: Covid-19, land surface temperature, urban heat island.

Introduction. The novel corona virus disease (later officially called Covid-19) originated in Wuhan, Hubei Province, China, in late 2019, and has infected many people worldwide. Consequently, on March 2020, the World Health Organization (WHO) declared the outbreak a pandemic.

Indonesia reported its first case in early March 2020, and ever since, the government has appealed to the public to reduce outdoor activities in order to curtail the potential spread. Consequently, many companies implemented the work from home (WFH) policy to protect their employees. By the beginning of May, 831 cases of death from 10,843 patients had been reported. Meanwhile, according to Ritchie et al (2020), the number of total confirmed deaths in the country increased by the factor of 2.1.

Jakarta, being the largest city in Indonesia, is the centre of government and business activities, followed by Surabaya, which is the second largest city in the country. Since these cities are metropolitan, and of great sizes, they are characterized by numerous human activities. Moreover, these activities, and the development of nearby cities, have created an urban heat island (UHI) in the area. As reported by Permatasari et al (2019), the land surface temperature (LST) of Jakarta was around 30-40^{o}C, while Surabaya was significantly lower, at 20-30^{o}C.

The population of Jakarta doubles during the daytime because of the workers coming from surrounding cities, such as Bogor, Depok, Tangerang, and Bekasi. Furthermore, the workers enter and exit the city through private and public transports, and this could trigger the creation of an UHI. The UHI effect is mostly affected by land cover change (Lo & Quattrochi 2003; Chen et al 2006; He et al 2007; Kim 2009; Su et al 2010; Du et al 2016; Wang et al 2017; Atasoy 2019), urbanization (Radhi et al 2013), urban vegetation (Wang & Akbari 2016; Herlina et al 2017; Hiemstra et al 2017; Werbin et al 2020), and anthropogenic heat (Shahmohamadi et al 2011; Zhou et al 2014).

Amidst the rapid spread of the virus, Jakarta became the center of the pandemic. Consequently, at the end of April 2020, the provincial government issued large-scale social restrictions (locally called PSBB), which is the same as the lockdown that was implemented in other countries. Similarly, the governments of other cities like Surabaya later issued the same policy, to ensure that the people reduced their outdoor activities.

The mobility index data on movements in DKI Jakarta and East Java Province, from March 28 to May 9, 2020 which was released by Google can be seen in Table 1. The data shows that movements in both Provinces reduced by about 90% compared to the baseline day, which is the median value from the 5-week period (Jan 3 – Feb 6, 2020).

Table 1

Mobility index report for Jakarta and East Java based on Google tracking (Google LLC 2020)

City	*Transport*	*Grocery and pharmacy*	*Retail and recreation*	*Workplace*	*Parks and outing*	*Residential*
Jakarta	-62%	-25%	-60%	-36%	-95%	+20%
East Java	-64%	-23%	-40%	-25%	-53%	+18%

Muhammad et al (2020), stated that the large-scale social restriction policy has a positive effect on the environmental temperature. Therefore, this study aims to compare the temperature humidity index (THI) of Jakarta and Surabaya before and during the pandemic. The hypothesis is that the restriction policy reduces the THI due to that it causes a decrease in human activities.

Material and Method

Description of the study site. Jakarta is the largest city in Indonesia and has a population of almost 11 million. Therefore, the city is the second largest in Southeast Asia after Manila. Its population doubles in daytime because of the workers that come from neighbouring cities such as Bogor, Depok, Tangerang, and Bekasi. Moreover, since the city is located at the equator line, it has a tropical climate. The temperature of Jakarta varies from 26.8^{o}C (around January) to 28.3^{o}C (around October), with an average of about 27.6^{o}C. The location of the two cities is shown in Figure 1.

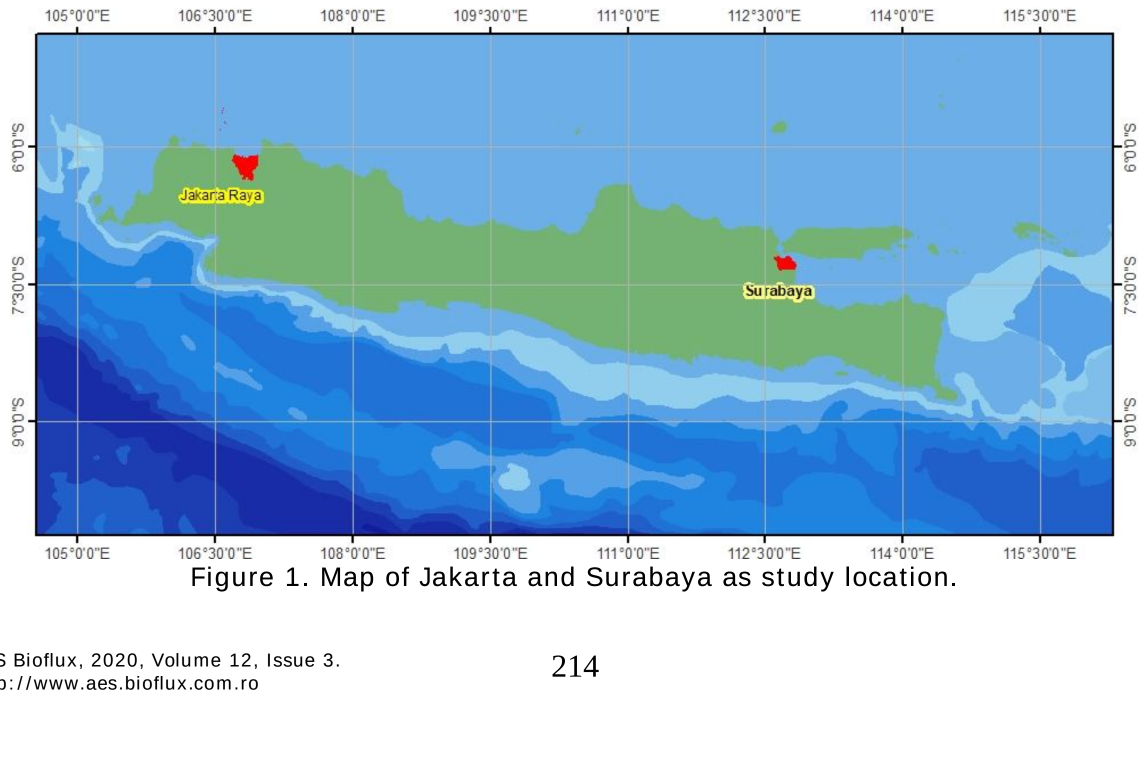

Figure 1. Map of Jakarta and Surabaya as study location.

Surabaya is the capital of East Java Province, and is the second largest city in Indonesia. Furthermore, the city has a population of almost 3 million, thus, is the second-biggest metropolitan area in the country. Surabaya is surrounded by satellite cities, including Gresik, Bangkalan, Mojokerto, Sidoarjo, and Lamongan, therefore, the city is more populated in the daytime. Meanwhile, the temperature therein varies from 23-31^{o}C.

Jakarta is the epicenter of the spread of the virus in Indonesia followed by Surabaya, which is the second largest city in the country. Due to the risks, the local governments of both cities imposed a policy which limited the activities of their citizens. This activity limitation has an impact on the creation of an urban heat island. Therefore, considering this claim, it became important that Jakarta and Surabaya be the focus of this research.

Data source and processing. Data was obtained from MODIS (MOD11A2 V6) Terra Land Surface Temperature and Emissivity 8-Day Global 1 km, which is a dataset in Google Earth Engine (GEE). Meanwhile, GEE is a cloud-based platform for geo-spatial data analysis provided by Google. It was designed to enable petabyte-scale, scientific analysis and visualization of geospatial datasets (Gorelick et al 2017). The MOD11A2 V6 product provides the average land surface temperature (LST) of an 8-day period. Meanwhile, LST is the radiative skin temperature of a land surface. Each pixel value in MOD11A2 is a simple average of all the corresponding MOD11A1 LST pixels collected within an 8 days period (Wan et al 2015). Moreover, MOD11A1 V6 is available in GEE data catalog (Google Earth Engine 2019).

To avoid bias of climatic condition due to different seasons, the dataset was filtered by acquisition period of April 1st – May 14th 2019, as before the outbreak data, and April 1st – May 14th 2020, as during the outbreak data. Furthermore, the UHI was calculated from the LST. According to Kaplan et al (2018), UHI can be extracted using the following formula:

$$UHI = LST + \frac{\sigma}{2}$$

where: σ is the standard deviation of the LST. The unit of UHI is the same as the unit of LST (^{o}C).

Thermal humidity index (THI) is the degree of discomfort experienced by an individual in warm weather, and it is a combination of temperature and humidity. Furthermore, THI was originally called the discomfort index. Relative humidity (RH) data were obtained from the Bureau of Meteorology, Climate and Geophysics of Indonesia. Meanwhile, the formula used in estimating the THI is as follows:

$$THI = \left(0.8 + \frac{RH}{500}\right) \times LST$$

Results and Discussion. The LST was measured by MODIS Satellite, and Figures 2 and 3 show the comparison of the average temperature distribution over Jakarta from April-May 2019 (before the outbreak) and during the same period the following year (during the outbreak). The figures clearly indicated that there was a slight decrease in the temperature due to the Covid-19 outbreak.

Quantitative information regarding the decrease in LST is shown in Table 2. Moreover, the table indicated that the LST decreased by 0.78^{o}C, from around 36.39^{o}C in 2019 to 35.62^{o}C in 2020 (see T_{ave} on Table 2). However, the RH remained the same. Similarly, as the temperature decreased, the THI also reduced, from 29.17 to 28.55^{o}C. This indicated that there was a better environmental condition during pandemic.

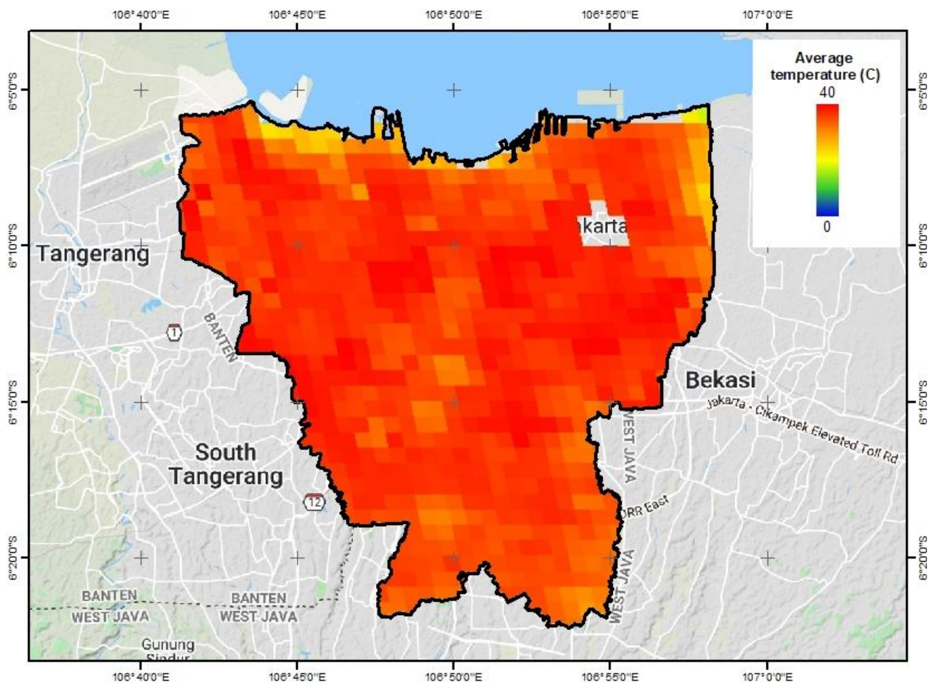

Figure 2. Temperature map over Jakarta before Covid-19 outbreak (2019).

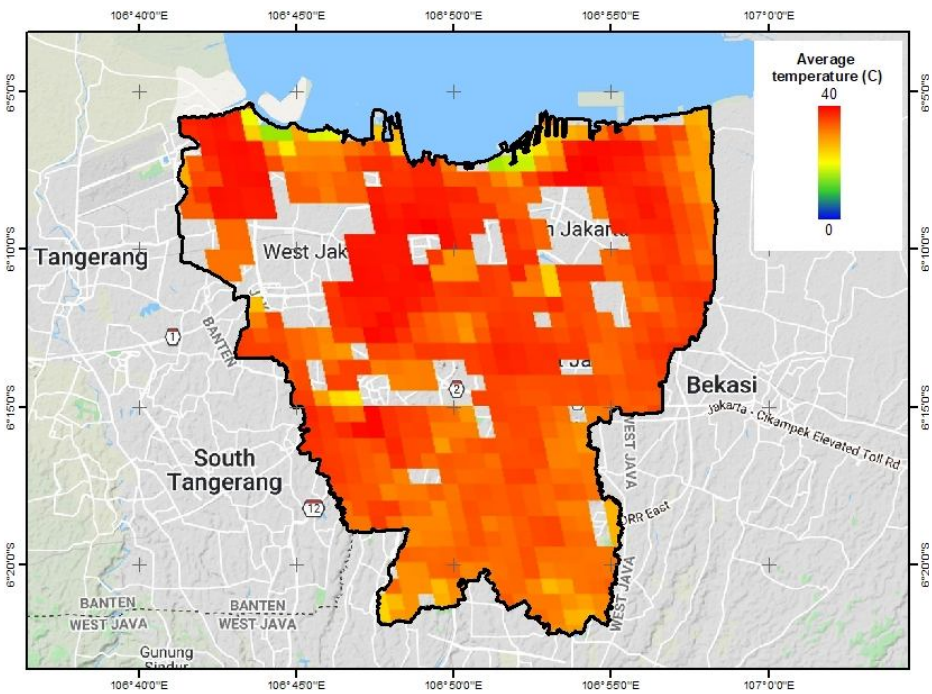

Figure 3. Temperature map over Jakarta during Covid-19 outbreak (2020).

Table 2

Comparison of the temperature parameters in Jakarta, before and during COVID-19 outbreak

	2019 (before Covid-19)	2020 (during Covid -19)
T_{min}	29.25	28.33
T_{max}	40.00	40.00
T_{ave}	36.39	35.62
RH	0.78	0.79
THI	29.17	28.55

Note: T_{min} = minimum temperature; T_{max} = maximum temperature; T_{ave} = average/mean temperature; RH = relative humidity; THI = temperature humidity index.

Another data which serves as a proof that the LST decreased is shown in Figure 4. This figure shows the temperature distribution in Jakarta, before and during outbreak. Furthermore, it indicated that the temperature was mostly between 36 and 37^{o}C in 2019 (around 160 pixels), while in 2020, it was between 35 and 36^{o}C. However, it should be noted that some of the land area in the 2020 data was masked due to the cloud that covered them.

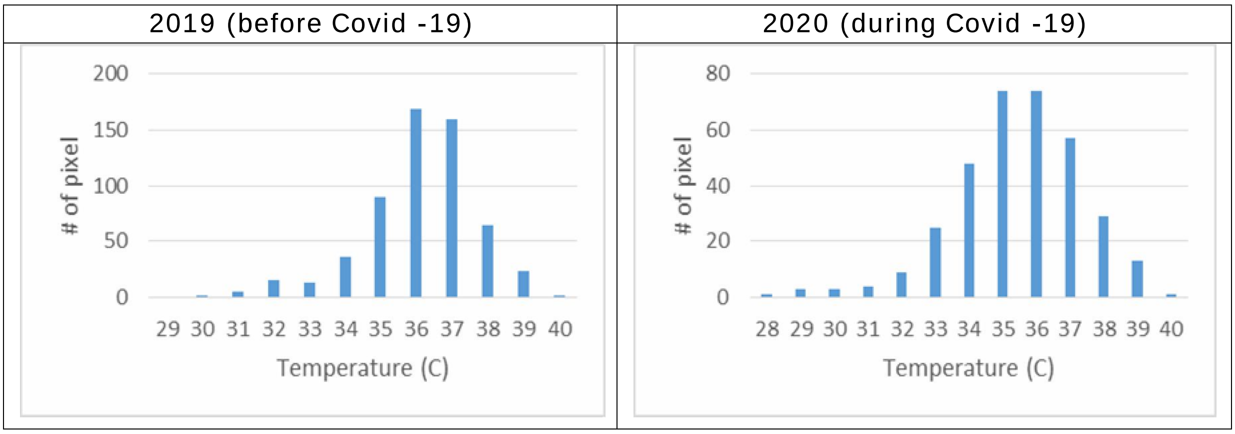

Figure 4. Temperature distribution in Jakarta, before and during COVID-19 outbreak.

Different situations were observed in Surabaya, as indicated by Figure 5 and Figure 6. These figures show the comparison of the average temperature distribution over the city from April-May 2019 (before the outbreak) and during the same period the following year (during the outbreak). The maps indicated that the temperature in some parts of Surabaya was increasing, instead of decreasing, especially the area indicated by a blue circle in Figure 5 and 6. This area was Rungkut, a large industrial park which was dominated by large factories. These factories increased the temperature condition around the area due to the carbon they produced, and this indicated that there was no decrease in activities during the outbreak in the area.

Table 3 shows that the temperature parameters in Surabaya, before and during the outbreak increased by 0.04^{o}C from 34.12 to 34.16^{o}C. However, this value was much lower than that of Jakarta. The increase in the average temperature was followed by an increase in THI by 0.03^{o}C, from 27.35 to 27.38^{o}C.

Table 3

Comparison of temperature parameters in Surabaya, before and during Covid-19 outbreak

	2019 (before Covid-19)	*2020 (during Covid-19)*
T_{min}	27.8	27.50
T_{max}	37.6	37.67
T_{ave}	34.12	34.16
RH	0.80	0.78
THI	27.35	27.38

Note: T_{min} = minimum temperature; T_{max} = maximum temperature; T_{ave} = average/mean temperature; RH = relative humidity; THI = temperature humidity index.

Another proof of the increase in temperature in Surabaya was Figure 7. This figure shows that the temperature distribution in the city was mostly about 36^{o}C, unlike in 2019, which was about 35-36^{o}C.

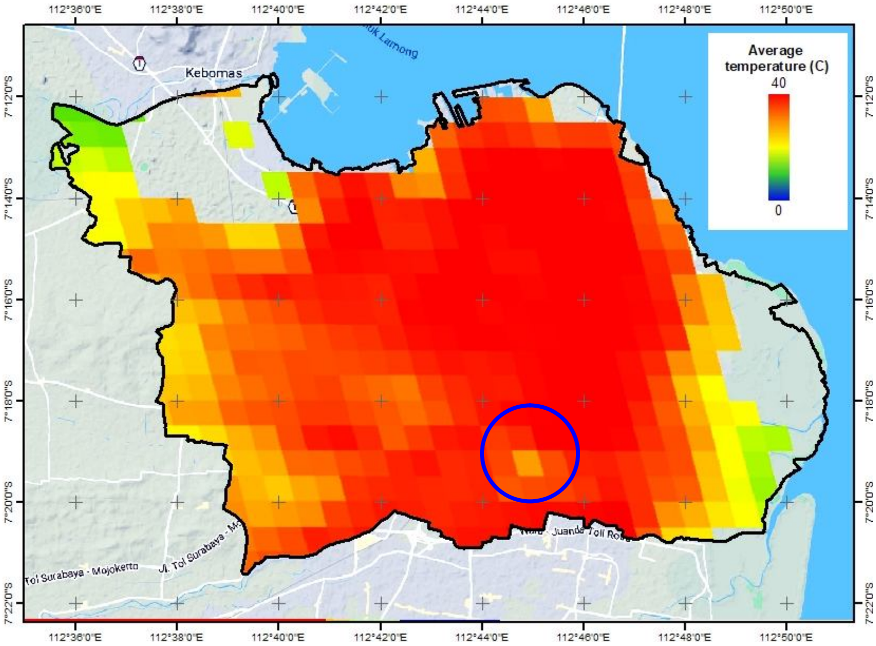

Figure 5. Temperature map over Surabaya before Covid-19 outbreak (2019).

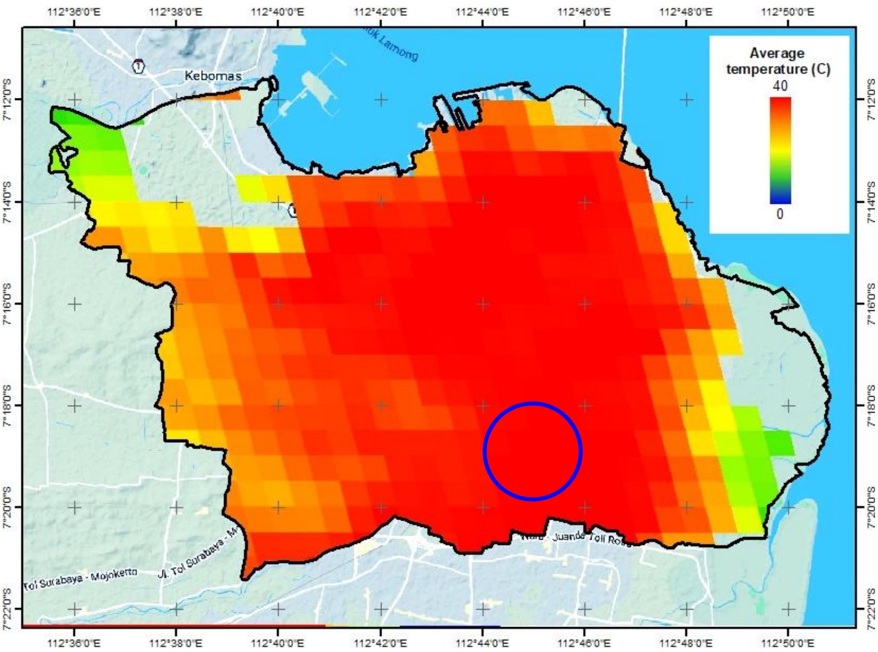

Figure 6. Temperature map over Surabaya during Covid-19 outbreak (2020).

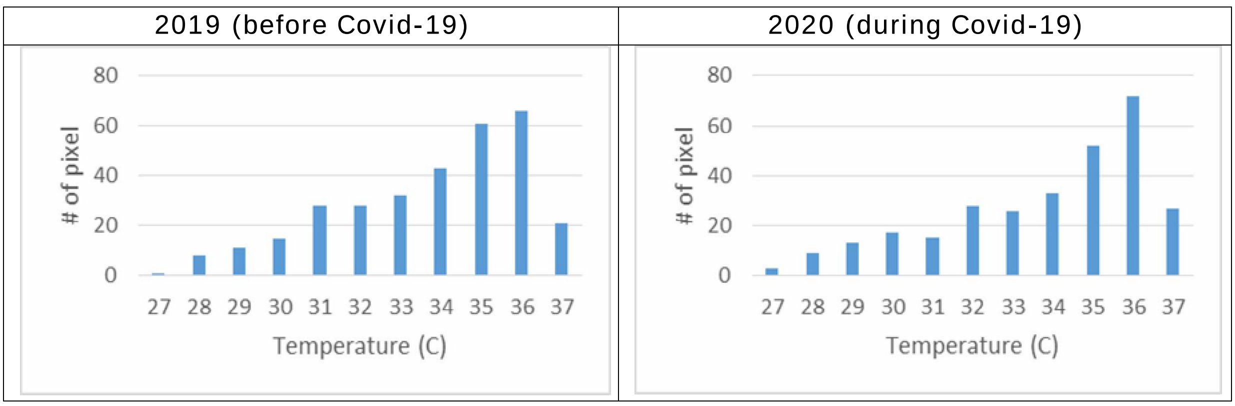

Figure 7. Temperature distribution in Surabaya, before and during Covid-19 outbreak.

The date-by-date temporal comparison of the average temperature of Jakarta and Surabaya is shown in Figures 8 and 9. Furthermore, these figures show that the temperature in Jakarta from the end of April till May 8 2020 was much lower than the baseline temperature during the same period in 2019. Meanwhile, in Surabaya, the temperature started to increase from April 22, and became higher than the baseline on May 9, 2020.

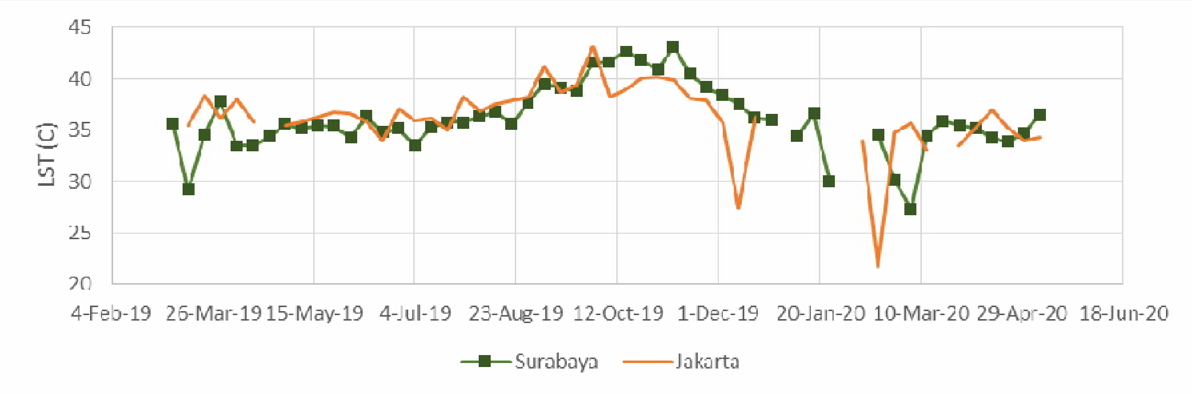

Figure 8. Dynamics of the temperature over Jakarta and Surabaya from March 2019 to May 2020.

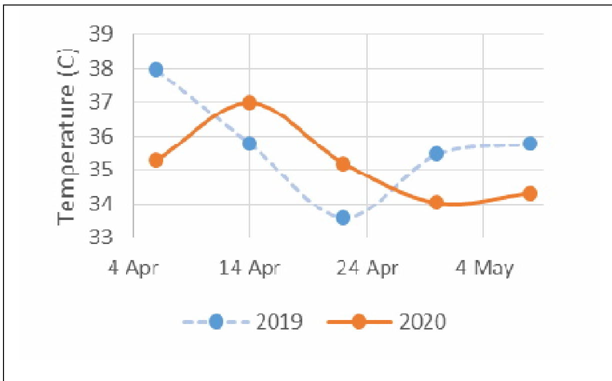	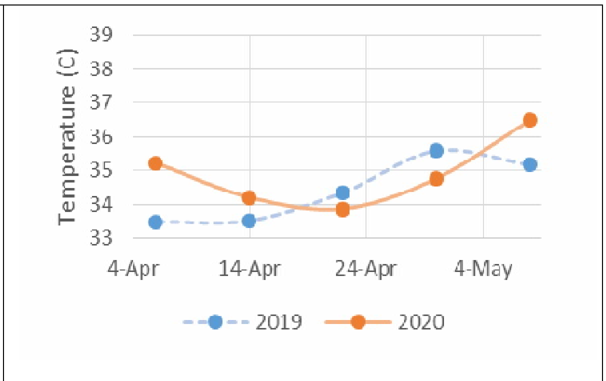
Jakarta	Surabaya

Figure 9. Temporal comparison of the temperature compared to the baseline over Jakarta and Surabaya.

The Mobility index reported by Google as shown in Table 1, indicated the facts as described above. This index showed that the rate at which people left their residential areas in both cities was decreasing. However, as stated in the report, the value decreased more in Jakarta compared to Surabaya. This indicated that during the outbreak, human activities in Jakarta were much lower than in Surabaya. Therefore, since this was a determinant factor of LST and THI, the temperature of Jakarta was lower than that of Surabaya.

Conclusions. The reduction in human activities during the COVID-19 outbreak caused a decrease in both the land surface temperature and thermal humidity index of Jakarta. However, in Surabaya, there was a slight increase in LST and THI. This increase most likely occurred because of the human activities in the city was higher than in Jakarta. Therefore, this study concludes that the restriction policy affected the thermal condition of both cities by reducing the THI. The Google Earth Engine application used could be accessed through this link, https://akwijayanto.users.earthengine.app/view/lst-jakarta-vs-surabaya-during-covid-19.

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