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Dynamics of Urban Heat Island and NO_2 Gas During the Covid-19 Pandemic

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Abstract

To know the COVID-19 pandemic's impact on the environment, an analysis of Urban Heat Island and pollutant gas was carried out. From March to June 2020, the Indonesian government implemented the Large-Scale Social Restrictions (PSBB) policy, requiring people to limit activities in public places. The data used are Land Surface Temperature (LST) from the Terra MODIS and Nitrogen Dioxide (NO_2) concentration from the TROPOMI sensor. The data is processed using the Google Earth Engine to produce comparative values before the PSBB implementation (2019), during (2020), and after (2021-2022). The LST will be derived into Surface Urban Heat Island (SUHI) to compare climate conditions in urban (Kendari) and rural areas (Ranomeeto, Lalonggasumeeto, North Moramo). The results show that reducing community activities during the pandemic was not able to reduce LST but succeeded in inhibiting the increase rate. The LST trend is more affected by rainfall variables where higher rainfall causes lower LST and vice versa. The SUHI value shows a downward trend, meaning that the Urban Heat Island effect has been inhibited. The most significant impact of PSBB was a 25.9% reduction in NO_2 concentration. These results prove that the COVID-19 pandemic has successfully restored environmental health constantly exposed to air pollution.

Keywords: COVID-19, Urban Heat Island, NO_2, PSBB, Land Surface Temperature

INTRODUCTION

The COVID-19 pandemic brought many changes in various aspects of human life worldwide. Since appearing in December 2019, many policies have been adopted to suppress the spread of this virus and reduce the impact on the safety of human life. One of the Indonesian government's strategic actions is the policy of Pembatasan Sosial Berskala Besar (PSBB), known as lockdown. The implementation of the PSBB policy starts at the end of March 2020 and until the beginning of June 2020. During this period, the PSBB required activities in public places to be maximally limited and replaced with activities from home.

Restrictions on human activity have a positive impact on environmental health. The emergence of COVID-19 as a pandemic caused air pollution to decrease, the air to become fresher and the waters to become cleaner, and awareness of more pristine living increased (Slamet, 2020). The PSBB policy causes activities with modes of transportation to decrease massively, which is one indicator of the Urban Heat Island phenomenon (Aprillia et al., 2020). Urban Heat Island (UHI) is a natural phenomenon related to climate, as indicated by the increasing temperatures in urban areas where the downtown area has a higher temperature than the surrounding rural area (Aprillia et al., 2020). The increase in temperature comes from the heat generated from the combustion process, residual exhaust gases from motorized vehicles, human activities, and certain types of building materials (Isnoor et al., 2021).

Surface Urban Heat Island (SUHI) is one part of an Urban Heat Island that occurs on the surface as a phenomenon of the balance of the earth's surface heat energy (Prastyo et al., 2022). The SUHI is observed through Land Surface Temperature (LST) data. This surface temperature reflects the heat energy of every object on the earth's surface. Surfaces covered by non-vegetation will produce higher temperatures than vegetated land because heat is not absorbed well. Motor vehicle emissions produce pollutant gases that trap the heat so that surface temperatures increase. Ultimately, urban areas with many development processes and using motorized vehicles will tend to be warmer.

The reduction in the use of motor vehicles during the PSBB period has been proven to reduce air pollution concentrations in many areas (Feng et al., 2023; Parhusip et al., 2022; Muhammad et al., 2020), mainly because transportation contributes around 70 - 85% of air pollution (Sunarta et al., 2022; Masito, 2018). One of the motor vehicle emissions that cause air pollution and health problems is Nitrogen Dioxide (NO_2). NO_2 is a pollutant gas with a characteristic brown color and sharp odor (Masito, 2018). NO_2 becomes a dangerous gas because it can cause lung swelling, nervous system disorders, convulsions, paralysis, bronchitis, and pneumonia, and increases susceptibility to respiratory infections to cause death (Ma'rufi, 2017). It was known in 2015 that air pollution dramatically contributes to growing disease globally (Cohen et al., 2017).

Using motorized vehicles directly affects the concentration of pollutant gases in the air (Masito, 2018; Istirokhatun et al., 2016). During the city lockdown period, NO_2 concentrations decreased significantly but quickly rebounded after the city lockdown was relaxed in the following month (Feng et al., 2023). In contrast to LST and UHI, the concentration of pollutant gases fluctuates more, even on a daily scale. Research related to motorized vehicle emissions in Bali during Nyepi has proven that limiting activities to just one day can significantly reduce the number of exhaust gases on that day (Wijaya et al., 2016; Aldrian, 2018). At the same time, UHI did not show any influence during Nyepi (Badriyah, 2014). The UHI and LST have more impact when human activities are restricted for long periods, such as during lockdowns. However, the relationship between the two still cannot be explained with certainty. The effects shown by UHI and LST also vary at different locations.

The problem in this research is how the COVID-19 pandemic had a good impact on the environment despite the harmful effects on the health and safety of human life. The positive impact here is not directly from the virus but through government policy, namely the PSBB, as a strategic action to prevent the spread of the Coronavirus. There are many factors to consider regarding the benefits of the pandemic, but this research is limited to the perspective of Urban Heat Island and air pollution only. Hopefully, this study can show the good side of the disaster that has hit the whole world, namely the COVID-19 pandemic, especially for the environmental health where we live. In addition, this research can also show the effects of urban heat island and air pollution, which are increasingly worrying in Kendari, like other cities in Indonesia.

RESEARCH METHODS

The data used in this study are Land Surface Temperature (LST) data and Nitrogen Dioxide (NO_2) concentration data. The data is determined based on the period when the strict PSBB was implemented from March to June 2020, and as comparative data, it is determined one year before and two years after the PSBB, namely in 2019 (before) and 2021 to 2022 (after). The step of collecting and processing the data uses a platform called Google Earth Engine (GEE) that has advantages in accessing remote sensing data and processing data quickly.

The indicator variable for analyzing the results of LST and SUHI is a meteorological element: rainfall. Rainfall data is processed from the ITACS website as a product of the Japan Meteorological Agency (JMA). Meanwhile, the indicator variable for analyzing NO_2 gas results is community mobility report data, a Google product. This mobility report examines the changes in response to city-locking policies in each country (Google LLC, 2022).

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The LST dataset comes from the Terra MODIS (Moderate Resolution Imaging Spectroradiometer) sensor from NASA with the product name MOD11A2V6. MOD11A2V6 product has a spatial resolution of 1000 meters and a temporal resolution of 8 days. This dataset is a derived product of MODIS raw data (Level 3, L3) whose direct result is Land Surface Temperature without radiometric or geometric corrections.

The LST data processing is enforced with the program code shown in Figure 1. The first command is to retrieve the dataset, filter it according to the required data date, and adjust it to the area or research location. The reduced data uses the mean function to obtain the average of the LST values. After that, a scale factor of 0.02 is calculated as the default value of the product. In addition, because the LST data is still in degrees Kelvin (K), it needs to be converted to Celsius (°C). The LST in celsius is then exported into raster and displayed spatially with the QGIS application.

```
var modis19 = ee.ImageCollection('MODIS/061/MOD11A2')
                        .filterDate('2019-03-01', '2019-06-30')
                        .select('LST_Day_1km')
                        .mean()
                        .clip(table);
var modis20 = ee.ImageCollection('MODIS/061/MOD11A2')
                        .filterDate('2020-03-01', '2020-06-30')
                        .select('LST_Day_1km')
                        .mean()
                        .clip(table);
var modis21 = ee.ImageCollection('MODIS/061/MOD11A2')
                        .filterDate('2021-03-01', '2021-06-30')
                        .select('LST_Day_1km')
                        .mean()
                        .clip(table);
var modis22 = ee.ImageCollection('MODIS/061/MOD11A2"')
                        .filterDate('2022-03-01', '2022-06-30')
                        .select('LST_Day_1km')
                        .mean()
                        .clip(table);
var celcius19 = modis19.multiply(0.02).subtract(273.15);
var celcius20 = modis20.multiply(0.02).subtract(273.15);
var celcius21 = modis21.multiply(0.02).subtract(273.15);
var celcius22 = modis22.multiply(0.02).subtract(273.15);
var suhuparam = {min: 15, max: 40, palette: ['blue,' 'green,' 'yellow,' 'orange,' 'red']};
Map. addLayer (celcius19, suhuparam,'SUHU RERATA TAHUN 2019');
Map. addLayer (celcius20, suhuparam,'SUHU RERATA TAHUN 2020');
Map. addLayer (celcius21, suhuparam,'SUHU RERATA TAHUN 2021');
Map. addLayer (celcius22, suhuparam,'SUHU RERATA TAHUN 2022');
```

Figure 1. Program Code to Process LST from the MODIS11A2V6 Dataset in GEE
(Source: Data Analysis, 2023)

The research location is Kendari city and three surrounding rural areas, which are the buffer zones, such as Ranomeeto, Lalonggasumeeto, and North Moramo Sub-Districts (Figure 2). The LST will be presented in graphs, tables, and maps showing the difference in surface temperature before, during, and after the implementation of the PSBB. The LST data will also be derived from surface urban heat island (SUHI) data to compare urban and rural climate conditions during the COVID-19 pandemic. The SUHI is calculated using Formula 1 (Mijani et al., 2023; Du et al., 2016) as follows:

$$SUHI = \textit{Mean}\ LST_{urban} - \textit{Mean}\ LST_{rural} \qquad (1)$$

Where SUHI (1) is Surface Urban Heat Island, Mean LST_{urban} is the average LST of Kendari city (^{0}C), and mean LST_{rural} is the average LST of Ranomeeto, Lalonggasumeeto, and North Moramo Sub-Districts (^{0}C).

Figure 2. Study Locations (Source: Data Analysis, 2023)

```
var interval1 = ee.ImageCollection("COPERNICUS/S5P/OFFL/L3_N02")
    .select('tropospheric_NO2_column_number_density')
    .filterDate('2019-03-01', '2019-06-30')
    .mean()
    .clip(table);
var interval2 = ee.ImageCollection("COPERNICUS/S5P/OFFL/L3_NO2")
    .select('tropospheric_NO2_column_number_density')
    .filterDate('2020-03-01', '2020-06-30')
    .mean()
    .clip(table);
var interval3 = ee.ImageCollection("COPERNICUS/S5P/OFFL/L3_NO2")
    .select('tropospheric_NO2_column_number_density')
    .filterDate('2021-03-01', '2021-06-30')
    .mean()
    .clip(table);
var interval4 = ee.ImageCollection("COPERNICUS/S5P/OFFL/L3_NO2")
    .select('tropospheric_NO2_column_number_density')
    .filterDate('2022-03-01', '2022-06-30')
    .mean()
    .clip(table);
var stacked_composite = interval1.addBands(interval2).addBands (interval3).add bands(interval4);
print('N02', stacked_composite.band names());
var options = {
  title: 'Grafik Kadar N02 Bulanan Tahun 2019 s.d 2022',
  hAxis: {title: 'waktu'},
  vAxis: {title: 'Kandungan N02'},
  linewidth: 1,
  point size: 4,
  };
var waktu = [0, 1, 2, 3];
var chart = ui.Chart. Image. regions (
    stacked_composite, geometry, ee.Reducer.mean(), 30, 'label', waktu)
      .setChartType('ScatterChart')
      .setOptions (options);
print(chart);
```

Figure 3. Program Code to Process NO_2 Data from the OFFL NO_2 Dataset (Source: Data Analysis, 2023)

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NO_2 data processing is enforced with the program code shown in Figure 3. The sequence is downloading the data, filtering according to the required date and location, and displaying data in a graphical form. Nitrogen Dioxide (NO_2) data comes from the TROPOMI (TROPOspheric Monitoring Instrument) sensor placed on the European Space Agency's Sentinel 5P satellite to monitor air pollution. The product used is OFFL NO_2, which has a spatial resolution of 3.5 x 7 Km^2 and one day of temporal resolution.

RESULTS AND DISCUSSION

Analysis of Land Surface Temperature and Surface Urban Heat Island

Land Surface Temperature from March to June in urban areas of Kendari city and the buffer zones show the same trend (Figure 4). There was an increase in surface air temperature from 2020 to 2021 and a decrease in 2022. The graph shows no significant temperature drop in 2020 when the PSBB policy was implemented. Even 2020 was warmer than the previous year. Figure 4 shows the average LST value in urban areas, ranging from 28.9 – 29.9 °C in the surrounding rural areas.

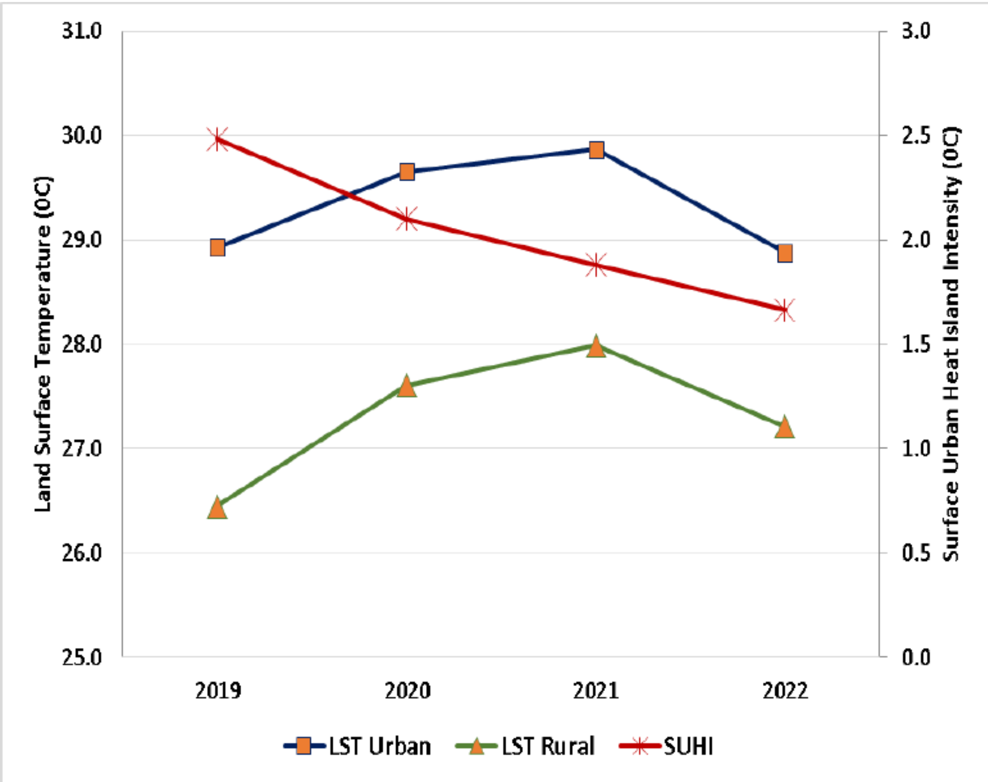

Figure 4. Graph of The Average Land Surface Temperature (LST) in Kendari City (Urban) versus in rural areas and Surface Urban Heat Island (SUHI) intensity from March to June

Areas range from 26.4 – 28.1 °C. Urban temperature always shows a value that is higher than rural temperature. This condition clearly shows that the Urban Heat Island phenomenon has occurred in Kendari city.

Figure 4 also shows a graph of the Surface Urban Heat Island (SUHI) trend, whose value decreases consistently until 2022. The highest SUHI value is in 2019, when the difference in urban and rural surface temperatures is the greatest, up to 2.5°C. In 2020, when the PSBB policy was implemented, the difference in LST in urban and rural areas was 2.1°C lower than before the PSBB. The reduced SUHI value indicates that the urban and rural temperature differences have become smaller. Even though it did not significantly reduce the surface temperature in 2020, the PSBB was quite able to suppress the Urban Heat Island (UHI) effect. The UHI effect here is when the urban and rural temperature differences get lower even though the surface temperatures in both locations are increasing. Many factors can increase temperature, but lower temperature differences in 2020 indirectly indicate that the PSBB has succeeded in inhibiting the rate of increase in urban temperatures. In other words, an increase in LST accompanied by a decrease in SUHI in 2020 indicates that the PSBB policy did not significantly affect Urban Heat Island in Kendari City but was successful enough in suppressing the effect.

Theoretically, there is a positive effect on the environment by limiting human activity during lockdowns worldwide. Several studies have shown that during the city lockdown period, there has been a reduction in surface temperature (Mijani et al., 2023; Purwanto et al., 2022; Patwary et al., 2022; Wijayanto et al., 2020). However, in several other studies, surface temperature increased (Feng et al., 2023; Parhusip et al., 2022; Wijayanto et al., 2020; Shikwambana et al., 2021). Air temperature responds differently to PSBB policy because it relates to climatic factors in that location.

The increased surface temperature is mainly due to climatic factors greater than human activities' influence (Feng et al., 2023; Du et al., 2016; Purwanto et al., 2022). For example, rainy conditions can cause relative humidity to increase and temperature to decrease (Hidayat et al., 2020). (Du et al., 2016) explained that temperature and rainfall correlate negatively. The higher the rainfall, the lower the air temperature. Especially when it rains continuously, humans can feel cooler air due to high relative humidity. The rain falling from the clouds can moisten the surrounding air as it dissipates dry and hot air.

Besides rain, low wind speed and little cloud cover can also cause the LST values to increase (Tursilowati, 2002). Clouds have the property of reflecting shortwave radiation from the sun. The number of clouds in the sky can reduce the radiation to the Earth because some radiation is reflected in space. Lack of cloud cover causes solar radiation to enter on a large scale, thus increasing the temperature on the Earth's surface. Moreover, in less windy air conditions, the air exchange decreases. Hot air accumulated on the surface moves slowly to balance with temperatures in other areas, which tend to be lower.

Figure 5 shows negative rainfall anomalies (lower than average) in 2020, 2021, and 2022. Meanwhile, in 2019, rainfall was a positive anomaly or higher than the average. This condition answers the ambiguity of land surface temperature in which 2019 had a lower value than 2020 (the lockdown period). Less rainfall in 2020 is the cause of higher surface temperatures during the pandemic than the previous year. This condition also weakens the effect of reducing community activities. The effect can also be seen in the following year, where the highest temperature in 2021 (Figure 4) corresponds to the event when the rainfall anomaly is at the lowest (see Figure 5).

Like the LST, the SUHI also shows different values at different locations. During the 2020 lockdown, the SUHI showed an increase (Parhusip et al., 2022; Purwanto et al., 2022), while in several studies, it showed a decrease (Feng et al., 2023; Mijani et al., 2023; Patwary et al., 2022). The rise and fall of SUHI is related to the difference between urban and rural temperatures, which can be smaller or larger. The SUHI is always positive because urban temperatures are always higher than rural temperatures.

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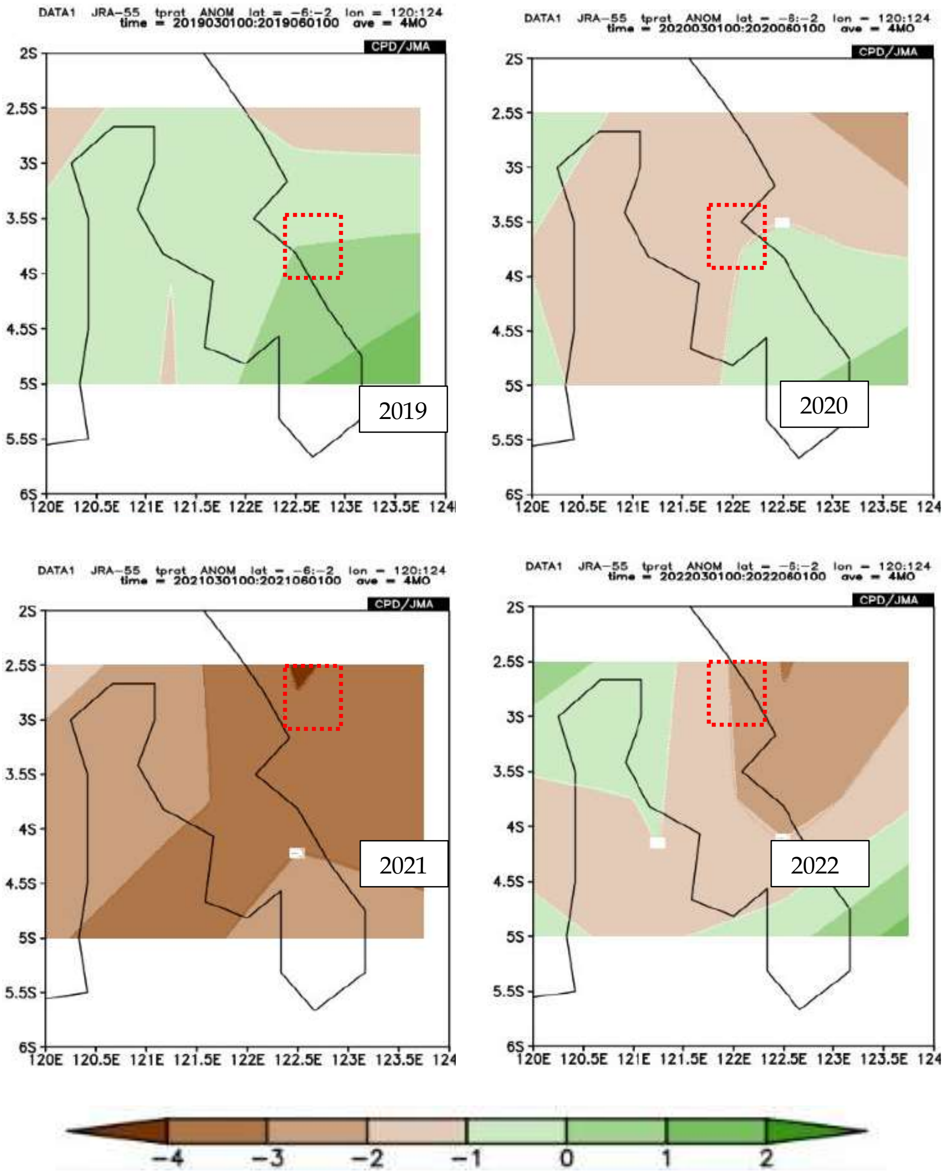

Figure 5. Average Rainfall Anomaly Map (mm/day) from March to June at the Study Location (Red Box) (Source: Itacs)

This anomaly of increased LST and SUHI is quite challenging to explain. A study conducted by Feng et al. explained that the lockdown was not the only main factor but was successful enough to inhibit the rate of increase in LST and SUHI compared to average years. This explanation is in line with the results of this study, where the temperature increase in 2020 in Kendari compared to the previous year was successfully suppressed so that it was lower than the increase in rural areas during the same period. Table 1 shows an increase in temperature during the PSBB period in the city of 0.8^{0}C, unlike in the buffer zone, which warmed more significantly at 1.2^{0}C. Until 2022, there has been a decrease in temperature, where the temperature in urban areas has decreased more than in rural areas, and the difference between the two temperatures is getting smaller.

Figure 6 shows that the distribution of land surface temperatures in urban areas is higher than in the buffer zones. In urban areas, surface temperatures can reach 36.0^{0}C; in the surrounding areas, the lowest is 20.0^{0}C. The center of heat distribution is in the Kadia Sub-District, the City center of Kendari. The heat then spreads to Kambu, Poasia, Wua-Wua, Baruga, Mandonga, Puuwatu, and West Kendari Sub-Districts. The outermost areas of Kendari city are still green, and a few residential areas are seen to have lower temperatures (Figure 2). The same goes for the surrounding areas (Ranomeeto, Lalonggasumeeto, and North Moramo Sub-Districts), which have a much lower temperature than the center of Kendari city. The urban area is warmer due to land cover in the form of asphalt, tiles, concrete, and buildings, as well as a need for green areas. Suburban areas covered by forests, agricultural land, plantations, and open green space tend to have lower temperatures. Building structures on urban land always have a low albedo and absorb and store more solar radiation energy, so the temperature increases compared to low-developed land (Tursilowati, 2002). Reducing wind speed due to building barriers also causes an increase in temperature in urban areas (Tokairin et al., 2006). Using motorized vehicles and electronic goods can also contribute heat to the environment, accumulating heat in urban areas.

Table 1. Differences in Land Surface Temperature Against the Previous Period

Year	PSBB status	LST Average (°C)		SUHI	LST difference ($LST_{(i)} - LST_{(i-1)}$)	
		Urban	Rural		Urban	Rural
2019	Normal	28.9	26.4	2.5	-	-
2020	Strict	29.7	27.6	2.1	0.8	1.2
2021	Relax	29.9	28.0	1.9	0.2	0.4
2022	More Relax	28.9	27.2	1.7	-1.0	-0.8

(Source: Research Results, 2023)

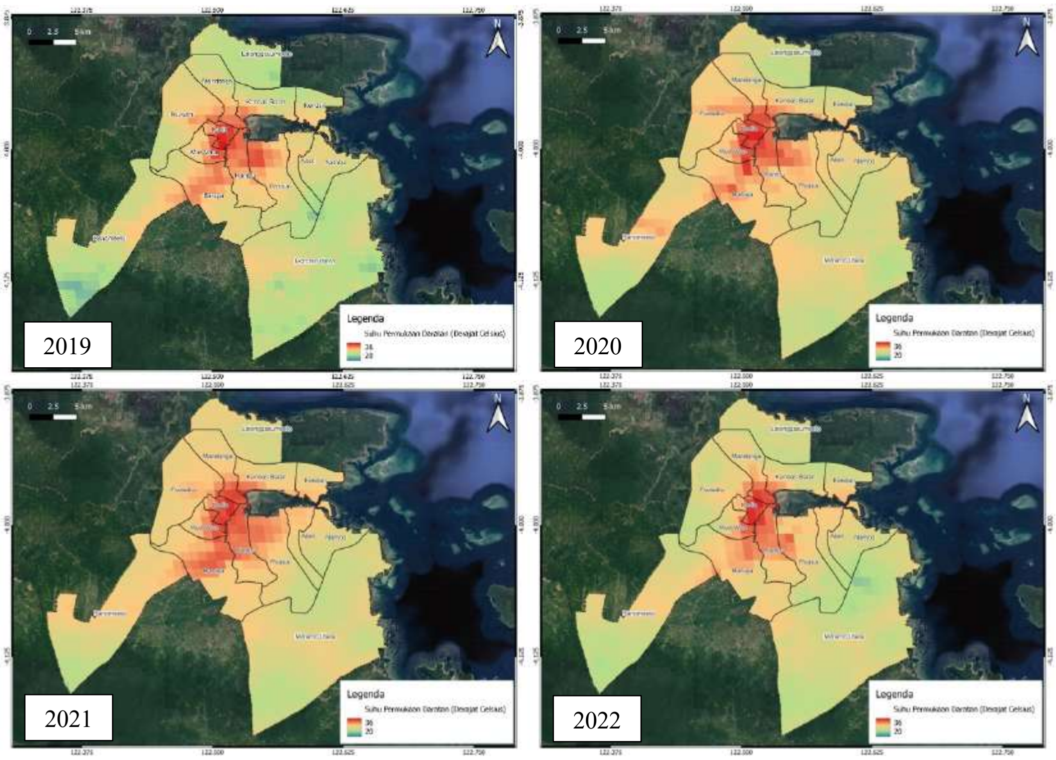

Figure 6. The Distribution of Average Land Surface Temperature (LST) from March to June in Kendari City and The Buffer Zone (Ranomeeto, Lalonggasumeeto, and North Moramo Sub-Districts)

Pollutant Gas Analysis

The NO_2 gas trend in Kendari City shows a decline in 2020 when the PSBB policy was implemented (Figure 7). NO_2 concentrations increased again in 2021 when the PSBB was relaxed and increased even higher in 2022 when all restricted activities previously reopened, including travel in and out of the city.

Table 2 shows that the reduction in NO_2 levels during the PSBB period compared to the previous year was very significant at 25.9%. However, it was immediately reversed in the following year, with an increase of up to 45.0% or almost half, and this value was higher than in 2019. People's movements which were restricted in 2020, after the government relaxed the PSBB, people returned to their normal activities and were even more productive (Table 3). The increase continued until 2022, when the Work from Home movement was reduced, especially when people were allowed to come home for Eid. After two years, the government banned homecoming activities; in 2022, people made large-scale homecoming using various modes of transportation. This homecoming activity increases the use of motorized vehicles and when people return to their homes. Ultimately, NO_2 emissions increased to 15.9% from the previous year (Table 2).

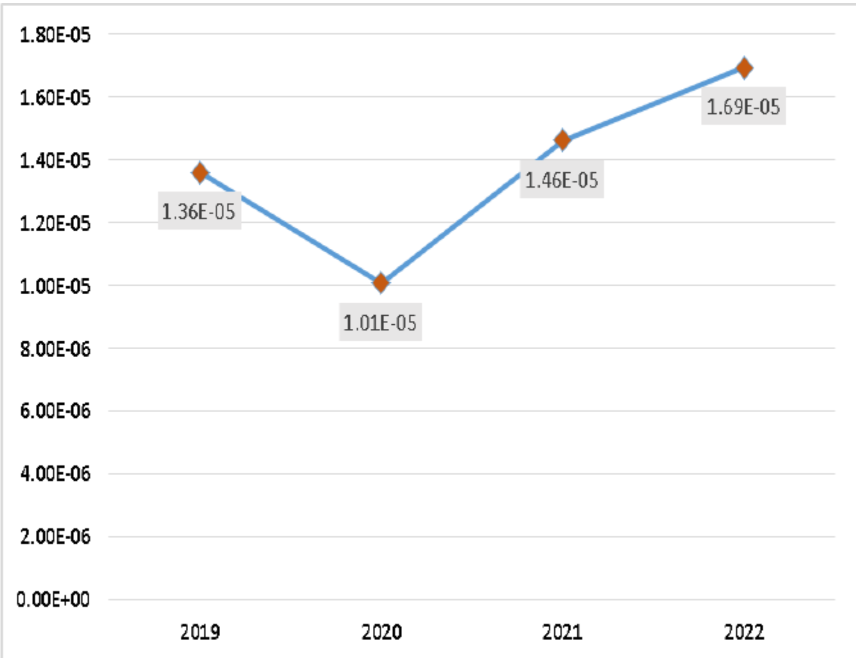

Figure 7. Graph of Average NO_2 Gas Concentration (mol/m²) in Kendari City from March to June (Source: Research Results, 2023).

Table 2. Average NO_2 Concentration from March to June

Year	PSBB Status	NO_2 Concentration (mol/m²)	Difference (%)
2019	Normal	1.36 x 10-5	-
2020	Strict	1.01 x 10-5	-25.9
2021	Relax	1.46 x 10-5	45.0
2022	More relax	1.69 x 10-5	15.9

(Source: Research Results, 2023)

Table 3. Trends in Community Mobility in Southeast Sulawesi Compared to Before the COVID-19 Pandemic

Year	Transportation Station	Workplace	Park	Residential Areas	Retail & Recreation	Food Store & Pharmacy	Average
2020	-41.47%	-16.83%	-18.57%	10.35%	-25.85%	-11.30%	-17.28%
2021	-3.65%	-15.58%	7.58%	1.04%	3.03%	34.98%	4.57%
2022	27.04%	28.58%	85.57%	14.59%	34.5%	70.76%	38.33%

(Source: Google LLC, 2022)

The trend of NO_2 gas concentration is proportional to the trend of community mobility presented in Table 3. Viewed from the average, the mobility of the people of Southeast Sulawesi increased from 2020 to 2022. During the strict lockdown period, mobilization generally decreased by 17.28%, where the highest reduction occurred at transportation stations at 41.47%, followed by mobility to retail & recreation, then to parks, workplaces, and food stores & pharmacies. At this time, people are limited in their activities outside the home, going to work, to school, or anywhere that can make interaction with other people. This prohibition caused all activities to be carried out from home, where the results can be seen from the mobility in residential areas during that period, which increased by 10.35%.

When the government started administering the COVID-19 vaccine and starting to recover economic conditions, the government then began relaxing the PSBB in 2021. The impact is that the trend of people's mobility has increased by 21.85% (difference of -17.28% and 4.57%) after a year of lockdown and increased again by 33.77% (difference of 4.57% and 38.33%) in 2022. Most people's movements in 2021 occurred at food stores and pharmacies and were associated with increasing public awareness of health following the outbreak of the deadly coronavirus. Most mobility in 2022 was to the parks related to a time when people were increasingly aware of the importance of maintaining physical health by exercising and psychological health by recreation.

Restricting people's mobility through the PSBB policy has proven successful in inhibiting the spread of COVID-19 disease (Ghiffari, 2020). Not only that, this study discovered that the PSBB also succeeded in reducing the concentration of NO_2 gas in the air. Several studies in other cities revealed the same results where the NO_2 level during the PSBB period significantly reduced (Feng et al., 2023; Parhusip et al., 2022; Mijani et al., 2023; Purwanto et al., 2022). The reduction in NO_2 levels in vehicles by 25.9% was almost the same as the reduction that occurred in Wuhan, China, Spain, France, Italy, and America (Mijani et al., 2023). Like the LST, the concentration of NO_2 in the air is influenced by more than 70% of meteorological conditions (He et al., 2017), such as rainfall and wind speed. The heavier the rain, the less NO_2 in the air because the rain washes the air column so that pollutant gases will flow with the rainwater (Serlina, 2020). Wind speed is also negatively correlated with NO_2 levels in the air, where strong winds can clean the air column by moving the pollution to the other areas (Serlina, 2020).

Figure 7 shows the concentration of NO_2 pollutant gas in Kendari City in the range of 1.01×10^{-5} to 1.69×10^{-5} mol/m^2. This value is still relatively low when compared to the average NO_2 level in Bali (Sunarta et al., 2022) and Bekasi (Parhusip et al., 2022). Even so, the people of Kendari City still need to be aware of reducing NO_2 gas emissions before the increase becomes more significant and dangerous. Real action that can be taken is to reduce the use of motorized vehicles and replace them with walking, cycling, or using public transportation. Another action is adding a green area that is useful for absorbing air pollution. Urban development that occurs continuously must be balanced with an awareness of maintaining urban air quality. Other cities continue to grow, but the air quality is worsening. Learning from that experience, I believe the city of Kendari must grow better. The emergence of the COVID-19 outbreak has provided an opportunity to restore the environment.

CONCLUSION

Land Surface Temperature (LST) trends in the urban area of Kendari City and the buffer zones (Ranomeeto, Lalonggasumeeto, and North Moramo Sub-District) show the same patterns before and after the COVID-19 pandemic. The trend indicates that the effect of reducing community activities during the pandemic (in the form of PSBB policy) was not able to reduce surface temperature but managed to inhibit the increase rate. The temperature increase during the PSBB period in Kendari city's urban areas by 0.7°C is smaller than the increase in the buffer zone by 1.2°C. It was found that the rainfall factor contributed more to land surface temperature trends. This statement can be seen from the fact that there was less rainfall during the PSBB period than before the PSBB period, which caused warmer land surface temperatures during the pandemic.

The Kendari City shows the effect of Urban Heat Island before, during, and after the PSBB, which is indicated by the average surface temperature being higher than the buffer areas. However, this effect seems to have been highest before the pandemic (2019) with the Surface Urban Heat Island (SUHI) value of 2.5°C. The SUHI value then continued to fall in the following period. This downward trend proves that the PSBB policy did not significantly affect Urban Heat Island in Kendari but successfully suppressed the effect.

The most significant impact of limiting activities during the pandemic in Kendari City can be seen from the concentration of the pollutant gas Nitrogen Dioxide (NO_2). The concentration of NO_2 gas during the PSBB period decreased by 25.9% compared to the previous period (2019), while the difference with the post-pandemic period was also quite large at 45.0%. This significant value proves that the level of air pollution in Kendari City (seen from NO_2 gas) has decreased during the period of activity restrictions during the COVID-19 pandemic.

In the end, restrictions on community activities during the COVID-19 pandemic succeeded in reducing the increased rate of surface temperatures, suppressing the Urban Heat Island effect, and, most importantly, significantly reducing the concentration of NO_2 pollutant gas. The COVID-19 pandemic has restored environmental health, and people are continuously exposed to air pollution through un environmentally friendly activities.

ACKNOWLEDGMENT

There are still many meteorological elements and other pollutant gases that can illustrate how the COVID-19 pandemic can restore environmental health. It is hoped that this study can be carried out in other cities because each city has its characteristics that may provide different results.

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