The Impact of COVID-19 Outbreak on Air Quality in Thailand.

Nutnaree Thongrueang* ・ Tomoki Nakaya*・Narumasa Tsutsumida**

Abstract: COVID-19 was first identified in China and has become a pandemic affecting many countries in the world. The government of Thailand had taken a strict ban on the movement of people and travel restrictions during the lockdown. Even though the lockdown was implemented for a short term, it had impact on the reduction of emissions from transport, industrial and other human activities. Therefore, this study aims to examine the association of air pollutants changes with human activities during the lockdown in Thailand. We firstly collect relevant data including night-time light satellite images as an indicator of human activities, and observations of air pollutants when the first lockdown was implemented. Further, using Sentinel-5P satellite observation, we examined the changes in air pollutants levels such as NO_2 and CO during lockdown as compared to air quality levels of the same periods in 2019. Finally, we applied GWR to examine the regional associations between the changes in air pollutants and human activities.

Keywords: GWR, lockdown, Sentinel-5P, Suomi NPP

１． Introduction

COVID-19 was first identified in Wuhan, China and is now a pandemic affecting many countries globally. The World Health Organization (WHO) declared the disease as pandemic on March 11, 2020 (Cucinotta and Vanelli, 2020). Globally, as of 12 June 2021, there have been 174,918,667 confirmed cases of COVID-19, including 3,782,490 deaths according to WHO. (covid19.who.int).

Most of the countries took the non-pharmaceutical including lockdown to reduce the risk of spreading and safe human health and life. Government of Thailand announced a lockdown starting midnight of March 26, 2020, putting its 68 million citizens inside their homes. There was a strict ban on the movement of people during this lockdown and activities such as public transport, shut down schools, colleges, and universities, as well as reduced local business travel and closing of businesses and non-essential activities.

Regarding air pollution situation in Thailand before the COVID-19 pandemic, the main air pollution contributors were power plants, factories, motor vehicles, forest fires, agricultural burning and open cooking. In the rural area, biomass burning including agricultural burning and forest fires was an important contributor to poor air quality (World bank,2002). Biomass burning leads towards the emission of greenhouse gases, smoke, particulates matter and air pollutants that affect to human health. (Arbex et al. ,2004). Due to the COVID-19 lockdown, such anthropogenic industrial, vehicular, and other commercial energy-consuming activities were restricted (Jain and Sharma, 2020).

To study how the COVID-19 affects the environments, we focused on the concentrations of CO and NO_2 in the air because the change of CO and NO_2 concentration was strongly linked to transportation emissions and these are common indicators of local air pollution exposure at various scales (Levy et al., 2014). More specifically, we will investigate the observations of air pollutants around the period from March 18, 2020to June 30, 2020 when the first lockdown and curfew was

* Graduate School of Environmental Studies, Tohoku university, email to nutnaree.thongrueang.s2@dc.tohoku.ac.jp
** Department of Information and Computer Sciences, Graduate School of Science and Engineering, Saitama University, Japan

implemented in Thailand due to the controlling transmission of COVID-19 pandemic. Then, we apply Geographically Weighted Regression (GWR) (Fotheringham et al., 2003) to examine the regional association between the changes in air quality and human activities by using the change of nightlight intensity.

2. The study area

The present study was conducted in Thailand, with 77 provinces and a population about 68 million and land area of 513,120 square kilometers. Geographically it lies between the latitude 5.37 ° N to 20.25 ° N and longitude 97.22 ° E to 105.37 ° E (Figure 1).

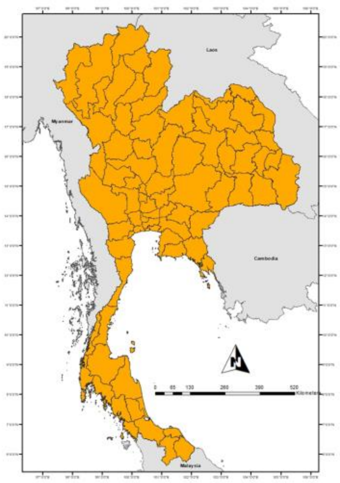

Figure 1. The study area, Thailand.

3. Air pollution reduction policies across Thailand (Lockdown).

Lockdown measures were implemented in varying degrees throughout the country, with public venues and businesses ordered to close. The public has cooperated relatively well with health advisories, and the country's robust public health infrastructure has been credited as a contributing factor to its relatively successful initial response. Easing of restrictions was gradually implemented from mid-May. The curfew was lifted in July and schools reopened in August. However, the state of emergency remained in effect.

4. Materials and methods

4.1 Data source and data preparation.

The NO_2 and CO data were derived from the TROPOspheric Monitoring Instrument (TROPOMI) onboard the Sentinel-5P satellite observation, and we used the Google Earth Engine (GEE) platform.

Sentinel-5P is a single satellite mission, as a part of the Global Monitoring for Environment and Security (GMES/Copernicus) program launched by the European Space Agency (ESA). Copernicus Sentinel-5P monitors the density of several atmospheric gases, aerosols, and cloud distributions affecting air quality and climate. The measurements are made by the new instrument called TROPOspheric Monitoring Instrument (TROPOMI). The TROPOMI is a multispectral imaging spectrometer that detects solar radiation reflected or scattered back to space from Earth's atmosphere and surface by providing timely measurements of atmospheric composition (Veefkind et al., 2012). Featuring a higher spatial resolution than its predecessors, of 7 × 3.5 km2 (along and across track), it offers a new potential for air quality research, making it suitable for polluting emission sources monitoring (Ialongo et al., 2020).

Night-Time Light data were collected from the Suomi National Polar-orbiting Partnership (Suomi-NPP) satellite observation, and we also used GEE platform with Java script API capability for the analyses. The Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB), sourced from the Suomi National Polar-orbiting Partnership (Suomi-NPP) satellite of the National Aeronautics and Space Administration (NASA)/National Oceanic and Atmospheric Administration (NOAA), provides multi-temporal night-time light data, which allows near-real-time monitoring because of its high repeat frequency (Elvidge et al.,2013). For this study, we used VIIRS-DNB Composites Version 1 data, which are the monthly average radiance composites. A composite VIIRS-DNB data were obtained from all collected VIIRS-DNB data in 2019 and 2020 using the median reducer in GEE to eliminate the maximum value of nighttime light and obtain more stable nighttime light data. Finally, the average DNB radiance values (avg_rad) were selected from the composite VIIRS-DNB data.

4.2 Estimation of air pollution emission and the relationship with human activities.

The entire Thailand have been selected for evaluating the effect of lockdown on air quality. Sentinel-5P and Suomi-NPP satellite remote sensing were utilized for evaluating the effects of lockdown period on the air quality levels in Thailand. For comparison purposes, the satellite-based air pollution was measured from March 18 to June 30 for both 2019 (before lockdown period) and 2020 (during lockdown period) when the first lockdown was implemented in Thailand. The concentrations of two key air pollutants, nitrogen dioxide (NO_2) and carbon monoxide (CO) were computed for both 2019 and 2020 using Sentinel-5P data. Night-Time Light data were used to examine the regional association between the changes in air quality and human activities. Annual concentrations of NO_2 and CO measures are provided by GEE. These pollution concentrations are reported at the level of 7km ×7 km grid-cells. The changes between 2019 and 2020 of each air pollutant were calculated following Percentage Change Formula by using Map Algebra (Raster Calculator) to perform geographic analysis. The relationship between air pollutants (CO and NO_2) and night-time light data as an indicator of human activities were explored by geographically weighted regression (GWR) to quantify regionally varying effects of the reduction of human activities on air pollutant concentrations during the pandemic outbreak phase across Thailand. We used the scalable variant of GWR for a large-sized data (Murakami et al., 2021), which is available in the R package of GWmodel.

5. Results

5.1 CO level changes in Thailand.

The comparison of daily CO values (mol/m^2) should deserve special interest to see the overall change between 2019 and 2020. In 2020, the decline can be seen in minimum, maximum and average CO with 0.02826 mol/m^2, 0.04469 mol/m^2 and 0.03887 mol/m^2, respectively, compared to the year before the pandemic. The minimum, maximum and average CO of 2019 were 0.02919 mol/m^2, 0.04582 mol/m^2, and 0.03976 mol/m^2. A significant decline was observed in June 2020 with the minimum value of 0.02826 mol/m^2 (Figure 2).

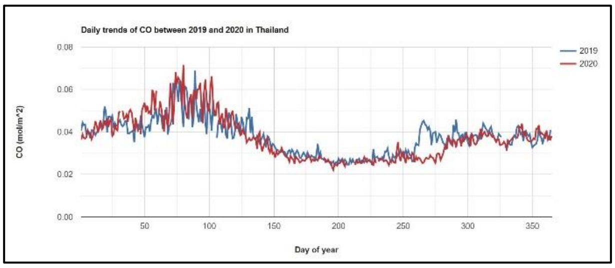

Figure 2. Daily trends of CO between 2019 and 2020 in Thailand.

5.2 NO_2 level changes in Thailand.

Through the comparison of daily NO_2 values (mol/m^2*10^5) between 2019 and 2020, the decreased levels during the pandemic were observed; the minimum, maximum and average NO_2 were 3.785 mol/m^2*10^5, 13.910 mol/m^2*10^5, and 5.437 mol/m^2*10^5, respectively, compared to the year before the pandemic. The minimum, maximum, and average NO_2 of 2019 were 3.826 mol/m^2*10^5, 14.664 mol/m^2*10^5, and 5.639 mol/m^2*10^5, respectively. A significant decline was observed in January 2020 with the minimum value of 3.826 mol/m^2*10^5 (Figure 3).

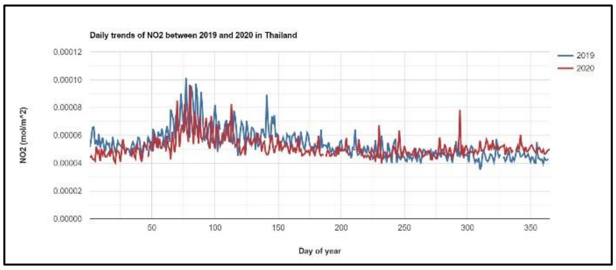

Figure 3. Daily trends of NO_2 between 2019 and 2020 in Thailand.

5.3 The percentage change of annual average of CO and NO_2 in two period (before/during COVID-19)

The results indicated that the annual average values of CO, and NO_2 concentrations in 2020 decreased from those in 2019 by 2.26%, and 3.58%, respectively (Figures 4 and 5).

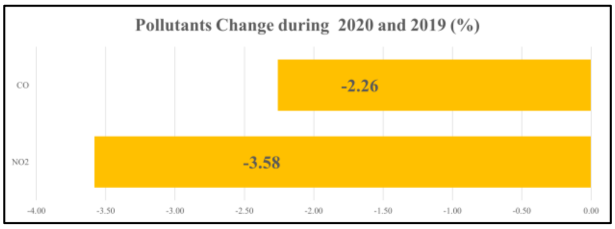

Figure 4. The percentage change of CO and NO_2 in 2020 from 2019.

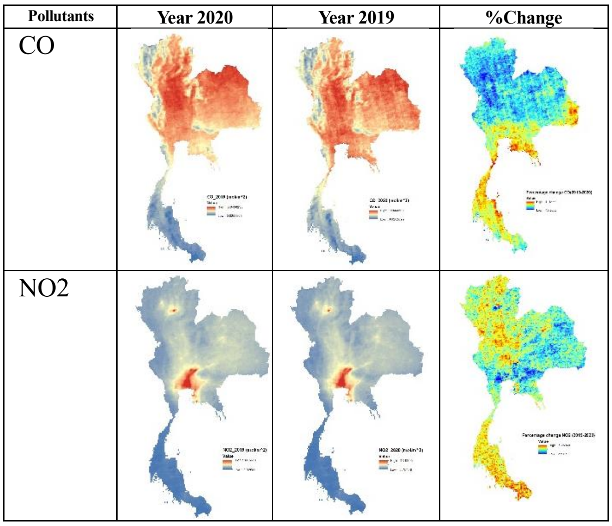

Figure 5. The spatial distribution map of the change of CO and NO_2 in 2020 compared to 2019.

Furthermore, we made the same comparison by considering the detailed periods of lockdown (March 18,2020 to June 30,2020) and the same period in 2019. The results showed that CO and NO_2 concentrations dropped by 0.32% and 10.28%, respectively, during lockdown compared to the same period in 2019 (Figures 6 and 7).

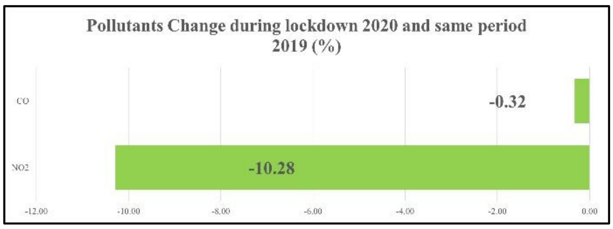

Figure 6. The percentage change of CO and NO_2 during the lockdown period in 2020 compared to the same period in 2019.

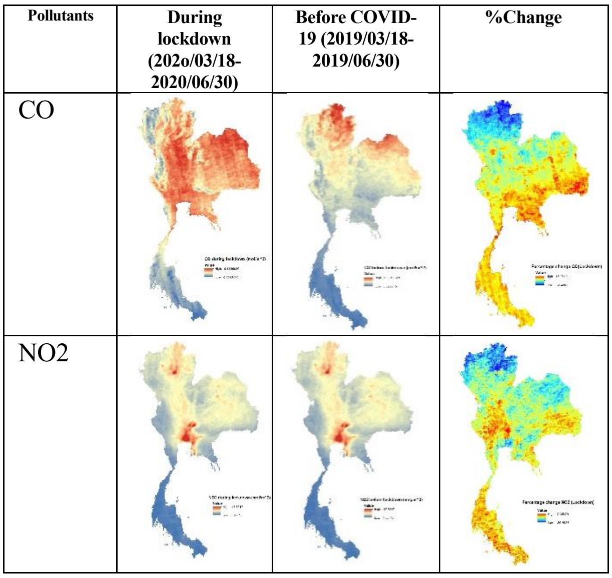

Figure 7. The spatial distribution map of the change of CO and NO_2 during the lockdown period compared to the same period in 2019.

The reduction proportions of NO_2 were most salient in the central part of Bangkok which has the main shopping, dining, and nightlife hubs of the city areas.

5.4 The association between night-time light and CO levels

We observed positive relationships between of the annual log-transformed night-time light and log-transformed CO levels, according to correlation coefficients between the variables; $r = 0.119$ for the year of 2019 and $r = 0.2149$ for that of 2020. For the lockdown period, the relationships between the variables were almost zero; $r = -0.0832$ for the period in 2019 and $r = 0.0714$ for that in 2020.

Using the annual change of logtransformed CO level as the dependent variable and logtransformed night-time light as the independent variable, we fit a GWR model to the data. The result of the GWR model showed that there were dominantly negative associations between the annual changes in night-time light and CO levels in the western and northern part of Thailand, while positive associations in southern and Northeastern part of the country (Figure 8).

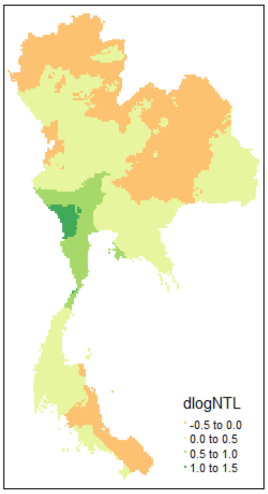

Figure 8. The GWR estimated coefficients of the annual change of night-time light between 2019 and 2020 to predict the annual change of CO level between 2019 and 2020.

5.5 The association between night-time light and NO_2 levels

Compared to the case of CO, we observed clearer positive relationships between of the annual log-transformed night-time light and log-transformed NO_2 levels, according to correlation coefficients between the variables; r = 0.547 for the year of 2019 and r = 0.488 for that of 2020. For the lockdown period, the correlation coefficients were r = -0.313 for the period in 2019 and r = 0.354 for that in 2020.

Using the annual change of logtransformed NO2 level as the dependent variable and logtransformed night-time light as the independent variable, we fit another GWR model to the data. The result of the GWR model showed that there were dominantly negative associations between the annual changes in night-time light and CO levels in the northern and central western parts of Thailand, while positive associations in southern and eastern part of the country (Figure 9).

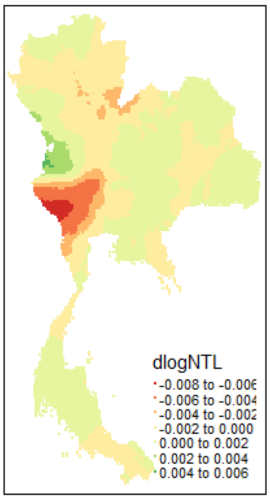

Figure 9. The estimated coefficient of night-time light variable and NO_2.

6. Discussion

In the whole of Thailand, the percentage change of CO values deceased by 2.26% during the COVID-19 pandemic. During the lockdown, the percentage change CO values dropped by 0.32% during the COVID-19 lockdown to compare with the same period in 2019. However, there was quite weak correlations between night-time light and CO in our study periods. Furthermore, GWR showed the negative correlation between night-time light variable and CO in the western and northern Thailand. Besides, positive correlation was found in southern and Northeastern Thailand.

For NO_2 level, the percentage change NO_2 values deceased by 3.58% during the COVID-19 pandemic. During the lockdown, the percentage change NO_2 values dropped by 10.28% during the COVID-19 lockdown to compare with the same period in 2019. Moreover, there was a positive correlation between night-time light and NO_2. Besides, the result of GWR indicated that there is negative correlation between night-time light and NO_2 in the northern part of Thailand. Moreover, the results showed that the positive relationship is in the central and eastern Thailand.

As the results of above mentioned, remote sensing of nighttime light emissions offers a unique perspective for investigations into some of these human behaviors which affect air pollutants. For example, the transportation emissions and an indicator of local air pollution exposure on a wide scale (Levy et al., 2014) However, there are CO and NO_2 sources emissions that do not come from transportation and human daily activities. In northern Thailand, there are power plants and forest fires that cause NO_2 emissions (World bank,2002). The combustion of charcoal fuel, which is commonly used in northern Thailand, causes pollution from sulfur dioxide (SO_2), carbon monoxide (CO) and nitrogen dioxide (NO_2) (College of Public Health Sciences, 2001). For example, the extreme air pollution that was emitted from the Mae Moh Power Plant in Lampang province, Thailand in 1992 and 1997 (Pollution Control Department, 2000) affected human health and property, animals, and plants in the surrounding area. Therefore, we recommend investigating the relationship of air pollutants level with other contributing factors for further studies, such as other meteorological factors, and other human activities.

Although we observed the decline of NO_2 level during the COVID-19 pandemic as expected, there are still several limitations in this study. We use Sentinel-5P (CO and NO_2 dataset) datasets which are only available on Google Earth Engine platform starting from July 2018, longer time-scale studies cannot be implemented to prove if the CO and NO_2 decline during pandemic is seasonal or not. Only comparison of monthly mean CO and NO_2 emission of 2019 and 2020 can be made in this study. Moreover, we recommend investigating the relationship of CO and NO_2 level fluctuation with other contributing factors for further studies, such as other meteorological factors, and regional transport of pollutants.

References

Arbex, Marcos Abdo, et al. *"Biomass burning and its effects on health."* Jornal Brasileiro de Pneumologia 30 (2004): 158-175.

College of Public Health Sciences. "*The Study of Effect of Air Pollution on Health in Mae Moh District Lampang Province*." Department of Health, Ministry of Public Health, Bangkok, Thailand (2001) (in Thai).

Cucinotta, Domenico, and Maurizio Vanelli. "*WHO declares COVID-19 a pandemic.*" Acta Bio Medica: Atenei Parmensis 91.1 (2020): 157.

Elvidge, Christopher D., et al. "*Why VIIRS data are superior to DMSP for mapping nighttime lights.*" Proceedings of the Asia-Pacific Advanced Network 35.0 (2013): 62.

Fotheringham, A. Stewart, Chris Brunsdon, and Martin Charlton. "*Geographically weighted regression: the analysis of spatially varying relationships*." John Wiley & Sons, 2003.

Ialongo, Iolanda, et al. "*Comparison of TROPOMI/Sentinel-5 Precursor NO $_2$ observations with ground-based measurements in Helsinki.*" Atmospheric Measurement Techniques 13.1 (2020): 205-218.

Jain, Suresh, and Tanya Sharma. *"Social and travel lockdown impact considering coronavirus disease (COVID-19) on air quality in megacities of India: present benefits, future challenges and way forward."* Aerosol and Air Quality Research 20.6 (2020): 1222-1236.

Levy, Ilan, et al. "*Evaluating multipollutant exposure and urban air quality: pollutant interrelationships, neighborhood variability, and nitrogen dioxide as a proxy pollutant.*" Environmental health perspectives 122.1 (2014): 65-72.

Murakami, Daisuke, et al. *"Scalable GWR: A linear-time algorithm for large-scale geographically weighted regression with polynomial kernels."* Annals of the American Association of Geographers 111.2 (2020): 459-480.

Pollution Control Department. "*Situation of Air Pollution in Decades on Thailand. Bangkok, Thailand*." (2000) http://www.pcd.go.th/public/Publications/print_report.cfm?task=report2543 (30 August 2021)

Veefkind, J. P., et al. "*TROPOMI on the ESA Sentinel-5 Precursor: A GMES mission for global observations of the atmospheric composition for climate, air* *quality and ozone layer applications.*" Remote sensing of environment 120 (2012): 70-83.

WHO coronavirus disease (COVID-19) dashboard. Geneva: World Health Organization; 2020 https://covid19.who.int/ (12 June 2020)

World Bank, *"Thailand Environment Monitor"*, World Bank, Bangkok, (2002).