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Effect of COVID-19 Movement Control Order Policy on Water Quality Changes in Sungai Langat, Selangor, Malaysia within Distinct Land Use Areas

(Kesan Dasar Perintah Kawalan Pergerakan COVID-19 terhadap Perubahan Kualiti Air di Sungai Langat, Selangor, Malaysia dalam Kawasan Guna Tanah Berbeza)

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ABSTRACT

For the first time in the 21st century, many nations have been forced to conduct a lockdown that restricts their industrial, transportation, and social activities to avoid the extensive COVID-19 spread. Therefore, our study aimed to analyze the status of water quality that was measured by suspended particulate matter (SPM) in Sungai Langat, Selangor, Malaysia using the remote sensing technique. The study was concerned with rivers located in distinct land-use areas such as high-density urban, low-density urban, and agricultural areas. The study period included before and after movement control order (MCO) periods that occurred in February 2020 and February 2021, respectively. The SPM levels in each period were calculated using the remote sensing technique through Landsat-8 OLI images then they were analyzed using statistical analysis. The results of the remote sensing technique showed the highest decrease of SPM levels during the MCO period was observed in Sungai Langat within a high-density urban area (34.1%). Then, the SPM levels in all Sungai Langat raised significantly after the MCO period with the highest change at 31.6%. Rainfall and erosion factors had a significant impact on the SPM level through natural processes but the COVID-19 restriction had a direct impact on the SPM level due to the restriction of industrial and social activities. The suspended activities have made the lower emission compared with before the COVID-19 period in 2019.

Keywords: COVID-19; lockdown remote sensing; river quality; soil loss

ABSTRAK

Buat pertama kalinya dalam abad ke-21, banyak negara telah terpaksa melakukan penutupan yang menyekat aktiviti perindustrian, pengangkutan dan aktiviti sosial untuk mengelakkan penularan COVID-19 secara meluas. Oleh itu, kajian ini bertujuan untuk menganalisis status kualiti air yang diukur dengan bahan zarahan terampai (SPM) di Sungai Langat, Selangor, Malaysia menggunakan teknik penderiaan jauh. Penyelidikan ini dijalankan di sungai yang terletak di kawasan guna tanah yang berbeza seperti kawasan bandar berkepadatan tinggi, bandar berkepadatan rendah dan kawasan pertanian. Tempoh kajian ialah sebelum dan selepas tempoh perintah kawalan pergerakan (MCO) pada Februari 2020 dan Februari 2021. Kepekatan SPM dalam setiap tempoh tersebut dianalisis menggunakan teknik penderiaan jauh melalui imej Landsat-8 OLI kemudian dianalisis menggunakan analisis statistik. Hasil kajian menunjukkan penurunan tertinggi kepekatan SPM dalam tempoh MCO ditemukan di Sungai Langat dalam kawasan bandar berkepadatan tinggi (34.1%). Kemudian, kepekatan SPM di keseluruhan Sungai Langat meningkat dengan signifikan selepas tempoh MCO dengan perubahan tertinggi iaitu 31.6%. Faktor jumlah hujan dan hakisan tanih memberi kesan yang besar kepada kepekatan SPM dalam sungai melalui proses semula, tetapi aktiviti MCO di kawasan kajian telah memberi kesan langsung kepada kepekatan SPM disebabkan oleh sekatan aktiviti perindustrian dan sosial. Aktiviti yang dihentikan telah menjadikan pelepasan bahan buangan yang lebih rendah berbanding sebelum tempoh COVID-19 pada tahun 2019.

Kata kunci: COVID-19; hakisan tanih; kualiti sungai; penderiaan jauh

INTRODUCTION

Based on the last report in February 2020, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) or known as COVID-19 has struck more than 200 nations around the world. Currently, the world was facing the second wave of COVID-19 and the wave is stronger than the first wave, the most confirmed cases, and casualties are being reported in India, Malaysia, and Singapore. These countries are now forced to perform a tight nationwide lockdown. Several studies have identified that the COVID-19 spread rapidly from person to person through respiratory droplets from the infected person or contact with objects that have already been contaminated by the infected person (Azuma et al. 2020; Zhou et al. 2021). In Malaysia, the first local transmission has been reported on February 6, 2020, then, since that day, the new cases significantly increase in the following weeks thus, the prime minister finally announces a nationwide lockdown on March 16, 2020.

Previous studies have agreed that anthropogenic activities are one of the primary contributors to pollution in our surroundings (Lian et al. 2018; Ravindra et al. 2020). Since industrial, commercial, transportation, and social activities are suspended for weeks, it is estimated that the mass of pollution to the environment will drop. The hydrosphere is one of the vulnerable subsystems on the planet earth. Thus, the status of pollution in the hydrosphere such as rivers, lakes, seas, and water bodies is prominent to be investigated. In the past few years, this sphere has been seriously contaminated due to industrial, development, agriculture, and urbanization activities. Many studies have analyzed the status of pollution in the hydrosphere all over the world. Chakraborty et al. (2021) reported that during the lockdown, the total nitrogen and phosphate have been diminished in the river in eastern India. Najah et al. (2021) also found the main industrial and domestic effluents that deteriorate a river ecosystem such as industrial wastewater, oil, fats, sludges, and plastics have been greatly minimized during the lockdown period. Recent studies have found that there is an improvement in water quality during the lockdown period in some countries such as Turkey (Tokatlı & Varol 2021), China (Qiu et al. 2020), and Nepal (Pant et al. 2021). But, these improvements of the environmental pollutions may just temporary state, they may escalate when the lockdown policy is revoked. The recent status of environmental pollution especially during the lockdown period is a prominent factor for analyzing the impact of the COVID-19 transmission on the environment within a certain period. Therefore, the remote sensing technique is widely used to monitor the changes in the environment. The technique has some advantages because it can be used in large coverage areas and give up-to-date conditions (Dong 2018).

However, if we analyze scrupulously in previous studies, a new study that considers the water quality within different land-use types in a one river course is still not investigated. Also, the association between the water quality and soil erosion rate in a particular watershed area is an important factor to be studied. Because the soil erosion rate parameters such as rainfall, erodibility of soil, length of the slope, land cover, and support practice can affect the water quality through the sedimentation transport process. Therefore, this current study would like to analyze the status of river water pollution in Sungai Langat, Malaysia which was divided into three main zones such as high-density urban, low-density urban, and agricultural areas during the COVID-19 lockdown period, and to examine the soil erosion rate parameters that affect the status of water quality. Because in this study we used the remote sensing technique thus, the concentration of suspended particulate matter (SPM) was chosen as an indicator of river water pollution.

MATERIALS AND METHODS

STUDY AREA

We select Sungai Langat that located in the Selangor region as our study area to evaluate its water quality (Figure 1). Sungai Langat is one of the longest river of Malaysia. The water flows from the upstream area in Hulu Langat to Kuala Selangor at the downstream area where Sungai Langat becomes the main river in the basin which flows in a southwesterly direction and drains into the Straits of Malacca. The main river course length is about 141 km, mostly situated around 40 km east of Kuala Lumpur. Sungai Langat has a total catchment area of approximately 1,815 km^2 and is formed by 15 sub-basins (Juahir et al. 2011).

In this study, we divided Sungai Langat into three different zones based on land use types. The first zone located upstream, Sungai Langat passes through Kajang city, one of the highest populations in the state of Selangor (>300,000 people), Malaysia, and one of a hotspot for COVID-19 cases. In the second and third zones located downstream, Sungai Langat passes through Kampung Labohan Dagang district with the lower population area (<100,000 people), and Sungai Langat passes through agricultural areas such as oil palm plantation. Excessive anthropogenic activities, discharge of industrial waste, domestic waste, illegal sewage release, and exposed river sites are some of the main causes of deterioration of common river water quality.

Selangor is presently the first most COVID-19 hit state of Malaysia having a total of 116,000 positive cases as of 27th April 2021. Malaysia goes firstly under a nationwide lockdown (Movement Control Order) on March 18th, 2020. During this period, the authority ordered the closure of much of the public activities including educational institutions, industries, malls, and national parks. Since then all the industrial, agricultural, and social activities came to a halt, and hence, the pollutant level due to these sources declined. Therefore this is a unique opportunity to study the water quality of Sungai Langat before MCO, during MCO, and after MCO periods.

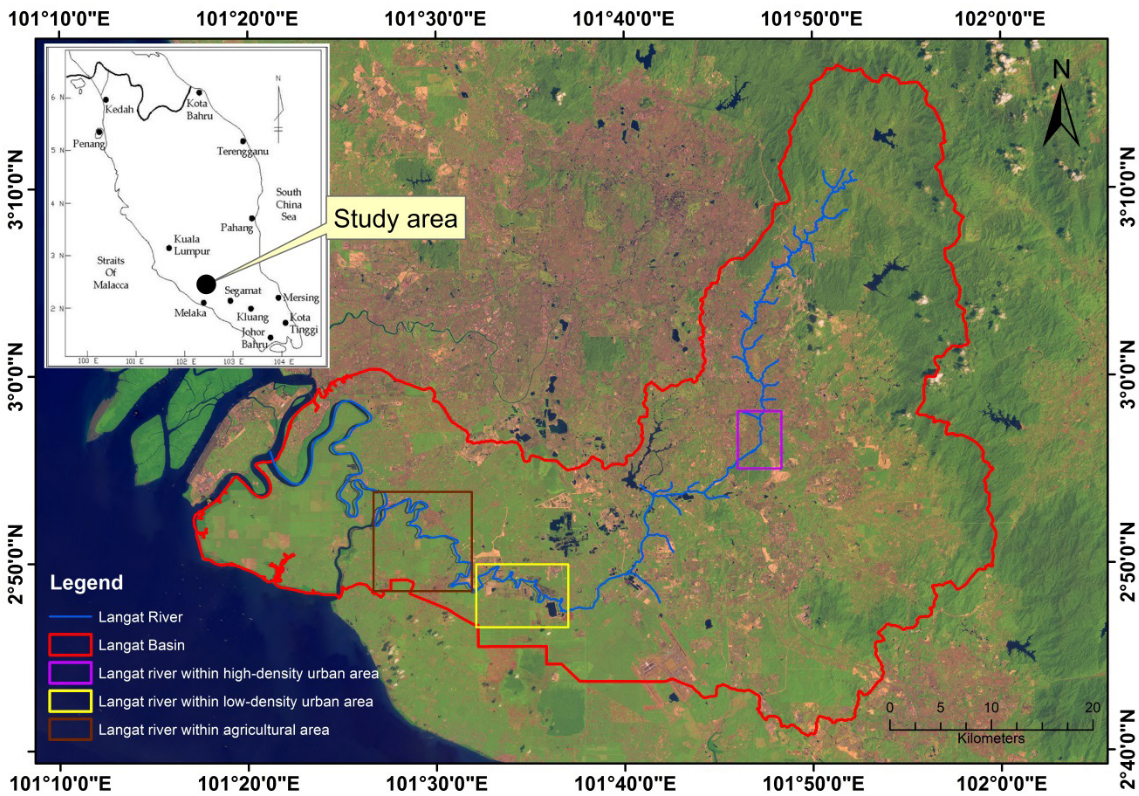

FIGURE 1. Location of Sungai Langat in Selangor, Malaysia

ACQUISITION OF LANDSAT-8 OPERATIONAL LAND IMAGER (OLI) AND PREPROCESSING

A total of 8 Landsat 8 OLI images (Path/Row: 127/58) of Sungai Langat, from November 2019 to February 2021, were downloaded to be used in this study. The 30 × 30 meters spatial resolution of the Landsat 8 images were acquired from the United States Geological Survey (USGS) website (www.earthexplorer.usgs.gov). The images had a type of level-2 Landsat image and have a good quality, meaning that they underwent a substantial improvement in the absolute geolocation accuracy of the global ground reference dataset. They have also been updated in terms of global digital elevation modeling sources and calibration and validation updates. The percentage of cloud cover in all images was ranged from 3% to 7%, indicating the sky was almost no cloud thus it can possibly conduct the image analysis accurately. The ArcGIS software Ver. 10 was used for pre-processing the satellite images using the formula as shown in Equation (1). This equation performs the first conversion of raw digital numbers (DN) to radiance values (using gain and bias values), then converts these radiance values to TOA reflectance values (using distance between the sun and earth in astronomical units, and solar zenith angle).

$$\rho_\lambda' = M_\rho Q_{cal} + A_\rho \quad (1)$$

where, ρ_λ' is the TOA reflectance with a correction for the sun angle, M_ρ Band-specific multiplicative rescaling factor from the metadata (Reflectance_Mult_Band_x, where x is the band number), A_ρ is Band-specific additive rescaling factor from the metadata (Reflectance_Add_Band_x, where x is the band number), Q_{cal} is Quantized and calibrated standard product pixel values (DN).

$$\rho_\lambda = \frac{\rho\lambda'}{\cos(\theta SZ)} = \frac{\rho\lambda'}{\sin(\theta SE)} \quad (2)$$

where ρ_λ = TOA planetary reflectance, θ_{SE} = Local sun elevation angle, θ_{SZ} = Local solar zenith angle; $\theta_{SZ} = 90° - \theta_{SE}$. After the preprocessing stage finished, we needed to remove the effect of land in the pixel, thus, we conduct a digitization process using ArcGIS software to create the shapefile of the river (river's boundary). So, we can easily extract only a body of a river from Landsat images.

SUSPENDED PARTICULATE MATTER (SPM) FROM SATELLITE-BASED DATA

In a previous study, Juahir et al. (2011) measured *in situ* SPM at the downstream area of Sungai Langat and reported that it was about 21.8 mg/L. In another study, Heng et al. (2006) showed that the *in situ* SPM measured in the upstream area of the river ranged between 12.7 mg/L and 18.7 mg/L. Both aforementioned studies suggested that the turbidity level in Sungai Langat is < 110 mg/L throughout the year. Therefore, we used a single band empirical algorithm to retrieve the SPM concentrations for waters as the SPM value is below the range of 110 mg/L. The SPM is computed from water-leaving reflectance of the red band (655 nm) using the following equation (Nechad et al. 2010):

$$\text{SPM} = \frac{A\rho w}{(1-\rho w)/C} \quad (3)$$

where ρ_W is water-leaving reflectance from the red band (655 nm); A and C are empirical coefficients: A = 289.29 and C = 0.1686. The performance of equation (3) is validated with SPM measurement from field activity. Therefore, we have used Pearson's correlation coefficient (R^2), mean absolute error (MAE), and root means square error (RMSE) analyses in this study. Our results find the values of R^2 is 0.90, MAE is 0.05, and RMSE is 0.09, indicating the good performance thus SPM values from satellite-based data can be applied for this study.

SOIL EROSION RATE ANALYSIS

The total soil erosion rate in the study area was estimated using the Revised Universal Soil Loss Equation (RUSLE) method by Wischmeier and Smith (1978). The formula was expressed in equation (4) herewith.

$$A = R \times K \times LS \times C \times P \quad (4)$$

where A was a total soil erosion rate (ton/ha.yr); R is a rainfall erosivity factor (MJ.mm/ha.yr); K is a soil erodibility factor (ton.ha) (ha.hr/MJ.mm); LS is a slope length (meter); C is a crop and management factor; and P is a support practice factor. Support practice (P) factor indicates the conservation and management practices like terracing or contouring that are found in the study area (Yusof et al. 2021). Furthermore, it is the link between the specific land management (i.e. terracing or contouring) with the soil erosion rate. P factor values are determined based on the latest land use map from Morgan (2005) and Department of Irrigation and Drainage (2010) where the urban, sub-urban, and agriculture areas have P values of 1.0, 0.7, and 0.4, respectively.

RESULTS

EFFECT OF MCO POLICY ON SPM CONCENTRATION

Figures 2-4 showed the distribution of SPM concentration in Sungai Langat that was located in different land-use types. These figures showed the SPM level during the MCO period as compared to before MCO period and 2019 period. The 5th February to 24th March 2020 SPM maps were dominated by yellow to brown colors (Figures 1-2), indicating a high SPM level, and green to dark blue colors (Figure 4), indicating a low SPM level. The great low SPM was observed in Sungai Langat within the high-density urban area, where on the 24th March 2020 SPM map had dark blue to green tones appearing in almost all entire river courses (Figure 2). While Sungai Langat (low-density urban area and agricultural area) also showed dark blue to green tones but they only appeared in eastern, and southeastern river courses that flow through the residential and industrial areas, indicating lower SPM levels (Figures 3-4). The dark blue to green tones appearing on 24th March 2020 SPM maps showed a progressive MCO policy which leads to low SPM levels in the river.

For quantitative analysis, the SPM concentration in Sungai Langat has been tabulated in Tables 1-2. The decreased SPM level during the MCO period has been recorded in all Sungai Langat. The highest decrease of

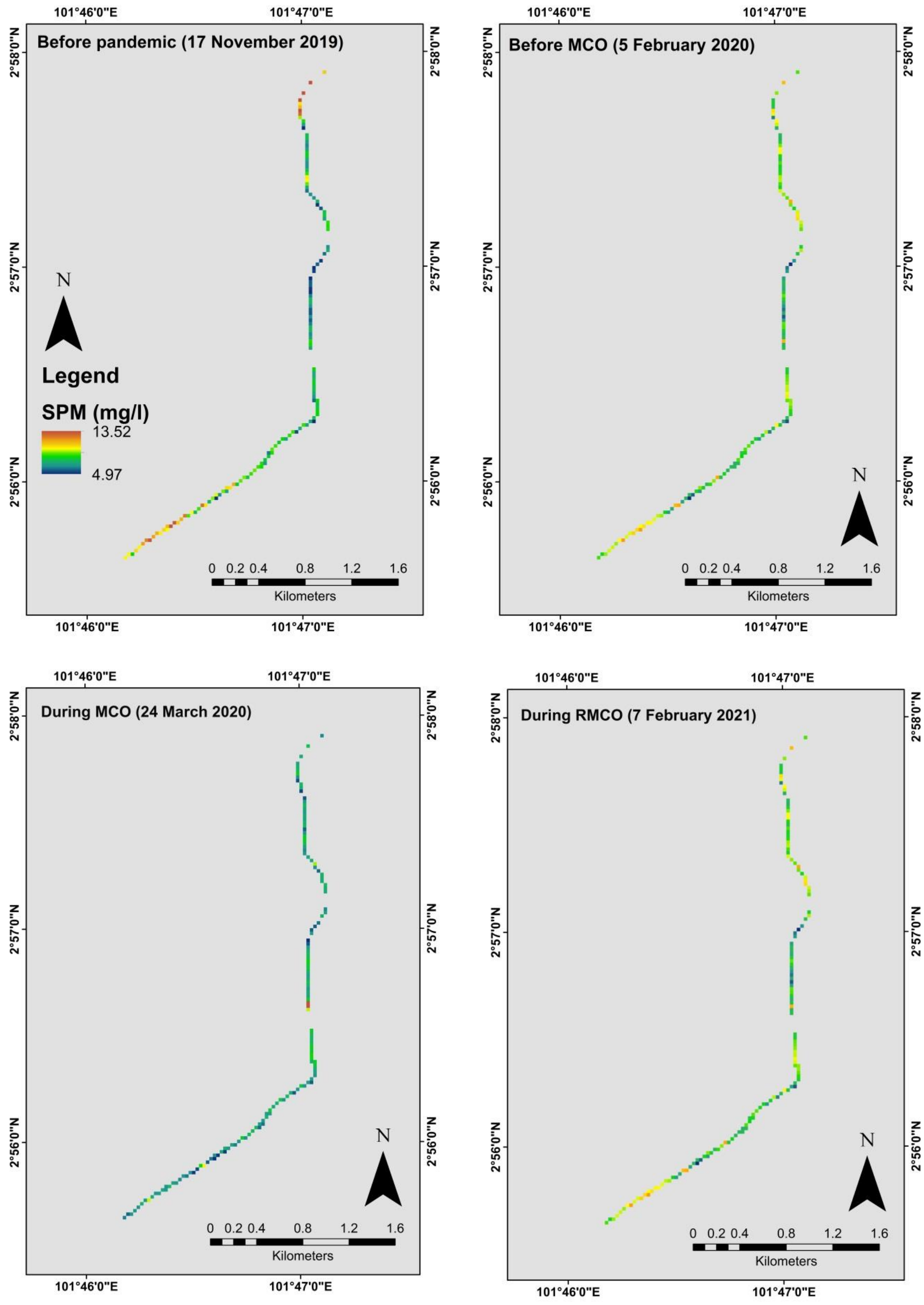

FIGURE 2. Suspended particulate matter (SPM) concentrations estimated for Sungai Langat within a high-density urban area in 2019, before MCO, during MCO, and after MCO periods

SPM level was observed in Sungai Langat within the high-density urban area (34.1%), followed by Sungai Langat within the agricultural area (22.2%), and Sungai Langat within the low-density urban area (9.5%) (Table 1). It indicated the implementation of MCO has resulted in the decline of SPM concentration in all Sungai Langat. As a whole, this suggested a major decline of 34.1% in SPM concentrations during the MCO period as compared with before the MCO period, while a decrease of 36% as compared to the previous year. After the MCO period, our result found there was a great increase of SPM level that recorded in Sungai Langat within the high-density urban area (31.6%), the low-density urban area (25.0%), and the agricultural area (4.3%) (Table 2).

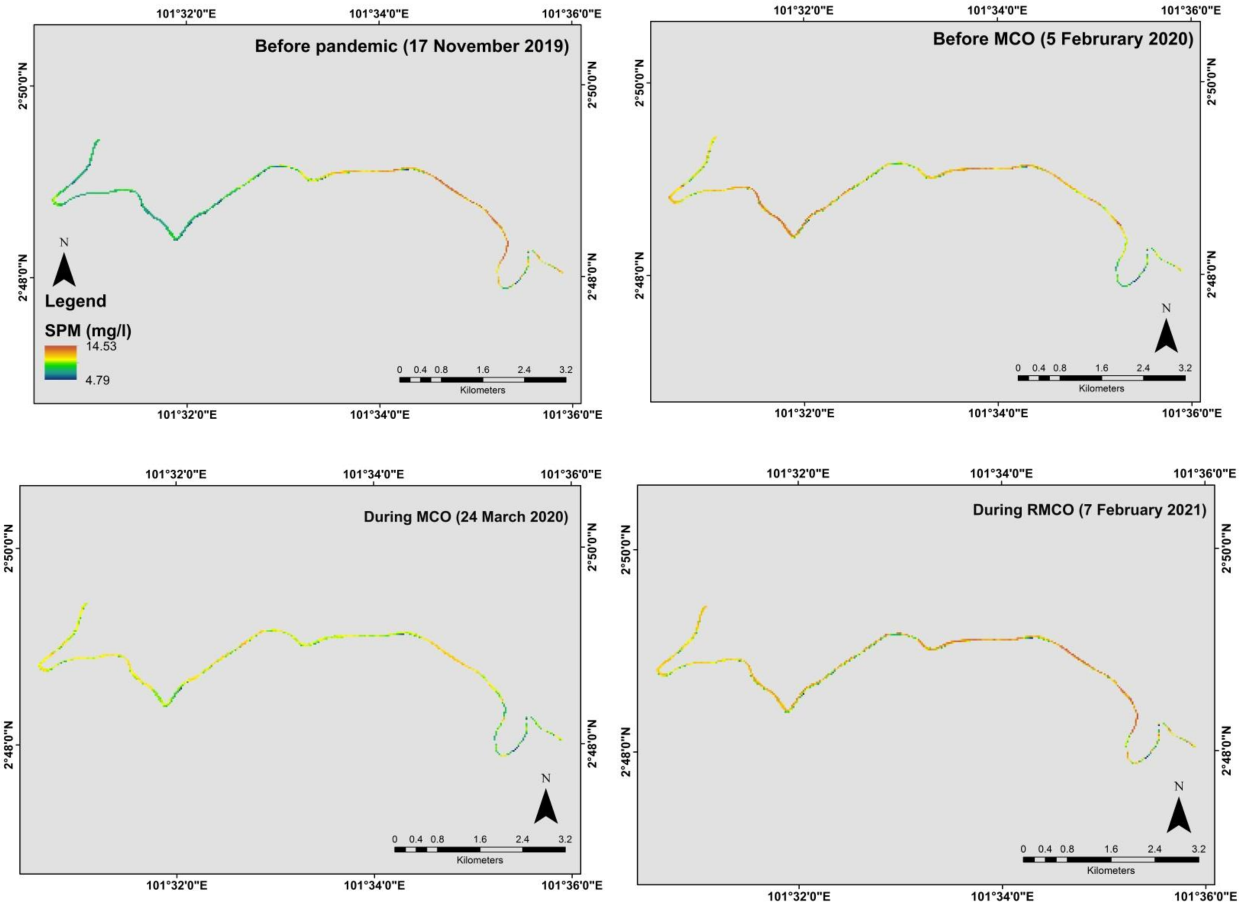

FIGURE 3. Suspended particulate matter (SPM) concentrations estimated for Sungai Langat within a low-density urban area in 2019, before MCO, during MCO, and after MCO periods

THE ASSOCIATION BETWEEN SOIL EROSION RATE AND SPM CONCENTRATION

In this study, we analyzed soil erosion rates in areas near the studied Sungai Langat using the RUSLE method. The highest rate of soil erosion was found in Sungai Langat within the high-density urban area. According to the three replicated points measurement, the soil erosion rate values in that area were above 100 ton/ha. yr (Table 3). This value indicated that the soil erosion rate was classified into high class. Contrarily, we observed a lower soil erosion rate in the other two Sungai Langat. For instance, Sungai Langat within the low-density urban area and Sungai Langat within the agricultural area showed soil erosion rate was less than 50 ton/ha. yr (low soil erosion class) (Table 3). Furthermore, if we correlated the SPM concentration and soil erosion factors during MCO period, we obtained the SPM concentration was positively significant correlated with soil erosion rate ($r = 0.87$, $p<0.01$), support practice factor ($r = 0.94$, $p<0.01$), land cover factor ($r = 0.95$, $p<0.05$), and length of the slope factor ($r = 0.78$, $p<0.05$) (Table 4). Meanwhile, there was a negative significant correlation between the SPM concentration and soil erodibility factor with $r = -0.68$, $p<0.05$ (Table 4). As a whole, all the soil erosion factors had significant effects on contributing the amount of SPM concentration in Sungai Langat.

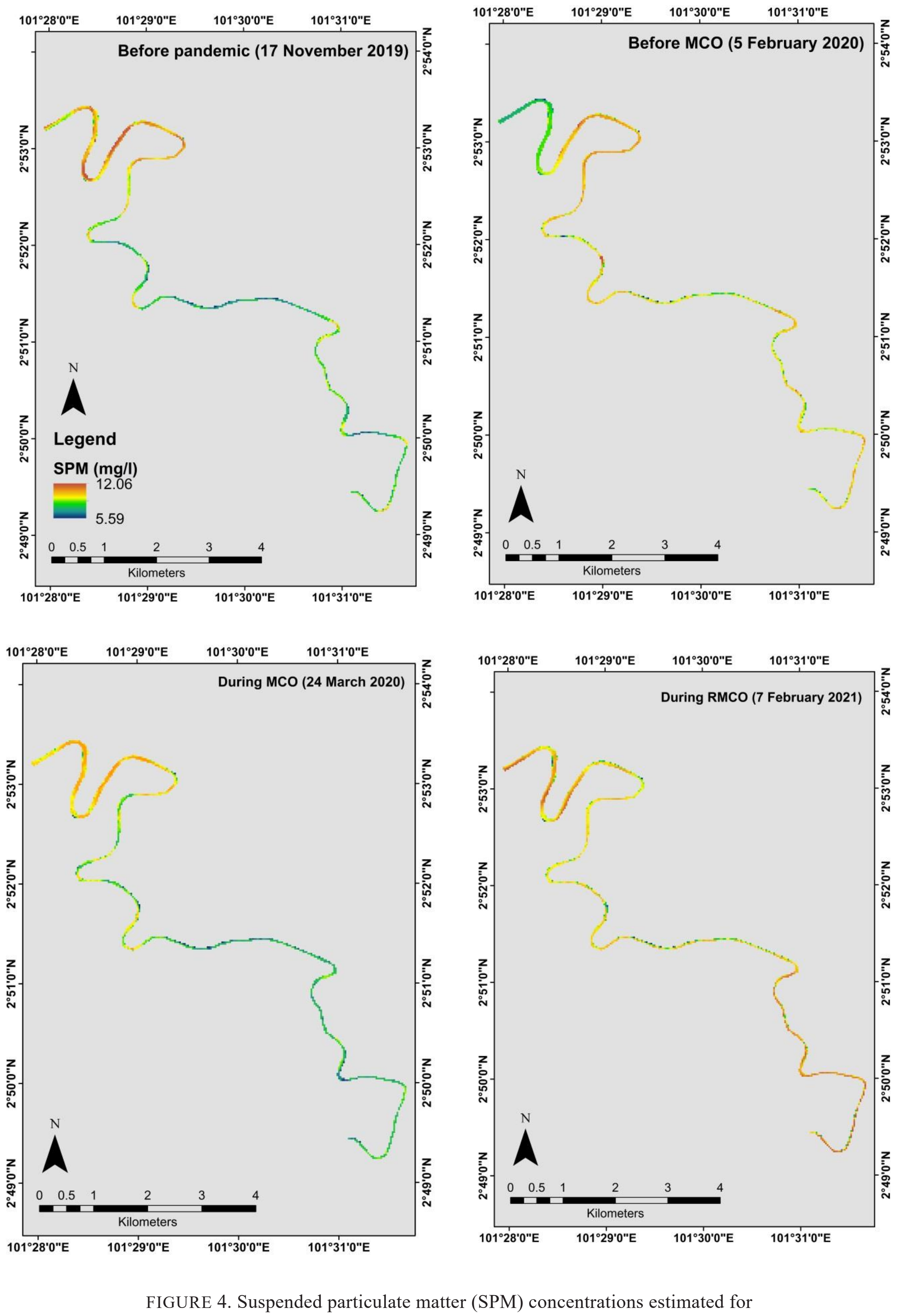

FIGURE 4. Suspended particulate matter (SPM) concentrations estimated for Sungai Langat within an agricultural area in 2019, before MCO, during MCO, and after MCO periods

TABLE 1. Mean SPM concentrations in three Sungai Langat before MCO and during MCO periods

River	Mean SPM (mg/L)		%Change
	Before MCO	During MCO	
	Jan-Feb 2020	March-Augst 2020	
Sungai Langat within high-density urban area	8.5	5.6	-34.1
Sungai Langat within low-density urban area	6.3	5.7	-9.5
Sungai Langat within agricultural area	9.0	7.0	-22.2

TABLE 2. Mean SPM concentrations in three Sungai Langat during MCO and after MCO periods

River	Mean SPM (mg/L)		%Change
	During MCO	After MCO	
	March-Augst 2020	Jan-Feb 2021	
Sungai Langat within high-density urban area	5.7	7.5	+31.6
Sungai Langat within low-density urban area	5.6	7.0	+25.0
Sungai Langat within agricultural area	7.0	7.3	+4.3

TABLE 3. Estimation of the soil erosion rate in the Langat basin during MCO period

River/Basin	Station	RUSLE parameters					
		R (MJ.mm/ ha.yr)	K (Ton. ha)*(ha.hr/ MJ.mm)	LS (m)	C	P	A (Ton/ha.yr)
Sungai Langat within high-density urban area	1	15364	0.03	0.85	0.25	1.0	117.53
	2	14289	0.04	0.85	0.25	1.0	127.52
	3	15298	0.03	0.85	0.25	1.0	126.78
Sungai Langat within low-density urban area	1	10120	0.04	0.53	0.23	0.70	36.26
	2	10085	0.05	0.53	0.23	0.70	45.60
	3	10135	0.05	0.53	0.23	0.70	45.83
Sungai Langat within agricultural area	1	15235	0.05	0.53	0.20	0.40	34.23
	2	10206	0.05	0.53	0.20	0.40	22.93
	3	10118	0.05	0.53	0.20	0.40	22.73

TABLE 4. Pearson's correlation between the RUSLE parameters and SPM values

	RUSLE parameters					
	R	K	LS	C	P	A
Pearson's correlation, *r*	0.48	-0.68*	0.78*	0.95*	0.94**	0.87**
P value	0.19	0.04	0.01	0.00	0.00	0.02

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed)

SPATIAL DISTRIBUTION OF RAINFALL IN LANGAT BASIN

In this study, we analyzed how the climate different during the movement control periods (MCO) to the times before and after. The monthly rainfall data was obtained from 26 rainfall stations in the surroundings of Langat basin from the year 2019 to 2021. The rainfall maps were produced using GIS software that divided into four different periods such as before the COVID-19 pandemic (November 2019), before MCO (February 2020), during MCO (March 2020), and after MCO (February 2021) (Figure 5). The study area had two monsoons, the southwest monsoon occurred from May to September, and the northeast monsoon from November to March. The southwest monsoon carried less precipitation during the period while the northeast monsoon was indicated by heavy rain. Therefore, this study covered all two monsoons that characterized the study area.

According to rainfall distribution maps, we found there was a decrease in the average rainfall intensity from before MCO to during MCO (173.7 to 85.7 mm). Then, the average rainfall intensity after MCO significantly decreased by 36.83 mm as compared with during the MCO period. The highest of average rainfall intensity in the study area was observed in November 2019 (before the COVID-19 pandemic) with a value of 255.9 mm.

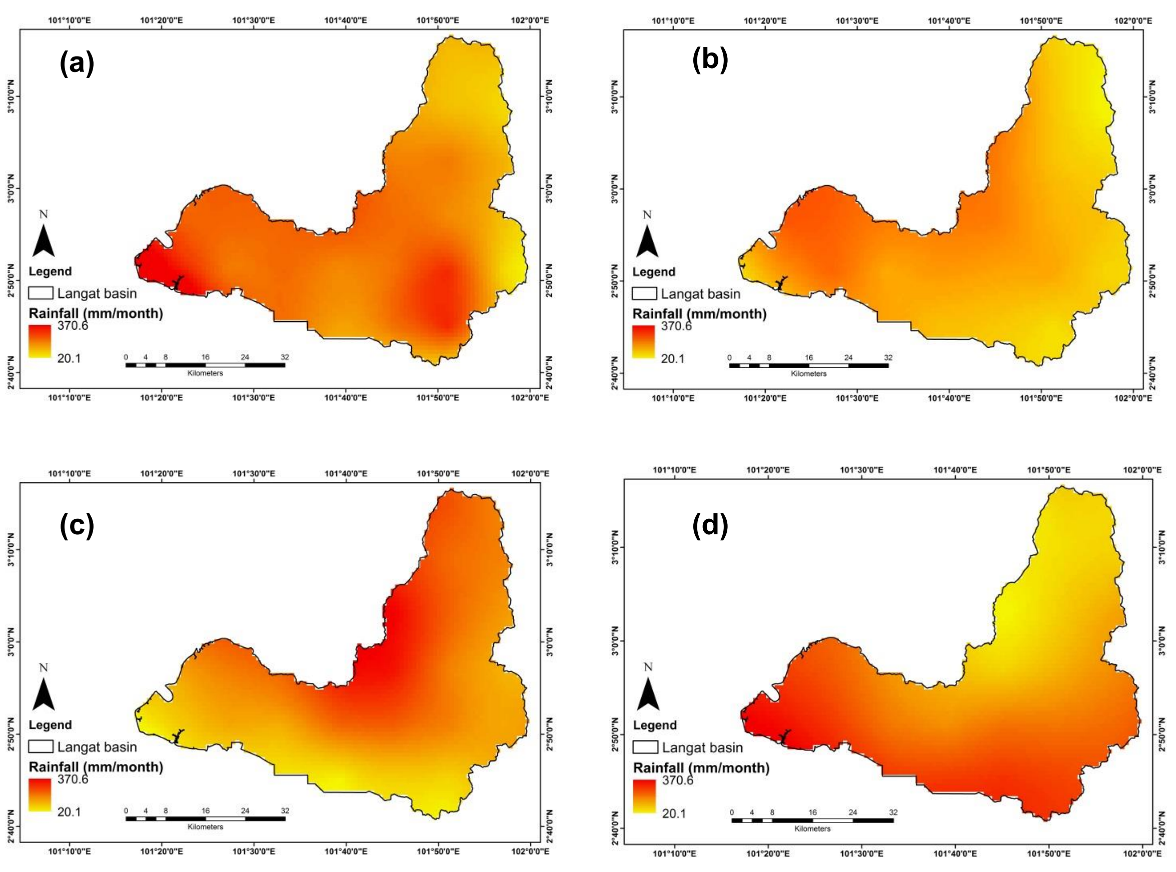

FIGURE 5. Spatial distribution of total ranfall within Langat basin (a) before pandemic in November 2019, (b) before MCO in February 2020, (c) during MCO in March 2020, and (d) after MCO in February 2021

DISCUSSION

This study was carried out to identify the impact of COVID-19 movement control order in a river water quality using remote sensing data. We chose Sungai Langat which was one of the most notable raw water resources for drinking water, industries, fishery, and agriculture in Selangor, Malaysia. Therefore, it is very prominent to understand the pollutant sources through point source pollution based on the land use activities that occurred around Sungai Langat. In this study, Sungai Langat was investigated into three zones based on land use types (high-density urban area, low-density urban area, and agricultural area) before the MCO period, during MCO, after MCO, and before the pandemic in 2019. The analysis of SPM concentrations in all Sungai Langat during the MCO period showed a lower value than those before MCO period. As a whole, we found the highest decrease in SPM level was observed in Sungai Langat within the high-density urban area with avalue of 34.1%. This result was slightly lower if we compared it with another study by Xu et al. (2021) who found a decrease in SPM level (48%) during the lockdown period in a highly-populated area at Min River, China. This decrease might be related to the lockdown duration, size of the population, geographical, and environmental characteristics in a particular area.

Based on a previous study, the most source of Sungai Langat pollution came from industrial discharge (58%), and domestic discharge (28%) (Basheer et al. 2017). In this study, the industrial wastes were mostly found in Sungai Langat within a high-density urban area. Thus, because the industrial activities were restricted during the MCO, Sungai Langat pollution in the area has been dropped. This assumption has been proved by our finding that Sungai Langat in the high-density urban areas indicated the decline in SPM concentration. Furthermore, in the other rivers such as low-density urban and agricultural areas, a high number of non-industrial pollutants (discharges of domestic wastewater and agricultural wastes) were commonly found in those areas. Because both rivers were located in the downstream area, they would receive more pollutants from the upstream.

For further analysis, we have analyzed after the MCO period (in February 2021) to ascertain the impact of industrial pollution load on Sungai Langat water quality. Our results showed the SPM level of all Sungai Langat has significantly increased after the MCO period with the highest value was observed in Sungai Langat within a high-density urban area (31.6%). The impact of disclosure of industrial sites during this period has led to a higher pollution load into Sungai Langat. But, the SPM values in Sungai Langat gradually raised after the MCO period because all human activities have been unleashed. Another possible reason for the low SPM concentration in Sungai Langat might be caused by the seawater intrusion into the river during the high tide. Specifically for Sungai Langat within the agricultural area which was located close to the mouth of Sungai Langat opening to the Malacca Straits. This condition could alter the physical and chemical properties of the river at the nearest point to the mouth (Yunus et al. 2020).

After the MCO period, the increase in SPM concentration was found in the entire Sungai Langat could also be resulted from the natural river sedimentation. The flow of sediments was usually influenced by several factors such as rainfall, erodibility of soil, length of the slope, land cover, and land conservation (Issaka & Ashraf 2017; Panagos & Katsoyiannis 2019). The upstream of Sungai Langat (high-density urban area) experienced a high amount of rainfall in early February 2021 and that could be the possible source of high SPM concentration on 7th February 2021. The MCO policy has made a significant impact on the river water quality, thus, we evaluated the soil erosion rate in Langat basin to identify the effect of natural river sedimentation. Our result suggested the highest risk of soil erosion was estimated in Sungai Langat within the high-density urban area. The erodibility of soil, length of the slope, land cover, and support practice factors were the main contributors to the high soil erosion rate in the area. Furthermore, the SPM concentration was highly associated with soil erosion rate and other soil erosion factors (soil erodibility, length of the slope, land cover, support practice). Therefore, the higher the soil erosion rate, the higher the SPM concentration.

In general, we knew that human behavior was not the only contributor to water quality changes (Delkash et al. 2018). We estimated other factors that influenced water quality in the study area, most notably rainfall. Numerous studies have found the increase of various pollutants levels including total suspended matter, nutrients, and microbes during heavy rainfalls (Corada-Fernández et al. 2017; García-Aljaro et al. 2017; Xu et al. 2019). A previous study by Clark et al. (2007) has obtained that dissolved organic carbon (DOC) increased from 36% to 50% during a high amount of rainfall. Therefore, in this study, we analyzed how the climate different during the movement control periods (MCO) to the times before and after. In summary, our result was consistent with previous studies that already mentioned the linkage between river pollution and rainfall event. When the amount of rainfall decreased especially during the MCO period, we obtained a lower SPM concentration in Sungai Langat. This was because the MCO period has limited human activities such as industrial, commercial, and transportation which then decreased the loadings of pollutants into the river. Thus, the rainfall factor was an agent which acted to accelerate the mobility of pollutants from the source. In this case, we believed the main factor that governed the river pollution was the MCO policy that could control human activities. Furthermore, we found a great increase in SPM concentration after the MCO period. Although this period was observed at a low amount of rainfall we still found a high SPM concentration in the river. Therefore, we assumed that the river pollution was not solely dependent on rainfall factors, but it was more affected by anthropogenic activities. The withdrawal of MCO policy in the study area has made the pollutions by industrial and domestic effluents to rise again.

Conclusions

Overall, this study found a significant change of SPM distribution in the three Sungai Langat before MCO and after MCO periods. The MCO situation has resulted in about a 34.1% drop in SPM concentrations in Sungai Langat within the high-density urban areas. In contrast, after the MCO period, there was a great increase in SPM level in Sungai Langat within the high-density urban area (31.6%), meaning the disclosure of industrial activities has given a significant impact on the increase of SPM concentration. According to the comparison of SPM values in all four periods of study and the correlation analysis, we showed that the soil erosion rate and climate factors were not the only contributors to the river water quality change in Sungai Langat, but the MCO policy that controlled the anthropogenic activities was the major source in altering the SPM concentration in Sungai Langat.

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