Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Impact of the wind conditions on COVID-19 pandemic: A new insight for direction of the spread of the virus

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ABSTRACT

COVID-19 pandemic is the global health crisis of our time. A recent study has found that the virus can remain viable in air for multiple hours, thus the spread of virus can be affected by wind conditions such as wind speed and direction. Therefore, this study aims to analyze the impact of wind conditions on COVID-19 pandemic in Jakarta, Indonesia. The wind parameters were evaluated using wind roses analysis to estimate the direction of spread of virus. The effect of meteorological factors such as wind speed, temperature, sunshine hours, rainfall and humidity on COVID-19 cases was examined using Spearman correlation test. Result of study reveals that a low wind speed is significantly correlated with a higher COVID-19 cases ($r = -0.314$; $p < 0.05$). Similarly, low temperatures and sunshine hours are correlated with a higher COVID-19 cases ($r = -0.447$; $p < 0.01$, $r = -0.362$; $p < 0.05$, respectively). However, there are not significant linear correlations between humidity and rainfall with COVID-19 cases ($p > 0.05$). In addition, wind rose diagrams indicate that the highest COVID-19 cases fits in with wind direction blows. In study area, the dominant wind direction blows to the Southeast and East parts of the area with wind speed value is low in range from 3.60 to 5.70 m/s. In conclusion, low wind speed is a contributor to increase COVID-19 cases.

1. Introduction

A novel human coronavirus, or common name for severe acute respiratory syndrome coronavirus (SARS-CoV-2, referred to COVID-19) is an infectious disease that is firstly emerged in Wuhan, China in late 2019. The World Health Organization (2020) has declared COVID-19 as public health emergency and an international concern after number of cases continue to increase in almost all over the world. Until May 18, 2020, there is more than 4.7 millions confirmed cases and 315 thousands death cases worldwide (World Health Organization, 2020). In Jakarta, Indonesia, the first COVID-19 case has been announced on March 2, 2020 (Ministry of Health Indonesia, 2020). Then, it increases to over five thousands cases on May 17, 2020. If total cases in Indonesia are compared with the average of all countries over the world, this country has been listed in fifty countries with the most COVID-19 cases.

The typical symptoms of COVID-19 infection such as dry cough, shortness of breath, high fever, sore throat and pneumonia (Holshue et al., 2020). To control the spread of virus, Indonesian government has conducted a preventive policy namely implementation of Large-scale Social Restrictions (PSBB). The PSBB is generally carried out for 14 days at home during the longest incubation period. The society are not allowed to do works or activities around the city except in mandatory situations. Also, the application of advance technology like Geographical Information System (GIS) is useful for this current situation to assist in mapping COVID-19 cases, delivering rapid information to society. The GIS method can be used to create spatial virus variation within a specific area as which reported by Lustig et al. (2017).

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Many studies have revealed that COVID-19 is transmitted person-to-person through direct contact and respiratory droplets (Li et al., 2020; Huang et al., 2020; Shereen et al., 2020). In addition, a recent study found that COVID-19 can be detected in aerosols up to 3 h post aerosolization, up to 4 h on copper, up to 24 h on 37 cardboard and up to 2–3 days on plastic and stainless steel (Doremalen et al., 2020). Because of the virus can remain viable in air for multiple hours, meteorological factors are reliable indicator in terms study of the viability, transmission and range of spread of virus (Chan et al., 2020). One of the meteorological factors which affect the spread of pollutant in air is wind speed and direction. Therefore, the wind parameters play important role in measurement of air pollutants such as biological contaminants include bacteria and virus.

Based on this reason, we hypothesized that a low wind speed can lead to increase in number of COVID-19 cases, because of the virus may stay viable in air for couple hours. Furthermore, changes in temperature, sunshine hours, humidity and rainfall can affect the COVID-19 spread. Many studies have discussed the effect of meteorological factors on COVID-19 pandemic in a particular area. Temperature and sunshine hours are very significantly correlated with COVID-19 cases (Prata et al., 2020; Thangriyal et al., 2020). Shifting in humidity and rainfall values can also affect the survival and transmission of the corona viruses (Auler et al., 2020; Islam et al., 2020; Oliveiros et al., 2020). However, all above studies do not elaborate in more details about how the effect of wind conditions on COVID-19 spread. Therefore, this current study aims to analyze the impact of wind conditions on COVID-19 pandemic. Unlike the previous studies, this paper suggests a new insight for direction of COVID-19 spread.

2. Materials and methods

2.1. Study area

Jakarta is capital and province of Indonesia, and centre of education, culture, economy and sociopolitic of the country. It is the world's eighth-most populous urban area after Lagos city, with population about 11 millions in this year. It lies between 6°12′35.01“S and 106°50’43.63”E and covers total area around 664.01 km^2. This study is conducted in five administrative cities in Jakarta such as Central Jakarta, South Jakarta, East Jakarta, West Jakarta and North Jakarta (Fig. 1).

2.2. Data collection

Data file for COVID-19 cases were collected from March 2, 2020 to May 13, 2020, from COVID-19 data records from Jakarta Health Department (www.corona.jakarta.go.id). For meteorological data, this study obtained them from Meteorology, Climatology and Geophysical Agency of Indonesia. Data file for meteorological variables are temperature, humidity, wind speed, wind direction, rainfall and sunshine hours.

2.3. Data processing

This study used WRPLOT View software to generate wind rose diagrams. It required several kinds of data such as wind speed, wind direction and coordinates (X,Y) of meteorological stations to yield wind profile outputs. The outputs from this software included wind rose diagram, frequency distribution table and wind class frequency distribution graph. In this study, wind speed and wind direction were analyzed with the WRPLOT View software to identify the possible affected areas of COVID-19 impact.

2.4. Statistical analysis

Spearman's rank correlation test was applied to examine the correlation between meteorological factors and the spread of COVID-19. Because of data used in this study are not normally distributed, thus we used Spearman correlation test. Statistical analyses were carried out using IBM SPSS Statistics 21 software.

3. Results and discussion

3.1. The relationship between wind speed and other meteorological factors with COVID-19 cases

Spearman correlation test has been carried out to analyze the effect of wind speed and other meteorological factors on COVID-19 cases (Table 1). Total COVID-19 cases shows a moderate negative correlation with wind speed ($r = -0.314$; $p < 0.05$) (Table 1). Based on this result, the study assumes that a lower wind speed can attribute to a higher COVID-19 cases. This situation can be illustrated by the survival and transmission of the virus in ambient air. Because of the virus can remain viable in air for couple hours, it indicates that a low wind speed tends to make the virus can stay longer and become more concentrated in same location or area and then it easily infect more people in that area. This result has been supported with previous study by Sahin (2020) who also found a negative correlation between wind speed and number of COVID-19 cases in Turkey with $r = -0.217$.

Furthermore, the wind speed is negatively correlated with total COVID-19 new cases ($r = -0.537$; $p < 0.01$). Total new cases in this result imply the addition of COVID-19 cases per day. This result reveals that a lower wind speed can accelerate the growth of new cases. It is consistent with other finding by Bashir et al. (2020) who found that wind speed was an environmental driver for increasing COVID-19 new cases in New York, USA.

To date, the studies regarding an association between wind speed and COVID-19 cases in Indonesia have not been carried out.

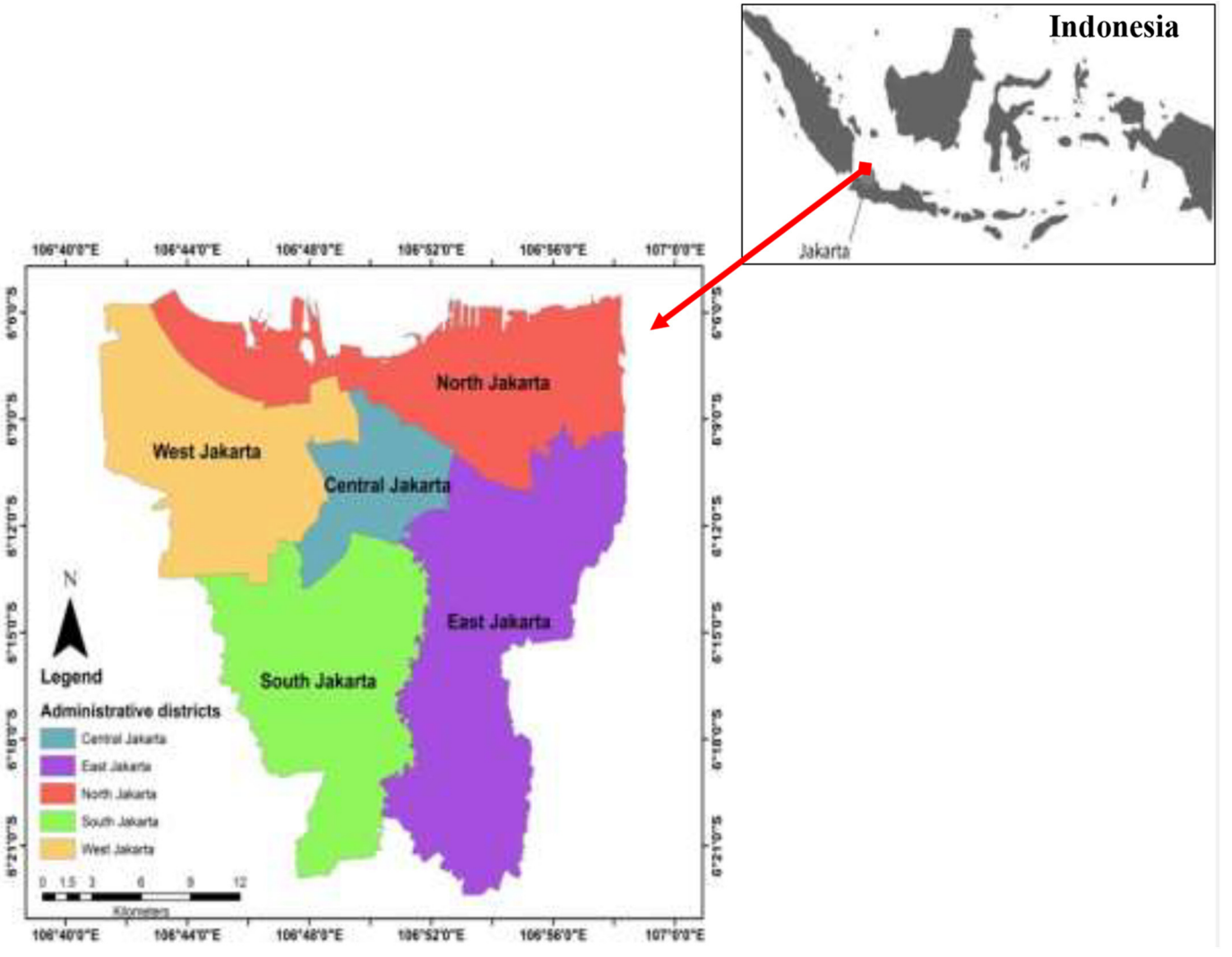


Fig. 1. Location of study area.

Table 1
Spearman correlation between wind speed and other meteorological factors with total cases, new cases and death of COVID-19.

	Meteorological variables	Total cases	New cases	Death
Spearman correlation coefficient	Temperature	−0.447**	0.176	−0.336*
	Humidity	−0.247	−0.195	−0.232
	Rainfall	0.139	0.143	0.156
	Sunshine hours	−0.362*	−0.103	−0.309*
	Wind speed	−0.314*	−0.537**	−0.320*

**, * signifies shows significance at 5% and 1%.

Hence, this current study is a prominent to give a new insight about the association between the two variables. In Jakarta, Tosepu et al. (2020) have found that temperature was positively correlated with COVID-19 cases ($r = 0.392; p < 0.01$). However, our study shows a different result from the previous study since we find a moderate negative correlation between the two variables (Table 1). Therefore, we attempt to compare our result to other studies such as in China (Siddiqui et al., 2020), Turkey (Sahin, 2020) and several countries (Rasul and Balzter, 2020), and eventually we can draw a conclusion that negative correlation is the best statistical decision to explain the association between temperature and COVID-19 cases because high temperatures can suppress the virus as which reported by Guo et al. (2020). But, for other meteorological factors like humidity and rainfall, the results are negligible due to no statistically significant correlation (Table 1). Moreover, this study finds a moderate negative significant correlation between temperature and COVID-19 death cases (Table 1). Ma et al. (2020) for the case of Wuhan, China also obtained a similar finding.

The other study by Asyary and Veruswati (2020) have investigated the effect of sunshine hours on COVID-19 incidence in Jakarta. Their study found that the sunshine hours was positively correlated with COVID-19 incidence ($r = 0.306$), this result contradicted with our study (Table 1). But in this circumstance, we strongly agree with the argument from Kowalski (2010) who implied that the ultraviolet light had the capability of destroying viruses, bacteria and fungi based on his hundreds of laboratory trials. Therefore, it can reveal that the longer sunshine hours is, the less the number of cases is. A recent technical report has demonstrated the ultraviolet light could be an effective measure for decontaminating surfaces that might be contaminated by the SARS-CoV-2 virus by activating photodimers in the genomes of microorganisms.

Additionally, this study tries to compare the results with other prior coronaviruses such as MERS-CoV and SARS-CoV-1. In Saudi Arabia, Altamimi and Ahmed (2020) have found that high temperature and ultraviolet index were very correlated with a higher MERS-CoV cases, while low wind speed and low humidity were contributors to increase MERS-CoV cases. According to their study, the effect of wind speed on coronavirus cases is in agreement with our findings, but for temperature factor, it seems that the MERS-CoV spread prefers in warmer weather condition. Specific meteorological conditions can be recognized as contributors of other coronavirus such as SARS-CoV-1. Change in temperature, wind speed and humidity were meterological variables which could affect SARS-CoV-1 transmission (Yuan et al., 2006).

Besides meteorological factors, a study by Zu et al. (2020) revealed that a denser population might also drive to a higher COVID-19 cases. For instance, New York City with population around 8.54 million and total confirmed cases has significantly increased to more than 189 thousands cases since the COVID-19 become pandemic. Similarly, in study area, Jakarta is also a capital city like New York, which make it is an ideal epicenter for the spread of COVID-19 to obtain a higher cases than other cities. Wang et al. (2020) have reported the same results in some big cities in China.

To support the wind speed can affect number of COVID-19 cases, this study has conducted correlation tests between the wind speed and other meteorological factors (Table 2). This study finds that the wind speed has significant correlations with temperature and rainfall (Table 2). According to Thangprasert and Suwanarat (2017), the correlation might occur because temperature and rainfall were under the effect of monsoon wind system of seasonal character. This study finds that there are close relationships between temperature and wind speed with number COVID-19 cases (Fig. 2-3). It may suggest that low wind speeds and temperatures, a higher number of cases. Among five main cities of Jakarta, East Jakarta city has been observed as the highest number of cases which also showed the lowest temperature and wind speed (28.14 ˚C and 1.3 m/s, respectively). In contrast, temperature and wind speed in other four cities are relatively higher, thus they tend to have lower cases (Fig. 2-3).

Table 2
Spearman correlation between wind speed with other meteorological factors.

Parameter	Wind speed	Temperature	Humidity	Rainfall	Sunshine hours
Wind speed	1	0.369*	−0.074	0.348*	−0.050
Temperature	0.369*	1	−0.791**	−0.563**	0.313
Humidity	−0.074	−0.791**	1	0.281	0.060
Rainfall	0.398*	−0.563**	0.281	1	−0.231
Sunshine hours	−0.050	0.313	0.060	−0.231	1

**, * signifies shows significance at 5% and 1%.

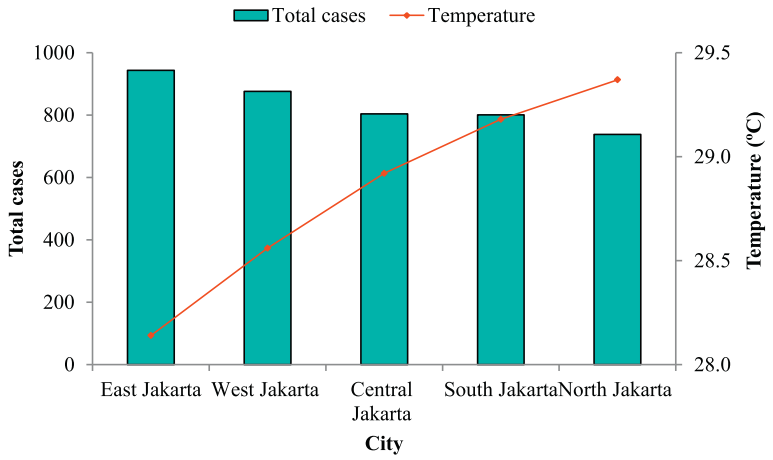


Fig. 2. Variation of total COVID-19 cases and temperature values against administrative cities in Jakarta.

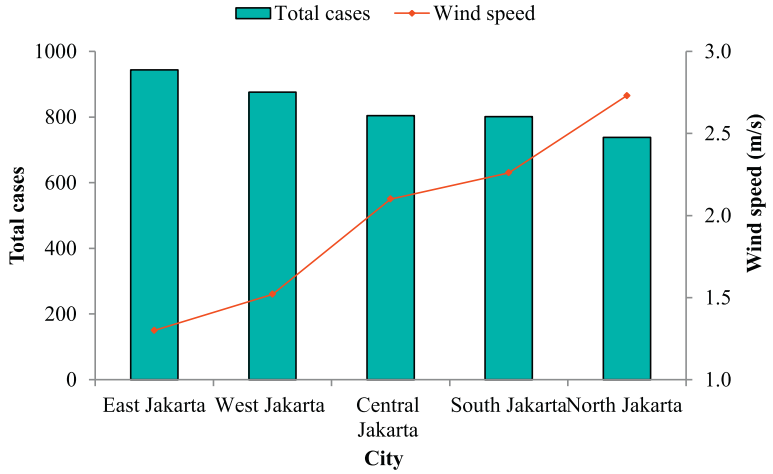


Fig. 3. Variation of total COVID-19 cases and wind speed values against administrative cities in Jakarta.

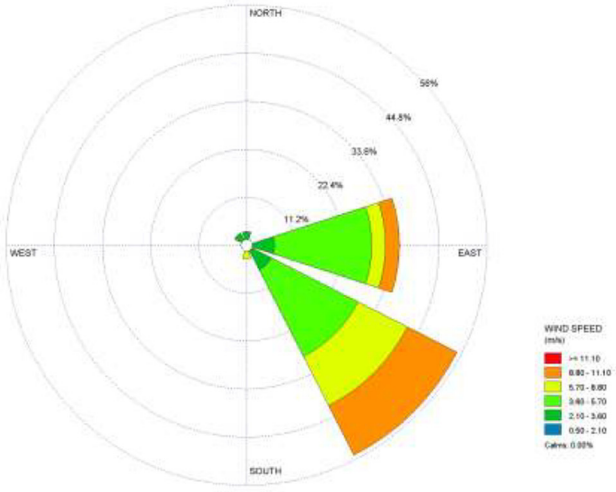
3.2. The wind rose output

The average of wind speed in study area is 5.04 m/s. Fig. 4 shows the wind rose diagrams during COVID-19 pandemic from March 2nd to May 13th 2020. In nature, wind direction in the southern hemisphere Indonesia is directly influenced by west and east monsoons. During first inter-monsoon, the wind usually blows from Siberia region to Australia continent (Bayong et al., 2008). It occurs from March to May in every year. The result of study indicates that the wind in study area dominantly blows towards SE and E directions from March to May (Fig. 4a-c). Wind speed in March is slightly higher than wind speed in other months, but for calm winds in all months are very low. During mid-May, the wind starts to blow significantly to SE and SW direction. However, the wind speed during that month is lower than prior months.

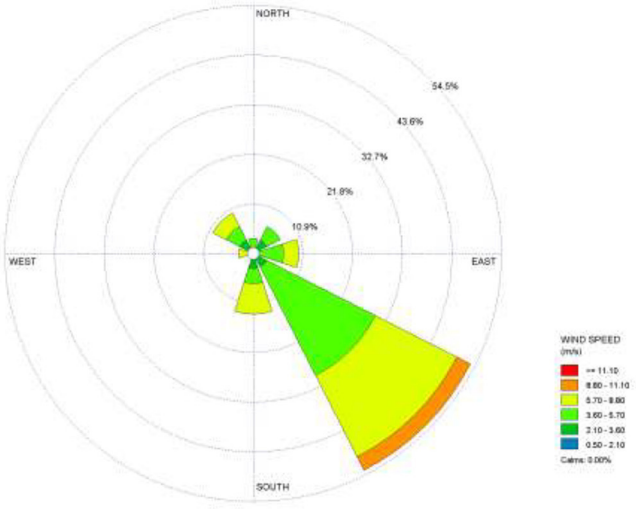
As depicted in Fig. 4, the wind direction affects number of COVID-19 cases in study area. It can be seen from the highest number of cases in East Jakarta city fits in with the direction of wind which blows to the Southeast. Wind class frequency distribution reveals the wind speed blows in range from 3.60 to 5.70 m/s for all months. If we consider that the wind brings the virus, thus the prevailing virus velocity may be at the range mentioned-above. This study estimates that the virus may spread over 6.75 km, it is proven by the distance calculation from the Central Jakarta where the first case of COVID-19 is discovered to the East of Jakarta, the highest number of cases at the present (Fig. 5).

Despite there are significant findings about the association between wind speed with total cases, new cases and death of COVID-19, but this study has some limitations. The COVID-19 cases can be affected by other factors such as biological properties of virus, people mobility, people endurance, population density and age of person. It is also essential to analyze air pollutants concentration such as CO, NO_2, SO_2, PM 2.5 and PM 10 in future works because the air pollutants and virus are simultaneously transported by the wind.

(a)



(b)



(c)

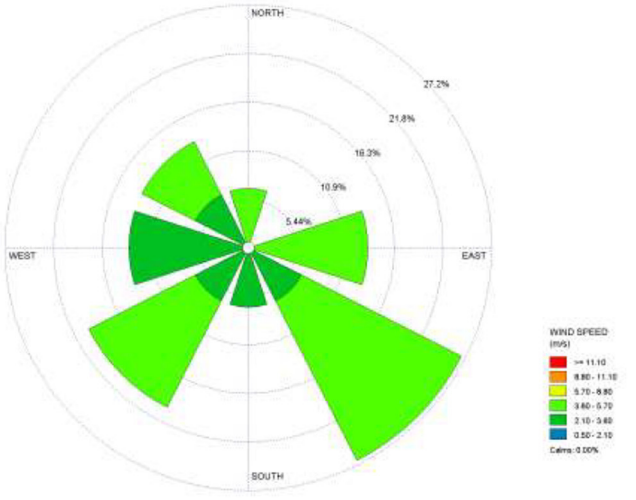


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Fig. 4. Wind rose diagrams during COVID-19 pandemic in (a) March, (b) April and (c) May 2020 in study area. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

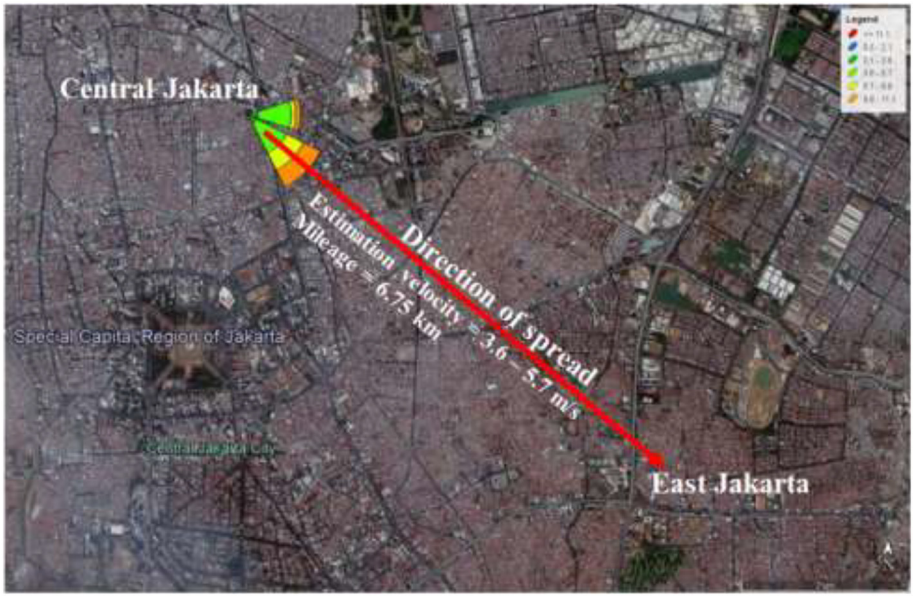

Fig. 5. Estimation of COVID-19 spread based on wind conditions in study area.

4. Conclusions

Wind conditions and other meteorological factors are important factors in facing COVID-19 pandemic. This study concludes that wind speed is significantly correlated with COVID-19 cases, indicating a lower wind speed, a higher number of COVID-19 cases. Also, low temperatures and sunshine hours can contribute to increase in number of COVID-19 cases. The direction of COVID-19 spread may be estimated using wind rose analysis while the range of virus spread can be predicted from the direction of wind. All these findings may provide a new insight to control the spread of COVID-19 outbreak.

Declaration of Competing Interest

The author declares that there is no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author's contributions

Muhammad Rendana carried out data collection, data analysis, design of the study, performed the statistical analysis and drafted manuscript. Author read and approved the final manuscript.

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