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The Climate Effect on COVID-19: Lessons Learned from the Pandemic in Jakarta

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Abstract

The global COVID-19 pandemic has presented humanity with difficult and unforeseeable hurdles. Among these challenges is understanding how climate-related aspects impact the survival of the SARS-CoV-2 virus. This study aimed to investigate the relationship between environmental factors, such as temperature, humidity, and rainfall, and the spread of COVID-19 cases in different regions. A time-and-place-based ecological study design was adopted, integrating geographic information systems and statistical techniques. Statistical testing revealed a significant association between humidity (p-value = 0.000; r = -0.777) and rainfall (p-value = 0.001; r = -0.561) with COVID-19 instances. However, no statistically significant relationship was found between temperature variables and COVID-19 cases. Due to the impact of changing weather conditions, governments may become concerned about developing tailored preventive and control measures, considering the varying risk levels associated with different locations.

Keywords: climate, COVID-19, spatial-temporal analysis

Introduction

Climate influences health through a variety of direct and indirect mechanisms.[1] Extreme weather, for example, can cause direct mortality from heatwaves, as well as leading to disturbed food systems, increased zoonoses, and food-, water-, and vector-borne diseases.[2] The indirect social and economic consequences of climate and weather shocks can drive households into poverty, a major determinant of poor health.[1] Epidemics, like weather and climate, know no boundaries and can endanger human health and societal stability. From the time when the coronavirus appeared in 2003 to the H1N1 outbreak in 2009, followed by the Ebola virus in West Africa in 2014, the Zika virus in the Americas in 2015, and most recently, the severe acute respiratory system coronavirus 2 (SARS-CoV-2) outbreak in China in 2019, they showed how rapidly infectious diseases can spread, causing severe consequences.[3,4] The emergence of these new illnesses is most noticeable in vulnerable societies, such as those with fast urbanizing areas, weaker health systems, underserved populations experiencing rising income inequalities, and severe social, ecological, and climatic changes.[1,2]

The coronavirus disease 2019 (COVID-19) pandemic has presented humanity with difficult and uncertain situations.[5] One aspect of these challenges revolves around the influence of climate-related elements, such as air temperature, humidity, and rainfall, on the survival of the SARS-CoV-2.[6-9] Several studies conducted globally have shown that climatic factors play a role in the occurrence of COVID-19 cases. One notable study conducted by Sobral, *et al.*, encompassing all countries impacted by COVID-19, revealed a link between temperature and the prevalence of SARS-CoV-2 infections.[9] It found that as average temperature decreased, the number of cases of SARS-CoV-2 infection tended to increase. Additionally, the study indicated a positive relationship between precipitation and the transmission of SARS-CoV-2.[9] Liu, *et al.*, explored the connection between absolute humidity and the quantity of COVID-19 cases in 30 provincial capitals in China.10 They found that meteorological factors, particularly absolute humidity, independently contribute to the transmission of COVID-19. The study suggested that lower temperatures, small temperature fluctuations throughout the day, and lower humidity levels facilitate the virus's spread.[10] According to Chen, *et al.*, wind speed, temperature, and relative humidity are influential factors in determining the extent of COVID-19 transmis-

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sion.[11]

This climate-related matter raises concerns among policymakers, particularly regarding the potential effects of climate variability and change on the well-being of marginalized and vulnerable communities. These communities include children, the elderly, women, low-income individuals, ethnic minorities, migrants or refugees, and those with underlying health conditions.[1,2] If the climate issues are not managed effectively, similar challenges will happen in the future.[5] This study employed a spatial and temporal approach to examine the connection between climate and COVID-19 cases. It aimed to provide valuable insights into the role of climate in COVID-19, which policymakers can utilize to develop mitigation strategies once the pandemic is over.

Method

Using an ecological design that allowed for real-time and location-based analysis through geographic information systems, a quantitative study approach was utilized. Statistical techniques were employed to test the collected data. The study population consisted of weekly COVID-19 case data recorded at the Special Capital Region of Jakarta Provincial Health Office from March to September 2020. In this study, the entire population was included in the sample (total sampling). The secondary data used encompassed daily reports of COVID-19 cases as well as climate variables, such as maximum, minimum, and average temperature, humidity, and rainfall in Jakarta from March to September 2020.

The data for this study were acquired from two websites: the Jakarta Provincial Health Office (https://corona.jakarta.go.id/id/data-pemantauan)[12] and the Indonesian Meteorological, Climatological, and Geophysical Agency (https://dataonline.bmkg.go.id/akses_data).[13] The collected information was compiled into a dataset spanning 31 weeks. This consolidation was done considering various factors, including the COVID-19 incubation period (5–6 days) and the uncertain time gap between the initial infection day and the sampling day.[14] Moreover, a basic map of Jakarta, delineating the boundaries of urban villages, was acquired from the GADM Map and Data site (https://gadm.org/maps/IDN/jakartaraya.html).[15] The coordinates for the weather monitoring stations were obtained online from https://www.gps-latitude-longitude.com/.[16] This study was conducted within the Jakarta province, which encompasses 261 urban villages.

To examine the distribution of various variables, including minimum, maximum, and average temperature (oC), humidity (%), rainfall (mm), and the number of COVID-19 cases, univariate analysis was employed. This descriptive and quantitative method involved presenting data through statistical distribution tables, line graphs, and thematic maps, aligning with the study objectives. Additionally, Pearson's product-moment correlation test was utilized to analyze the relationship between climate factors and COVID-19. The technique used in this study specifically assessed the likelihood of a relationship's existence (p-value<0.05), closeness (r), and direction.

Furthermore, the strength of the associations was qualitatively categorized into four groups: absence/weak relationship (r = 0.00–0.25), moderate relationship (r = 0.26–0.50), strong relationship (r = 0.51–0.75), and very strong/perfect relationship (r = 0.76–1.00).17 The correlation value also indicated whether the relationship was positive or negative. The value (r) was used to evaluate the relationship, with r = 0 indicating no linear relationship, r = –1 representing perfect negative linearity, and r = 1 representing perfect positive linearity.[17] Furthermore, both univariate and bivariate analyses were conducted in the Faculty of Public Health Universitas Indonesia computer laboratory using SPSS 21.

To examine the relationship between the variables, spatial analysis was employed. An interpolation technique was utilized to create a combined map illustrating the occurrences of COVID-19 cases and climate factors within a specified community. The following steps were taken to estimate climate variables beyond the measurement locations (weather stations) using the Jakarta grid map interpolation: First, a grid map consisting of five weather monitoring stations was generated. The specific values or attributes of the points, such as longitude and latitude, were interpolated by integrating them into the attribute table of the climate variable data. These coordinate points were then merged onto the climate variable map.

Additionally, the vector data representing the independent variables were digitized by inputting the geographic data related to climate variables onto a base map. The subsequent step involved processing and selecting a color symbol (using a single-band pseudo-color) with a range of red hues. Consequently, the data size led to the creation of a digital classification system for climate variables that distinguished between high and low values. Subsequently, considering the specific community, the vector data representing the dependent variable were digitized by integrating spatial data on COVID-19 rates into the base map. This involved data processing and selecting a point symbol (centroid) to represent the locations. A digital classification system for COVID-19 cases was also established, categorizing them as major or minor based on the illness data.

Next, the interpolation option within the plugin was employed to interpolate the two vector maps. This process resulted in creating an interpolated raster plot, which was then utilized to examine or predict the values of the climate variables in each urban village. The resulting color gradients and point symbols did not convey specific ratios. Instead, they represented ordinal numbers, such as the fluctuation of climate variables from high to low and the counts of viral cases. The digital representation of colors was achieved using the QGIS software, employing a single-band pseudo-color with a range of red hues. The colors were grouped into five classes, with very dark red indicating very high values, dark red indicating high values, red indicating medium values, light red indicating low values, and white indicating very low values.

To depict the spread of the virus, dot symbols (centroids) were utilized, varying in size from large to small. Likewise, the size of the point symbols was digitally determined using either a basic marker or a standard symbol from the QGIS software, adopting a linear classification scale ranging from 0 to 17. The spatially analyzed data were utilized to generate thematic graphics and maps that displayed the time–location relationship patterns. This spatial analysis was conducted in conjunction with the statistical correlation results using QGIS 3.0 in the Faculty of Public Health Universitas Indonesia computer laboratory.

Results

Analysis of the relationship between humidity and COVID-19 cases in Jakarta showed a significant correlation, with a strong level of closeness and a negative trend, meaning that when humidity levels were lower, the like-

Table 1. Correlation Test Between Climate Variables and COVID-19 Cases

Variable	COVID-19 Case	
	p-value	r
Minimum temperature	0.200	0.237
Maximum temperature	0.076	0.324
Average temperature	0.280	0.200
Humidity	0.000	-0.777
Rainfall	0.001	-0.561

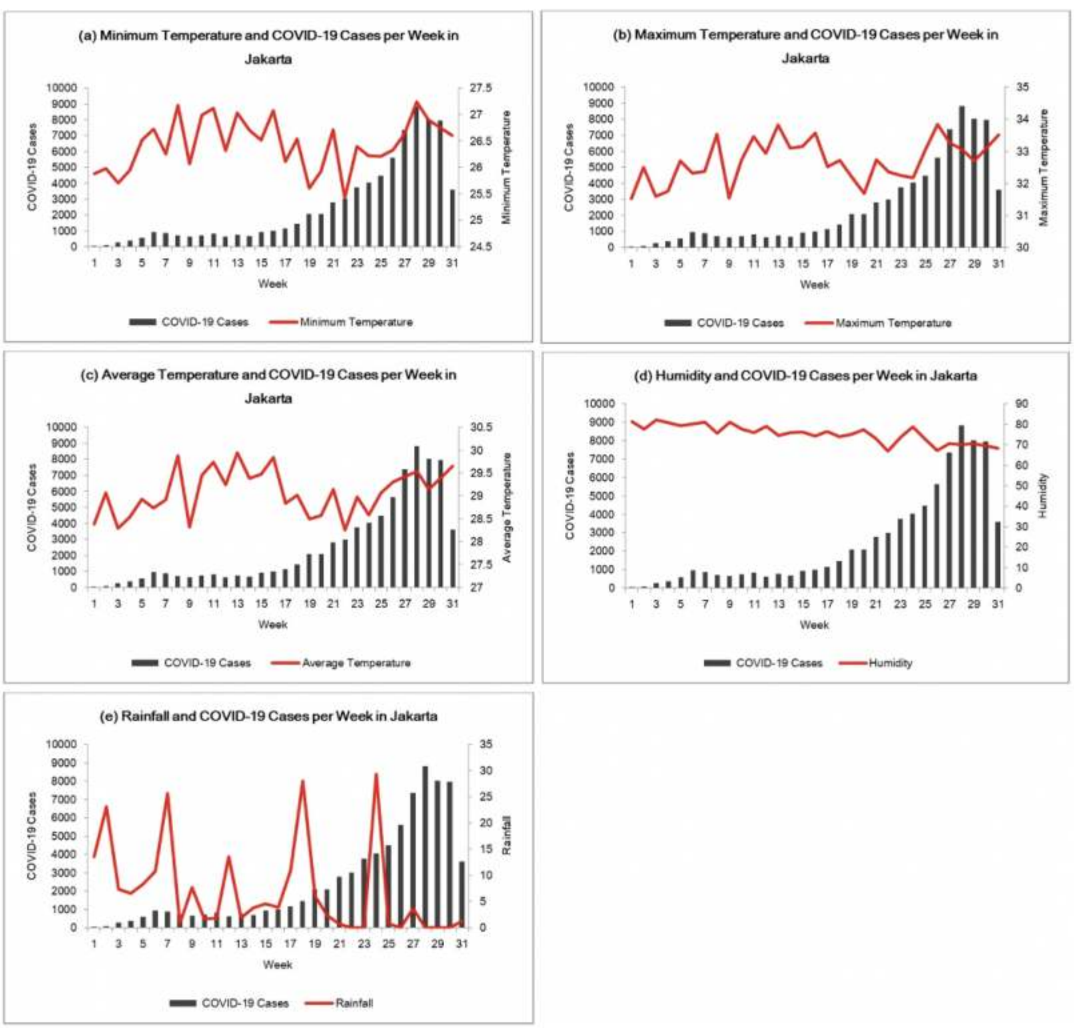

Figure 1. Climate Patterns and COVID-19 Cases

lihood of COVID-19 cases would be higher, and vice versa. Similarly, the correlation test between rainfall and COVID-19 data in Jakarta showed a significant relationship, with a strong level of closeness and a negative pattern. These results suggested that an increase in rainfall could potentially lead to a decrease in COVID-19 cases (Table 1).

In the weekly graph (Figure 1), the weather pattern shows similarities with the monthly pattern. The minimum, maximum, and average temperatures showed similar trends to the COVID-19 cases, while the humidity and precipitation variables showed opposite trends to the COVID-19 cases.

The spatial representation of humidity and COVID-19 cases revealed that urban villages with lower humidity levels experienced an earlier increase in cases than those with higher humidity. In July, there was a notable spike in cases, particularly in West Cempaka Putih (114 cases), Lagoa (101 cases), and Kebon Bawang urban villages (101 cases). In August, a higher number of COVID-19 cases were reported in several urban villages, including West Pademangan (158 cases), Lagoa (144 cases), Cilincing (131 cases), West Semper (109 cases), West Cempaka Putih (106 cases), and South Rawabadak (105 cases). These urban villages stood out in comparison to the surrounding areas (Figure 2).

The spatial map of rainfall and COVID-19 cases revealed a recurring pattern of changing rainfall levels each month. The surge in COVID-19 cases was not observed solely in urban neighborhoods with low or moderate rainfall. To illustrate, in June, there was an increase in cases in Kenari (114 cases), followed by West Cempaka Putih in July (114 cases), and in August, there was a rise in Lagoa (144 cases), Cilincing (131 cases), West Semper (109 cases), and South Rawabadak urban villages (105 cases). Nevertheless, some urban villages with high rainfall also experienced increased COVID-19 cases. For instance, in April, Petamburan (100 cases) reported an increase, while in July, both Lagoa (101 cases) and Kebon Bawang urban villages (101 cases) showed a rise. Additionally, in August, West Pademangan (158 cases), Johar Baru (127 cases), and West Cempaka Putih urban villages (106 cases) had increased cases. This data highlighted that increased COVID-19 cases could occur in urban villages with high, medium, or low rainfall levels (Figure 3).

Discussion

Learning from the COVID-19 pandemic will enable a more robust emergency response to possible similar events. This study's results make it possible to identify solutions related to the role of climate in influencing the pandemic, which can then be used for future control of COVID-19 and other infectious diseases affected by climate variables.

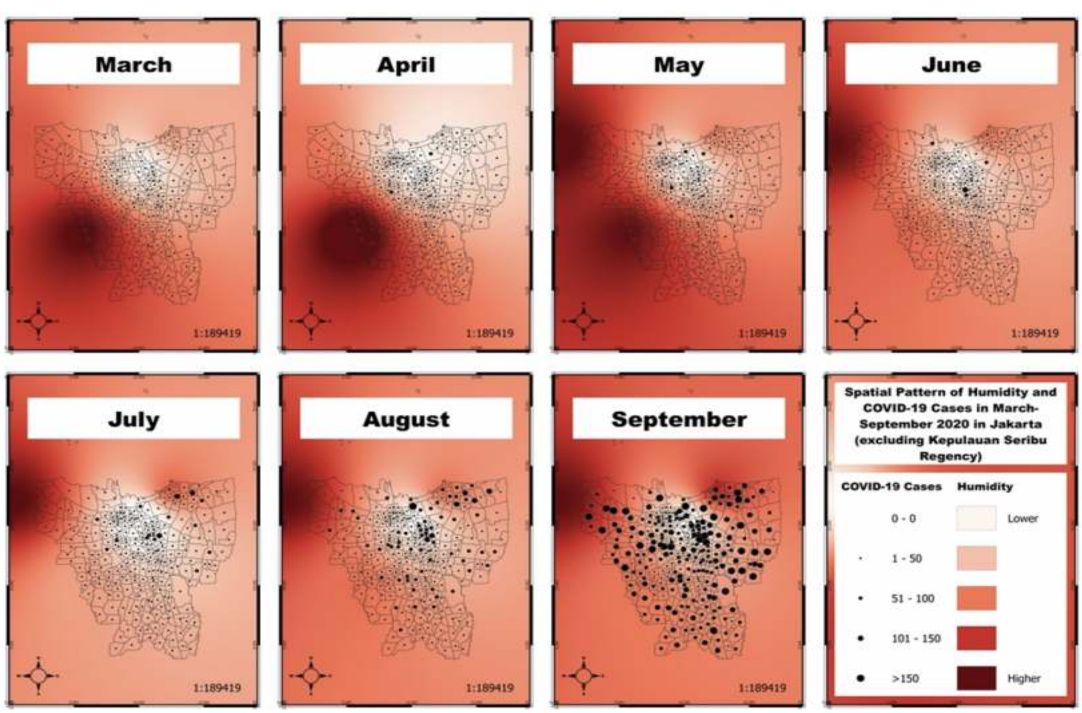

Figure 2. Spatial Patterns of Humidity with COVID-19 Cases[12,13]

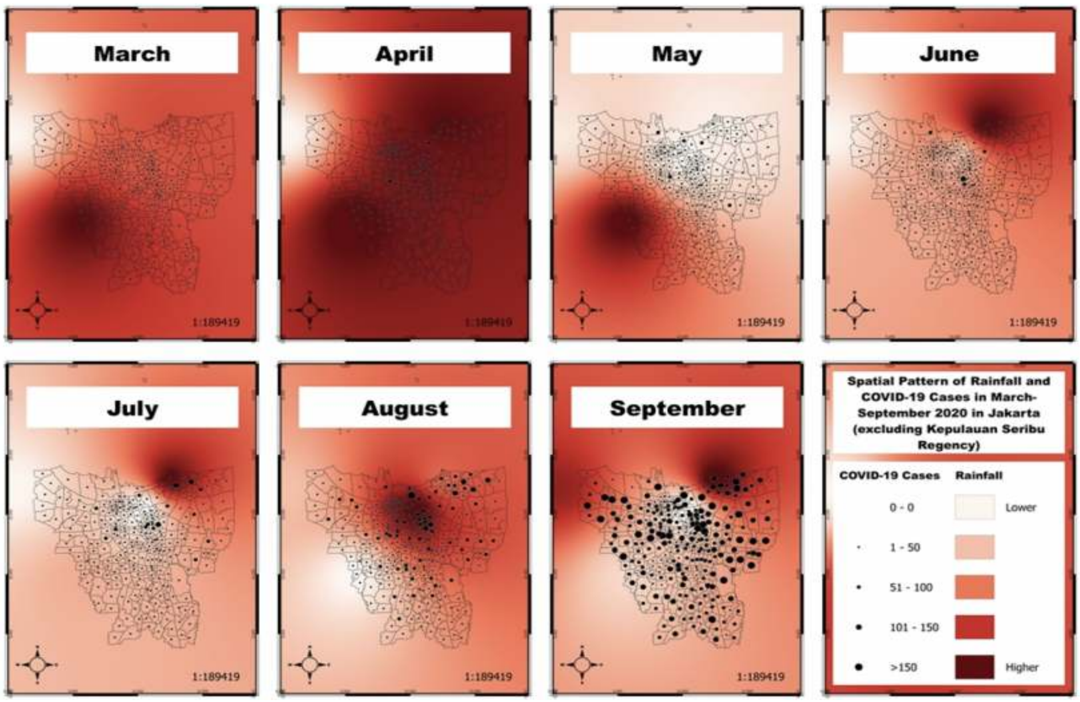

Figure 3. Spatial Patterns of Rainfall with COVID-19 Cases[12,13]

Temperature and COVID-19

According to this study, there was no significant association between temperature (minimum, maximum, and average) and COVID-19 cases in Jakarta. These findings were congruent with a study in Norway, which found that the minimum and average temperature variables were not substantially correlated with COVID-19 cases.[18] The implications contradict the recent findings by Tosepu, *et al.*, who evaluated the association between average temperature and COVID-19 cases in Jakarta.[19] According to that study, the average temperature was significantly correlated with COVID-19 cases. However, several other variables (minimum and maximum temperatures) showed no significant correlation with COVID-19,[19] which is still consistent with this study.

Many studies from different nations concur that raising the temperature might hasten the inactivation of SARS-CoV-2, although it still takes time.[8,20,21] At the temperature conditions in Jakarta, which ranged from 25.42°C to 33.85°C, the inactivation process of SARS-CoV-2 took under two days on the surfaces of stainless steel, glass, cotton cloth, and vinyl, two days on polymer paper surfaces, and under five days on a paper surface without any attempt at disinfection.[13,21] These facts confirm that SARS-CoV-2 can still be transmitted to people who do not properly implement health protocols and large-scale social restrictions. This condition is increasingly becoming a threat, related to the results of the Statistics Indonesia poll on public behavior in September 2020, which found that around 26.46% of the general population still did not implement health protocols effectively.[22,23]

Although this study reported a statistically insignificant relationship between temperature and COVID-19 cases, it is still possible to review the relationship through weekly graphical analysis in Jakarta, which shows a trend of COVID-19 cases increasing as temperature increases. In addition, several other factors also play a role in influencing COVID-19 cases in large cities, such as Jakarta, including high mobility, population density, and household conditions.[18]

Humidity and COVID-19

The correlation analysis of humidity and COVID-19 cases in Jakarta revealed a significant relationship with a very strong correlation. The negative sign indicated that the lower the humidity, the higher the number of COVID-19 cases. Furthermore, Biryukov, *et al.*, stated that an increase in relative humidity from 20% to 80% shortened the half-life of the SARS-CoV-2 virus from 15.3 hours to 8.3 hours.[24] Prayitno, *et al.*, proposed that relative humidity affects the effectiveness of sunlight in the virus inactivation process.[8] The average humidity in Jakarta ranges from 66.93% to 82.14%, and this showed a decline from March to September 2020, correlating with an increase in the half-life of the SARS-CoV-2 virus.[13,24] The persistence of this virus on the surface of objects or in the air can increase the likelihood of transmission to people who do not follow proper health protocols.[23]

An epidemiological study in Bangladesh showed high humidity can significantly decrease COVID-19 transmission.[25] Meo, *et al.*, found an association between a reduction in daily cases and fatalities from COVID-19 and an increase in humidity (negative correlation) in the Gulf Cooperation Council countries.[26] This finding contradicts those of Tosepu, *et al.*, who concluded that humidity is not correlated with COVID-19 cases.[19]

Weekly graphical analysis in Jakarta showed that COVID-19 cases have increased along with a decrease in humidity. This result aligned with spatial analysis, which showed that urban villages with low humidity experience more cases earlier than those with high humidity. These results further strengthen the significance of the relationship between humidity and the negative pattern of COVID-19 cases in Jakarta.

Rainfall and COVID-19

The analysis of the relationship between rainfall and COVID-19 cases in Jakarta revealed a strong and significant correlation. Interestingly, the direction of this relationship was inverse, as the amount of rainfall and the number of cases appeared to be inversely related. These findings aligned with a study in the United States, which found a notable negative correlation between rainfall and COVID-19 cases.[27] Similarly, a study conducted in Norway revealed a strong relationship with a negative correlation between rainfall recorded at 7:00 a.m. and COVID-19.[18] There are several theories for this inverse relationship, one of which is that people are likelier to stay at home during the rainy season.[18] Interestingly, these findings contradict the results of a previous study conducted in Jakarta, which explored the connection between rainfall and COVID-19 cases. According to that study, rainfall had no significant correlation with COVID-19 cases.[19]

The results obtained from the graph analysis were consistent with the correlation examination on the relationship between rainfall and COVID-19 cases in Jakarta. The findings indicated a strong and significant negative association, suggesting that a decrease in rainfall corresponds to an increase in COVID-19 cases. Moreover, the spatial analysis demonstrated that rainfall patterns exhibit consistent monthly variations. The increase in cases occurred in urban villages with low, moderate, and high rainfall. It can be concluded that high and low rainfall conditions do not affect the pattern of the spread of COVID-19 cases.

These spatial analysis results differed from the correlation above, which showed a relationship between rainfall and COVID-19 cases in Jakarta. The difference between the statistical and spatial analysis results between rainfall and COVID-19 could be caused by the spatial pattern of cases generated from the addresses of sufferers, which may differ from the location of transmission. As a result, the spatial pattern of cases may not align with the real pattern when observed from the site of infection.[14] These limitations could be taken into consideration in future study.

Conclusion

Environmental conditions with high humidity and rainfall can reduce COVID-19 cases. Although this study reported a statistically insignificant relationship between temperature and COVID-19 cases, it is still possible to review the relationship through weekly graphical analysis in Jakarta, which shows a trend of COVID-19 cases increasing as temperature increases. Nevertheless, society can take lessons from this study to always be vigilant and continue to implement health protocols in light of climate's role in affecting pandemic conditions. In addition, the Special Capital Region of Jakarta Provincial Health Office needs to consider these geographical and temporal differences to implement more specific COVID-19 prevention and control strategies based on the varying levels of risk in regions with diverse climatic conditions.

Abbreviations

COVID-19: coronavirus disease 2019; SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus-2.

Ethics Approval and Consent to Participate

This study was approved by the Research and Community Engagement Ethical Committee, Faculty of Public Health, University of Indonesia, No. 210/UN2.F10.D11/PPM.00.02/2021.

Competing Interest

The authors declare that there are no significant competing financial, professional, or personal interests that might have affected the performance or presentation of the work described in this manuscript.

Availability of Data and Materials

COVID-19 cases data: https://corona.jakarta.go.id/id/data-pemantauan

Climate data: https://dataonline.bmkg.go.id/akses_data.

The base map of Jakarta: https://gadm.org/maps/IDN/jakartaraya.html.

Coordinates of the weather monitoring station: https://www.gps-latitude-longitude.com/

Authors' Contribution

VYS: designed the methods, acquired the funding, and critically revised the important intellectual content. END: completed overall manuscript structure and critical revision for essential intellectual content. YAS: significant contributions to the concept, work design, data interpretation, data collection, analysis, and paper drafting. DS: final approval of the version to be published and critical revision for essential intellectual content. E: data analysis and made critical revisions to the important intellectual content.

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