Identification of Spatial Clusters of COVID-19 in Yogyakarta using Moran’s Index

Dyah Respati Suryo Sumunar¹, Nursida Arief², Nurul Khotimah³
¹,²,³ Department of Geography Education, Faculty of Social Science, Universitas Negeri Yogyakarta
dyah_respati@uny.ac.id

Abstract. Various studies on the spreading pattern of COVID-19 were carried out because, every day, there are always new progresses from scientists about this virus, including its unique characteristics in each region with different geographical conditions. The objective of this research is to find the spatial distribution pattern of COVID-19 and to identify the climate parameters influencing it in the Yogyakarta. This study used Moran's Index in analyzing COVID-19 distribution pattern. The results of the analysis show that out of 5 regencies/cities in Yogyakarta, Sleman Regency has the highest average spread of COVID-19 or an average infection rate of 1.09, followed by Bantul with 0.75. Kulonprogo is the regency with the lowest number of cases. The result of Moran's index of 0.32 means that there are correlation between cases. The correlation between temperature and infection rate is $R^2 = 0.05$, while the correlation between humidity and infection rate is $R^2 = 0.003$. The spread of COVID-19 in Yogyakarta is more influenced by mobility or interactions between infected and uninfected individuals.

1. Introduction
Corona Virus Disease 19 (COVID-19) is part of a type of coronavirus that attacks the immunity of the human body and can cause fatality. Preventive efforts were not only carried out by the affected areas, but also several other countries that were not affected, such as closing tourist access and closing several flight routes. It is due to the findings that the movement of humans from one place to another could trigger the transmission of COVID-19 [1,2]. In Indonesia, although several preventive steps have been taken by the government, such as quarantine at home, wearing masks, social distancing, physical distancing and Large-Scale Social Restrictions, the number of confirmed cases tends to increase [3]. Therefore, studies on the spread of COVID-19 continue to be carried out by scientists through various scientific disciplines. This prompted geographers to assess the ecological factors that influence the transmission and survival of the virus although there is no agreement among experts whether geographical factors, such as climate, affect the speed of transmission of COVID-19. There is no supporting evidence that if the weather is warmer, the number of cases will decrease, as happened in Brazil with tropical temperatures ranging from 16.8-27.4º C, which has a negative linear relationship with the number of confirmed cases [4]. In contrast to several previous researchers, some studies have shown that temperature has a positive relationship with the transmission of the coronavirus [5-7]. The risk of virus increase is greater at lower temperatures because it can increase suspended particles in the atmosphere [8]. An open environment that has high temperature and humidity is an environmental condition that is less ideal for the spread of coronavirus cases. On the other hand, low temperature and...
low humidity can facilitate the transmission of SARS coronavirus [9-11]. The aim of the study is to observe the COVID-19 spatial distribution pattern and to identify geographical parameters that influence the transmission of COVID-19. The case study was conducted in Yogyakarta, which is one of the provinces with fairly high mobility in Indonesia. Yogyakarta is a tourism and student city where migrants come from various regions [12-14].

This study uses geographic information system in the analysis of covid distribution patterns as well as analysis of influencing climatic factors. Currently, Geographic Information System (GIS) has become a vital tool in analyzing and visualizing the spread of COVID-19 [15]. The development of GIS technology is able to present real time data related to the progress of the pandemic [16]. GIS plays an important role in the visualization and tracking of confirmed cases, prediction of regional transmission, as well as spatial segmentation of risk levels and prevention [15,16,17]. Ecological variables in various locations, such as surface temperature, often form patterns like gradients or clusters due to the reactions and interactions of geological, climatic, topographic and biological factors [20]. Therefore, these patterns can be analyzed using the spatial autocorrelation tool in ArcGIS.

Spatial autocorrelation is measured by scalar statistics, which are the function of the values observed in each plot and the values on neighboring plots [21]. Among several spatial autocorrelation methods, such as Getis-Ord General G [22,23], incremental spatial autocorrelation [24], multi-distance spatial cluster analysis [25,26], the Moran's Index is a widely used method to evaluate distribution patterns [20,27,28]. Moran's Index helped in validating statistically identified patterns [29]. This study is expected to support researchers and the government in identifying the pattern of the spread of COVID-19 in Yogyakarta from a geographic and environmental perspective.

2. Methodology
2.1. Study Area
Yogyakarta is located at 7°47′S and 110°22′E (Figure 1). It has an area of 3,133.15 km2 with a population of 3,594,290 [30]. Geographically, Yogyakarta is located in the middle of Java Island. There is Merapi Volcano in the north, which is one of the active volcanoes in Indonesia, and there are coastal plains in the south which located on the edge of the Indian Ocean. Administratively, Yogyakarta is located between Klaten Regency in the northeast, Wonogiri Regency in the southeast, Purworejo Regency in the west, Magelang Regency in the northwest and the Indian Ocean in the South. Yogyakarta consists of four regencies and 1 municipality, namely Kulonprogo, Bantul, Gunung Kidul, Sleman and Yogyakarta City.

![Figure 1. Study area](image-url)
Moran's I was used as the first measure of spatial autocorrelation. The values range from -1 to 1. A value of “1” means perfect positive spatial autocorrelation, while a value of “-1” indicates perfect negative spatial autocorrelation, and a value of “0” means a random spatial pattern [31]. A high positive Moran's I value implies the target value is similar to its environment and its location is spatially clustered, which includes the high-high clusters (high value in high-value environments) and low clusters (low value in low-value environments). If the value of Moran's I is negative, it means that it is a spatially potential outlier or different from the surrounding values [29]. Spatial autocorrelation means that there is a dependence between variable values at neighboring or proximal locations or a systematic pattern of variable values across locations on the map due to common underlying factors [32].

3. Results and Discussion
The first confirmed case in Yogyakarta was on March 13, 2020 in Sleman Regency. It then quickly spread to other areas in Yogyakarta. This research observed at the distribution of COVID-19 cases until June 16, 2020 throughout the regencies/cities in Yogyakarta (Table 1).

Table 1. Distribution of key variables by Sub-district

| City           | Latitude&longitude | Population | Study period (days) | Total cases | Total deaths | Average temperature | Average humidity | Inf. Rate |
|----------------|--------------------|------------|---------------------|-------------|--------------|---------------------|-----------------|-----------|
| Bantul         | 7.88461°S 110.33411°E | 974.211    | 20/03-16/06 (88)    | 66          | 2            | 32,01              | 66,67           | 0.75      |
| Gunung Kidul   | 7.96668°S 110.602561°E | 768.215    | 25/03-16/06 (84)    | 50          | 1            | 31,24              | 61,18           | 0.59      |
| Kulonprogo     | 7.645°S 110.0269°E   | 471.793    | 26/03-16/06 (85)    | 11          | 0            | 29,51              | 68,63           | 0.12      |
| Sleman         | 7.68167°S 110.32333°E | 1.068.377  | 13/03-16/06 (95)    | 104         | 4            | 30,87              | 69,12           | 1.09      |
| Kota Yogyakarta| 7° 48′5″ S and 110 ° 21′52″ E | 412.487    | 18/03-16/06 (90)    | 33          | 1            | 32,72              | 69,41           | 0.36      |

*Inf. Rate = Number of infected/ Days of infection [32]*

Table 1 shows the regency with the largest population, namely Sleman, is directly proportional to the highest number of COVID-19 cases, namely 104 cases. Kulonprogo Regency has the least number of cases and a smaller population than the other four districts. More people are likely to be infected with the virus in densely populated areas and it has the potential for active spread of COVID-19 to other areas [34]. In contrast, Yogyakarta City has more cases than Kulonprogo even though it has a smaller population. In other studies, population density is not an important factor in the spread of COVID-19 [17]. The climate data in Table 1, namely temperature and humidity, are the results of field measurements carried out in June 2019. The results of the analysis of the two climate parameters have no correlation with the number of infections or the number of the spread of COVID-19 in Yogyakarta. It is presented in Figure 2 and Figure 3. Several previous studies have shown the same thing where temperature and humidity have a negative correlation with the spread of COVID-19 [5,33,35].
Figure 2 shows that the correlation between temperature and the infection rate is very weak (R² = 0.05), similarly with the correlation for humidity and infection rate (R² = 0.003). This means that the climate does not have a significant effect on the spread of COVID-19. However, ecological variables such as temperature and humidity which are measured in various locations can be considered as random processes with a certain degree of correlation with itself in space so that it becomes a challenge for conducting statistical tests for correlation with other variables [20]. Spatially, the humidity and temperature maps in Yogyakarta are presented in Figure 4 and Figure 5. When viewed from the COVID-19 distribution map (Figure 6), it shows that the distribution of COVID-19 is clustered in adjacent districts. In Gunungkidul Regency, the spread of COVID-19 is clustered in three adjacent sub-districts, namely Wonosari, Semanu and Karangmojo Districts. Likewise in other districts, it clustered in adjacent sub-districts.
Figure 4. Map of Humidity in Yogyakarta

Figure 4 shows the highest humidity level, namely 77.99%, while the lowest is 34.36%. Gunung Kidul is the regency with the lowest average humidity compared to Bantul, Kulon Progo and Yogyakarta Regencies. However, on the map of COVID-19 distribution (Figure 6), Yogyakarta City, parts of Sleman and parts of Bantul, which tend to have high humidity, are the COVID-19 clusters.

Figure 5. Map of Temperature in Yogyakarta

Figure 5 shows the high temperatures are distributed in Yogyakarta City, part of Sleman and parts of Bantul. Kulonprogo and northern Slemants have lower temperatures. Spatially, the temperature distribution pattern also has a reversed pattern to the spatial distribution of COVID-19 in Yogyakarta (Figure 6). The Yogyakarta City and Bantul, which have higher temperatures, are actually the COVID-19 clusters.
The results of Figure 6 were analyzed using Moran's Index (Figure 7) to find the spatial correlation between areas affected by COVID-19. The results show Moran's I index value of 0.32, which is in the range of 0<\textit{I}\leq 1 and indicates a positive spatial autocorrelation. It can be concluded that between regions affected by COVID-19, they have a similar or almost clustered data pattern [34]. This shows that the transmission of COVID-19 is more due to the mobility or movement of individuals from one place to another which causes interactions to form clusters.

![Figure 7. Curve of Moran’s Index](image)

Given the z-score of 4.9899106261, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.
Temperature significantly changes COVID-19 infection in Yogyakarta, based on the results of Moran's Index analysis, is clustered, where the affected areas are inter-related. COVID-19 cases in Yogyakarta are not evenly distributed across regions but form clusters in adjacent areas. This shows that the transmission of COVID-19 is influenced by interactions between individuals in one affected area and then there is mobility so that the cases will form new clusters in other areas. The climatic factors, namely humidity and temperature, do not show a significant effect on the spread of COVID-19. In some areas, such as Yogyakarta City and parts of southern Sleman Regency which have high temperatures, the number of COVID-19 cases is higher than in areas with lower temperatures.

4. Conclusion
The spatial distribution of COVID-19 in Yogyakarta, based on the results of Moran's Index analysis, is clustered, where the affected areas are inter-related. COVID-19 cases in Yogyakarta are not evenly distributed across regions but form clusters in adjacent areas. This shows that the transmission of COVID-19 is influenced by interactions between individuals in one affected area and then there is mobility so that the cases will form new clusters in other areas. The climatic factors, namely humidity and temperature, do not show a significant effect on the spread of COVID-19. In some areas, such as Yogyakarta City and parts of southern Sleman Regency which have high temperatures, the number of COVID-19 cases is higher than in areas with lower temperatures.

Acknowledgments
The authors would like to thank to the Institute for Research and Community Service, Yogyakarta State University for providing financial support for this research.

References
[1] Shereen M A, Khan S, Kazmi A, Bashir N, and Siddique R, COVID-19 infection: Origin, transmission, and characteristics of human coronaviruses, J. Adv. Res., vol. 24, pp. 91–98, 2020
[2] Sasidharan M, Singh A, Torbaghan M E, and Parlikad A K, A vulnerability-based approach to human-mobility reduction for countering COVID-19 transmission in London while considering local air quality, Sci. Total Environ., vol. 741, p. 140515, 2020.
[3] Djalante R et al, Review and analysis of current responses to COVID-19 in Indonesia: Period of January to March 2020, Prog. Disaster Sci., vol. 6, p. 100091, 2020.
[4] Prata D N, Rodrigues W, and Bermejo P H, Temperature significantly changes COVID-19 transmission in (sub)tropical cities of Brazil, Sci. Total Environ., vol. 729, p. 138862, 2020.
[5] Casanova I M, Jeon S, Rutala W A, Weber D J, and Sobsey M D, Effects of air temperature and relative humidity on coronavirus survival on surfaces, Appl. Environ. Microbiol., vol. 76, no. 9, pp. 2712–2717, 2010.
[6] van Doremalen N, Bushmaker T, and Munster V J, Stability of middle east respiratory syndrome coronavirus (MERS-CoV) under different environmental conditions, Eurosurveillance, vol. 18, no. 38, pp. 1–4, 2013.
[7] Xie J and Zhu Y, Association between ambient temperature and COVID-19 infection in 122 cities from China, Sci. Total Environ., vol. 724, p. 138201, 2020.
[8] Qi H et al., COVID-19 transmission in Mainland China is associated with temperature and humidity: A time-series analysis,” Sci. Total Environ., vol. 728, p. 138778, 2020.
[9] Sajadi M M, Habibzadeh P, Vintzileos A, Miralles-wilhelm F, and Amoroso A, This preprint research paper has not been peer reviewed. Electronic copy available at: https://ssrn.com/abstract=3550308,” Ssrn, no. 410, pp. 6–7, 1992.
[10] Bannister-Tyrrell M, Meyer A, Faverjon C, and Cameron A, Preliminary evidence that higher temperatures are associated with lower incidence of COVID-19, for cases reported globally up to 29th February 2020, Nat. Sci., vol. 15, no. 5, pp. 55–68, 2017.
[11] Chan K H, Peiris J S M, Lam S Y, Poon L L M, Yuen K Y, and Seto W H, The effects of temperature and relative humidity on the viability of the SARS coronavirus, Adv. Virol., vol. 2011.
[12] Cahya G A, Mahendra Y K D, and Damanik I I, Malioboro as a value of Special District of Yogyakarta City, IOP Conf. Ser. Earth Environ. Sci., vol. 70, no. 1, 2017.
[13] R. Abd Rahman and R. Ramli, “The History of Yogyakarta, and Education City,” Int. Proc.
[14] Herliana E T, Preserving Javanese Culture through Retail Activities in Pasar Beringharjo, Yogyakarta, Procedia - Soc. Behav. Sci., vol. 184, pp. 206–213, 2015.

[15] Mollalo A, Vahedi B, and Rivera K M, GIS-based spatial modeling of COVID-19 incidence rate in the continental United States, Sci. Total Environ., vol. 728, p. 138884, 2020.

[16] Franch-Pardo L, Napoletano B M, Rosete-Verges F, and Billa L, Spatial analysis and GIS in the study of COVID-19. A review, Sci. Total Environ., vol. 739, p. 140033, 2020.

[17] Huang R, Liu M, and Ding Y, Spatial-temporal distribution of COVID-19 in China and its prediction: A data-driven modeling analysis, J. Infect. Dev. Ctries., vol. 14, no. 3, pp. 246–253, 2020.

[18] Kumari M, Sarma K, and Sharma R, Using Moran’s I and GIS to study the spatial pattern of land surface temperature in relation to land use/cover around a thermal power plant in Singrauli district, Madhya Pradesh, India, Remote Sens. Appl. Soc. Environ., vol. 15, no. May, p. 100239, 2019.

[19] Czaplewski R L, Reich R M, and Bechtold W A, Spatial Autocorrelation in Growth of Undisturbed Natural Pine Stands Across Georgia, For. Sci., vol. 40, no. 2, pp. 314–328, 1994.

[20] Peeters A et al., Getis-Ord’s hot- and cold-spot statistics as a basis for multivariate spatial clustering of orchard tree data, Comput. Electron. Agric., vol. 111, pp. 140–150, 2015.

[21] Sarp G and Duzgun S, Morphometric evaluation of the Afşin-Elbistan lignite basin using kernel density estimation and Getis-Ord’s statistics of DEM derived indices, SE Turkey, J. Asian Earth Sci., vol. 111, pp. 819–826, 2015.

[22] Zhang Y et al., “Cluster of human infections with avian influenza a (H7N9) cases: A temporal and spatial analysis,” Int. J. Environ. Res. Public Health, vol. 12, no. 1, pp. 816–828, 2015.

[23] Khormi H and Kumar L, “Identifying and visualizing spatial patterns and hot spots of clinically-confirmed dengue fever cases and female Aedes aegypti mosquitoes in Jeddah, Saudi Arabia., Dengue Bulletin vol. 35, pp. 15–34, 2011.

[24] Arroyo-Mora J P, Svob S, Kalacska M, and Chazdon R L, Historical patterns of natural forest management in Costa Rica: The good, the bad and the Ugly, Forests, vol. 5, no. 7, pp. 1777–1797, 2014.

[25] Tepanosyan G, Sahakyan L, Zhang C, and Saghatelyan A, The application of Local Moran’s I to identify spatial clusters and hot spots of Pb, Mo and Ti in urban soils of Yerevan, Appl. Geochemistry, vol. 104, no. October 2018, pp. 116–123, 2019.

[26] Yuan Y, Cave M, and Zhang C, Using Local Moran’s I to identify contamination hotspots of rare earth elements in urban soils of London, Appl. Geochemistry, vol. 88, pp. 167–178, 2018.

[27] Fu W J, Jiang P K, Zhou G M, and Zhao K L, Using Moran’s i and GIS to study the spatial pattern of forest litter carbon density in a subtropical region of southeastern China, Biogeosciences, vol. 11, no. 8, pp. 2401–2409, 2014.

[28] BPS-Statistics of Daerah Istimewa Yogyakarta, Daerah Istimewa Yogyakarta Province in Figures 2020, Yogyakarta, 2020.

[29] Tu J and Xia Z G, Examining spatially varying relationships between land use and water quality using geographically weighted regression I: Model design and evaluation, Sci. Total Environ., vol. 407, no. 1, pp. 358–378, 2008.

[30] Griffith D A, Spatial Autocorrelation, A. B. T.-I. E. of H. G. (Second E. Kobayashi, Ed. Oxford: Elsevier, 2020, pp. 355–366.

[31] Ahmadi M, Sharifi A, Dorosti S, Jafarzadeh S, G houshchi, and Ghanbari N, Investigation of effective climatology parameters on COVID-19 outbreak in Iran, Sci. Total Environ., vol. 729, p. 138705, 2020.

[32] Kang D, Choi H, Kim J H, and Choi J, Spatial epidemic dynamics of the COVID-19 outbreak in China, International Journal of Infectious Diseases, vol. 94, pp. 96–102, 2020.

[33] Wu Y et al., Effects of temperature and humidity on the daily new cases and new deaths of COVID-19 in 166 countries, Sci. Total Environ., vol. 729, pp. 1–7, 2020.