Jurnal Berkala Epidemiologi
Volume 11 No 2. May 2023. 151 – 159
p-ISSN: 2301-7171; e-ISSN: 2541-092X
DOI: 10.20473/jbe.v11i22023.151–159
https://e-journal.unair.ac.id/JBE/
Email: jbe@fkm.unair.ac.id / jbepid@gmail.com

Jurnal Berkala
EPIDEMIOLOGI
PERIODIC EPIDEMIOLOGY JOURNAL

ORIGINAL ARTICLE

SPATIAL AND TEMPORAL ANALYSIS OF COVID-19 CASES DISTRIBUTION IN SUKOHARJO REGENCY

Analisis Spasial dan Temporal Distribusi Kasus COVID-19 di Kabupaten Sukoharjo

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ARTICLE INFO

Article History:
Received April, 6th, 2022
Revised form August, 19th, 2022
Accepted March, 3rd, 2023
Published online May, 30th, 2023

Keywords:
spatial analysis;
temporal analysis;
COVID-19;
spatial distribution

Kata Kunci:
analisis spasial;
analisis temporal;
COVID-19;
distribusi spasial

ABSTRACT

Background: COVID-19 has become a public health challenge in Sukoharjo Regency, as its cumulative cases reached 15,258 confirmed cases with 1,380 deaths (CFR 9.04%). Spatial and temporal analysis can provide an overview of the spatial and temporal factors associated with the disease and explain the analysis of the disease distribution in a population to clarify the transmission mechanism. **Purpose:** This study aimed to provide an overview of the spatial and temporal distribution of COVID-19 cases in the Sukoharjo Regency and determine the spatial autocorrelation of the distribution of COVID-19 cases in the Sukoharjo Regency. **Methods:** This was an observational study with an ecological design. The data used was Secondary data collected from the Health Office of Sukoharjo, with the population of all COVID-19 confirmed cases recorded by the Health Office of Sukoharjo from 2020 to 2021. The sample was 15,528 patients. **Results:** The highest number of COVID-19 cases in Sukoharjo Regency was found in the Baki Sub-district (242.23/10,000 people). In comparison, the lowest number of cases was found in the Polokarto Sub-district (114.60/10,000 people). The Sukoharjo Regency experienced two waves of COVID-19, and its peak occurred in July 2021. The results showed spatial dependence in the COVID-19 case distribution with a Moran'sI value of 0.36, z-score of 7.50, and p-value <0.01. **Conclusion:** The highest number of COVID-19 findings occurred in July 2021, and there was spatial autocorrelation in the distribution of COVID-19 cases in the Sukoharjo Regency with a clustered transmission pattern.

ABSTRAK

How to Cite: Hastari, W. I., Lolita, D. A., & Fauzi, L. (2023). Spatial and temporal analysis of COVID-19 cases distribution in Sukoharjo regency. *Jurnal Berkala Epidemiologi*, *11(*2), 151-159. https://dx.doi.org/10.20473/jbe.v11i2 2023. 151-159

Latar Belakang: *Kemunculan kasus COVID-19 telah menjadi tantangan kesehatan masyarakat di Kabupaten Sukoharjo seiring dengan ditemukannya jumlah kasus kumulatif yang mencapai 15.258 kasus terkonfirmasi dengan 1,380 kematian (CFR 9.04%). Analisis spasial dapat memberikan gambaran terkait faktor ruang dan waktu yang berhubungan dengan penyakit dan menjelaskan analisis persebaran penyakit dalam suatu populasi untuk memperjelas mekanisme penularan yang telah banyak digunakan sebagai salah satu alat untuk mengembangkan strategi pencegahan dan pengendalian COVID-19.* ***Tujuan:*** *Penelitian ini bertujuan untuk memberikan gambaran terkait distribusi spasial dan temporal kasus COVID-19 di Kabupaten Sukoharjo serta mengetahui autokorelasi spasial distribusi kasus COVID-19 di Kabupaten Sukoharjo.* ***Metode:*** *Penelitian ini merupakan penelitian observasional dengan menggunakan desain penelitian ekologi. Data yang digunakan adalah data sekunder yang diperoleh dari Dinas Kesehatan Kabupaten Sukoharjo dengan menggunakan seluruh kasus terkonfirmasi COVID-19 yang tercatat oleh Dinas Kesehatan Kabupaten Sukoharjo tahun 2020 – 2021. Sampel yang digunakan adalah seluruh total populasi yang berjumlah 15,258 pasien.* ***Hasil:*** *Kasus COVID-19 tertinggi di Kabupaten Sukoharjo ditemukan di Kecamatan Baki (242.23/10,000 penduduk) sedangkan kasus terendah terletak di Kecamatan Polokarto (114.60/10,000 penduduk). Kasus COVID-19 di Kabupaten Sukoharjo telah mengalami dua gelombang dan puncaknya terjadi pada Juli 2021. Hasil penelitian ini menunjukkan nilai Morans'I 0,36, z-score 7,50, dan p-value <0,01.* ***Kesimpulan:*** *Penemuan kasus COVID-19 tertinggi terjadi pada Juli 2021 dan adanya autokorelasi spasial pada distribusi kasus COVID-19 di Kabupaten Sukoharjo dengan pola penyebaran berkelompok (klaster).*

INTRODUCTION

Coronavirus Disease 2019 (COVID-19) is a disease caused by SARS-CoV-2. The first case and cluster were reported in Wuhan, China in December 2019. Common symptoms include fever, cough, fatigue, and anosmia (loss of taste or odor). The less common symptoms that may develop during infections are headache, diarrhea, irritated eyes, sore throat, aches, pain, and skin rash. Other severe symptoms include shortness of breath, difficulty breathing, confusion, loss of speech or mobility, and chest pain (1).

The WHO declared COVID-19 as a Public Health Emergency of International Concern on January 30, 2020, and officially announced COVID-19 as a global pandemic starting on March 11, 2020. According to the World Health Organization by December 31, 2021, a cumulative total of 286,582,541 confirmed cases and 5,430,949 death (CFR 1.89%) have been reported globally (1). In Indonesia, the cumulative total of confirmed cases reached 4,262,720, of which 144,094 cases were reported (CFR 3.38%) (2). Central Java, one of the provinces with the highest population, has reported 486,907 confirmed cases, with 32,523 deaths (CFR 6.68%) (3). By December 31, 2021, a cumulative total of 15,258 confirmed cases and 1,380 deaths were reported by the Health Official of Sukoharjo Regency (4).

The emergence of coronavirus disease (COVID-19) has caused a massive global health crisis. It has also affected transportation, mobility, education, socioeconomic status, and others (5,6). Therefore, the United Nations defined the COVID-19 pandemic as a health crisis and an economic, humanitarian, security, and human rights crisis (7). Various health intervention strategies have been implemented to control this pandemic. Some countries have designed various strategies and policies related to containment and mitigation to reduce mortality, morbidity, and disease burden (8).

The correlation between infectious disease transmission and spatial variables has been discovered and used in public health to combating contagion (9). To respond to an infectious disease epidemic, an in-depth analysis must be conducted to identify the trends, risks, and factors associated with the transmission mechanism (10). Spatial analysis methods are widely used in public health, particularly ecological studies, to detect spatial

clusters. The investigation results could contribute to stakeholders developing health service program planning and policy evaluation (11). This method can provide an overview of the factors associated with the disease and explain disease distribution analysis in a population (12). It also enables information generation to support the government's rapid response strategies for prevention and control interventions and action (13). Therefore, identifying the spatial and temporal changes in the distribution of COVID-19 has become essential for clarifying its transmission mechanism (14).

Previous epidemiological studies have explored the spread of COVID-19, including its spatial distribution patterns and associated factors. The spread of COVID-19 is influenced by crowds and enabled by social, environmental, biological, and economic factors. Every country and region is affected differently and has a unique disease magnitude pattern and associated factors (12). Sukoharjo declared an outbreak status after the first case finding of COVID on March 23rd, 2022. A total of 15,258 cases (IR: 167.31/10,000) and 1,380 deaths (CFR: 9.04%) were recorded. There were 10,960 symptomatic cases (71.83%) and 4,298 asymptomatic cases (28.17%). During 2020 – 2021, the highest peak of cases was in July – September 2021. The highest cases were in Baki (IR 242.23/10,000), and the lowest was in Bulu (114.60/10,000). The moderate and high cases were likely in crowded areas in the central and northern parts of the Sukoharjo Regency (4).

The factors distinguishing this study from previous research are the time, place, and method. This study used a temporal and spatial analysis technique to identify the disease movement completed with the map to provide the COVID-19 case distribution. This study aimed to investigate the distribution of COVID-19 in the Sukoharjo Regency based on space (spatial) and period (temporal).

METHODS

This study was a descriptive observational study. This study was conducted using an ecological study design with a spatial approach. This study was conducted in Sukoharjo Regency between February and March 2022. The data were obtained from the COVID-19 Response Acceleration Task Force website of the Sukoharjo Regency with an observation period from April 2020 to December 31, 2021. The population used in this study was all of the COVID-19 confirmed cases recorded by the Health Office of Sukoharjo from the first case finding in April 2020 until December 31, 2021. The sample comprised 15,258 patients, all of whom had confirmed COVID-19 cases recorded by the Sukoharjo Health Office. The scope of this study was limited to the Sukoharjo Regency. The data used in this study were secondary data obtained from the distribution map embedded in the Sukoharjo Regional Task Force for the Acceleration of COVID-19 Response (corona.sukoharjokab.go.id/). This study was approved by the Health Research Ethics Committee of Universitas Negeri Semarang (Approval Number:091/KEPK/EC/2022).

Documentation was performed to recapitulate the desired data from the source. The existing data were then processed to identify the spatial and temporal distribution of COVID-19 cases in Sukoharjo Regency. Moran's Global Index and Local Indicator of Spatial Association (LISA) analysis tests were conducted to determine the spatial relationship dependence among the regions/neighborhoods. This research was carried out from February 2022 to March 2022 in the Sukoharjo Regency.

RESULTS

The Sukoharjo Regency is one of Central Java Province's regencies, consisting of 12 sub-districts and 167 villages. It has a territory of 46,666 ha, with 911,966 inhabitants. Astronomically, it is located in between 110 42′ 6.79″ EL – 110 57′ 3.70″ EL and 7 32′ 17.00″ NL – 7 49′ 32.00″ NL. Surakarta City and Karanganyar Regency directly limit this regency on the north side, Karanganyar Regency on the east side, Wonogiri Regency and Gunung Kidul Regency on the South side, and the Klaten Regency and Boyolali Regency on the west side.

As of December 31, 2021, a total of 15,258 COVID-19 confirmed cases (incidence 167.31/10,000 population) with a total of 1,380 deaths (CFR 9.04%) were recorded by the Health Office of Sukoharjo. The confirmed cases were dominated by symptomatic rather than asymptomatic cases, at 71.83% (10,699/15,258) and 28.17% (4,298/15,258), respectively. Among the reported cases, 90.90% (13,870/15,258) recovered, and 9.04% (1,380 /15,258) died. The sub-district with the highest recovery rate was Mojolaban, while the sub-districts with the highest fatality and case incidence rates were Mojolaban,

Polokarto, and Baki. The details are presented in Table 1.

Table 1
COVID-19 Magnitude in Sukoharjo

Districts	Recovery Rate	CFR	Incidence (/10.000 population)
Weru	90.51%	9.49%	127.57
Bulu	92.44%	7.56%	163.97
Tawangsari	91.90%	8.10%	147.37
Sukoharjo	89.59%	10.34%	146.06
Nguter	91.86%	8.14%	201.62
Bendosari	89.11%	10.69%	159.06
Polokarto	87.95%	11.65%	114.60
Mojolaban	93.10%	6.90%	216.29
Grogol	88.62%	11.38%	145.54
Baki	92.19%	7.75%	242.23
Gatak	91.79%	8.21%	137.45
Kartasura	91.29%	8.71%	197.86
Kabupaten	90.90%	9.04%	167.31

Source: Health Office of Sukoharjo, 2021

Figure 1 shows that the development of new confirmed cases in Sukoharjo Regency has fluctuated from the first case discovery in April 2020 until December 2021 (end of research observation). The number of cases rose in September 2020 and peaked in January 2021. The increasing number of cases reoccurred in June 2021 and peaked in July 2021. The number of deaths significantly spiked between August 2021 and September 2021.

Figure 2 shows the distribution of cumulative COVID-19 cases in the Sukoharjo Regency based on space/place (spatial) and time (temporal). The case distribution movement map is presented by region on a subdistrict scale over three months. Based on Figure 2, it can be seen that the spread of cumulative cases in Kartasura Sub-district is significant. It can be seen from the color change from yellow to reddish-orange and then to red. Meanwhile, the spread of cumulative cases, which tends to be slow, occurs in the Gatak, Weru, Bulu, and Tawangsari sub-districts. Spatial analysis with Moran's I was carried out to determine the pattern of COVID-19 case distribution and to identify spatial dependence. The results showed spatial dependence with a cluster distribution pattern (Moran's Index 0.36; z-score 7.50; and p-value <0.01).

Figure 3 is a significance map showing the spatial relationships (spatial autocorrelation) between one neighborhood and others. The Sukoharjo Regency contains 167 villages. Among the 167 villages, 18 had high-high autocorrelation (HH), 1 had low-low autocorrelation (LL), and 148 had no autocorrelation (insignificant). A more straightforward and detailed explanation regarding the z-scores and p-values can be found in Table 2.

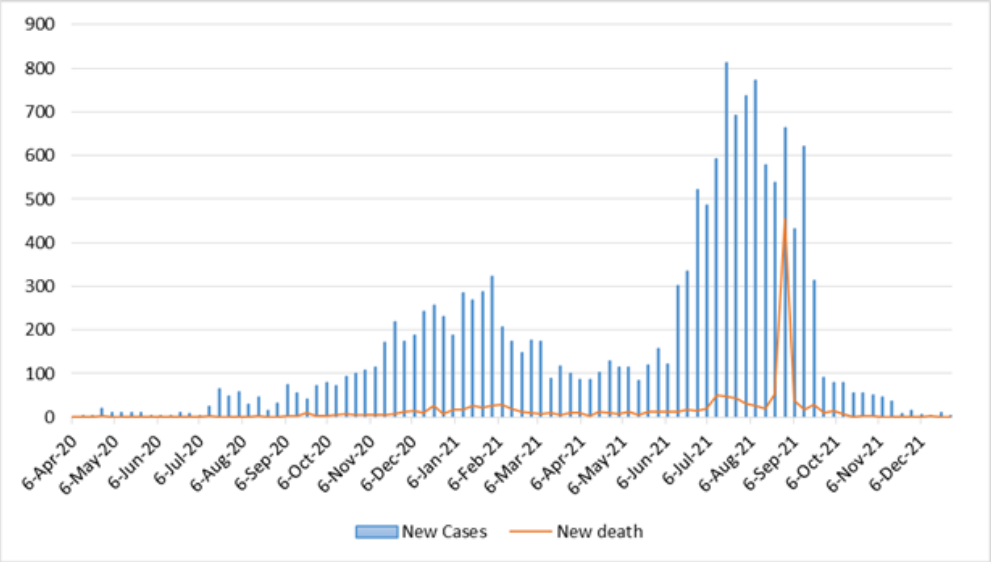

Figure 1. Weekly COVID-19 Cases Finding

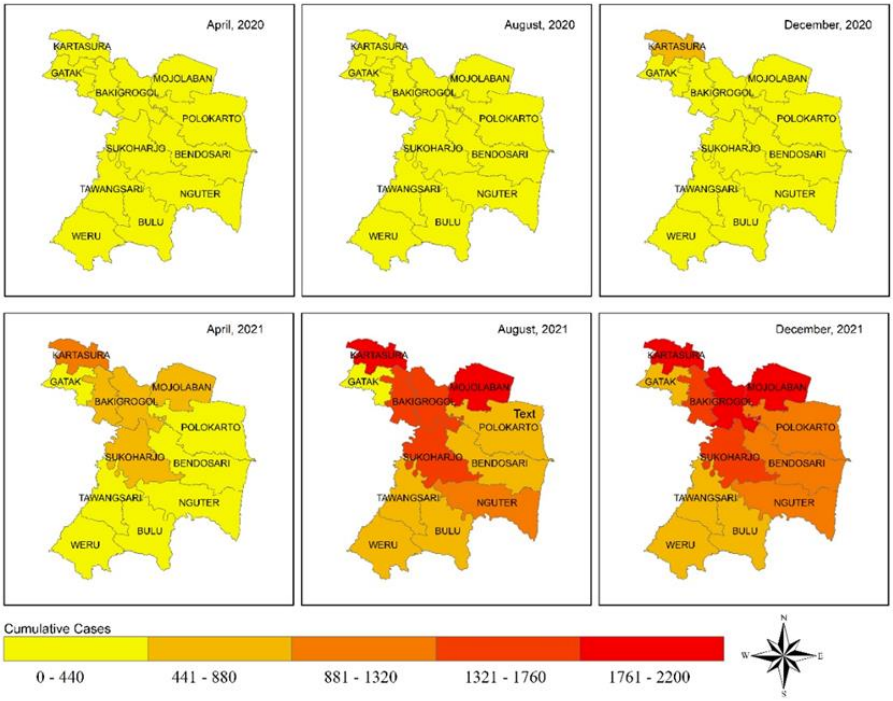

Figure 2. The Distribution Map of COVID-19 Cases in Sukoharjo Year 2020 – 2021

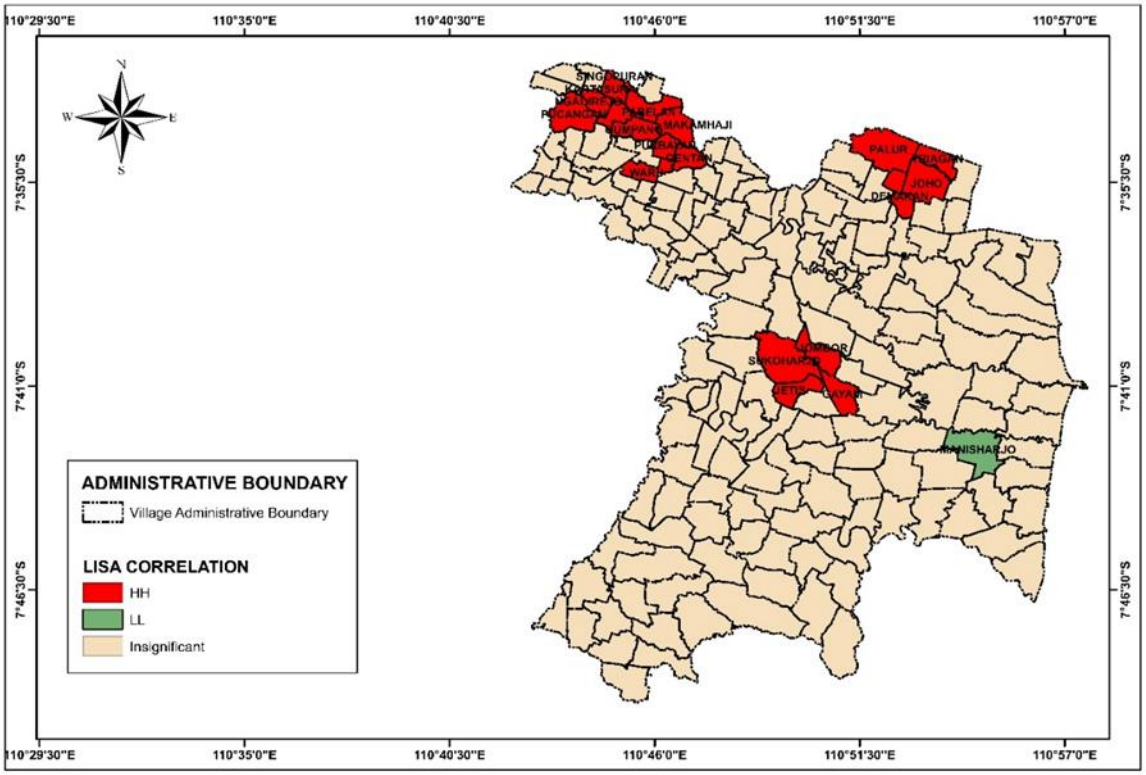

Figure 3. The Significance Map of COVID-19 Case Distribution

Table 2
Local Indicator of Spatial Association of COVID-19 Distribution in Sukoharjo Regency

Sub-district	Village	Z-Score	*p*-Value	Status
Mojolaban	Joho	2.94	<0.01	High-High
Mojolaban	Triagan	3.67	<0.01	High-High
Mojolaban	Palur	5.02	<0.01	High-High
Mojolaban	Demakan	3.05	<0.01	High-High
Baki	Waru	2.07	0.04	High-High
Baki	Gentan	6.80	<0.01	High-High
Baki	Purbayan	10.46	<0.01	High-High
Kartasura	Gumpang	5.75	<0.01	High-High
Kartasura	Kartasura	3.43	<0.01	High-High
Kartasura	Ngadirejo	3.43	<0.01	High-High
Kartasura	Pabelan	5.37	<0.01	High-High
Kartasura	Pucangan	2.32	0.02	High-High
Kartasura	Singopuran	3.09	<0.01	High-High
Kartasura	Makamhaji	10.98	<0.01	High-High
Sukoharjo	Gayam	9.06	<0.01	High-High
Sukoharjo	Sukoharjo	3.94	<0.01	High-High
Sukoharjo	Jetis	2.01	0.04	High-High
Bendosari	Jombor	5.03	<0.01	High-High
Bendosari	Manisharjo	2.02	0.04	Low-Low

DISCUSSION

COVID-19 patients have various a wide range of clinical manifestations. Some patients have no symptoms (asymptomatic), while others have mild to severe symptoms, such as fever, fatigue (fatigue), cough, anorexia, malaise, sore throat, nasal congestion, headache, pneumonia, ARDS, sepsis, and septic shock (15). COVID-19 confirmed cases in the Sukoharjo Regency were dominated by symptomatic cases rather than asymptomatic cases. Based on the prognosis, 13,870 patients recovered and 1,380 died (CFR 9.04%). This means that the fatality rate was higher than the fatality rate at the provincial (6.68%) and national (CFR 3.38%) (2,3).

The Sukoharjo Regency has 12 sub-districts with unique characteristics. The northern subdistricts of Sukoharjo have a higher population density than the subdistricts in the southern part. The highest population density was found in Kartasura, whereas the lowest was in Bulu. The northern parts also have higher mobility because there are many crowded spots, such as supermarket/shopping, transportation, and industry centers. These physical and economic factors played a role in COVID-19 distribution. The region's capacity to manage disease risk and the availability of health care (i.e., primary health care, hospital) also influenced the case findings. The better capacity and accessible health care facilities would increase the case finding of COVID-19 cases (16,17).

The COVID-19 case distribution map (Figure 2) shows that the spread of COVID-19 in Sukoharjo began in the Kartasura subdistricts. Eventually, it headed south, which was in the central part of Sukoharjo. COVID-19 cases were highly distributed in the northern part of Sukoharjo, such as Kartasura, Mojolaban, Grogol, Baki, and Sukoharjo. This probably occurred because the areas have high mobility because they are close to Surakarta City. This finding is in line with the studies conducted by Fatima et al. (12) and Rex and Borgers (18), who stated that there was a positive correlation between high transmission of COVID-19 and high population mobility through air and land transportation. Moreover, the northern part of the Sukoharjo

Regency is a business and economic center. A study conducted by Ren et al (19) also showed that urban areas with high socioeconomic activities had a higher risk of COVID-19 transmission. In China, the early stage of transmission is associated with migration from Wuhan, which means that the higher the migration (mobility and population movement), the higher the number of cases. However, as the epidemic developed, migrating residents could transmit the virus to others, enabling local transmission (20).

The sub-districts in the Sukoharjo Regency with the highest population density are Kartasura, Grogol, Baki, Gatak, and Mojolaban. These places also had the highest cumulative COVID-19 cases from 2020 to 2021 (Figure 2). Studies conducted in Bengkulu and China have found that population density has a positive association with COVID-19 transmission (21). Another study conducted by Puspitaningrum et al (22) in the Klaten Regency, whose characteristics were similar to those of Sukoharjo, also showed similar results, in which the highest cases were found in the Wonosari Sub-districts, which have large areas, rapid population growth, and high population density. This is also in line with a study conducted in Semarang Regency. The results showed that the highest number of cases in Semarang Regency were found in the sub-districts with higher population density, such as Tengaran, Ambarawa, Pabelan, Tuntang, Susukan, Kaliwungu, Ungaran Barat, and Ungaran Timur (23). A study conducted by Ghiffari (24) showed a contrary result that there was a negative correlation between the population and COVID-19 transmission. The population was not the main factor influencing the spread of SARS-CoV-2, but rather the interaction between individuals in a community and population mobility.

Indonesia has experienced two waves of the COVID-19 pandemic. The wave shown by the graph of COVID-19 confirmed cases in Sukoharjo (Figure 1) is in line with the movement of the COVID-19 cases wave at the national level. In Indonesia, a second wave of COVID-19 cases occurred from June 2021 to August 2021 (25). The second wave was larger than the first wave, indicating a higher number of confirmed cases compared to the previous wave, with the number of deaths increasing significantly from late August 2021 to early September 2021 (Figure 1). This accelerated transmission was also influenced by the Delta variant invasion, which was first discovered in India. This variant has the ability to transmit faster than the original variant (ancestral) (26).

The spatial analysis of COVID-19 transmission in Sukoharjo Regency using Moran's Index test showed that there was spatial dependency among the regions in COVID-19 transmission with a clustered distribution pattern. Moran's index is used to measure spatial autocorrelation, which is the extent to which data that are similar or dissimilar is similar to its neighboring region (27). The significance of Moran's Index indicates that transmission does not occur randomly but is influenced by the surrounding areas. A study conducted in Semarang Regency revealed that the distribution pattern of COVID-19 confirmed cases in Semarang Regency in September was clustered with (analysis of nearest neighbor (ANR) test score of <1 and a Z-score scored of-14.57 (23). This is in line with the results of a study from India, which showed a positive significant spatial autocorrelation in COVID-19 distribution with a clustered pattern (16). Research in Brazil, Iran, and Italy also revealed that the transmission of COVID-19 was influenced by spatial effects (28,29). A study in China also showed a positive relationship between spatial distribution and the number of positive confirmed cases, indicating an agglomeration trend (30). In this study, hotspots were found in the following sub-districts: Mojolaban, Bendosari, Baki, Kartasura, and Sukoharjo. Coldspots were found in the Bendosari subdistrict.

Research Limitations

The limitation of this study is that it does not examine analyses such as the Standard Deviational Ellipse (SDE) because of data limitations. In addition, this study does not involve other variables, such as socio-demographic, economic, or other factors. Therefore, future research should involve other variables to determine the association or correlation between them and conduct further in-depth spatial analyses.

CONCLUSION

COVID-19 cases in the Sukoharjo Regency were dominated by symptomatic cases. The highest cases were found in the Baki Sub-district, and the lowest cases were in the Polokarto Sub-district. The Sukoharjo Regency has experienced two waves of COVID-19 cases, with its peak occurring in July 2021. The analysis test showed a

positive spatial autocorrelation in the distribution of COVID-19 cases in the Sukoharjo Regency with a clustered pattern.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

AUTHOR CONTRIBUTIONS

WIH: Conceptualization, Methodology, Drafting. DAL: Data Analysis, Data visualization, and investigation. LF: supervision, validation, review, and editing.

ACKNOWLEDGMENTS

The authors would like to thank the Health Office of Sukoharjo Regency for providing the data on COVID-19 case distribution and making the data publicly available.

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