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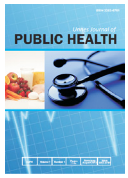

Spatial Distribution COVID-19 Cases Based on Location Quotient (LQ) in Batang Regency, Central Java Province

Heni Isniyati[1]✉, Eram Tunggul Pawenang[2], Mustafa Daru Affandi[2]

[1]Public Health Laboratory, Sports Science Faculty, Universitas Negeri Semarang
[2]Public Health Department, Sports Science Faculty, Universitas Negeri Semarang

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Abstract

The COVID-19 distribution pattern in Batang, an area on the north coast of Central Java between Pekalongan and Semarang, has shown an increase to 9,924 cases since it was first identified on April 4, 2020, until December 2021. The rise in COVID-19 cases in Batang is influenced by various environmental characteristics, including population density and altitude of the area. This research aims to analyze the contribution of these environmental factors to the increase in cases, using a spatial approach based on location quotient (LQ) in Batang Regency over two consecutive years. The research follows a descriptive study with an explanatory spatial approach and has a sample size of 248 villages. The findings reveal that out of the 248 villages with confirmed COVID-19 cases, 53 (21.4%) villages showed a very high potential distribution (LQ>1.2), while 25 (10.1%) villages exhibited a low potential distribution (0.80<LQ<0.95). The analysis of Moran's Index autocorrelation for the distribution pattern of COVID-19 cases in 2020 and 2021 showed significant results, with a probability value < 0.01 and a standard value > 2.58, indicating a cluster distribution pattern. This research helps identify areas with the potential to spread COVID-19 cases, ranging from highest to lowest, thereby assisting the government in formulating policies to overcome COVID-19 cases in Batang Regency.

INTRODUCTION

The World Health Organization (WHO) officially announced "COVID-19" as the name of the new disease caused by the novel coronavirus, which was first identified in Wuhan, China, on February 11, 2020. Furthermore, on March 11, 2020, WHO declared that the world was hit by a COVID-19 pandemic because it was spreading rapidly to many countries, including Indonesia (WHO, 2021).

COVID-19 cases in Indonesia are distributed across all regions, not only in big cities but also in smaller cities and regencies, including those that were not previously suspected, such as Batang Regency. This regency is located in Central Java, with a territory that includes coastal areas (the north coast road), hills, and mountains. More people in Batang Regency live around the north coast highway than in the mountainous areas (Central Agency on Statistics of Batang Regency, 2020). The number of confirmed COVID-19 cases in Batang Regency has increased to 9,924 from the initial identification on April 4, 2020, until December 2021 (Health Service of Batang Regency, n.d.).

The severity of COVID-19 transmission across districts can be influenced by various factors, including the mobility capacity of the population, migration to other areas, the availability of health infrastructure, transportation, and high

✉ Corespondence Address:
Semarang, Indonesia
E-mail: heni0882@gmail.com

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economic activity or density of migrant workers (Qi et al., 2020). HL. Blum's research indicated that health status is influenced by several factors, with environmental factors accounting for 40%, behavior for 30%, health care for 20%, and genetic (heredity) factors for 10%. Environmental factors encompass population demography and geography. Research by Nelwan (2020) showed that areas with high population density experience an increase in the number of COVID-19 cases. Additionally, a study by Rovetta & Castaldo (2020) found that 60% of COVID-19 cases occurred in densely populated areas with levels of Particulate Matter 10 (PM10) in the air exceeding the threshold and in areas with minimum temperatures. PM10 is an airborne particle with a diameter smaller than 10 micrometers that contributes to disease and may lead to death due to heart or lung disease.

The risk of COVID-19 distribution in an area is directly proportional to population density, indicating that higher population density in a sub-district corresponds to a higher risk of COVID-19 transmission in that area (Rani et al., 2020). In research conducted by Midya, AI & Roy, S (2021), geographical variations were found to result in different COVID-19 death rates. Villages adjacent to sub-regencies showed potential vulnerability to spreading COVID-19 cases. Andree Ehlert's study in 2021 stated that socioeconomic, demographic, and health level variables at the regional level were related to the number of cases and the incidence of COVID-19 deaths in Germany during the early to mid-June 2020 period. The study used a multivariate spatial model covering 401 regions in Germany, and it demonstrated that the number of cases and death rates had a positive and significant correlation with the incidence of epidemics, the average age of sufferers, population density, and the number of elderly individuals in the population (Ehlert, 2021).

Epidemiological models show that the rate of disease transmission by viruses is affected by the altitude of the region, where transmission rates tend to be lower in the highlands (> 1,000 masl) compared to the lowlands (< 1,000 masl). Similarly, evaluation results of differences in patient recovery rates, case fatality ratios, and the number of undiagnosed cases demonstrate that the severity of COVID-19 decreases in areas above 1,000 meters above sea level. Hence, altitude significantly influences the reduction of COVID-19's impact (Arias-Reyes et al., 2021).

Batang Regency, covering an area of 78,864.16 hectares, is divided into 15 sub-districts comprising 248 villages, with a population density of 967 people/km². Analysis of routine field data conducted by the health office and the COVID-19 emergency response team in Batang District reveals that the variation in the number of COVID-19 cases in each village in Batang Regency is influenced by population density. Regions with higher population density tend to have a higher number of COVID-19 cases. However, the understanding of the potential impact of environmental factors on the transmission of the coronavirus remains limited.

The ease of access to mobility and information in the community can contribute to an increase in the number of positive cases every day. The pattern of COVID-19 case distribution in the community can be identified through clusters. Clusters represent a pattern of disease case distribution with related events occurring within a certain group, connected by an event in the same period.

Spatial-based research on disease distribution patterns plays a crucial role in controlling and limiting the spread of COVID-19 in an area. Research-based on a spatial approach using Geographic Information System (GIS) tools is one of the efforts aimed at curbing the increase and expansion of cases in an area. Through spatial analysis, various natural phenomena, including maps and disease distribution patterns, especially during the ongoing COVID-19 pandemic, can be described (Sunardi et al., 2005).

Numerous researchers have adopted a spatial analysis approach in their studies during the COVID-19 pandemic. Zhixiang Xie (2020) indicated that the characteristics of epidemic distribution are positively correlated with global and local spatial correlations. Global spatial correlations show a change in the process from agglomeration to decentralization, while local spatial correlations indicate a significant affinity to layouts distinguished in the 'high to high' and 'low to low' group types (Xie et al., 2020).

Location Quotient (LQ) is a specific method used to describe the uniqueness of an area by comparing it with national conditions (Florence 1939; Walter 1992; Vandoros et al. 2013; Photis 2016). Essentially, LQ compares the concentration capacity of a phenomenon, characteristic, occupation, or group within a certain administrative area with a broader coverage (Vandoros et al., 2013). Florence (1939) explained that the location quotient is a result of a particular location that can be used to measure geographic concentration in an area. In the case of COVID-19, LQ is calculated to measure the geographical concentration of COVID-19 in each province of Iran, compared to the geographical concentration of COVID-19 in the entire country (Hazbavi, 2020). LQ analysis shows that most provinces in Iran have high levels of COVID-19 concentration compared to the concentration within the country, indicated by an LQ value > 1. Another research, which used a spatial approach based on location quotients in India, revealed that the distribution pattern of confirmed COVID-19 cases formed clusters, with high-concentration areas having high LQ scores. This influenced the COVID-19 case death ratio in India (Ghosh et al., 2020).

Spatial analysis is a well-developed method used in various subjects to analyze phenomena in society based on space or territory. It has a wide scope, and one of its applications is geographic information systems (GIS). GIS is a technological system composed of multiple geographic features with tabular data, used to analyze, map, and assess real-life problems (Scholten & de Lepper, 1995). Research on the influence of environmental characteristics on disease spread patterns is essential to prevent an increase in COVID-19 cases. Spatial analysis approaches using geographic information systems are carried out to identify geographical factors related to the distribution and incidence pattern of COVID-19 infections, which can inform public health policy-making efforts to control the virus (Jesri et al., 2021).

METHODS

This research is descriptive with an explanatory spatial approach. The study involved reviewing COVID-19 data from the Batang Regency Health Office, which is the authorized institution responsible for managing COVID-19 data in the region. The data review spanned from April 2020, when the first COVID-19 patient was discovered, to December 2021, covering the period of the pandemic. The study focused on the rural areas of Batang Regency, with a sample size of 248 villages, and the research unit was the village itself. The variables examined in the research were the number of COVID-19 cases, population density, and area altitude. The research instrument utilized recorded case data, population demographics, and altitude information obtained from the Health Service and the Central Agency on Statistics.

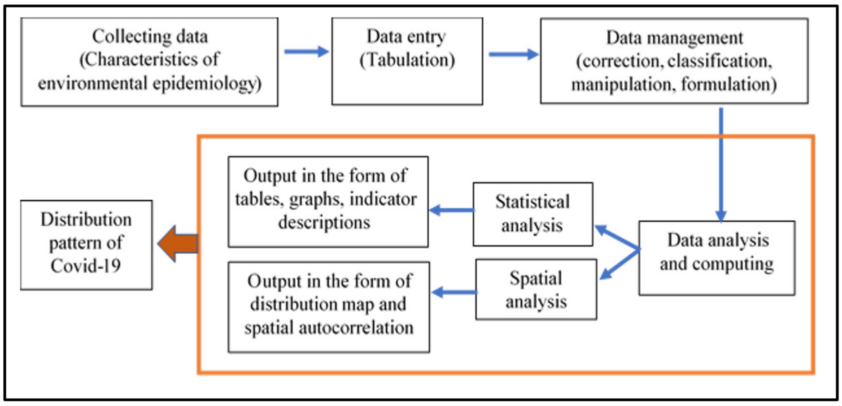

Figure 1. Method Flow

The research began with data collection, encompassing environmental epidemiological characteristics consisting of periodic COVID-19 case data, demographic data on the population, and the area's altitude. Subsequently, the data underwent input into tabulations, followed by data management steps, which included data correction, classification, and formulation.

The research data was subjected to both statistical and spatial analysis. The statistical analysis involved describing the frequency, proportion, and correlation of environmental factors with the distribution of the number of COVID-19 cases in Batang Regency. On the other hand, spatial analysis was used to represent the tabulation results in thematic maps. These maps included the LQ distribution, using different colors to indicate variations in geographic concentration values, as well as a map depicting the distribution of COVID-19 cases and Moran's index values in Batang Regency for two consecutive years. The interpretation of the results in this study comprised spatial explanations and the autocorrelation of Moran's index values, which were narrated while considering literacy. The Batang Regency Health Office significantly contributed to this research by providing data on the number of COVID-19 cases. Additionally, population and topographic data were obtained from the Central Agency on Statistics through the annual report of Batang Regency in 2020. The demographic map of Batang Regency was obtained and processed based on the geospatial homepage using Geographic Information System (GIS) software.

RESULTS AND DISCUSSION

All areas in Batang Regency were affected by COVID-19 in 2021. The village with the highest accumulation of COVID-19 cases in 2021 reported 494 cases, while the lowest reported only 1 case.

Table 1 shows the distribution of accumulated COVID-19 cases and the number of villages with confirmed cases in Batang Regency, arranged from the lowest to the highest. The total number of COVID-19 cases in each village in Batang Regency ranged from 1 to 494 cases from January 2020 to December 2021. Kauman had the highest accumulated cases during the study period, with 494 cases, while Binangun had the lowest accumulation, with only 1 case during the study period. A study by Dayun Kang on the distribution of COVID-19 cases in mainland China revealed that the disease spread rapidly from one region to another since the beginning of the pandemic. Therefore, research on disease distribution patterns in mainland China with a spatial approach is considered important to prevent further transmission to different types of environments (Kang et al., 2020).

Table 1. Accumulation of Cases and the Number of Villages Detected by COVID-19 (January 2020 to December 2021)

amount case	amount village	(%)	Cumulative percentage	amount case	amount village	(%)	Cumulative percentage	amount case	amount village	(%)	Cumulative percentage	amount case	amount village	(%)	Cumulative percentage
1	1	.4	.4	20	2	.8	54.4	41	2	.8	83.5	88	1	.4	93.1
2	2	.8	1.2	21	6	2.4	56.9	42	2	.8	84.3	90	1	.4	93.5
3	4	1.6	2.8	22	7	2.8	59.7	43	1	.4	84.7	91	1	.4	94.0
4	3	1.2	4.0	23	5	2.0	61.7	44	1	.4	85.1	92	1	.4	94.4
5	7	2.8	6.9	24	8	3.2	64.9	45	4	1.6	86.7	93	1	.4	94.8
6	10	4.0	10.9	25	8	3.2	68.1	49	1	.4	87.1	117	1	.4	95.2
7	11	4.4	15.3	26	4	1.6	69.8	50	2	.8	87.9	118	1	.4	95.6
8	7	2.8	18.1	27	3	1.2	71.0	58	1	.4	88.3	119	1	.4	96.0
9	11	4.4	22.6	28	2	.8	71.8	59	1	.4	88.7	121	1	.4	96.4
10	6	2.4	25.0	29	5	2.0	73.8	62	1	.4	89.1	128	1	.4	96.8
11	10	4.0	29.0	30	2	.8	74.6	63	1	.4	89.5	129	1	.4	97.2
12	13	5.2	34.3	31	1	.4	75.0	69	1	.4	89.9	134	1	.4	97.6
13	11	4.4	38.7	32	7	2.8	77.8	71	1	.4	90.3	136	1	.4	98.0
14	5	2.0	40.7	33	2	.8	78.6	74	1	.4	90.7	185	1	.4	98.4
15	6	2.4	43.1	35	1	.4	79.0	76	1	.4	91.1	200	1	.4	98.8
16	7	2.8	46.0	37	2	.8	79.8	82	1	.4	91.5	202	1	.4	99.2
17	3	1.2	47.2	38	2	.8	80.6	83	1	.4	91.9	249	1	.4	99.6
18	5	2.0	49.2	39	4	1.6	82.3	84	1	.4	92.3	494	1	.4	100.0
19	11	4.4	53.6	40	1	.4	82.7	86	1	.4	92.7	Total	248		100.0

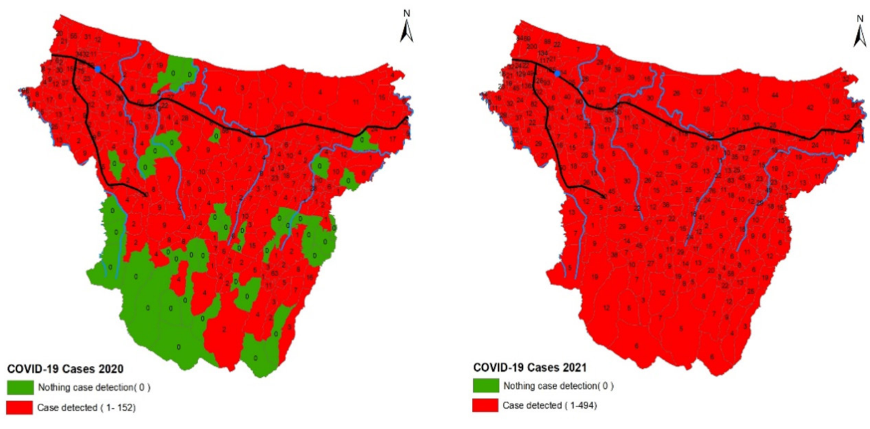

Figure 2. Distribution of COVID-19 Cases in 2020 and 2021

The map above illustrates the increase in the number and distribution of COVID-19 cases in 2020 and 2021. Areas with no COVID-19 cases are colored green, while areas with identified CO-

VID-19 cases are colored red. In 2020, there were 39 green-colored areas, indicating no COVID-19 cases were identified. However, in 2021, all areas were red-colored, indicating that all areas were confirmed to have COVID-19 cases.

Population density has a positive correlation with the number of COVID-19 cases, indicating that higher population density in an area leads to an increase in the number of cases. This is related to the transmission of the virus through droplets or the air, highlighting the importance of social distancing to minimize the spread of the virus from COVID-19 cases to others. In Batang district, the average population density is 1.523 persons/km², ranging from 40 persons/km² to 17.163 persons/km². Areas with high population density may experience a higher increase in cases due to limited space for maintaining distance, making it challenging to carry out social distancing optimally. Wong's study (2021) also supports this finding, as he observed that population density effectively predicts an increase in the number of accumulated infection cases at the district level in the US. Population density contributed significantly to the regression value (57%) and the spatial model (76%). It is crucial to pay attention to infection spread in each district and include vulnerable population subgroups in the transmission model to predict the impact of COVID-19, particularly at the district level. Another study by R. Pascoal (2022) based on COVID-19 data from France found a correlation between density and the incidence of death from COVID-19, suggesting that population density should be considered complementary information for epidemiological models, together with microscopic and macroscopic population sizes (Pascoal & Rocha, 2022).

Table 2. Correlation of Environmental Characteristics with the Number of Covid-19 Cases

	Correlation		***COVID-19 Case***
Spearman's rho	Population Density	Correlation Coefficient	.501**
		Sig. (2-tailed)	.000
		N	248
	Altitude of Area	Correlation Coefficient	-.496**
		Sig. (2-tailed)	.000
		N	248

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

Regarding altitude, the average elevation in Batang district is 280 masl, ranging from 8 masl to 800 masl. The results of the altitude area test and the number of COVID-19 cases showed a significant negative correlation (-0.496) with a p-value <0.01. This indicates that the altitude of the area influences the distribution of COVID-19 cases, and the pattern of COVID-19 case distribution in Batang Regency follows the same trend in 2020 and 2021. Research by Cano-Perez indicates a negative and significant correlation between the incidence of COVID-19 cases and deaths and the altitude of the area, suggesting that living in the highlands is associated with a lower mortality impact from COVID-19. There are differences in survival rates between infected patients living in highlands and lowlands, with the group in the highlands showing longer survival and milder disease severity (Simbaña-Rivera et al., 2022). Similarly, Stephens conducted multi-state and county studies considering policy enforcement, environmental factors, and social issues such as compliance with public health guidelines, population demographics, and social attributes. His research revealed that areas above 1,915 masl had an inverse correlation with COVID-19 occurrence, whereas little or no association was found with increased elevation (Stephens et al., 2021).

Spatial autocorrelation is a type of spatial

Table 3. Spatial Autocorrelation and Distribution Pattern of COVID-19 Cases in 2020 and 2021

Year	Spatial Autocorrelation			
	Moran's Index	Z-score	P-value	**Distribution Pattern**
2020	0,436	18,165	0,000	Clustered
2021	0,519	22,387	0,000	Clustered

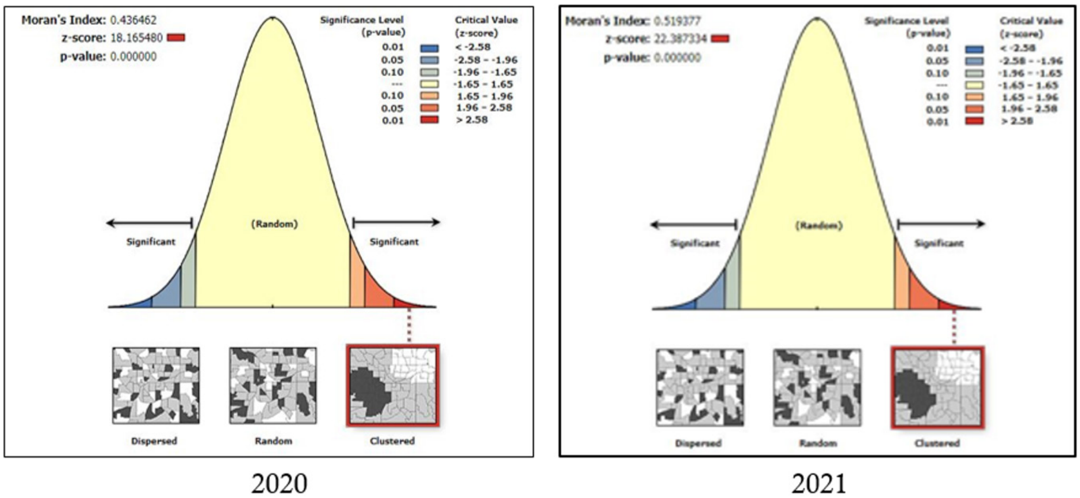

Figure 3. Graphic of autocorrelation with Moran index in 2020 and 2021

analysis that aligns with the fundamental concept of the First Law in Geography by Waldo Tobler (1971), stating that objects close together in space are more similar than those farther apart. Moran's index is a tool used to measure correlation, ranging from -1 to 1, to determine the general characteristics of spatial patterns, whether they are clustered, random, or dispersed.

The pattern of case distribution in both the 2020 and 2021 periods formed a cluster with a significant spatial autocorrelation value of <0.01 and a standard value of >2.58. A Moran's index value between 0 and 1 indicates positive spatial autocorrelation, where a systematic pattern is formed based on the proximity or adjacency between regions. Moran's index is a global index that compares attribute values of an area with other areas. Its advantages include quick results and diverse purposes, such as identifying differences, characteristics, significance, and objective functions. However, Moran's index does not provide information on spatial patterns in specific local areas because it is a global index. To address this limitation, it can be combined with other analytical tools to account for local patterns. The use of Moran's Index extends beyond understanding spatial patterns and data variations; it also aids decision-making to achieve optimal outcomes.

This aligns with research conducted by Yi Han et al. (2021), where a spatial autocorrelation approach was used to calculate the Moran index values, revealing that the distribution pattern of COVID-19 cases in Beijing has been closely clustered since June 21, 2020 (Han et al., 2020).

In Figure 3, the graphic of autocorrelation illustrates the pattern of case distribution in

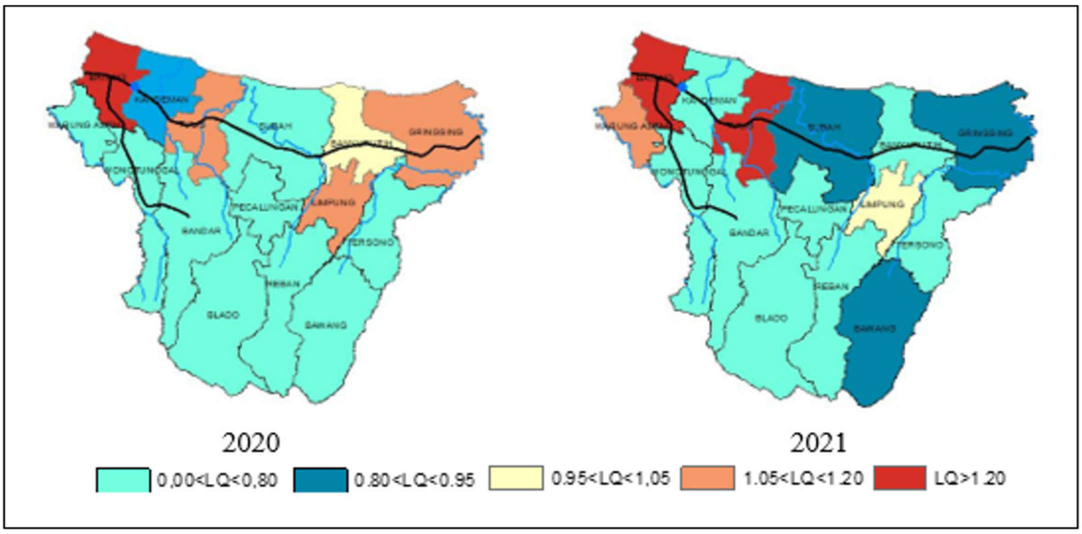

Figure 4. Distribution of COVID-19 Cases Based on Location Quotient (LQ) in 2020 and 2021

the periods 2020 and 2021, forming clusters with Moran's index values of 0.436 in 2020 and 0.519 in 2021. This indicates the presence of autocorrelation or adjacency relationships between regions in Batang Regency from 2020 to 2021. The distribution of cases in the form of clusters in the pattern of COVID-19 case distribution in Batang district demonstrates a significant closeness or neighborly relationship between districts, where regions influence each other, resulting in spatial clustering or tendencies.

According to the LQ (Location Quotient) analysis, approximately 54.8% of villages in Batang Regency fall within areas with very low potential ($0 < LQ < 0.8$), 10.9% in low potential ($0.80 < LQ < 0.95$), 5.3% in medium potential ($0.95 < LQ < 1.05$), 8% in high potential ($1.05 < LQ < 1.2$), and 21% in very high potential ($LQ > 1.2$). The areas with the highest LQ distribution are situated along the main regency roads and in low-lying areas.

Figure 4 illustrates the distribution of areas based on LQ in Batang Regency. It indicates that areas with easy access to transportation and proximity to the regency capital have a higher potential for widespread COVID-19 cases compared to areas that are farther from the regency's main roads. Topographic conditions, specifically the higher population density in the lowlands compared to the highlands, contribute to the distribution pattern of COVID-19 cases in Batang Regency, with the potential for spread (LQ) being higher in the lowlands. This finding aligns with research conducted by Hazbavi on spatial-temporal analysis of COVID-19 events in Iran, which also utilized LQ and found differences in LQ indexes in most provinces in Iran with $LQ > 1$ (Hazbavi et al., 2020).

CONCLUSION

The distribution pattern of COVID-19 cases in 2020 and 2021, obtained through a spatial approach in this research, shows a cluster pattern. Statistical tests reveal a significant relationship between environmental characteristics, including population density and altitude, and an increase in COVID-19 cases. Consequently, there is a spatial relationship of proximity or neighborliness between regions in Batang Regency, influencing the distribution pattern of COVID-19 cases. Spatial analysis based on LQ identifies 53 villages located at an altitude of <200 masl (lowland) with moderate to high population density as having the highest potential for cases, exhibiting positive autocorrelation. This suggests a neighborly relationship in the distribution of COVID-19 cases between regions in Batang Regency. This study demonstrates that spatial analysis based on environmental characteristics is a recommended method for describing patterns of disease transmission and determining the distribution of cases in an area.

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