Disease Prevention and Public Health Journal
Vol. 19, No. 1, March 2025, pp. 01-10

e-ISSN: 2720-9997

Mapping and Clustering COVID-19 Cases in Kudus District

Dyah Retno Safitri[1], Dwi Sarwani Sri Rejeki[2*], Sri Nurlaela[3], and Rosita Dwi Jayanti[4]
[1,2,3,4] Department of Public Health, Faculty of Health Sciences, Jenderal Soedirman University, Banyumas, Indonesia
*corresponding author: dwi.rejeki@unsoed.ac.id

ARTICLE INFO

Article history
Received August 18, 2024
Revised January 22, 2025
Accepted February 17, 2025

Keywords
Coronavirus disease 2019
Spatial
Clustering
Kudus district

ABSTRACT

Background: Kudus District contributed the high case fatality rate (10%) of Coronavirus Disease at the end of 2020 in Central Java Province, one of the provinces which was the center of Coronavirus Disease transmission in Indonesia. Spatial analysis is useful for identifying areas of grouping or clusters of cases that indicate high risk areas so that prevention measures can be developed specifically in those areas. This study aimed to map and identify clusters of Coronavirus Disease cases in Kudus District. **Method**: An observational method with a case study design was conducted involving all confirmed cases of Coronavirus Disease from January to April 2021 in Kota Subdistrict, totaling 257 cases. Spatial analysis included overlay and buffering processed using ArcGIS, and clustering processed using SaTScan. **Results**: The study results showed that cases tended to be spread evenly across all villages, with the highest number of cases (8.2%) observed in Mlati Norowito Village. Spatial analysis revealed that the majority of cases were concentrated in villages with a population density of 8,001-12,000 people/km^2 (51.7%) and villages with a number of social assistance recipients of 801-1,200 (36.6%), residing less than 250 meters from health care facilities (50.5%) and less than 250 meters from public facilities (59.14%), and four secondary clusters of Coronavirus Disease cases were identified. **Conclusion**: A higher cases of Coronavirus Disease were identified in villages with a high population density, a large number of social assistance recipients, close proximity to health care and public facilities, and four secondary clusters were identified.

Introduction

Coronavirus Disease 2019 (COVID-19) is a respiratory disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus [1]. This disease is transmitted between humans, mainly through droplets [2] and usually occurs in people who have close contact [3]. Since it was first reported on December 31 2019 in China, the SARS-CoV-2 virus was declared a global pandemic by the World Health Organization (WHO) on March 11 2020 [1]. The spread of COVID-19 in Indonesia also occurred in a short period of time. Forty days after the first confirmed case of COVID-19 was reported on March 2 2020, COVID-19 has spread to all provinces (34 provinces) in Indonesia [4]. As of December 31 2020, the cumulative number of confirmed cases of COVID-19 in Indonesia reached 735,124 cases with a Case Fatality Rate (CFR) of 3% (21,944 deaths) [5]. There were 5 provinces identified as centers of COVID-19 transmission in Indonesia, one of which was Central Java [6].

Kudus District has been identified as a contributor to elevated number of COVID-19 cases in Central Java Province. As of December 31 2020, Kudus District Government reported 3,567 confirmed cases of COVID-19 with a high CFR of 10% (363 deaths) [7]. In response, the District Government has implemented measures to address the outbreak, including issuance of a regent's regulation mandating the enforcement of health protocol laws. However, from January to April 2021, the district witnessed a consistent rise in daily cases, with the majority of the affected population being native residents. Previously, an ecological study in Jakarta, Indonesia showed that sub district with high population density, slum areas and low education levels had a high risk of transmitting COVID-19. [8].

One tool that can be used to formulate policies and make decisions regarding the implementation of infectious disease control measures is the result of information from spatial analysis [9]. In simple terms The function of spatial analysis is to map things using spatial data, see how things relate to each other, identify patterns or trends in the data, see what they mean, and finally decide what action to take [10]. Mapping a disease is important in epidemiology because it can identify areas of high risk [11]. Spatial analysis of COVID-19 is able to provide an overview of the distribution of COVID-19 cases geographically using a map and showing areas of grouping or clusters of cases so that preventive measures can be developed and focused in that area [12,13].

The results of spatial analysis in Indonesia succeeded in identifying five provinces on Java Island which were the epicenters of transmission of COVID-19 in Indonesia. Mobility and high population density in the area allow transmission of COVID-19 to occur quickly [6]. The results of the spatial analysis of COVID-19 in Jakarta also showed that more cases were found in areas with high population density and many public facilities [14]. Spatial analysis in Beijing, China showed that clusters of COVID-19 cases were found in the area around Xifandi Market and population density was also a factor that increased the spread of COVID-19 at the research location [15]. From these several spatial studies, understanding the dynamics of transmission in local communities is very important for planning a strategy for preventing COVID-19 [13].

Until now, there has been no mapping of COVID-19 cases in Kudus District. This study aimed to map and identify clusters of COVID-19 cases in Kota Village, which was the village with the highest number of COVID-19 cases in Kudus District. Thus, the results of this study can be used as a basis for policies in prevention measures that can be developed specifically in the COVID-19 case cluster area. It is hoped that this will prevent a COVID-19 outbreak from occurring in the future.

Materials and Method

This research used an observational method with a case study design and was conducted from November 2022 to March 2023. The research subjects were all individuals who were confirmed to have COVID-19 from January to April 2021 in Kota Village, a total of 257 cases. The data sources that were used in this study included both primary and secondary data. The primary data collected included the geographical location of the subject's residence, their history of contracting the COVID-19, history of comorbid diseases, and history of vaccination. The geographical location of the subject's residence was marked using a Global Positioning System (GPS) tool. The history of contracting COVID-19, history of comorbid diseases, and history of vaccinations were obtained through in-person interviews using a structured questionnaire. Secondary data included date of illness, age, gender and occupation obtained from the Kudus District Health Office, population density from data from the Kudus District Central Statistics Agency, number of social assistance recipients from the Kudus District Social, Women's Empowerment and Child Protection Office, location health care facilities (public health centers, hospitals, clinics) from the Kudus District Health Office, and public facility locations (traditional markets, supermarkets, bus terminals, city parks, entertainment areas, schools) from the Public Works and Spatial Planning Office.

A comprehensive data analysis was conducted, encompassing both univariate and spatial analyses. The spatial analysis included methodologies such as overlay, buffering, and clustering. Statistical Program for Social Science (SPSS) software was used to conduct univariate analysis, ArcGIS software for overlay and buffering analysis, and SaTScan software to conduct clustering analysis. Univariate analysis was used to determine the frequency distribution of age, sex, occupation, history of infection, history of comorbid diseases, and history of vaccinations. An overlay analysis was conducted to find out the distribution of COVID-19 cases based on population density and the number of recipients of social assistance. Buffering analysis was conducted to determine the distribution of COVID-19 cases based on areas formed from the locations of health care and public facilities, each within a radius of less than 250 meters. Clustering analysis was conducted to determine clusters or groupings of COVID-19 cases using the Space-Time Permutation Model. The aggregate time used in this analysis was 14 days which is the longest incubation period for COVID-19. This research had received approval from the Health Research Ethics Commission, Faculty of Health Sciences, Jenderal Soedirman University No. 951/EC/KEPK/XII/2022 and research permit from the Kudus District National and Political Unity Agency with letter number 070/060/39.00/2023.

Results

This study involved 257 confirmed cases of COVID-19 which were recorded from January to April 2021 in Kota District, Kudus District. Table 1 shows a higher prevalence of cases among women (54.9%) compared to men, with the majority (8.2%) cases occurring in the Mlati Norowito Village. The average age of the cases was 44 years, with the youngest was 3 years old and the oldest was 86 years. As many as 47.9% of cases were unemployed. Furthermore, 54.5% of cases stated that they had contracted it from friends/neighbors. Judging from the history of comorbid diseases, there were more cases with no history of comorbid diseases (59.1%) than cases with comorbid diseases. Meanwhile, 71.6% of cases had been vaccinated up to dose 2.

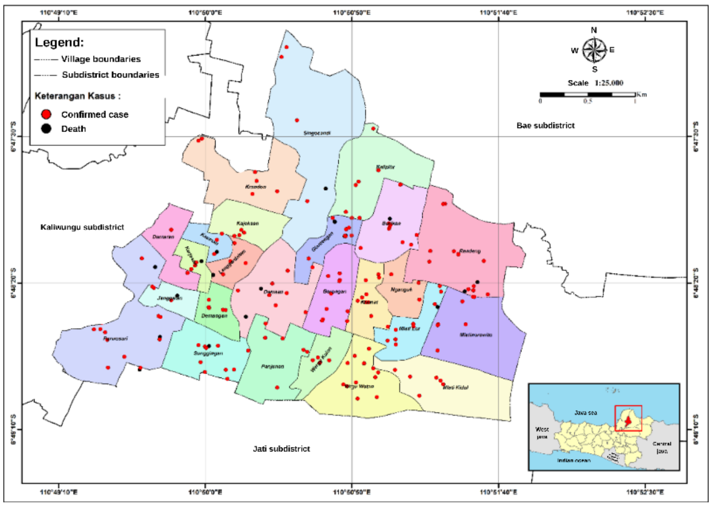

Figure 1. Map of the Distribution of Confirmed Cases of COVID-19 in Kota Subdistrict, Kudus District from January to April 2021

Figure 1 shows that confirmed cases of COVID-19 in Kota District, Kudus Regency from January to April 2021 were found in all villages. These cases tend to be evenly distributed across all villages (25 villages). Figure 2a shows that COVID-19 cases tend to occur in more densely populated areas. As many as 51.7% of cases were in areas with category two population density (8001-12,000 people/km2). The area included 11 villages namely Demangan, Wergu Wetan, Mlati Kidul, Nganguk, Kramat, Langgardalem, Kauman, Damaran, Krandon, Glantengan, Barongan Villages. In fact, several cases (6.7%) were also found in areas with the highest population density (> 16,000 people/km2), covering 3 villages namely Sunggingan, Panjunan, and Kerjasan. Most of the cases (36.6%) were in areas with a total number of social assistance recipients of 801-1200 people as seen in Figure 2b. The area included 8 villages namely Janggalan, Mlati Kidul, Mlati Lor, Mlati Norowito, Nganguk, Kramat, Kajeksan and Burikan Villages. Meanwhile, in areas with a smaller number of social assistance recipients (100-400 people), the cases found were also lower (4.3%). This area covers 2 areas, namely Kauman and Kerjasan Villages (Figure 2b).

Table 1. Confirmed Cases of COVID-19 in Kota Subdistrict, Kudus District based on Their Characteristics in January-April 2021

Variables	**Confirmed Case of COVID-19**	
	n	**%**
Residence (Village)		
Mlati Norowito	21	8.2
Purwosari	20	7.8
Barongan	20	7.8
Wergu Wetan	17	6.6
Mlati Kidul	15	5.8
Kramat	14	5.4
Burikan	14	5.4
Mlati Lor	13	5.1
Krandon	12	4.7
Singocandi	12	4.7
Rendeng	12	4.7
Sunggingan	10	3.9
Kauman	10	3.9
Langgar Dalem	9	3.5
Wergu Kulon	8	3.1
Demaan	8	3.1
Kaliputu	7	2.7
Janggalan	6	2.3
Panjunan	6	2.3
Kajeksan	6	2.3
Demangan	5	1.9
Nganguk	5	1.9
Glantengan	4	1.6
Damaran	2	0.8
Kerjasan	1	0.4
Sex		
Male	116	45.2
Female	141	54.9
Occupation		
Employed	118	45.9
Student	16	6.2
Unemployed	123	47.9
History of infection		
Family	42	16.3
Friends/Neighbors	140	54.5
Not known	74	28.8
History of comorbid disease		
Yes	103	40.1
No	152	59.1
Vaccine history		
Not yet vaccinated	14	5.4
Have had vaccination 1	54	21.0
Have had vaccination 1 and 2	184	71.6
Have had vaccination 1, 2 and booster	5	1.9

More cases (50.5%) lived close to health care facilities, namely within a radius of less than 250 m as seen in Figure 3a. In addition, Figure 3b shows the distribution of cases close to public facilities. It was recorded that 59.14% of cases lived within a radius of less than 250 m from public facilities.

a) b)

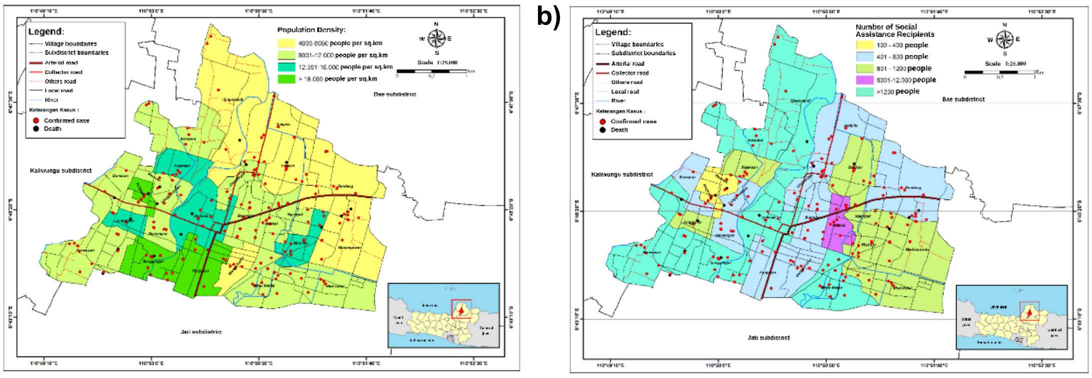

Figure 2. Overlay Maps of COVID-19 Confirmed Cases in Kota Subdistrict, Kudus District from January to April 2021, with a) Population Density and b) Number of Social Assistance Recipients

a) b)

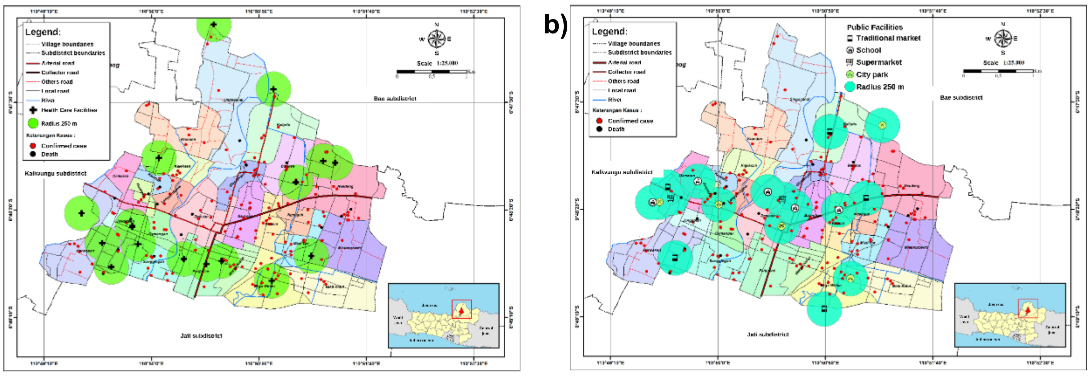

Figure 3. Buffering Maps (within a Radius of Less than 250 m) of COVID-19 Confirmed Cases in Kota Subdistrict, Kudus District from January to April 2021, with **a)** Health Care Facilities and **b)** Public Facilities

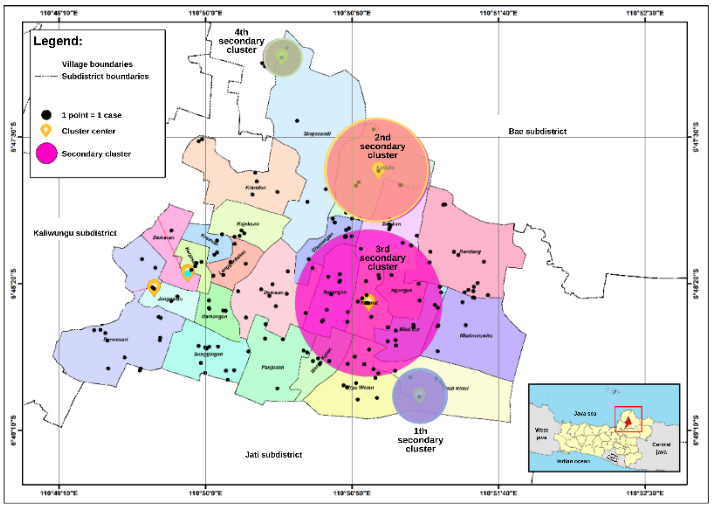

Figure 4. Clustering Map of Confirmed Cases of COVID-19 in Kota Subdistrict, Kudus District from January to April 2021

Figure 4 presented the results of the clustering analysis of confirmed cases of COVID-19 in Kota Subdistrict Kudus District from January to April 2021. Clustering analysis with an aggregate time of 14 days showed that the most likely cluster (primary cluster) was not identified and 4 secondary clusters were identified. The first secondary grouping area or cluster, totaling 13 cases, was within the scope of the Mlati Norowito, Mlati Lor and Mlati Kidul Villages. This cluster was centered at coordinates 6.811950 mT, 110.855340 mU with a radius of 360 m. The second secondary cluster area, which totaled 7 cases, was within the scope of the Singocandi, Kaliputu and Burikan Villages. This cluster was centered on coordinates 6.794860 mT, 110.849730 mU with a radius of 540 m. The third secondary cluster area, totaling 3 cases, was found in Janggalan Village and was centered at coordinates 6.806020 mT, 110.828460 mU with a radius of 210 m. The fourth secondary cluster area, totaling 7 cases, was within the area of Barongan, Kramat, Panjunan, Wergu Kulon and Wergu Wetan Villages. This cluster was centered on coordinates 6.812630 mT, 110.844000 mU with a radius of 490 m.

Discussion

Confirmed cases of COVID-19 in Kota Subdistrict, Kudus District from January to April 2021 were spread across all villages. Kota Subdistrict was an urban area and the most densely populated sub-district in Kudus District [16]. A previous study in Zimbabwe showed that urban provinces had significantly more COVID-19 cases than rural provinces in 2020 [17]. At the beginning of the pandemic, COVID-19 cases in China were concentrated in urban areas. More than 60% of confirmed COVID-19 cases in China were detected in Wuhan City by the end of March 2020 [18]. A similar situation also occurred in the United States where confirmed COVID-19 cases as of March 15, 2020 occurred in 79% of urban areas and 3% of rural areas [19]. The dense population and high social interaction in urban areas make it possible for the spread of COVID-19 to occur quickly [20].

The study found that the number of COVID-19 cases was higher in women than men. A previous study in Guangdong, China showed that women were more at risk of being infected with SARS-CoV-2 than men [3]. It may be due to several reasons, including women playing a dominant role in the household to take care of family members, allowing them to have closer and longer contact with COVID-19 cases [3]. In this study, the number of COVID-19 cases was higher in people who were unemployed than those who were employed and students. There was a discrepancy with the results of the study by Lan et al (2020) which stated that people who worked and interacted directly with customers had a high risk of contracting COVID-19 [21]. The study showed a finding that the majority of respondents stated that they had a history of being infected from friends or neighbors. Chaw et al (2020) showed that one of the risk factors for COVID-19 transmission is contact with relatives, namely people who do not live in the same house as the case [22]. Small informal gatherings with family or friends that are often held at someone's residence either inside or outside the home or visiting each other are social activities that can increase the risk of contracting COVID-19 [23]. The majority of COVID-19 cases in this study did not have a history of comorbidities. Previous studies also showed that most COVID-19 cases did not have comorbidities [24]. Comorbidities were known to increase the risk of severe COVID-19 [25]. The COVID-19 cases in this study had mostly received COVID-19 vaccinations 1 and 2. A study in the UK showed that although there were confirmed cases of COVID-19 after receiving vaccination, asymptomatic COVID-19 cases were more common in vaccinated cases than in unvaccinated cases [26].

The COVID-19 case cluster resulting from spatial analysis in this research was a secondary cluster. This cluster was a grouping of cases whose illness spanned the same 14 days and the distance of residence between cases that were close together. The emergence of this secondary cluster could indicate faster transmission in the cluster area. Villages which were included in the secondary cluster area tended to have a high population density and had a large number of recipients of social assistance. These results were in line with research in DKI Jakarta which stated that the COVID-19 cases from January 2021 to October 2021 spatially showed a clustered distribution pattern and the majority of areas that became hotspots for cases were areas with large populations [27]. Study in Northeastern Brazil showed that there were 11 clusters of COVID-19 cases which indicated that the cluster area was at high risk of rapid transmission. The cluster of cases with the highest incidence rate was in the Salvador metropolitan area, which was the most populous region in Northeastern Brazil [28].

The overlay results in this study showed that more cases of COVID-19 were found in sub-districts with high population density. These results were similar to studies in Magelang districts, Indonesia, Beijing, China and Algeria, North Africa, which showed density had a positive correlation with the number of COVID-19 cases [15,29,30]. The SARS-CoV virus easily spreads through droplets when people are in close contact at a distance of 3-6 feet or 0.9-1.8 m [31]. Social distancing restrictions were difficult to implement in densely populated areas, which could increase the rate of transmission of COVID-19 [8].

COVID-19 cases in this study were more commonly found in sub-districts that had a large number of social assistance recipients. In Indonesia, social assistance is provided to individual experiencing economic disadvantage [32]. Consequently, underprivileged communities are an indicator of residential conditions. These groups tended to have poor sanitation and large numbers of people per residence, making it difficult to prevent COVID-19 [33].

The buffer results in this study showed that most of the COVID-19 cases live close to public facilities. In the past, similar to research in Beijing, China which showed that there was a COVID-19 cluster around Xifandi Market because public places such as markets were places where many people gathered [15]. A COVID-19 outbreak in Tianjin, China also occurred in a department store [34,35]. Poor air ventilation in closed public places was one of the suspected causes of the spread of COVID-19 cases [34]. Outbreaks of COVID-19 have also been reported in indoor public places of worship [36–38]. The absence of physical distancing measures in these places of worship during the outbreak contributed to the transmission of COVID-19 [36]. Public places that had not implemented health protocols allowed the transmission of COVID-19 to occur [39].

The majority of COVID-19 cases lived close to health care facilities. In line with study on spatial patterns in Jakarta, it was stated that a high number of COVID-19 cases were found near health care facilities [14]. The large number of cases in areas near health care facilities was probably due to easy access to care, allowing COVID-19 cases to be recorded. Individuals experiencing symptoms of COVID-19 require access to health care facilities to confirm their diagnosis [40]. The COVID-19 seroprevalence study in Bantul, Indonesia showed that the highest seropositivity was in semi-urban areas due to limited and concentrated diagnostic facilities in urban areas. This allowed positive cases to go undiagnosed. Better surveillance management in urban areas resulted in cases in urban areas being reported more quickly and earlier than those in semi-urban areas [41].

The strength of this study was the collection of primary data, especially the coordinates of the residence of COVID-19 patients. This allows for precise mapping of the spatial distribution of the disease. Taking these coordinates can truly describe the location of the disease. Meanwhile, this study has a limitation, namely that this study only describes COVID-19 cases in one year or time period. It would be interesting if it was done temporally over 5 years or 10 years.

Conclusion

Confirmed cases of COVID-19 in this study tended to be found more often in villages that had a high population density, a large number of recipients of social assistance, lived close to health care facilities and public facilities, and 4 secondary clusters were identified. It is important for the Kudus District Government to conduct cross-sector coordination in developing COVID-19 prevention measures that focus on the COVID-19 cluster area.

Declaration

Acknowledgments: The authors would like to gratitude to the Kudus Regency Government and the Faculty of Health Sciences, Jenderal Soedirman University, for granting permission to conduct this study. The authors also thank to all respondents and all parties who have contributed to the success of this study.

Conflicts of Interest: There are no conflicts of interest either in this research or in this paper.

References

1. Jin Y, Yang H, Ji W, Wu W, Chen S, Zhang W, et al. Virology, Epidemiology, Pathogenesis, and Control of COVID-19. *Viruses.* 2020; 12(4):372. https://doi.org/10.3390/v12040372.
2. World Health Organization. Coronavirus disease (COVID-19): How is it transmitted? 2021. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/question-and-answers-hub/q-a-detail/coronavirus-disease-covid-19-how-is-it-transmitted.
3. Liu T, Liang W, Zhong H, He J, Chen Z, He G, et al. Risk factors associated with COVID-19 infection: a retrospective cohort study based on contacts tracing. *Emerg Microbes Infect*. 2020; 9:1546–1553. https://doi.org/10.1080/22221751.2020.1787799.
4. Aisyah DN, Mayadewi CA, Diva H, Kozlakidis Z, Siswanto, Adisasmito W. A spatial-temporal description of the SARSCoV-2 infections in Indonesia during the first six months of outbreak. *PLoS One*. 2020; 15(12):e0243703. https://doi.org/10.1371/journal.pone.0243703.
5. Kementerian Kesehatan Republik Indonesia. Situasi Terkini Perkembangan Coronavirus Disease (COVID-19) 2020. https://infeksiemerging.kemkes.go.id/situasi-infeksi-emerging/situasi-terkini-perkembangan-coronavirus-disease-covid-19-31-desember-2020.
6. Eryando T, Sipahutar T, Rahardiantoro S. The Risk Distribution of COVID-19 in Indonesia: A Spatial Analysis. *Asia-Pacific J Public Heal*. 2020; 32(8):450–452. https://doi.org/10.1177/1010539520962940.
7. Badan Penanggulangan Bencana Daerah Kabupaten Kudus. Infografis Kedaruratan dan Kebencanaan Kab. Kudus Tahun 2020 2020. https://bpbd.kuduskab.go.id/infografis-2020/.
8. Zakianis, Adzania FH, Fauzia S, Aryati GP, Mahkota R. Sociodemographic and environmental health risk factor of COVID-19 in Jakarta, Indonesia: An ecological study. *One Heal*. 2021; 13:100303. https://doi.org/10.1016/j.onehlt.2021.100303.
9. Rejeki DSS, Nurhayati N, Aji B. A spatiotemporal analysis of dengue hemorrhagic fever in Banyumas, Indonesia. *Int J Public Heal Sci*. 2021; 10(2):231–240. https://doi.org/10.11591/ijphs.v10i2.20713.
10. Charles AC, Armstrong A, Nnamdi OC, Innocent MT, Obiageri NJ, Begianpuye AF, et al. Review of Spatial Analysis as a Geographic Information Management Tool. *Am J Eng Technol Manag.* 2024; 9(1):8–20. https://doi.org/10.11648/j.ajetm.20240901.12.
11. Konstantinoudis G, Schuhmacher D, Rue H, Spycher BD. Discrete versus continuous domain models for disease mapping. *Spat Spatiotemporal Epidemiol*. 2020; 32:100319. https://doi.org/10.1016/j.sste.2019.100319.
12. Ballesteros P, Salazar E, Sánchez D, Bolaños C. Spatial and spatiotemporal clustering of the covid-19 pandemic in ecuador. *Rev Fac Med.* 2021; 69(1):e86476. https://doi.org/10.15446/revfacmed.v69n1.86476.
13. de Souza APG, de Miranda Mota CM, Rosa AGF, de Figueiredo CJJ, Candeias ALB. A spatial-temporal analysis at the early stages of the COVID-19 pandemic and its determinants: The case of Recife neighborhoods, Brazil. *PLoS One*. 2022; 17(5):e0268538. https://doi.org/10.1371/journal.pone.0268538.
14. Dahlia S. Analisis Pola Spasial Pesebaran Kasus Covid-19 Menggunakan Sistem Informasi Geografis Di DKI Jakarta. *J Geogr Edukasi Dan Lingkung.* 2021; 5(1):101–108. https://doi.org/10.22236/jgel.v5i2.7098.
15. Han Y, Yang L, Jia K, Li J, Feng S, Chen W, Zhao W, Pereira P. Spatial distribution characteristics of the COVID-19 pandemic in Beijing and its relationship with environmental factors. *Sci Total Environ*. 2021; 761:144257. https://doi.org/10.1016/j.scitotenv.2020.144257.
16. Badan Pusat Statistik Kabupaten Kudus. *Kabupaten Kudus dalam Angka 2021*. Kudus: Badan Pusat Statistik Kabupaten Kudus; 2021.
17. Silwangani B, Munodawafa D, Chadambuka A. COVID-19 Infections and Deaths between Rural and Urban Provinces of Zimbabwe, 2020: A Spatial Variations Analysis. *Texila Int J Public Heal*. 2023; 11(3):1–12. https://doi.org/10.21522/TIJPH.2013.11.03.Art029.
18. Li X, Zhou L, Jia T, Peng R, Fu X, Zou Y. Associating COVID-19 severity with urban factors: A case study of Wuhan. *Int J Environ Res Public Health*. 2020; 17(18):6712. https://doi.org/10.3390/ijerph17186712.
19. Paul R, Arif AA, Adeyemi O, Ghosh S, Han D. Progression of COVID-19 From Urban to Rural Areas in the United States: A Spatiotemporal Analysis of Prevalence Rates. *J Rural Heal.* 2020; 36(4):591–601. https://doi.org/10.1111/jrh.12486.

20. Cuadros DF, Branscum AJ, Mukandavire Z, Miller FDW, MacKinnon N. Dynamics of the COVID-19 epidemic in urban and rural areas in the United States. *Ann Epidemiol*. 2021; 59:16–20. https://doi.org/10.1016/j.annepidem.2021.04.007.
21. Lan FY, Suharlim C, Kales SN, Yang J. Association between SARS-CoV-2 infection, exposure risk and mental health among a cohort of essential retail workers in the USA. *Occup Environ Med*. 2021; 78(4):237–43. https://doi.org/10.1136/oemed-2020-106774.
22. Chaw L, Koh WC, Jamaludin SA, Naing L, Alikhan MF, Wong J. Analysis of SARS-CoV-2 transmission in different settings, Brunei. *Emerg Infect Dis*. 2020; 26(11):2598–2606. https://doi.org/10.3201/eid2611.202263.
23. Centers for Disease Control and Prevention. Holiday celebrations and small gatherings 2020. https://stacks.cdc.gov/view/cdc/96983.
24. Chen N, Zhou M, Dong X, Qu J, Gong F, Han Y, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. *Lancet.* 2020; 395(10223):507–513. https://doi.org/10.1016/S0140-6736(20)30211-7.
25. Pshenichnaya N, Zhuravlev G, Lizinfeld I. Predictors of severe course of COVID-19 depending on comorbid background. *Int J Infect Dis*. 2022; 116. https://doi.org/10.1016/j.ijid.2021.12.106.
26. Antonelli M, Penfold RS, Merino J, Sudre CH, Molteni E, Berry S, et al. Risk factors and disease profile of post-vaccination SARS-CoV-2 infection in UK users of the COVID Symptom Study app: a prospective, community-based, nested, case-control study. *Lancet Infect Dis*. 2022; 22(1):43–55. https://doi.org/10.1016/S1473-3099(21)00460-6.
27. Siahaan A, Utomo B, Yuliana R, Makful M, Risma R, Salama N. Distribusi spasial Covid-19 di DKI Jakarta, Indonesia (Januari 2021 - Oktober 2021). *J Heal Epidemiol Commun Dis*. 2022; 7:84–92. https://doi.org/10.22435/jhecds.v7i2.5552.
28. Gomes DS, Andrade LA, Ribeiro CJN, Peixoto MVS, Lima SVMA, Duque AM, et al. Risk clusters of COVID-19 transmission in Northeastern Brazil: Prospective space-time modeling. *Epidemiol Infect*. 2020; 148:e188. https://doi.org/10.1017/S0950268820001843.
29. Kadi N, Khelfaoui M. Population density, a factor in the spread of COVID-19 in Algeria: statistic study. *Bull Natl Res Cent*. 2020; 44:138. https://doi.org/10.1186/s42269-020-00393-x.
30. Purwoko S, Cahyati WH, Zainuddin Z, Kusrini I. Distribusi Spasial Kepadatan Penduduk dan Jumlah Kejadian Covid-19 Mingguan di Kabupaten Magelang. *J Sehat Mandiri*. 2021; 16(2):10–20. https://doi.org/10.33761/jsm.v16i2.466.
31. Centers for Disease Control and Prevention. Scientific Brief: SARS-CoV-2 Transmission 2021. https://www.cdc.gov/coronavirus/2019-ncov/science/science-briefs/sars-cov-2-transmission.html.
32. Anhar R, Kariem MQ, Febriyanti D. Implementasi Kebijakan Bantuan Sosial Tunai Pada Masa Pandemi Covid-19 Di Dinas Sosial Kota Palembang. *JISIP UNJA (Jurnal Ilmu Sos Ilmu Polit Univ Jambi)*. 2023; 7(1):38–48. https://doi.org/10.22437/jisipunja.v7i1.24246.
33. Friesen J, Pelz PF. COVID-19 and slums: A pandemic highlights gaps in knowledge about urban poverty. *JMIR Public Heal Surveill*. 2020; 6(3):e19578. https://doi.org/10.2196/19578.
34. Chen T, Guo S, Zhong P. Epidemic characteristics of the COVID-19 outbreak in Tianjin, a well-developed city in China. *Am J Infect Control*. 2020; 48(9):1068–1073. https://doi.org/10.1016/j.ajic.2020.06.006.
35. Jiang G, Wang C, Song L, Wang X, Zhou Y, Fei C, et al. Aerosol transmission, an indispensable route of COVID-19 spread: case study of a department-store cluster. *Front Environ Sci Eng*. 2021; 15:46. https://doi.org/10.1007/s11783-021-1386-6.
36. Bert F, Lo Moro G, Peano A, Previti C, Siliquini R. Outbreaks of COVID-19 in indoor places of worship: a systematic review. *Perspect Public Health*. 2022; 144(2):86–97. https://doi.org/10.1177/17579139221118218.
37. James A, Eagle L, Phillips C, Hedges DS, Bodenhamer C, Brown R, et al. High COVID-19 Attack Rate Among Attendees at Events at a Church — Arkansas, March 2020. *MMWR Morb Mortal Wkly Rep*. 2020; 69:632–635. https://doi.org/10.15585/mmwr.mm6920e2.
38. Katelaris AL, Wells J, Clark P, Norton S, Rockett R, Arnott A, et al. Epidemiologic Evidence for Airborne Transmission of SARS-CoV-2 during Church Singing, Australia, 2020. *Emerg Infect Dis*. 2021; 27(6):1677–1680. https://doi.org/10.3201/eid2706.210465.
39. Yanti NPED, Nugraha IMADP, Wisnawa GA, Agustina NPD, Diantari NPA. Pengetahuan Publik tentang Covid-19 dan Perilaku Publik. *J Keperawatan Jiwa*. 2020; 8(4):485–490.
40. Turner-Musa J, Ajayi O, Kemp L. Examining Social Determinants of Health, Stigma, and

COVID-19 Disparities. *Healthcare.* 2020; 8(2):168. https://doi.org/10.3390/healthcare8020168.

41. Ahmad RA, Indriani C, Arisanti RR, Nanda RO, Mahendradhata Y, Wibawa T. Seroprevalence of SARS-CoV-2 and risk factors in Bantul Regency in March-April 2021, Yogyakarta, Indonesia. *PLOS Glob Public Heal*. 2023; 3(6):e0000698. https://doi.org/10.1371/journal.pgph.0000698.