



Effect of Population Density and Altitude on COVID-19 : A Spatial Pattern

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Abstract

The Covid-19 pandemic that has been going on since March 2020 has spread rapidly, with high mortality In Indonesia. Central Java, Covid-19 remains a disease with a Case Fatality Rate (CFR) of 4.4% and is above Indonesia's CFR of 3.0%. In Magelang itself, positive cases of Covid-19 in 2020 reached 4418 and were among the top 3 cases in Central Java Province. This study's purpose was to spatially describe the distribution of new cases of Covid-19 in terms of population density and elevation of the sub-district area in Magelang. The type of research is descriptive quantitative with ecological studies using a spatial approach. The results showed that the distribution of new cases of Covid-19 has a unique pattern in mapping based on population density and altitude. Some of the new distribution cases showed a distribution pattern following the regional elevation and almost entirely following the pattern of population density. The increase of Covid-19 tends to be higher in areas with high-density populations and low-altitude regions. This study concludes that the distribution pattern of new Covid-19 cases is influenced by population density and the area's height during the peak period of new Covid-19 cases in 2020 at Magelang.

Introduction

The Corona Virus Disease 2019 (Covid-19) pandemic established by the World Health Organization (WHO) at the end of January 2020 is still a significant health problem today (WHO, 2021). Covid-19 is an infectious disease from the Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (Yuliana, 2020). The virus initially infects animals and infects each other between animals, but in its development, it can infect humans (Munster et al., 2020). WHO released data until June 2021; it was noted that the virus had spread to 216 countries and infected 175,306,598 people worldwide, with 3,792,777 deaths (2,16)(WHO, 2021).

Indonesia recorded 743,198 cases of Covid-19 from March 2, 2020, to December 31, 2020, with 109,963 active cases. Of these cases,

Central Java Province has a Case Fatality Rate (CFR) of 4.4% and is above the national CFR(3,0 %) (Kemenkes RI, 2021). Covid-19 cases in Central Java are spread across regencies and cities, with the number of positive confirmed cases as of the end of December 2020 being 93,030 cases, with a cure rate of 77,136 and a death rate of 5,729 people. Magelang Regency is the Regency with the second-highest number of cases in Central Java, which is 4,418 cases in 2020, below the number in Semarang City (Dinkesprov Jawa Tengah, 2021). In less than a year since the initial declaration of the Covid-19 pandemic, the addition of cases in Magelang Regency and the death rate is high.

The fast transmission speed of Covid-19 requires strenuous efforts from local governments to prevent more comprehensive transmission (Merlin & Vanchapo, 2021). The

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acceleration of regional development triggers the emergence of urbanization and global population movements (Nugroho et al., 2021). This situation risks increasing population concentration, along with high economic growth. Increasing population concentration in certain areas will ultimately increase the potential for interaction between residents. On the other hand, the low number of medical personnel will create obstacles to handling Covid-19 and controlling it (Yang et al., 2021). The location of Magelang Regency is in an area directly adjacent to the Capital of Central Java Province, namely Semarang and Sleman Regency, DI Yogyakarta Province. The existence of two large cities flanking Magelang Regency has the potential to have a high level of population mobility and is very at risk for spreading the Covid-19 infectious disease (Desai, 2020).

Location-based information systems or spatial data can be used to assist the government in preventing the spread of Covid-19. Dissemination of information that utilizes map visualization utilizing Geographic Information Systems (GIS) is important because it can help map the risk of disease distribution in a location, determine disease distribution patterns, and predict the speed of disease spread (Sulistiyawati et al., 2016; Pourghasemi et al., 2020). Many factors can trigger an increase in the spread of Covid-19 in the community (He et al., 2021); one of the factors that are suspected to be the causative factor is the indirect factor which is closely correlated with the geographical conditions of a region (Franch-Pardo et al., 2020). Geographical conditions with a spatial approach are recommended to be used as one of the epidemiological observations that support the prevention of Covid-19 (Andersen et al., 2021).

One of the spatial variables that need to be considered is the area's height. The region's altitude that affects air condition is related to the genomic or non-genomic adaptation pattern of the virus (Pun et al., 2020). The area's altitude is also related to the work function of

the lungs in breathing (Huang et al., 2020). Considering that the lungs are currently the main focus of Covid-19 treatment, the regional altitude variable needs more attention in handling and preventing Covid-19 (Breevoort et al., 2020). In addition to geographic factors, population demographics also affect the rate of disease spread, where one indicator is the population density level of an area. People who live in dense areas, such as big cities or regional economic centres, have a higher probability of interacting with residents because of economic motivation (Yusrina et al., 2018). This condition can potentially increase the risk of transmitting infectious diseases, because the transmission of Covid-19 occurs between humans (Chan et al., 2020; Li et al., 2020; Hu et al., 2013).

Many studies related to the incidence of Covid-19 took place in Magelang Regency, but not many have used a spatial approach and compared between sub-districts. A spatial approach can help see the distribution pattern of the spread of infectious diseases, including Covid-19. The spatial approach can help to see the distribution pattern with specific characteristics, such as population density, public service locations, stations, places of worship, health services, and others (Sembiring et al., 2022). The spatial approach can detect clusters of disease cases and analyze patterns of disease spread that has the potential to become extraordinary events (KLB) or pandemics in the community (Saran et al., 2020). So that by studying the pattern of disease spread based on regional characteristics, the increase in repeated cases will be prevented. In addition, if an outbreak or pandemic of a similar disease occurs, the pattern can be used as a guide for area-based prevention and control measures.

Research with a spatial approach is essential to be able to see the differences in problems between sub-districts related to population health because each sub-district has different characteristics, thus requiring alternate handling and interventions (Siqueira et al., 2021). This study spatially analyzes new Covid-19 cases in Magelang Regency based

on cases at the sub-district level to describe the distribution of Covid-19 events in each sub-district related to space and region. In this study, spatial analysis is used to see the correlation between space/region and cases of Covid-19 and the factors that influence it, such as population density and altitude.

The purpose of this study is to describe the distribution of new cases of Covid-19 spatially in terms of population density and altitude of the sub-district in Magelang Regency in November and December 2020, which is the peak period of Covid-19 transmission by utilizing the Geographic Information System.

Methods

The data used in this study are regional elevation data and population density data from the Central Statistics Agency (BPS) of Magelang Regency in 2020 (BPS Kabupaten Magelang, 2021). Daily Covid-19 case data per sub-district was obtained from the official source of the Magelang Regency Government. Regional administration digital data in the form of maps obtained from the official website of the Geospatial Information Board (BIG). The research took place in Magelang Regency, Central Java Province, which has 21 sub-districts, and took time from April to May 2021. The analysis and mapping process was carried out with the help of QGIS software version 3.10. This research is quantitative descriptive research with an ecological study. An ecological analysis is useful for seeing the population health level in an area or location (Breevoort et al., 2020). The data collection method in this study was based on secondary data sourced from the official website of the Magelang Regency Government regarding Covid-19 and data from the Magelang Regency BPS. Data for all residents who have been confirmed positive for Covid-19 are data that have passed the polymerase chain reaction (PCR Test) in November-December 2020. The sample is the total population. The unit of analysis in this study is 21 sub-districts included in the administrative area of Magelang Regency.

Results and Discussion

Data on the distribution of Covid-19 cases in Central Java Province in 2020 can be

seen in table 1 below:

Table 1. Covid-19 cases at the Regency/City level in Central Java Province.

Location City	n	%
Semarang	11038	12%
Surakarta	1998	2%
Pekalongan	1394	2%
Magelang	1008	1%
Tegal	972	1%
Salatiga	908	1%
Regency		
Magelang	4418	5%
Kebumen	4116	4%
Wonosobo	3999	4%
Kendal	3985	4%
Banyumas	3793	4%
Jepara	3719	4%
Kudus	3542	4%
Demak	3181	3%
Cilacap	2948	3%
Blora	2786	3%
Sragen	2720	3%
Tegal	2656	3%
Temanggung	2631	3%
Sukoharjo	2545	3%
Pemalang	2529	3%
Semarang	2487	3%
Klaten	2327	3%
Karanganyar	2313	3%
Boyolali	2198	2%
Batang	2139	2%
Purbalingga	1865	2%
Purworejo	1798	2%
Pati	1712	2%
Pekalongan	1545	2%
Rembang	1463	2%
Brebes	1415	2%
Banjarnegara	1334	1%
Wonogiri	1182	1%
Grobogan	1081	1%
Total	91745	100%

Sources : Report of Central Java Health Office in 2020

In table 1, it can be seen that the area with the second-highest Covid-19 in Central Java Province, with 4418 cases (5%), is Magelang Regency and is under Semarang City, with 11038 cases (12%). Furthermore, the spatial-temporal analysis of Covid-19 events in Magelang Regency per sub-district in November 2021, and December 2021 is displayed in a bar chart

on the map in Figure 1.

Figure 1 shows that the distribution of cases from November to December 2020 varies and is spread over 21 sub-districts. Mertoyudan District is the sub-district with the highest total cases, namely 702 cases (14%), followed by Mungkid District with 413 (8.3%) and Borobudur District with 386 (7.8%). Meanwhile, Pakis Sub-district is the sub-district with the lowest addition of cases, namely 88 cases in 2 months (1.8%). Almost all sub-districts experienced increasing cases from November 2020 to December 2020. However, one sub-district experienced a decrease, namely Salaman District, which fell from 153 to 122.

The distribution of Covid-19 events in the Magelang Regency area in 2020 reached its

peak in November and December 2020. The increase in cases occurred in all sub-districts in Magelang Regency. Although several sub-districts experienced a decrease in cases, overall, Magelang Regency was designated as a red zone at the end of 2020. The pattern of spreading highest Covid-19 occurred in the south-central zone of the Magelang Regency, where Mertoyudan, Mungkid, and Borobudur sub-districts were the three highest sub-districts with the incidence of Covid-19. Mertoyudan District is located on a transportation route between two provinces, namely Central Java Province and Yogyakarta D.I Province, where the incidence of new Covid-19 cases is the highest compared to the surrounding areas in November-December 2020.

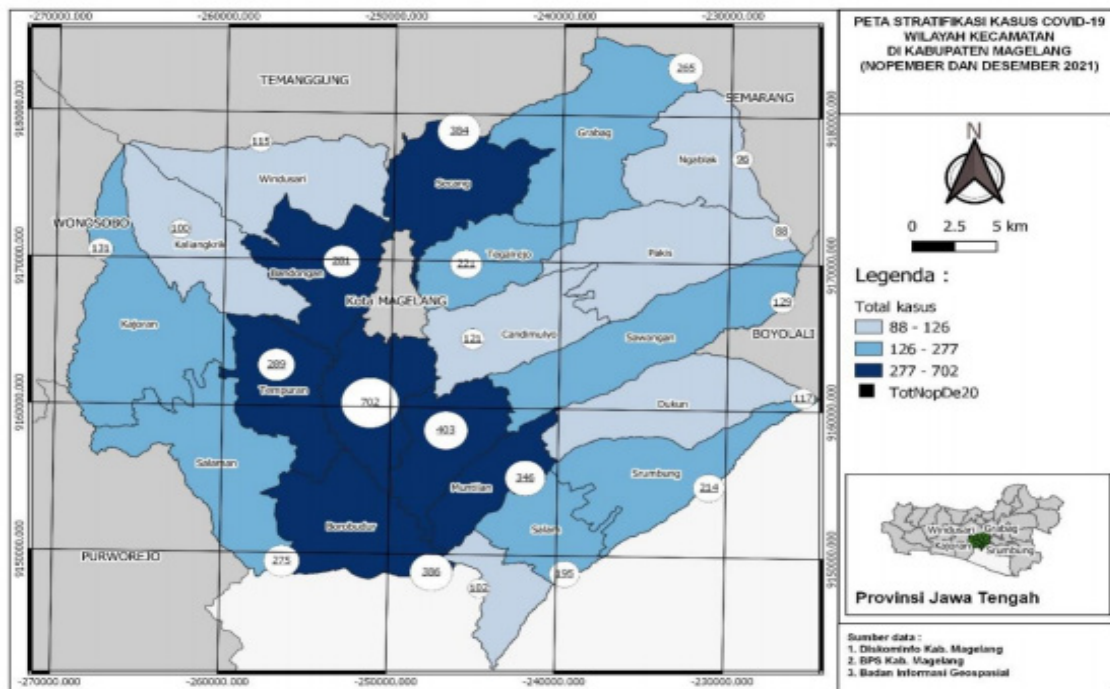


Figure 1. Stratification map of Covid-19 cases in the District of Magelang in November 2020 and December 2020

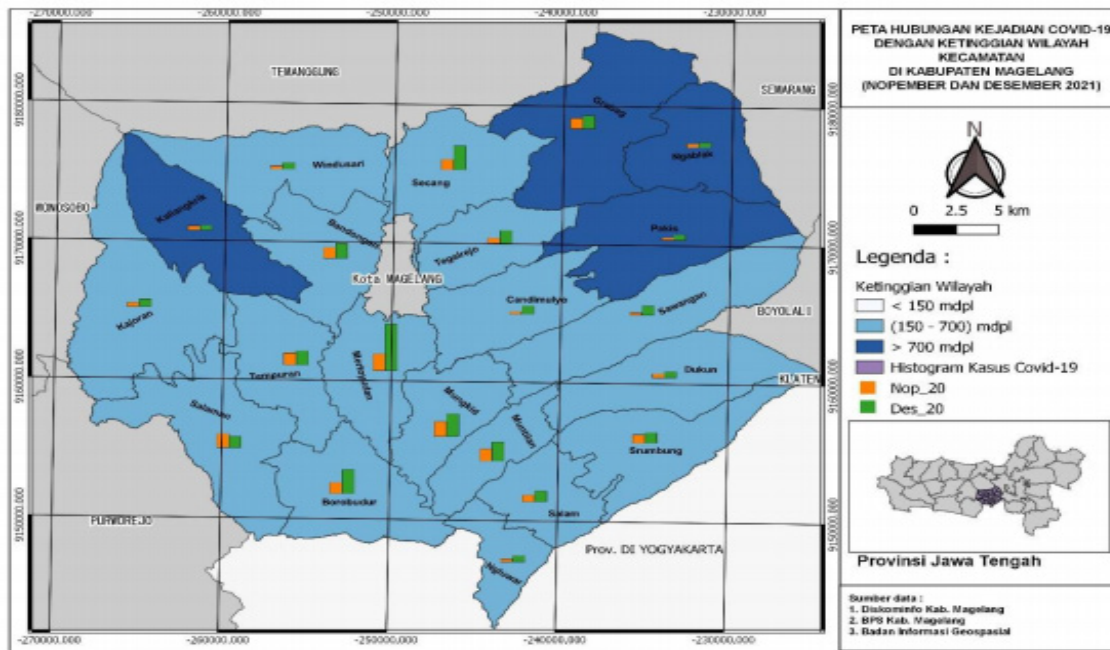


Figure 2. Map of the Relationship between Covid-19 Incidence and the Altitude of the Sub-District in Magelang Regency in November 2020 and December 2020.

The sub-districts around the Mertoyudan are sub-districts with a high average number of cases compared to other sub-districts in Magelang Regency. But the distribution of cases also occurs evenly in the western and eastern zones. In other words, the distribution of cases, although concentrated in the middle zone for the highest, occurs evenly in all sub-districts in Magelang Regency. It can be interpreted that several factors causing the even and widespread distribution of Covid-19 cases in this district.

Based on Figure 2 above, the distribution of Covid-19 cases occurred in all sub-districts in Magelang Regency. The first to third highest cases occurred in sub-districts located in the central and southern parts of Magelang Regency with an altitude of 150–700 meters above sea level. The highest was in Mertoyudan District with a total of 702 cases (14%), with an increase in cases from 185 to 517 in December 2020 or an additional 179%. Next in second and third place are Mungkid and Borobudur

Subdistricts, with 413 (8.3%) and 386 cases (7.8%). Meanwhile, areas with elevations above 700-meters above sea level are in the northeastern part of Magelang Regency and generally have a total number of cases between 28 and 60.

Four sub-districts in Magelang Regency have an average altitude of above 700 meters above sea level. Namely, Ngablak Districts (1378 meters above sea level), Pakis (841 meters above sea level), Kaliangkrik (823 meters above sea level), and Grabag (702 meters above sea level) are the sub-districts with the lowest additions of Covid-19 cases in Magelang District, Pakis District (88), Ngablak (96), and Kaliangkrik (100). Meanwhile, the sub-districts, which are located at an average altitude of 202 to 347 masl, are the sub-districts with the addition of medium to high cases, the Mertoyudan sub-district, which is at an altitude of 347 masl, is the sub-district with the highest new cases addition (702).

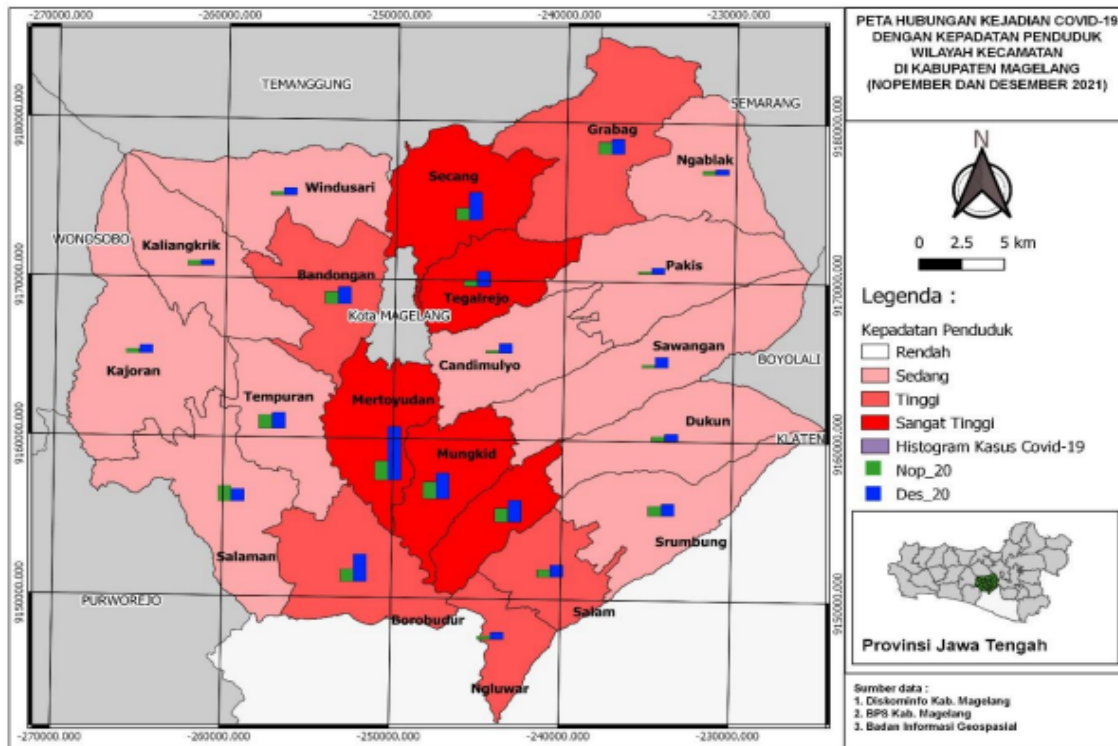


Figure 3. Map of the Relationship between Covid-19 Incidence and Population Density per District in Magelang Regency in November 2020 and December 2020

Based on population density, there are five sub-districts with a very high density between 1520 - 2794 people/km², one of which is Mertoyudan District, which is the sub-district with the highest addition of cases; the other sub-districts are Secang, Mungkid, Muntilan, and Tegalrejo Districts. The sub-districts with a high population density between 1074 - 1519 people/km² are the Districts of Grabag, Bandongan, Borobudur, Salam and, Ngluwar. Of the five sub-districts, Borobudur Sub-district is included in the category of adding high cases, namely 386 cases (7.8%). Meanwhile, other sub-districts are categorized as sub-districts with moderate population density, between 600 - 1073 people/km² (Figure 3).

The interaction between the infectious agent causing the disease (agent) and the host (host) has long been known to be influenced by environmental factors (environment) (WHO, 2021). The area's altitude is an environmental condition that needs attention in the event of Covid-19, considering that air conditions have a close relationship with the pattern of genomic and non-genomic virus adaptation (Pun et al., 2020). The results of previous studies also

showed similar results. A literature review explains the relationship between regional altitude and the incidence of Covid-19, where high areas have a smaller transmission rate than lower areas (Millet et al., 2021). Research in the United States by matching population density between areas with an altitude of <914 meters above sea level(MASL) and > 2133 MASL showed similar results. Higher altitude can reduce infection rates and lower the risk of death (Stephens et al., 2021). Research in Colombia involving 70 cities at an altitude of 1-3,180 MASL shows that living in a highland location can reduce the risk of transmitting Covid-19, especially by reducing mortality rates (Cano-Pérez et al., 2020).

The ability of the virus, which may be weakened due to drastic changes in air and temperature in high areas, is supposed to help the air around the highlands become cleaner during the Covid-19 pandemic (Semple & Moore, 2020). Another study conducted in the highlands of Tibet, Bolivia, and Ecuador found that the adaptive capacity of the lung function of the inhabitants of these regions could protect them from the severe effects of COVID-19

exposure compared to lower areas (Arias-Reyes et al., 2020). Lifestyle and social factors, such as more physical activity carried out by residents in the highlands, can explain why in highland areas, the fatality rate due to Covid-19 tends to be lower. Residents at high altitudes are also less likely to be obese, which can increase the severity of COVID-19. Therefore, the symptoms of COVID-19 at high altitudes tend to be mild or asymptomatic. It could also be the reason for the low level of Covid-19 in the highlands because people with mild or no symptoms tend not to get tested and recover independently (Stephens et al., 2021).

The results of other studies show different things. Research in Peru shows that altitude does not affect the fatality rate but can reduce the risk of transmitting Covid-19 cases (Segovia-Juarez et al., 2020). Research conducted in Manado City explains the opposite. It found regional altitude does not affect on Covid-19 cases in sub-districts within the city of Manado (Nelwan, 2020).

The increase in population is directly proportional to an area's population density. In addition, economic growth in urban areas will encourage rural residents to live around urban areas because there is hope for life improvement (Ren et al., 2020). Given that the incidence of Covid-19 can be transmitted between humans (Chan et al., 2020; Li et al., 2020). It can be interpreted that the higher the pattern of interaction between residents due to economic reasons and regional growth will have the potential to increase the transmission of infectious diseases between residents such as Covid-19 (Ranscombe, 2020).

Very high population density is one of the variables that can facilitate disease transmission between residents and the spread of disease in areas with high population density. Research conducted in Algeria links population density with high patterns of interaction between residents. The transmission of the SARS-CoV-2 virus only requires a distance of about 1 meter. The droplets are in the form of an aerosol that spreads through the air from the nose and mouth of the patient, so the risk of transmission due to high interaction patterns between residents will be higher (Kadi & Khelfaoui, 2020; Setti et al., 2020).

Other research explains that increasing population density can be used as a predictor of the spread of Covid-19 in the United States (Wong & Li, 2020). In addition, this study also explains the close correlation between population density and disease distribution in the smallest area in an area at the district level. Population density is closely related to the movement and mobilization of people in an area; the fulfillment of basic needs and economic motivation is one of the factors that can increase the movement and interaction of the population in areas with high density and dense inter-provincial crossroads. The sub-districts on the main crossing have a high rate of economic growth and movement between residents (Kemenkes RI, 2021). This situation can surely increase the risk of transmission between residents if no efforts are made to limit the movement of people.

Conclusions

Based on the spatial pattern analysis conducted, the distribution pattern of Covid-19 in Magelang Regency spreads evenly across all sub-districts in November-December 2020, which is the highest month of cases. The high average addition of new cases occurred in the middle zone, an area with a relatively high population density compared to other regions. Almost all sub-districts with high population density are areas with high average cases, but this does not apply to all sub-districts with high population density. Meanwhile, areas with elevations below 700 meters above sea level are also the sub-districts with the highest additions of Covid-19 cases. On the other hand, for sub-districts with an altitude above 700 masl, there was low new cases addition in November and December 2020, except for sub-districts located in the middle zone of Magelang Regency. The results of this study can be the basis for the Magelang Regency Government to increase stricter prevention efforts for the middle zone area so that the current sloping Covid-19 case does not increase again. In addition, the results of this study can also be the basis for prevention and control efforts if one day there is an outbreak of the disease with transmission patterns and virus characteristics similar to Covid-19.

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