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Exploring The Spatial Relationship Between Covid-19 and Poverty in Indonesia: A Moran's I Approach

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Abstract

Background: COVID-19 has emerged as a pervasive infectious disease globally. Between 2020 and 2022, Indonesia experienced over 6.4 million COVID-19 cases and more than 157,000 confirmed deaths. Aside from vaccination efforts, the spread of COVID-19 is influenced by socioeconomic conditions, particularly poverty. Impoverished communities are especially vulnerable to COVID-19 due to limited access to healthcare services and high population density in living areas. This research aims to explore the spatial relationship between poverty and COVID-19 in Indonesia during 2021-2022.

Methods: This study employs an ecological design, focusing on the spatial relationship between COVID-19 incidence rates and poverty levels across Indonesian provinces. The analysis is conducted using Moran's I, a spatial autocorrelation statistic, to determine the extent of clustering of COVID-19 cases about poverty.

Results: In 2021, East Nusa Tenggara had the lowest COVID-19 incidence rate at 517.56 per 100,000 population, while DKI Jakarta recorded the highest. During 2022, Bali remained the province with the highest incidence rate at 318.99 per 100,000 population, whereas Aceh had the lowest at only 1.43 per 100,000 population in 2022. The average poverty rate in Indonesia in 2021 was 10.76%, which slightly decreased to 10.24% in 2022. The difference between the minimum and maximum poverty percentages in both years was insignificant. Bivariate analysis shows that Moran's I value was -0.101 in 2021 (significant) and 0.042 in 2022 (not significant).

Conclusion: The spatial distribution of COVID-19 cases across Indonesian provinces in 2021 and 2022 exhibited significant variation influenced by multiple factors, such as vaccination programs and the percentage of poverty. However, this study has limitations due to secondary data that may not capture the real condition of COVID-19 and poverty dynamics.

Keywords: *COVID-19, Moran's I, Poverty, Spatial Analysis.*

Introduction

COVID-19 has emerged as a pervasive infectious disease globally, responsible for over 6.5 million confirmed deaths worldwide by the end of 2022[1]. The pandemic spread rapidly in Asia following the initial outbreak in Wuhan, China, with over 652 million confirmed cases in the Asia-Pacific region by the end of 2022[2]. In Indonesia, between 2020 and 2022, the country experienced over 6.4 million COVID-19 cases and more than 157,000 confirmed deaths[3]. In response, the Indonesian government launched an extensive vaccination campaign from 2021 to 2022, administering over 200 million vaccine doses to the population. This mass vaccination effort significantly reduced the incidence and mortality rates of COVID-19 in the country, with a marked decrease in new cases following the initiation of the vaccination program[4].

Aside from vaccination efforts, the spread of COVID-19 is influenced by socioeconomic conditions, particularly poverty. Impoverished communities are especially vulnerable to COVID-19 due to limited access to healthcare services, poor nutrition, and high population density in living areas[5]. The intersection of poverty and health disparities underscores the importance of examining the spatial relationship between these factors to inform public health strategies. In many regions, higher poverty levels have been linked to increased vulnerability to COVID-19 infection and worse health outcomes. This is due to other factors, such as reduced ability to adhere to public health measures, exacerbating the virus's spread. Studies have shown that impoverished communities often face greater challenges in managing the pandemic, even when vaccination rates are high[6,7]. It is important to do spatial analysis to comprehend the correlation between the distribution of COVID-19 cases and poverty in Indonesia[8], given the nation's varied socio-environmental settings. Indonesia, an archipelagic country comprising over 17,000 islands, exhibits considerable regional differences in infrastructure, healthcare accessibility, and economic situations. Spatial analysis identifies high-risk zones and hotspots, facilitating targeted actions and resource distribution[9]. This is essential for efficient pandemic control, particularly in densely

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populated and impoverished areas where the virus can proliferate swiftly.

This research aims to explore the spatial relationship between poverty and COVID-19 in Indonesia during 2021-2022, employing Moran's I as the analytical framework. By investigating this relationship, the study seeks to provide insights into the geographic patterns of COVID-19 spread about socioeconomic disparities. These findings can inform targeted public health interventions that address the needs of vulnerable populations, ultimately contributing to more equitable health outcomes during and beyond the COVID-19 pandemic.

Methods

Study design and setting

This study employs an ecological design, focusing on the spatial relationship between COVID-19 incidence rates and poverty levels across Indonesian provinces. The analysis is conducted using Moran's I, a spatial autocorrelation statistic, to determine the extent of clustering of COVID-19 cases about poverty. The research is set in Indonesia, a Southeast Asian country with diverse socioeconomic and demographic characteristics across its 35 provinces (prior to the expansion of the province). The study period spans 2021 and 2022, during which the country faced varying degrees of COVID-19 impact.

Data collection procedure

This study utilizes a document-based research approach, drawing on secondary data sources to analyze the spatial relationship between COVID-19 incidence rates and poverty levels in Indonesia. COVID-19 incidence rates per 100,000 population were calculated using data on confirmed COVID-19 cases obtained from the Humanitarian Data Exchange[10]. This data is then divided by population estimates sourced from official demographic statistics provided by the Central Bureau of Statistics (BPS-Statistics Indonesia)[11]. By integrating these datasets, the study ensures a comprehensive analysis of COVID-19 spread about population density and poverty across Indonesian provinces between 2021 and 2022.

Statistical analysis

Moran's I is a measure of spatial autocorrelation developed by Patrick Alfred Pierce Moran in 1950. It quantifies the degree to which a variable is similarly distributed across space, indicating whether the observed spatial pattern is clustered, dispersed, or random[12]. Moran's I value ranges from -1 to +1. Positive values indicate spatial clustering of similar values (high-high or low-low), while negative values suggest spatial dispersion, where high values are surrounded by low values and contrariwise[13]. A value of zero implies a random spatial pattern. This study uses Moran's I to assess the spatial relationship between COVID-19 incidence rates and poverty levels across Indonesian provinces. By identifying patterns of spatial clustering or dispersion, the analysis aims to provide insights into the geographic distribution of COVID-19 about socioeconomic disparities. The Z-score, which represents the standard deviation, helps to determine the statistical significance of the Moran's I value. A high absolute Z-score indicates a significant spatial pattern, either clustering or dispersion, while a Z-score close to zero suggests no significant spatial autocorrelation[14].

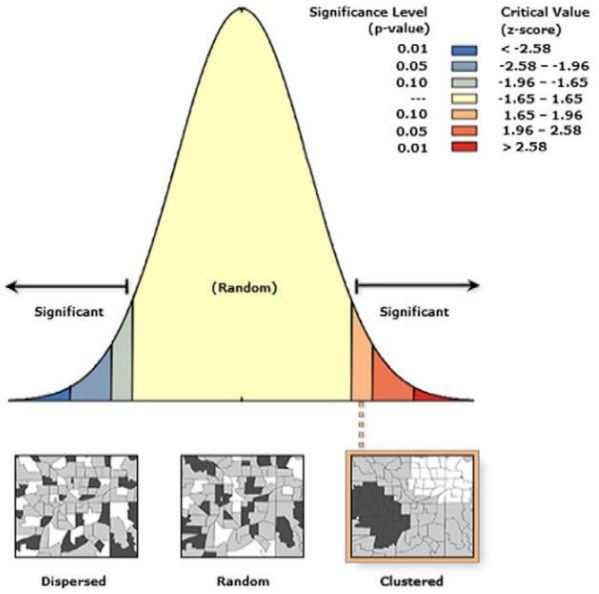


Figure 1. Moran's I Demonstration of Spatial Pattern[15]

Result

Distribution of COVID-19 Cases in 2021-2022

The results indicate that during 2021, the average number of COVID-19 cases per province was approximately 125,295.7 for all. Gorontalo reported the fewest cases, while DKI Jakarta had the highest number of cases. The distribution of COVID-19 cases varied across provinces. In 2021, provinces such as DKI Jakarta (857,765 cases), West Java (702,722 cases), and Central Java (482,009 cases) recorded the highest case numbers, indicating concentrated outbreaks in highly populated regions.

In 2022, the average number of COVID-19 cases dropped significantly to 1,970.76 per province. Aceh reported the lowest incidence of cases, with only 79 cases, while Bali, as both an island and a single

province, had the highest number, totaling 14,414 cases. A sharp decline was observed, with provinces like DKI Jakarta (11,114 cases), West Java (3,091 cases), and Central Java (3,482 cases) showing significantly lower-case numbers. Meanwhile, some provinces like Papua (1,696 cases) and South Sulawesi (4,807 cases) still had relatively high case counts compared to others.

Regarding the number of COVID-19 cases, regions with large populations also tend to contribute to higher case numbers. Calculating COVID-19 cases per 100,000 population provides a more comprehensive picture. In 2021, East Nusa Tenggara had the lowest COVID-19 incidence rate at 517.56 per 100,000 population, while DKI Jakarta recorded the highest. In the following year, after the government implemented COVID-19 vaccination programs, Bali remained the province with the highest incidence rate at 318.99 per 100,000 population. In contrast, Aceh had the lowest at only 1.43 per 100,000 population in 2022. For a comprehensive overview of the comparative distribution of COVID-19 cases per population, refer to Figure 2.

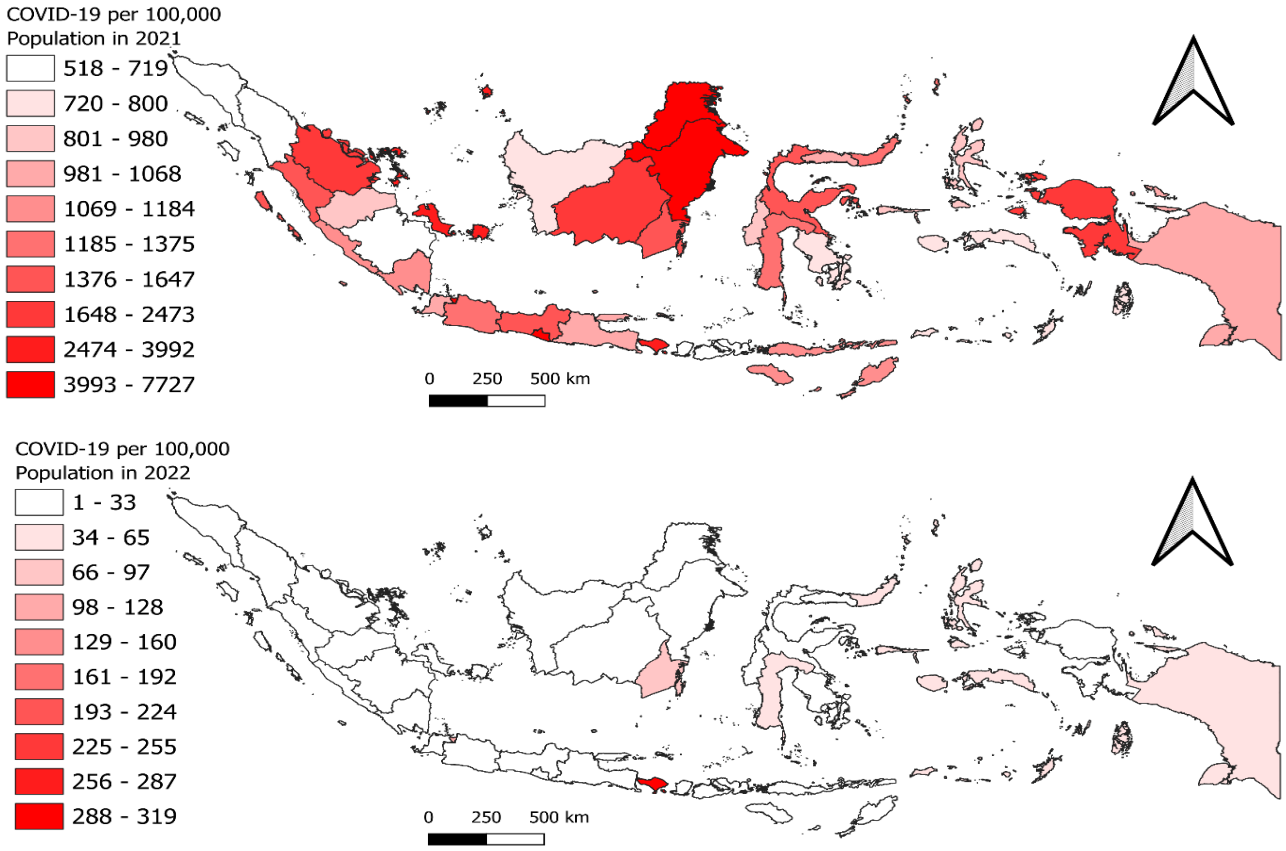


Figure 2. COVID-19 per 100,000 Population in Indonesia

Poor Percentage of Province in Indonesia 2021-2022

The average poverty rate in Indonesia in 2021 was 10.76%, which slightly decreased to 10.24% in 2022. The difference between minimum and maximum poverty percentages in both years was insignificant. In 2021, Bali had the lowest poverty rate at just 4.53%, while Papua had the highest at 26.86%. In 2022, the Bangka Belitung Islands recorded the lowest poverty rate at 4.45%, whereas Papua remained the highest at 26.56%. Throughout the COVID-19 pandemic, Papua consistently had the highest poverty rate in Indonesia. The data indicates a general decrease in poverty percentages across most provinces from 2021 to 2022. However, some provinces, such as Bali and Kepulauan Riau, experienced a slight increase in poverty rates. The highest poverty rates in both years were recorded in Papua and Papua Barat, reflecting persistent economic disparities in these regions. Conversely, provinces like Bali, Kepulauan Bangka Belitung, and Kalimantan Selatan consistently had the lowest poverty rates.

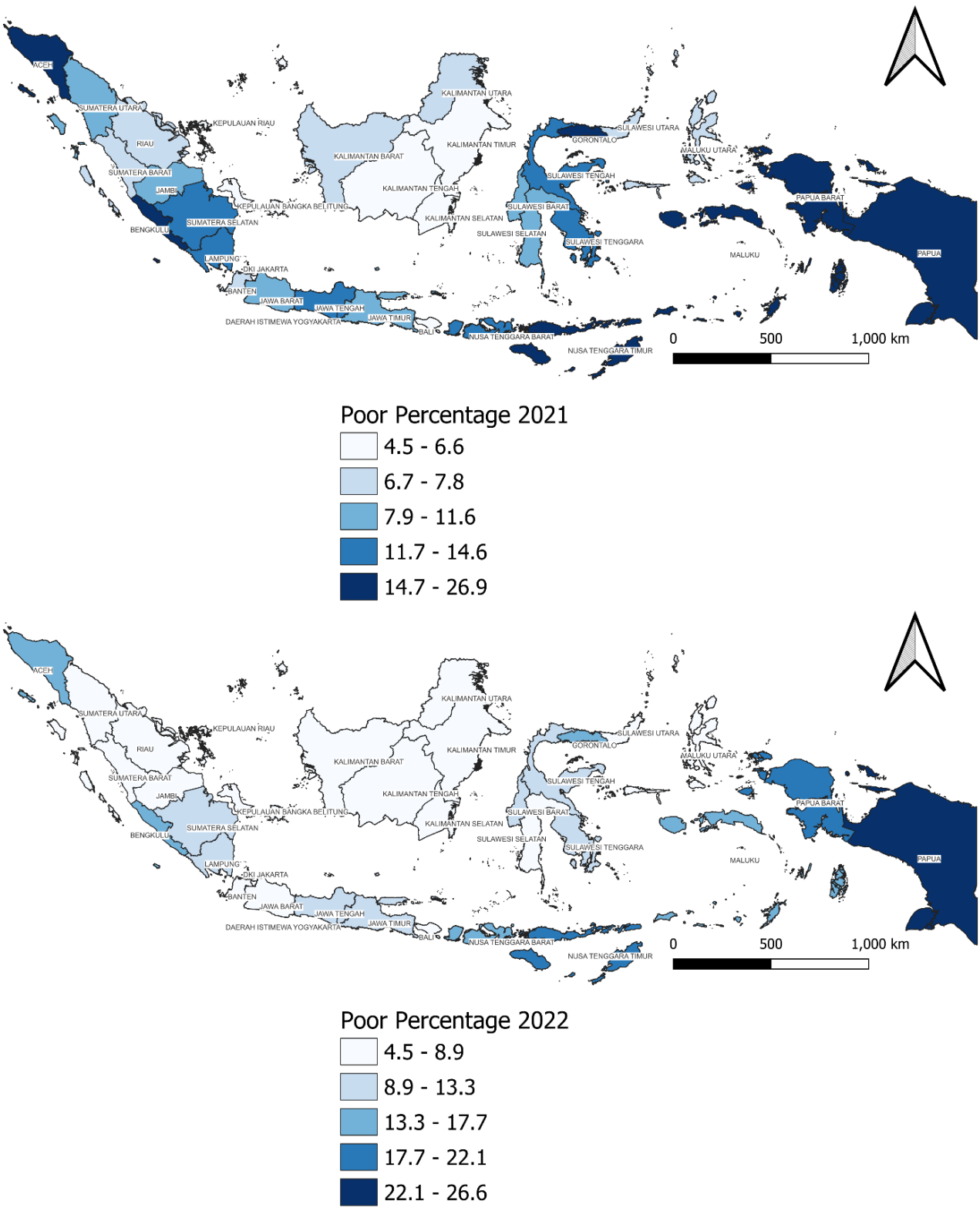


Figure 3. Poor Percentage in Indonesia During COVID-19

Bivariate Analysis of COVID-19 Cases and Poor Percentage in Indonesia

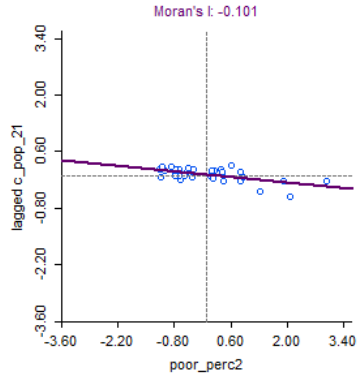
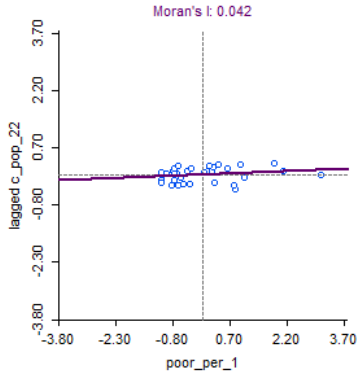
A bivariate spatial analysis was conducted to examine the relationship between COVID-19 cases per 100,000 population and the percentage of poor populations across provinces in Indonesia. Moran's I measure spatial autocorrelation, indicating how similar or dissimilar values are distributed across a geographic area.

The bivariate analysis of the percentage of impoverished populations and the incidence of COVID-19 per 100,000 individuals in 2021 and 2022. These findings present a rather contrasting picture between the years 2021 and 2022. In 2021, the

Moran's I value was -0.101, with a Z-score of -2.766 and a p-value of 0.014. This negative Moran's I value suggests a slight inverse spatial autocorrelation, indicating that provinces with higher poverty rates tended to have lower COVID-19 incidence rates and the other way around. This year shows statistical significance, as the p-value is below the typical threshold of 0.05, confirming that the observed spatial pattern is unlikely to have occurred by chance. This suggests a notable spatial dispersion between poverty and COVID-19 incidence in this quadrant.

In 2022, although not statistically significant, the positive Moran's I value implies a weak positive spatial autocorrelation with a p-value of more than 0.05 and a Z-score close to zero. Nevertheless, the positive Moran's I value indicates that provinces with high poverty rates tend to have equally high numbers of COVID-19 incidence cases.

Table 1. Spatial Correlation of Poor Percentage and COVID-19 Incidence

Moran's I Quadrant	Year	Moran's I Value	Z-Score	p-value
	2021	-0.101	-2.766	0.014
	2022	0.042	0.917	0.133

Discussion

The distribution of COVID-19 cases across provinces in Indonesia in 2021 and 2022 highlights significant spatial variation[16], which can be attributed to multiple factors, including population density, healthcare infrastructure, and government responses, particularly vaccination programs[17]. Each region has distinct geographical and demographic conditions, and even districts within a single province can exhibit different characteristics. Additionally, infrastructure and economic status disparities persist not only between districts and provinces but also between these regions and the national capital[18]. These variations contribute to the differing impacts of COVID-19 across the country, as regions with better healthcare infrastructure and economic resources may be better equipped to handle the pandemic. In contrast, those with limited resources and higher population density may face greater challenges[19].

In 2021, highly populated regions such as DKI Jakarta, West Java, and Central Java experienced concentrated outbreaks with substantial case numbers. This aligns with the findings of a study by Hikmawati, Isna, and Ragil Setiyabudi[20], which concluded that population density and urbanization were key determinants of the higher incidence of COVID-19 in large metropolitan areas. DKI Jakarta, with its dense population and high mobility, was expected to be the province with the highest caseload (857,765 cases), as cities with large populations have more opportunities for the virus to spread rapidly due to higher interpersonal interactions.

In contrast, the significant drop in case numbers in 2022, particularly with regions like Aceh and Sumatera Island reporting much lower incidence rates, could be attributed to the successful implementation of public health measures such as vaccinations. As highlighted in Sinuraya et al.[21],

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vaccination programs significantly reduced the severity of COVID-19 cases and the spread of the virus, contributing to a marked decrease in new infections. The study demonstrated that areas with higher vaccination coverage experienced lower case rates in 2022. Aceh, with its lower vaccination uptake, was an outlier with a notably reduced incidence rate, likely due to the protective health behaviors adopted by its population[22].

Further, examining COVID-19 incidence rates per 100,000 population provides additional insights into the regional disparities. Provinces like DKI Jakarta and Bali had significantly higher rates per 100,000 population in 2021 and 2022. This supports findings from other spatial studies, which observed that despite lower case totals, regions with higher population densities (like Bali) continued to have higher rates per 100,000, even with reduced absolute case numbers[23]. The substantial vaccination campaigns likely mitigated the overall case numbers but did not eliminate the underlying spatial inequalities in the incidence rates.

In 2021, there was a negative correlation between COVID-19 incidence and poverty rates in Indonesia. This suggests that regions with higher poverty rates had lower COVID-19 incidence rates[1]. This could be due to lower levels of knowledge about COVID-19 among impoverished populations, limited access to healthcare services, and reduced mobility due to lockdowns and government advisories[3].

Unique moran's I value in 2021, an inverse correlation was observed between COVID-19 incidence and poverty rates across Indonesian provinces, suggesting that regions with higher poverty levels reported lower case numbers. Several factors may explain this pattern. First, limited access to healthcare and information among impoverished communities could lead to underreporting COVID-19 cases[24]. A study in 2022 found that areas with higher poverty rates tend to have lower awareness and knowledge about COVID-19, reducing testing and case reporting[25]. Second, inadequate healthcare infrastructure in economically disadvantaged regions makes it difficult for residents to seek medical attention and undergo COVID-19 testing. Additionally, restricted mobility among low-income populations due to lockdown measures and government advisories may have further contributed to lower reported cases[26]. According to Khoirunurrofik et al., individuals in poorer communities are more likely to comply with mobility restrictions, as their socioeconomic circumstances already limit movement[27]. As a result, while poverty generally poses challenges to healthcare access, it may have indirectly led to lower reported COVID-19 incidence in 2021 due to reduced mobility and underreporting. Besides, poorer regions receive economic support from the Indonesian government during COVID-19[28]. Another reason for the negative relationship between COVID-19 cases and poorer regions stems from lockdown conditions. These areas experience reduced job mobility while still receiving government aid, thus mitigating economic protection issues[29]. This condition tends to lower the probability of COVID-19 transmission in poorer regions during 2021.

In 2022, the positive Moran's I value, in contrast to the negative value observed in 2021, can be attributed to the successful implementation of government vaccination programs, which significantly reduced the overall number of COVID-19 cases. This shift resulted in a different scenario compared to 2021, where COVID-19 incidence was heavily influenced by the socioeconomic conditions of impoverished communities, leading to underreporting due to limited testing availability and knowledge[30]. In 2022, despite the overall reduction in cases, the positive Moran's I value suggests that areas with higher poverty rates continued to experience COVID-19 cases[31]. This may be due to the persistence of the virus in these regions, where access to healthcare and vaccinations remained limited. Additionally, the socioeconomic disparities that affected the spread of the virus in previous years were still present, with impoverished populations facing ongoing challenges in accessing healthcare services and adhering to preventive measures, as discussed in the study by Surendra et al.[23]. This contrast highlights the evolving dynamics of COVID-19 distribution in Indonesia, influenced by both public health interventions and underlying socioeconomic factors. The Indonesian government has undertaken substantial measures, including the execution of a statewide immunization initiative and the establishment of social safety nets. Nonetheless, there remains potential for enhancement, especially in engaging marginalized populations and guaranteeing fair access to healthcare and immunizations.

Conclusions

The spatial distribution of COVID-19 cases across Indonesian provinces in 2021 and 2022 exhibited significant variation influenced by multiple factors such as vaccination programs and percentage of poverty. In 2021, regions with higher poverty rates experienced lower COVID-19 incidence due to limited knowledge, reduced testing, and restricted mobility

among impoverished populations. However, the successful implementation of vaccination programs in 2022 led to a significant reduction in overall COVID-19 cases. Despite this, areas with higher poverty rates continued to report COVID-19 cases due to persistent socioeconomic disparities and limited access to healthcare and vaccinations. The evolving dynamics of COVID-19 distribution underscore the importance of targeted public health interventions and equitable access to healthcare resources to address the ongoing challenges faced by vulnerable populations. One limitation of this study is its reliance on spatial analysis and secondary data sources, which may not capture real-time changes and nuanced local dynamics affecting COVID-19 incidence and reporting.

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Author Contribution

Study design	:	L, ABK, UE
Data acquisition	:	UE, L, ABK
Data analysis	:	ABK, L, UE
Manuscript writing	:	ABK, L, UE

Competing Interests

The authors declared no conflict of interest about the content of this article.

Abbreviation

BPS	:	*Badan Pusat Statistik*
DKI	:	*Daerah Khusus Ibukota*

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