International Journal Of Health, Engineering And Technology (IJHET) *E-ISSN 2829 - 8683*
Volume 5, Number 1, May 2026, *Page. 700 - 709*
Email : editorijhess@gmail.com

Mapping And Analysis Of Measles Cases In Children Aged 1-9 Years In Situbondo Regency In 2024

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Abstract

This study aims to map and analyze measles cases in children aged 1-9 years in Situbondo Regency in 2024, based on measles immunization coverage and population density. Using a descriptive analytical method with an ecological study approach and secondary data from the 2024 East Java Health Profile, the unit of analysis was 17 sub-districts in Situbondo Regency. Spatial analysis was conducted using Health Mapper and GeoDa for Global Moran's I and Bivariate Local Indicator of Spatial Association (BiLISA). The results showed that measles immunization coverage in all sub-districts has not reached the national target of 95%, with Panji District having the highest proportion of cases. Global Moran's I analysis found a significant negative spatial autocorrelation between immunization coverage and measles cases (I = -0.330, p = 0.015), indicating that areas with high immunization coverage tend to be adjacent to areas with low cases, and vice versa. Meanwhile, for population density, no significant spatial autocorrelation was found (I = 0.217, p = 0.053), although densely populated areas tended to have a higher proportion of cases. This indicates that while immunization coverage has a clear spatial relationship with measles cases, population density is not the sole determining factor.

Keywords: Spatial Analysis, Measles, Immunization Coverage, Situbondo Regency, Population Density.

INTRODUCTION

Measles is a contagious infectious disease caused by the measles virus of the genus Morbillivirus in the family Paramyxoviridae. It spreads through respiratory droplets when an infected person coughs, sneezes, or comes into direct contact with an infected individual. Fever, cough, runny nose, conjunctivitis, and a maculopapular rash are the most common clinical symptoms of measles. In children, the disease can cause serious complications, including pneumonia, diarrhea, and encephalitis (Yahmal, 2021).

Despite the availability of effective immunization for many years, measles remains a global public health problem. Measles outbreaks occurred periodically before widespread immunization programs were introduced, resulting in significant morbidity and mortality, particularly in children. Due to its high transmissibility, the disease can spread rapidly among vulnerable populations. Therefore, immunization as a preventive measure is the most important strategy for controlling measles (Buchair et al., 2025).

One example of a public health intervention aimed at increasing protection against specific diseases is immunization. Immunization programs have demonstrated effectiveness in reducing the incidence of vaccine-preventable infectious diseases, such as measles. High vaccination coverage can build herd immunity (*herd immunity*) which protects people who are not yet immune. Conversely, low vaccination rates can increase the likelihood of measles transmission in the population (Yuliani, 2019).

The spread of infectious diseases can be influenced by environmental factors and regional characteristics, in addition to immunization. High population density can increase the frequency of interactions between individuals, thereby increasing the risk of transmission.Diseases spread through droplets. Compared to sparsely populated areas, densely populated areas are more vulnerable to the spread of infectious diseases. For this reason, population density is often used as an indicator in epidemiological analyses of infectious diseases (Pratiwi et al., 2021).

A large population, relatively high population density, and uneven vaccination coverage across regions can increase the risk of the spread of infectious diseases, such as measles. According to data from the East Java Health Profile, measles cases are still present in several sub-districts in Situbondo

Regency, with a relatively high number of cases in 2024 (East Java Provincial Health Office, 2024). Therefore, to support disease control initiatives, an analysis that can explain the geographic distribution of measles cases is needed.

Spatial analysis using Geographic Information Systems (GIS) is one technique that can be used to understand how diseases spread. The spatial distribution of disease cases can be seen using spatial mapping, making it easier to identify high-risk areas. The government can use this data to identify priority areas for public health interventions. With this context in mind, this study aims to map and analyze measles cases in children aged 1-9 years in Situbondo Regency in 2024 based on measles immunization coverage and population density.

RESEARCH METHODS

This study uses a descriptive analytical method with an ecological study approach to describe the spatial relationship between measles cases, measles immunization coverage, and population density in Situbondo Regency in 2024. The ecological approach was used because the data analyzed were aggregated at the regional level, not at the individual level. The unit of analysis in this study was the 17 administrative sub-districts in Situbondo Regency.

This study used secondary data sourced from the 2024 East Java Health Profile. The data collected included the proportion of measles cases (per 100,000 population), measles immunization coverage (%), and population density (people/km²) in each sub-district. The data was then processed to determine the distribution of measles cases, combined with measles immunization coverage and population density in each sub-district.

The research instrument was the official document, the 2024 East Java Health Profile. The dependent variable was the number of measles cases, while the independent variables were measles immunization coverage and population density. Spatial analysis was conducted using software.*Health Mapper*version 4.3.0.0 to display thematic case distribution. Spatial statistical analysis was performed using GeoDa software to perform spatial autocorrelation analysis using Global Moran's I and Bivariate Local indicators of Spatial Association to determine the spatial distribution pattern of measles cases and to determine the spatial relationship between measles cases and measles immunization coverage and population density in Situbondo Regency. This study has two hypotheses as follows:

1. There is a spatial relationship between measles immunization coverage and the number of measles cases in children aged 1-9 years in Situbondo Regency in 2024.
2. There is a spatial relationship between population density and the number of measles cases in children aged 1-9 years in Situbondo Regency in 2024.

The measles immunization coverage variable is classified into two categories: low if immunization coverage is <95% (yellow indicator) and high if immunization coverage is ≥95% (green indicator). This classification refers to the measles elimination target set by the World Health Organization, namely immunization coverage of at least 95% to achieve herd immunity and prevent measles virus transmission in the community (WHO, 2023). Population density variables are classified into five categories, namely very low if 133.54 - 584.98 people/km² (blue indicator), low if 584.99 - 1,036.42 people/km² (green indicator), moderate if 1,036.43 - 1,487.86 people/km² (yellow indicator), high if 1,487.87 - 1,939.30 people/km² (orange indicator), and very high if 1,939.31 - 2,390.73 people/km² (red indicator). The distribution of measles cases in 17 sub-districts in Situbondo Regency is depicted using dot symbols with one dot representing one measles case per 100,000 residents aged 1-9 years. Meanwhile, measles immunization coverage and population density are displayed in the form of color gradations on thematic maps using Health Mapper.

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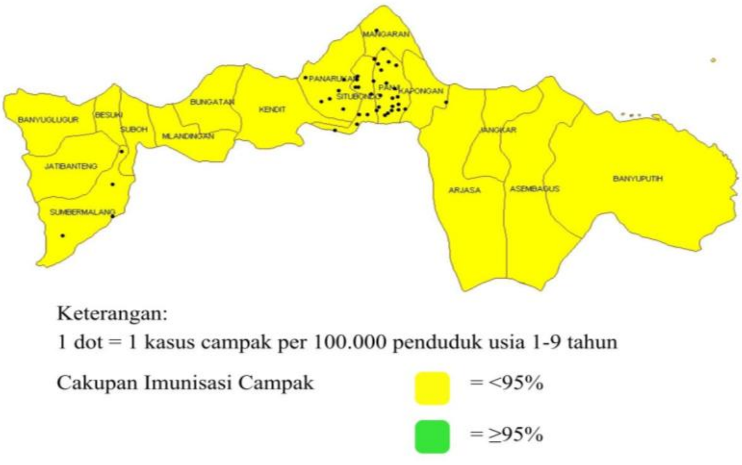
RESULTS AND DISCUSSION

This results section presents an overview of the distribution of measles cases in children aged 1-9 years in Situbondo Regency in 2024 based on spatial analysis. The results include the distribution of measles cases based on measles immunization coverage and population density, as well as an analysis of spatial relationships between variables using spatial statistics methods.

Distribution of Measles Cases in Children Aged 1-9 Years Based on Measles Immunization Coverage in Situbondo Regency in 2024



Source: East Java Health Profile 2024

Figure 1. Distribution of Measles Cases in Children Aged 1-9 Years with Measles Immunization Coverage in Situbondo Regency in 2024

Based on Figure 1, it can be seen that all sub-districts in Situbondo Regency still have lower measles immunization coverage compared to the national target of 95%. Panji Sub-district has the highest proportion of measles cases, namely 24 cases per 100,000 residents aged 1-9 years, with an immunization coverage of 83.61%, which is still below the national target of 95%. Situbondo and Panarukan Sub-districts also show a fairly high proportion of cases, respectively, 12 and 7.2 cases per 100,000 residents aged 1-9 years with low immunization coverage, namely 70.01% and 60.46%. This condition indicates that areas with immunization coverage that has not reached the herd immunity target (95%) still have the potential to experience measles cases. Therefore, sub-districts with a high proportion of measles cases and low immunization coverage need to be prioritized in efforts to increase immunization coverage as part of measles incident control.

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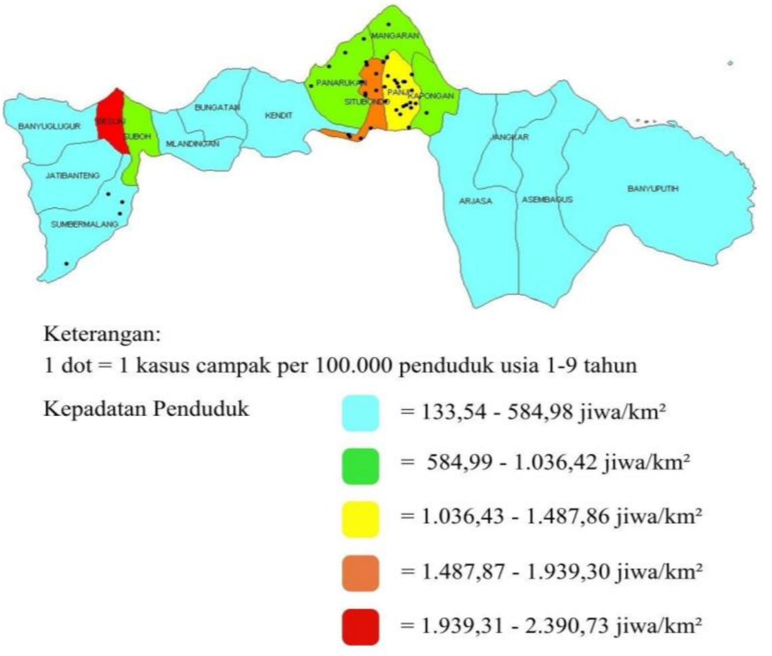
Distribution of Measles Cases in Children Aged 1-9 Years Based on Population Density in Situbondo Regency in 2024



Source: East Java Health Profile 2024

Figure 2. Distribution of Measles Cases in Children Aged 1-9 Years by Population Density in Situbondo Regency in 2024

Based on Figure 2, it can be seen that areas with higher population densities tend to have a greater proportion of measles cases than areas with lower population densities. Panji District shows the highest proportion of measles cases, namely 24 cases per 100,000 residents aged 1-9 years, with a population density of 1,457.66 people/km², which is included in the category of areas with medium population density. In addition, Situbondo District has a fairly high proportion of measles cases, namely 12 cases per 100,000 residents aged 1-9 years with a population density of 1,708.01 people/km², which is classified as an area with high population density. This condition indicates that areas with a tendency for high population density have a greater potential for disease transmission because the frequency of contact between individuals increases. Therefore, sub-districts with a high proportion of cases accompanied by a tendency for high population density, such as Panji and Situbondo Sub-districts, can be priority areas in measles control and prevention efforts, especially through increasing immunization coverage and strengthening disease surveillance.

Spatial Relationship between Measles Immunization Coverage and Measles Cases in Children Aged 1-9 Years in Situbondo Regency in 2024

A spatial analysis was conducted to determine the spatial relationship between measles immunization coverage and measles cases in children aged 1-9 years in Situbondo Regency in 2024. The method used in this analysis was Global Moran's I, which aims to identify spatial autocorrelation patterns and observe trends in inter-regional relationships based on measles immunization coverage. The results of this analysis are presented in Table 1.

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Table 1. Global Moran's I Test between Measles Immunization Coverage and Measles Cases

Year	I	E[I]	P-value	Z-score
2024	-0.330	-0.062	0.015	-2,389

Source: East Java Health Profile 2024

Based on table 1, the results of the spatial relationship analysis between measles immunization coverage and the number of measles cases in children aged 1-9 years in Situbondo Regency in 2024 using Global Moran's I, after the test obtained the Moran's I Index value (-0.330) < E[I] (-0.062), Z-score (-2.389) < Z/2 (1.96), and P-value (0.015) < (0.05) for a 95% confidence level. Because the P-value is smaller than the significance level and the Z-score value is below the critical threshold, these results indicate a significant negative spatial autocorrelation with a dispersed pattern. This means that there is a spatial relationship between measles immunization coverage and measles cases, but it is negative, where adjacent areas tend to have opposite characteristics, namely areas with high measles immunization coverage tend to be adjacent to areas with low measles cases. Conversely, areas with low immunization coverage are adjacent to areas with high measles cases.α

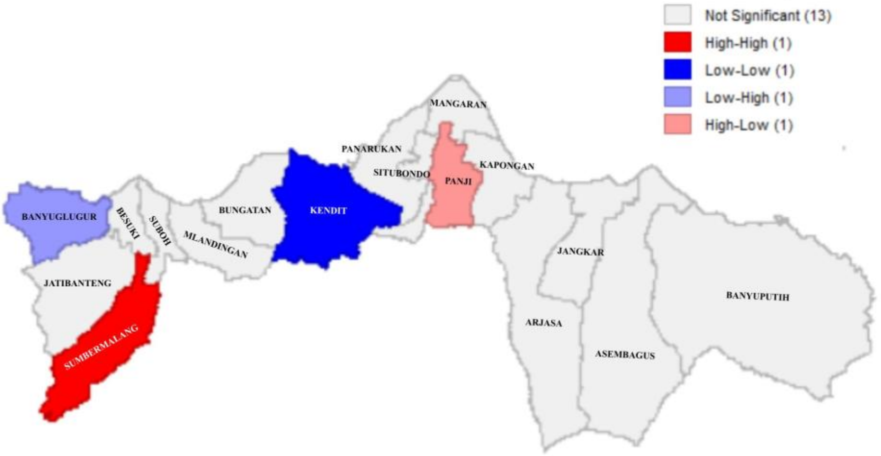

Figure 3. Map of Measles Case Clusters with Measles Immunization Coverage

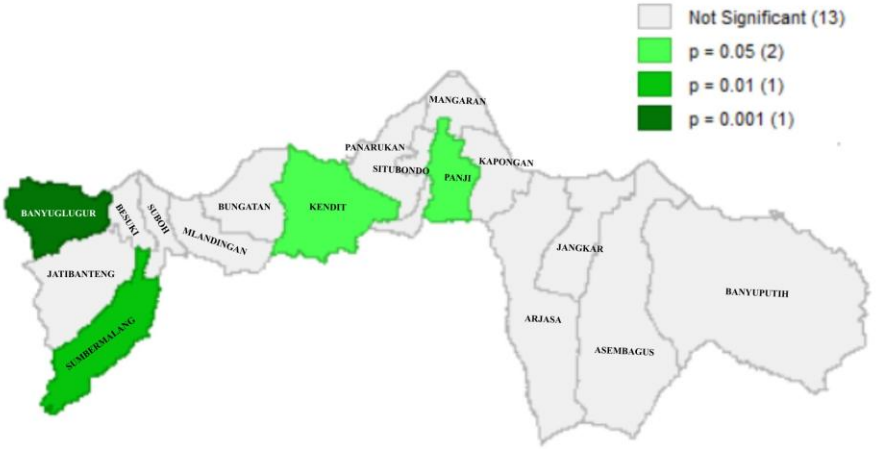

Figure 4. Map of the Significance of Measles Cases with Measles Immunization Coverage

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Based on the results of the Bivariate Local Indicator of Spatial Association (BiLISA) analysis presented in Figures 3 and 4, the relationship between measles immunization coverage and the number of measles cases shows a widespread pattern across Situbondo Regency. In Figure 3, the High-High quadrant is shown in red and occurs in Sumbermalang District. This indicates that the area has high immunization coverage and is surrounded by areas with a high number of measles cases. Then, in the Low-Low quadrant, shown in dark blue, is found in Kendit District, indicating low immunization coverage and is surrounded by areas with low measles cases. Then, in the High-Low quadrant, shown in pink, is found in Panji District, indicating an area with quite high measles immunization coverage, but surrounded by areas with low measles cases. In the Low-High quadrant, shown in purple, is found in Banyuglugur District, indicating an area with low measles immunization coverage but surrounded by areas with high measles cases.

Based on Figure 4, there are four sub-districts that fall into the significant category ($p < 0.05$), namely Banyuglugur, Sumbermalang, Kendit, and Panji, which means there is a relationship between measles immunization coverage and measles cases. Meanwhile, the other 13 areas fall into the not significant category, indicating that the spatial relationship between immunization coverage and measles cases in these areas is random.

Spatial Relationship between Population Density and Measles Cases in Children Aged 1-9 Years in Situbondo Regency in 2024

A spatial analysis was conducted to determine the spatial relationship between population density and measles cases in children aged 1-9 years in Situbondo Regency in 2024. The method used in this analysis was Global Moran's I, which aims to identify spatial autocorrelation patterns and determine whether the distribution of measles cases tends to be clustered, dispersed, or random based on population density. The results of this analysis are presented in Table 2.

Table 2. Global Moran's I Test between Population Density and Measles Cases

Year	I	E[I]	P-value	Z-score
2024	0.217	-0.062	0.053	1,753

Source: East Java Health Profile 2024

Based on Table 2, the results of the analysis of the spatial relationship between population density and the number of measles cases in children aged 1-9 years in Situbondo Regency in 2024 using Global Moran's I. After the test, the Moran's I Index value was obtained (0.217) < E[I] (-0.062), Z-score (1.753) < $Z\alpha/2$ (1.96), and P-value (0.053) > (0.05) for a 95% confidence level. Because the P-value is greater than the significance level and the Z-score value is below the critical threshold, these results indicate the absence of significant positive spatial autocorrelation with a distribution pattern that tends to be clustered. This means that there is no spatial relationship between population density and measles cases, where areas with high population density are not always adjacent to areas with high measles cases, and areas with low population density are also not always adjacent to areas with low measles cases.

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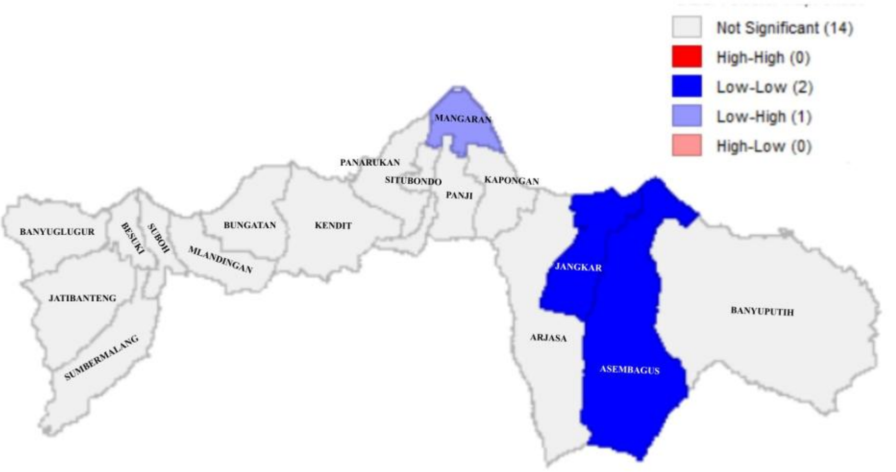

Figure 5. Map of Measles Case Clusters with Population Density

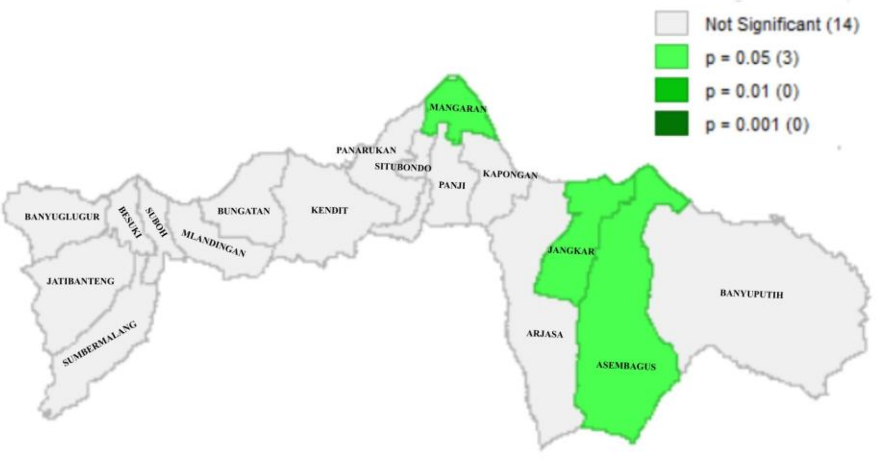

Figure 6. Map of the Significance of Measles Cases with Population Density

Based on the results of the Bivariate Local Indicator of Spatial Association (BiLISA) analysis presented in Figures 5 and 6, the relationship between population density and the number of measles cases shows a clustered pattern in Situbondo Regency. In Figure 5, the Low-High quadrant is found in Mangaran District, indicating that the area has a low population density and is surrounded by districts with a high number of measles cases. The Low-Low quadrant is found in Jangkar and Asembagus Districts, indicating that these areas have a low population density and are surrounded by districts with a low proportion of measles cases.

Based on Figure 6, three sub-districts fall into the significant category ($p < 0.05$), namely Mangaran, Jangkar, and Asembagus, indicating a relationship between population density and measles cases. Meanwhile, the other 14 areas are classified as not significant, indicating there is no strong spatial relationship between population density and measles cases.

Discussion

Distribution of Measles Cases Based on Measles Immunization Coverage

The study results show that measles immunization coverage in all sub-districts in Situbondo Regency in 2024 has not reached the national target of 95%. This target was set to establish herd immunity so that measles virus transmission can be prevented in the community. If immunization coverage does not reach the target, herd immunity will not be optimally formed, resulting in a higher risk of measles transmission and an increase in the number of measles cases. Epidemiologically, immunization is a very important public health intervention to prevent infectious diseases. Research by Yuliani (2019) shows that low measles immunization coverage is influenced by several factors such as maternal knowledge, family support, and access to health services. The study also explains that low immunization coverage can result in groups of children who are still vulnerable to measles infection, increasing the risk of disease transmission in the community.

According to Griffin (2018), the live attenuated MeV vaccine can induce a humoral immune response in the form of antibodies as well as a cellular immune response that develops gradually over months. This vaccine is able to provide protection against infection from all MeV genotypes. The level of protection is most closely related to the quality and quantity of neutralizing antibodies produced after vaccination, although T cells are also thought to play a role in providing protection. Antibodies capable of neutralizing measles virus infectivity are primarily directed against the hemagglutinin (H) protein, with additional contributions from antibodies against the fusion (F) protein. In addition, the H protein also contains important epitopes for CD8+ T cells. High-avidity antibodies against the H protein are required to neutralize wild-type measles virus infection mediated by the SLAM receptor on lymphoid cells, but are not required to neutralize vaccine virus infection mediated by the CD46 receptor on Vero cells commonly used to measure measles virus neutralizing antibody levels. Research in macaque monkeys has shown that the presence of neutralizing antibodies can predict protection against measles (characterized by the appearance of a rash), but not necessarily against infection. While T cells alone are not sufficient to provide protection against infection or disease, they do play a role in helping clear viral RNA from the body.

The results of spatial analysis using Global Moran's I showed a significant negative spatial autocorrelation between measles immunization coverage and measles cases. This pattern indicates that areas with high immunization coverage tend to be located near areas with low measles cases, while areas with low immunization coverage tend to be located near areas with higher measles cases. This pattern indicates a spatial relationship between immunization coverage and the distribution of measles cases in Situbondo Regency. Research conducted by Arianto et al. (2018) showed that immunization status is a risk factor associated with measles incidence. The results of this study showed that toddlers who did not receive measles immunization were more likely to experience measles compared to toddlers who had received measles immunization. This condition indicates that low immunization coverage can increase children's vulnerability to measles infection in an area. Therefore, increasing measles immunization coverage is an important step in efforts to prevent and control measles incidence in the community. From a public health perspective, areas with low immunization coverage and a high proportion of measles cases need to be prioritized in health intervention programs. Efforts that can be made include increasing immunization coverage through implementing immunizations according to schedule, increasing access to health services, and strengthening disease surveillance programs to detect measles incidents early.

Distribution of Measles Cases by Population Density

The results of the study indicate that areas with higher population densities tend to have a higher proportion of measles cases compared to areas with lower population densities. Panji and Situbondo sub-districts are areas with a relatively high proportion of measles cases and have a relatively high population density compared to other sub-districts. Population density is one factor influencing the spread of infectious diseases. According to the World Health Organization (2024), the measles virus spreads through droplets or liquid splashes from the respiratory tract of sufferers when coughing and sneezing, or through inhalation of air inhaled by someone with measles. The measles virus remains active and infectious in the air or on infected surfaces for up to two hours. For this reason, the transmission rate is very high. One person infected with measles can cause up to 18 secondary infections. Therefore, environmental conditions with high population density can increase the opportunity for measles transmission in a population.

However, the Global Moran's I analysis showed no significant spatial autocorrelation between population density and measles cases in Situbondo Regency. This indicates that areas with high population density are not always adjacent to areas with high measles cases, and vice versa. This means that population density does not show a strong spatial relationship pattern with the distribution of measles cases in the study area. This indicates that population density is not the only factor influencing measles incidence. The spread of measles can also be influenced by other factors such as immunization coverage, environmental conditions, and community characteristics in a region. From a public health perspective, areas with high population density still require attention in efforts to control infectious diseases. These areas have the potential to experience faster disease spread if there are cases of infection due to the high interaction between individuals within the community.

CONCLUSION

Mapping results show that all sub-districts in Situbondo Regency have not yet achieved the national measles immunization coverage target of 95% by 2024, with Panji and Situbondo Sub-districts having the highest proportion of cases. Spatial analysis indicates a negative autocorrelation between immunization coverage and measles cases, meaning areas with low immunization coverage tend to have higher cases. Although high population density is associated with increased cases, the relationship is not statistically significant. Therefore, increasing immunization coverage is key to establishing herd immunity and controlling the spread of measles.

Public education needs to be improved to ensure complete and timely measles immunization. Access to immunization services also needs to be expanded, especially in areas with low coverage. Furthermore, strengthened surveillance is needed for early case detection. Local governments are expected to prioritize interventions in sub-districts with low immunization coverage and high case numbers, such as Panji and Situbondo.

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