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Spatial analysis of rabies-transmitting animal bite cases in North Tapanuli Regency, North Sumatera Province in 2016-2020

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Abstract

Purpose: Rabies is a priority strategic disease because it has an impact on socio-economic and public health. This study aims to describe the incidence of rabies-transmitting animal bite cases in North Tapanuli Regency in 2016-2020, contribute to understanding the dynamics of cases, and provide effective information in controlling cases of animal bites that transmit rabies. **Methods:** Ecological study using aggregated data. The data was collected from monthly reports of rabies cases at the North Tapanuli Regency Health Service in 2016-2020. As a unit analysis, all districts are used. QGIS and GeoDA software are used for data analysis. Through GeOda software, spatial autocorrelation analysis was carried out globally using Moran's I test and locally using the LISA test. **Results:** Rabies-transmitting animal bite cases had a dispersed pattern in 2016 ($I<E[I]$) and a clustered pattern ($I>E[I]$). Globally, there is positive spatial autocorrelation in rabies-transmitting animal bite cases between districts in North Tapanuli Regency in 2017 and 2020 (p-value < 0.05). Moran's cluster map shows that locally in 2016-2020, the districts in the quadrant I (*High-High*) are Siborongborong and Sipoholon. Quadrant II (*Low-High*) is Adiankoting and Pagaran. Quadrant III (*Low-Low*) is Pangaribuan, and quadrant IV (*High-Low*) is Pahae Jae and Pangaribuan. **Conclusion:** Globally, cases of animal bites that transmit rabies in North Tapanuli Regency occur in clusters. It means that the number of bite cases in one area is related to the number of cases in other nearby areas. Therefore, rabies control program interventions in areas with high observation values must be prioritized so they do not spread to areas with low observation values.

Keywords: animal bite; autocorrelation; rabies; spatial analysis

INTRODUCTION

Rabies is a *neglected disease* [1,2]. According to WHO (2013), rabies is reported to occur in 92 countries and is endemic in 72 of them, but almost all reported rabies cases (95%) occur in Asia and Africa [3]. Based on global death tolls, deaths from rabies in Asia are estimated at 59.6%, and in Africa, they are estimated at 36.4% [4]. In Southeast Asia, rabies is endemic in eight of 11 countries, with deaths estimated at 45% each year, and this figure represents the global disease burden [5].

In Indonesia, the Ministry of Health reported that in 2022, rabies-transmitting animal bites increased by 82,04% from 2021 (57.257 cases to 104.229 cases). Likewise, cases of rabies/lyssa and deaths due to rabies also increased by 64,52% in 2022 compared to 2021 (62 cases to 102 cases) [6]. Data from the Indonesian Ministry of Health (2019) shows that the probability of a lyssa case occurring from rabies-transmitting animal bites in Indonesia in 2010–2018 was 0.16 percent. It means that of the total incidence of rabies-transmitting animal bites, 0,16% of them were positive for rabies or Lyssa and died [2].

Based on the number of reported cases of rabies in humans per million people from 2010 to 2018, North Sumatra Province (which includes Nias, North Tapanuli, Simalungun, and Humbang Hasundutan Regency) has the most heavily infected areas in Indonesia, with 499 new Lyssa cases per 1,000,000 people [2]. Of these four regencies, it is known that North Tapanuli Regency has twice been an area with rabies outbreaks in North Sumatra; this occurred in 2017 [7] and then again in 2023. Data revealed by the Head of the North Tapanuli Regency Health Service shows that in January–May 2023, there were 285 cases of dog bites, and one person died [8].

In the 2019 National Master Plan for Rabies Eradication in Indonesia by the Directorate General of Animal Husbandry and Animal Health, Ministry of Agriculture, it is stated that the implementation of the rabies control and mitigation program towards a rabies-free Indonesia by 2030 will be carried out in stages according to the situation and conditions of rabies in the regions. In the initial stages of implementing rabies liberation, it is necessary to know the current conditions and status of rabies in the area. Furthermore, there is a need for a rabies risk assessment in each region to determine priority locations for control toward liberation, which is carried out jointly between the central and regional governments. One of the approaches used in eradicating rabies is the zone approach based on geographical conditions [9].

A zonal approach based on geographic conditions can be carried out using spatial analysis. Spatial analysis is a data analysis method useful for identifying and analyzing disease patterns in an area. Spatial analysis produces visual aids like disease maps, providing spatial correlation information and disease risk mapping. Hopefully, it can be a reference for a surveillance system to determine early warning indicators and efforts to prevent and control rabies [10]. Therefore, this study aims to examine the global and local spatial effects of cases of rabies-transmitting animal bites in North Tapanuli Regency in 2016–2020.

METHODS

This research is an ecological study using aggregate data. The data collected in this research is secondary data obtained from monthly reports on the discovery and treatment of rabies cases at the North Tapanuli Regency Health Service for 2016–2020. The research was conducted in 15 districts in North Tapanuli Regency. All districts in North Tapanuli Regency were used as units of analysis.

The choropleth map in this research was created using QGIS software. Following the Global Moran's Index to identify global autocorrelation, this study analyzes spatial patterns using Local Indicators of Spatial Autocorrelation (LISA). This analysis uses GeoDa software. The null hypothesis in this study is that there is no spatial autocorrelation between district areas in North Tapanuli Regency (I = E). Then, the alternative hypothesis is that there is a positive spatial autocorrelation between district areas in North Tapanuli Regency (I > E). In this research, the significance level used is 95%. An area is said to have statistically significant spatial autocorrelation if the significance value (p-value) is less than 0.05 in the Global Moran's Index and LISA analysis results.

Global Moran's Index and LISA range from -1 to +1, where a negative number indicates negative autocorrelation, a value of 0 indicates no autocorrelation and a positive value indicates positive autocorrelation. If there is negative autocorrelation, adjacent regions tend to have different attribute values, but the space will form a pattern like a checkerboard. On the other hand, if there is positive autocorrelation, adjacent areas will form clusters with almost the same characteristics and attribute values. It means that the number of rabies-transmitting animal bite cases in one area is related to the number of cases in other nearby areas. Autocorrelation indicates that rabies-transmitting animal bite cases in one district do not occur randomly but are related to rabies-transmitting animal bite cases in the surrounding districts. Global Moran's Index assesses autocorrelation in a region in general, in this case, North Tapanuli Regency. Then, LISA is used to assess local spatial autocorrelation between the districts in North Tapanuli Regency to see hotspot and coldspot areas. Hotspot areas are areas with high cases surrounded by low cases, while coldspot areas are areas with low cases surrounded by high cases [10]. This analysis will produce information from Moran's I and LISA Cluster Maps [11].

RESULTS

Our data shows an increasing trend of rabies-transmitting animal bites in North Tapanuli Regency in 2016-2020 (**Figure 1**). Based on this trend, it is necessary to look at the spatial distribution pattern of cases of animal bites that transmitted rabies in 2016–2020 in the North Tapanuli Regency, respectively (**Table 1**).

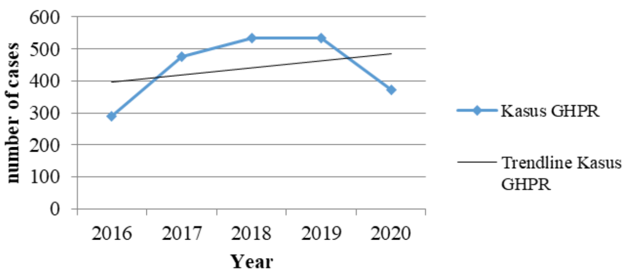

Figure 1. Trends of rabies-transmitting animal bites on North Tapanuli Regency in 2016–2020

Table 1. Moran's index of rabies-transmitting animal bites on North Tapanuli Regency in 2016-2020

Year	Moran's Index	Expected Index	Z-score	P-value	Pattern
2016	-0,0922	-0,0714	-0,1118	0,498	Dispersed
2017	0,2849	-0,0714	2,0099	0,029	Clustered
2018	0,0797	-0,0714	0,9178	0,184	Clustered
2019	0,1971	-0,0714	1,5733	0,075	Clustered
2020	0,3598	-0,0714	2,5448	0,013	Clustered

Table 1 show that in 2016 cases of rabies-transmitting animal bites in North Tapanuli Regency had a dispersed pattern (I<E[I]) with a p-value > α, which means that globally there is no spatial autocorrelation in rabies-transmitting animal bite cases between districts in North Tapanuli Regency.

Rabies-carrying animal bite cases in North Tapanuli Regency have a clustered pattern (I> E[I]) with a p-value < ± in 2017 and 2020. This means there is positive spatial autocorrelation in rabies-carrying animal bite cases between districts in North Tapanuli Regency in 2017 and 2020. Meanwhile, in 2018 and 2019, cases of rabies-transmitting animal bites in North Tapanuli Regency had a clustered pattern (I> E[I]) with a p-value > α, which means that globally, there is no spatial autocorrelation in cases of rabies-transmitting animal bites between district areas in North Tapanuli Regency in 2018 and 2019. It means that in 2016, 2018, and 2019, rabies-transmitting animal bite cases between areas in North Tapanuli Regency were not connected, or there was no interaction, especially between neighbors. Meanwhile, in 2017 and 2020, rabies-transmitting animal bite cases between one area and another in North Tapanuli Regency were known to be interconnected, or there was interaction, especially among neighbors. Then, the local correlation between districts can be shown in **Table 2** and **Figure 2.**

Our data shows that Moran's cluster map shows that the districts in quadrant I (*High-High*) are Siborongborong (2016–2020, except 2018) and Sipoholon (2017–2019). It means that in 2016–2020, these two areas were areas with high cases of rabies-transmitting animal bites and surrounded by areas with high cases. The districts in quadrant II (*Low-High*) are Adiankoting (2016-2018) and Pagaran (2018). This indicates that despite the surrounding areas having high rates of rabies-transmitting animal bites, these two areas have low rates. So, Adiankoting and Pagaran Districts must be careful with their surrounding areas or neighbors.

Table 2. Moran's cluster map of rabies-transmitting animal bites on North Tapanuli Regency in 2016-2020

Cluster	District				
	2016	2017	2018	2019	2020
High – High	Siborongborong	1. Siborongborong 2. Sipoholon	Sipoholon	1. Siborongborong 2. Sipoholon	Siborongborong
Low – High	Adiankoting	Adiankoting	1. Adiankoting 2. Pagaran	-	-
Low – Low	-	Pangaribuan	Pangaribuan	Pangaribuan	-
High – Low	Pahae Jae	Pahae Jae	-	Pahae Jae	Pangaribuan

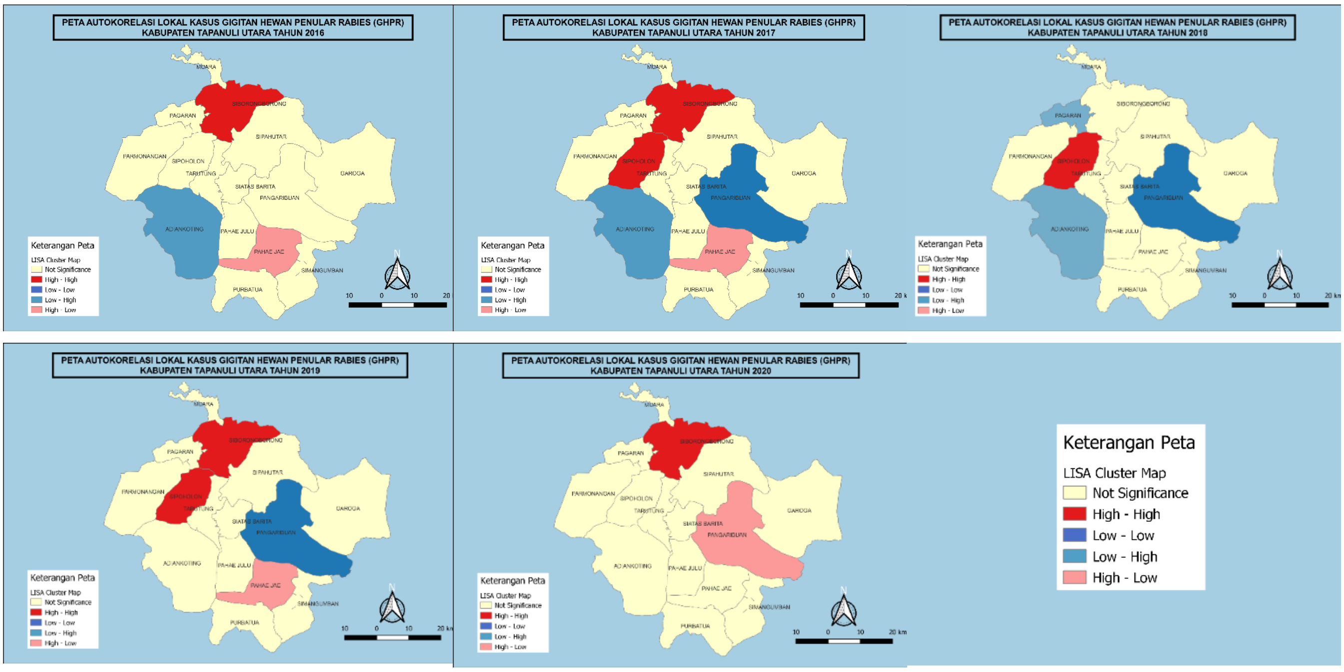

Figure 2. Moran's cluster map of rabies-transmitting animal bites on North Tapanuli Regency in 2016-2020

The district in quadrant III (*Low-Low*) is Pangaribuan (2017-2019). It means that this area is an area with low cases of rabies-transmitting animal bites and is surrounded by areas with low cases.

Furthermore, the districts in quadrant IV (*High-Low*) are Pahae Jae in 2016, 2017, and 2019 and Pangaribuan in 2020. This indicates that while there are areas nearby with low cases of rabies-transmitting animal bites, this area has high cases. So, areas around Pahae Jae and Pangaribuan Districts must be carefully considered.

DISCUSSION

The spread of rabies-transmitting animal bite cases in the North Tapanuli Regency occurred clustered in 2017-2020. This is following the behavioral study that shows the model for the incidence of infectious diseases such as rabies is a cluster pattern [10]. This is in line with research on dog behavior in Bali Province, which states that dogs are perpetrators of the rabies transmission cycle (host maintenance), which has a wide reach. The maximum roaming distance for dogs is 4 km [12,13], so this has the potential for local transmission to occur. The spatial pattern of rabies cases in humans and animals in the Dutch East Indies (the Dutch colony that became modern Indonesia after World War II) stated that spatially rabies cases formed a clustered pattern, namely on the west and east coasts of Sumatra, Batavia Regency, East Java, West Java, Kalimantan, and West Nusa Tenggara [14].

The results of the autocorrelation test based on the significance of Moran's index in this study show that globally, there is spatial autocorrelation in cases of rabies-transmitting animal bites between districts in North Tapanuli Regency in 2017 and 2020. It means that in 2017 and 2020, cases of rabies-transmitting animal bites in one area (district) will have links to other areas nearby (neighbors). The results of this study are in line with research in Iran, that there is positive spatial autocorrelation (Global Moran's I = 0,27, p-value = 0,001) in cases of rabies-transmitting animal bites in Iran. LISA test found that about 7% of districts in the north and northeast, 18% in the west and south, and 3% in the central part of Iran are significant hotspots, coldspots, and spatial outliers (p-value $\leq$ 0.05) [15].

This is in line with the aim of spatial autocorrelation, namely to assess the level of spatial dependence or correlation between regional observation values and neighboring region observation values [11,16]. Spatial autocorrelation refers to the fact that data located close together makes it possible to obtain the same results as data from locations that are far apart [17]. This is under the concept of Tobler's Law which states that "*Everything is related to everything else, but near things are more related than distant things*" [11].

Global spatial autocorrelation in this case is the Moran index which does not provide information on spatial patterns in certain areas [18]. Therefore, information on the tendency of spatial correlation at each location is needed to determine LISA [18]. *The Local Indicator of Spatial Association (LISA) shows spatial autocorrelation in each part of a variable. It can determine the spatial correlation for each point or the correlation with the value next to it* [19]. From the results of local analysis tests (a result of Moran's I *Scatter plot*), there are points spread between quadrants I, II, III, and IV. Quadrant I, HH (*High-High*) shows areas that have high observation values surrounded by areas that have high observation values. Quadrant II, LH (*Low-High*) shows areas with low observation values but surrounded by areas with high observation values. Quadrant III, LL (*Low-Low*) shows areas that have low observation values surrounded by areas that also have low observation values. Quadrant IV, HL (*High-Low*) shows areas with high observation values but surrounded by areas with low observation values [20].

Monitoring the area regarding cases of rabies-transmitting animal bites is important. Rabies cases in one area affect other nearby areas, apart from that it also describes the level of risk of an area for rabies. This spatial correlation results in districts becoming hotspot areas and coldspot areas. Spatial correlation produces hotspots (high-case areas surrounded by low-case areas), and coldspots (low-case areas surrounded by high-case areas) [10]. In this research, the hotspot areas are Pahae Jae and Pangaribuan Districts, while the coldspot areas are Adiankoting and Pagaran Districts. About spatial epidemiology, it is important to investigate the spatial patterns of rabies-transmitting animal bites and identify areas that are truly at risk and in need. Several important methodological issues must be considered when conducting spatial analysis. This will be useful for efforts to overcome cases of rabies-transmitting animal bites in North Tapanuli Regency.

CONCLUSION

This study provides an overview of global and local spatial correlations, allowing us to conclude that rabies-transmitting animal bite cases occur in clusters. Therefore, case handling or rabies control program intervention in areas with high observation values (*High-High* and *High-Low*) must be prioritized so that it does not spread to areas with *Low-Low* observation values so that the number of rabies-transmitting animal bite cases can be reduced and Extraordinary incidents of rabies cases no longer occur in North Tapanuli Regency.

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