SPATIAL AUTOCORRELATION ANALYSIS USING THE MORAN AND LISA INDEX ON THE SPREAD OF MALARIA DISEASE IN NORTH SUMATRA PROVINCE

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ABSTRACT
Malaria is a disease caused by protozoan infection of the Plasmodium genus, characterized by symptoms of alternating chills and prolonged fever. During the period of 2018-2022, the province of North Sumatra experienced an increase in malaria cases. This research aims to comprehend the spread of malaria cases in North Sumatra Province during that period through univariate analyses. This study uses secondary data obtained from the North Sumatra Provincial Health Office which includes the number of malaria cases. In the univariate analysis, the Moran’s Index test revealed positive global spatial autocorrelation in 2021 and 2022, indicating inter-district/city connectivity and clustered patterns of malaria distribution in North Sumatra Province (I>E[I]). LISA analysis identified different clusters each year, but Hot Spots consistently occurred in Asahan Regency (2021-2022) and Batubara Regency (2022), while a Cold Spot persisted in South Tapanuli Regency for 3 years (2020-2022).

Keywords: Spatial Autocorrelation; Moran Index; LISA; Malaria
INTRODUCTION

Malaria is a disease caused by infection with protozoa of the genus Plasmodium and is easily recognized by the symptoms of hot and cold chills and prolonged fever. Rapid population growth, migration, poor sanitation and overcrowded areas help facilitate the spread of the disease (Faiz et al., 2013) (Rokhayati et al., 2022). The opening up of new lands and the movement of people from villages to cities (urbanization) have enabled contact between mosquitoes and humans living in these areas (James & Nyoman, 2006). Mosquitoes infected with the parasite can move from one area to another and spread the malaria parasite to that area. Thus, the number of people in an area infected with malaria will affect the number of people in neighboring areas infected with the disease (DINIARI et al., 2020).

Half of Indonesia's population lives in areas where malaria typically develops. There are an estimated 30 million cases of malaria each year, and only approximately 10 percent of them go to a health facility for treatment. This is because there are still 396 regencies (80 percent) in Indonesia that are malaria endemic, making Indonesia one of the countries that are still vulnerable to malaria. (Purnama, 2016). North Sumatra Province is located in the west of Indonesia, the region consists of beaches, lowlands, and highlands, as well as the Bukit Barisan mountain range that stretches in the middle from north to south with a tropical climate (BPS_Sumut, 2020). The topography and climate in this region have the potential to cause malaria to develop. Based on data from the Central Bureau of Statistics (BPS) of North Sumatra, the number of malaria incidents in 2020 was 20,720 cases. Twenty-one of 33 districts/cities have been classified as malaria-free in 2020. Geographical areas and high community mobility are still the main sources of transmission and challenges to malaria elimination efforts in North Sumatra (Fahmi et al., 2022).

To make policies that anticipate and reduce malaria cases, responsible parties urgently need data on how malaria cases spread globally and locally in North Sumatra Province. Based on the description above, spatial data analysis can be used to identify research on the spread of malaria in North Sumatra Province using the Moran Index method and Local Indication of Spatial Autocorrelation (LISA). LISA as a statistic that meets the criteria that the LISA value of each region can be used to provide clues to the existence of significant clustering of spatial relationships of the same value around the area and the sum of the LISA values for the entire region is comparable to the value of the Moran index (Lee & Wong, 2001).

Spatial autocorrelation is a measure of how similar objects in a space are based on time, region and distance. It indicates that the value of an observation in region i is affected by the value of an observation in a neighboring region, e.g. region j (i ≠ j). Spatial autocorrelation occurs when the distribution of variables has a systematic pattern. Attribute values in a particular area are related to attribute values in adjacent or neighboring areas, known as spatial autocorrelation (et al., 2016). In the health sector, spatial autocorrelation can be used to analyze disease distribution patterns. It can even map the vulnerability of an area to disease occurrence (Syamsir et al., 2020). Spatial autocorrelation can look at how Malaria spreads in a region, or even how Malaria cases correlate with demographic conditions in the region. For example, spatial autocorrelation can look at how Malaria cases correlate with population density levels in large cities. Moran's index and Local Indication of Spatial Autocorrelation (LISA) are tools that can be used to perform spatial autocorrelation analysis.

The Moran index is used to detect spatial randomness and shows the presence of clustered patterns or trends in space. The Moran index is obtained by comparing the value of observations in an area with the value of observations in other adjacent areas (Habinuddin, 2021). The Moran index does not provide information on spatial patterns in certain areas. Therefore, it is
necessary to determine the tendency of spatial relationships in each location using LISA (Mailanda et al., 2022). The results of the Moran Index determination can be used to identify local autocorrelation. In the context of spatial autocorrelation, this is used to determine the region that contributes most to the trend of events occurring in that area. The higher the local Moran value provides information that adjacent areas have similar values or form a clustered distribution (Lee & Wong, 2001).

In this study, spatial autocorrelation analysis was conducted univariately. Positive spatial autocorrelation suggests that values in nearby locations are similar and tend to form clusters. Conversely, negative spatial autocorrelation indicates that neighboring locations have dissimilar values and tend to disperse (Wuryandari et al., 2011). Univariate spatial autocorrelation is conducted using the Univariate Moran's I and Univariate Local Moran's I (LISA) tests. Global Moran's I test to determine the spatial autocorrelation of malaria incidence in North Sumatra Province in 2018 - 2022. The LISA test is used to determine the pattern of distribution of malaria incidence in each region and its significance.

With this analysis, it will be easier to combat health problems, especially infectious diseases, because this analysis finds information about the relationship between regions and disease cases. The results of spatial analysis can help policymakers determine the best locations for health interventions to stop the spread of malaria. In addition to knowing case trends, this study also aims to determine Univariate Spatial Autocorrelation using the Moran Index and LISA on the distribution of malaria in North Sumatra province in 2018-2022.

METHOD

This research was conducted at the North Sumatra Provincial Health Office using observational research, because it was carried out by observing secondary data that was already available. In addition, all data covering the study variables were collected simultaneously.

Data Collection Technique

The data used in this research is secondary data, where researchers obtain the data from several agencies. This research is limited based on regency/city units. The data were analyzed spatially to determine whether or not spatial autocorrelation occurred in each district / city and how the shape of the spatial distribution pattern occurred from the results of the spatial autocorrelation process. The data collected includes data on the total number of malaria cases in each district / city of North Sumatra Province in 2018-2022 obtained from the North Sumatra Provincial Health Office and data on the Percentage of Households using Septic Tanks/SPALs as a Place for Fecal Disposal for each regency/city in North Sumatra Province in 2018 - 2022, obtained from the Central Bureau of Statistics (BPS) of North Sumatra Province.

Data Analysis

The stages of spatial data analysis are as follows:
1. Conducting data exploration, namely the process of merging data on district administrative boundary maps with data on the number of malaria cases. The merging process is carried out to obtain spatial data that visually represents qualitative and quantitative data;
2. Creating a spatial weighting matrix with the inverse-distance method where the calculations used are as follows:

\[ w_{ij} = \frac{1}{d_{ij}} \quad i \neq j \]  \hspace{1cm} (1)
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\[ d_{(i,j)} = \sqrt{(u_i - u_j)^2 + (v_i - v_j)^2} \]  

\( d_{(i,j)} \) = The euclidean distance between regions i and j, for \( i, j = 1, 2, ... n \)
\( u_i \) = Latitude coordinate of region i
\( u_j \) = Latitude coordinate of region j
\( v_i \) = Longitude coordinate of region i
\( v_j \) = Longitude coordinate of region j

3. Calculating univariate spatial autocorrelation where Univariate spatial autocorrelation is obtained by calculating the value of the Moran index and LISA. According to Anselin (Anselin, 1999), the Moran Index is one of the global spatial techniques used to determine the presence or absence of spatial autocorrelation between locations. The classification of the Moran Index value in showing spatial patterns can be classified with 3 categories, which can be seen in table 1 as follows.

<table>
<thead>
<tr>
<th>Moran Index</th>
<th>Pattern</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I &gt; E[I] )</td>
<td>Clustered</td>
<td>Points that are close together indicate the same observed characteristics (positive spatial autocorrelation). No particular pattern of points based on observed characteristics (no spatial autocorrelation)</td>
</tr>
<tr>
<td>( I &lt; E[I] )</td>
<td>Uniform</td>
<td>Adjacent points indicate the characteristics of different observations (negative spatial autocorrelation)</td>
</tr>
<tr>
<td>( I = E[I] )</td>
<td>Random</td>
<td></td>
</tr>
</tbody>
</table>

The Moran index is written as follows:

\[ I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{S_0 (n \sum_{i=1}^{n} (x_i - \bar{x})^2)} \] (3)

or

\[ I = \frac{n(\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}Z_iZ_j)}{S_0 (n \sum_{i=1}^{n} Z_i^2)} \] (4)

\( I \) : Moran index value
\( n \) : number of event locations
\( x_i \) : value at location i
\( x_j \) : value at location j
\( \bar{x} \) : average of the number of variables or values at the corresponding location \( \bar{x} \) for \( x_i \) or \( x_j \)
\( W_{ij} \) : element \( ij \) of the (standardized) spatial weight matrix \( W \)
\( S_0 \) : sum of the weight matrix elements

To identify whether spatial autocorrelation exists or not, a Moran Index significance test is conducted. The Moran Index test hypothesis is as follows.
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**Hypothesis Testing**

- **$H_0$:** $I = 0$ there is no spatial autocorrelation
- **$H_1$:** $I \neq 0$ there is spatial autocorrelation

Test statistics:

\[ Z(I) = \frac{I - E[I]}{\sqrt{Var(I)}} \]  

The expected value of the Moran Index is

\[ E(I) = I_0 = -\frac{1}{n-1} \]  

To infer the presence of autocorrelation, it is necessary to compare the statistical value of statistic $I$ with the expected value $E(I)$ or $I_0$. If the value of $I > I_0$ means that there is positive autocorrelation, it shows a clustering pattern. Conversely, there is negative autocorrelation when $I < I_0$ indicating that the pattern tends to spread. If $I = I_0$ then there is no autocorrelation and has an uneven spread pattern.

Hypothesis testing of the Moran Index parameter can be done as follows:

- **$H_0$:** $I = 0$ there is no spatial autocorrelation
- **$H_1$:** $I \neq 0$ there is spatial autocorrelation

Cliff and Ord derived the moments of the Moran Index assuming that the observations are random free images of a normal population. Under this assumption, the expected value of the Moran Index $E(I)$ is:

\[ E(I) = -\frac{1}{n-1} \]  

and $Var(I)$ is the variance value for the normal approximation:

\[ E(I^2) = \frac{A - B}{C} \]  

Where:

\[ A = n[(n^2 - 3n + 3)S_1 - S_2 + 3S_0^2] \]
\[ B = D[(n^2 - n)S_1 - 2nS_2 + 6S_0^2] \]
\[ C = (n-1)(n-2)(n-3)S_0^2 \]
\[ D = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^4}{(\sum_{i=1}^{n}x_i - \bar{x})^2} \]

so,

\[ Var(I) = E[I^2] - [E(I)]^2 \]
\[ = \frac{A - B}{C} - \left[ -\frac{1}{n-1} \right]^2 \]
\[ = \frac{n[(n^2 - 3n + 3)S_1 - S_2 + 3S_0^2] - D[(n^2 - n)S_1 - 2nS_2 + 6S_0^2]}{(n-1)(n-2)(n-3)S_0^2} \]
\[ - [E(I)]^2 \]
\[ = \frac{n^2S_1 - nS_2 + 3S_0^2}{(n^2 - 1)S_0^2} - [E(I)]^2 \]  

by:

\[ S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} \text{ and} \]
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\[ S_1 = \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} (W_{ij} + W_{ji})^2 \]

\[ S_2 = \sum_{i=1}^{n} (\sum_{j=1}^{n} W_{ij} + \sum_{i=1}^{n} W_{ji})^2 \]

\[ Z(I) : \text{Test statistic of the Moran Index} \]
\[ E(I) : \text{Expected value of Moran Index} \]
\[ Var(I) : \text{Moran Index Variance Value} \]
\[ S_1 : \text{The sum of the standardized weight matrices is squared and divided by 2} \]
\[ S_2 : \text{Sum of the squares of the sum of the weight matrices } W_{ij} \text{ and } W_{ji} \text{ which is standardized} \]

This test rejects \( H_0 \) if the value \( |Z(I)| > Z_{\alpha/2} \) with \( \alpha/2 \) for 95% confidence degree. On malaria cases in North Sumatra Province in 2018-2022, hypothesis testing was carried out by comparing the \( Z \) value with the \( Z_{\alpha/2} \) value at the 5% significance level (1.96).

The Global Spatial Autocorrelation, specifically the Moran Index, fails to furnish details about spatial patterns in specific regions. Hence, it becomes essential to acquire information regarding the inclination of spatial relationships in each location, and this can be achieved through the Local Indicator of Spatial Autocorrelation (LISA). According to Yuriantari (Yuriantari et al., 2017) LISA for each region \( i \) is written:

\[ L_i = \frac{(x_i - \bar{x})}{m_2} \sum_{j=1}^{n} w_{ij} (x_j - \bar{x}) \]  \hspace{1cm} (10)

by,
\[ m_2 = \sum_{i=1}^{n} \frac{(x_i - \bar{x})^2}{n} \]

Where:
\[ E[L_i] = \frac{-w_i}{n-1} \text{ and} \]
\[ Var(L_i) = w_{i(2)} \left( \frac{n - m_4}{m_2^2} \right) + 2w_{i(kh)} \left( \frac{2m_4}{m_2^2} - n \right) \frac{w_i^2}{(n-1)(n-2)} - \frac{w_i^2}{(n-1)^2} \]

\[ w_{i(2)} = \sum_{j \neq i} w_{ij}^2 \]
\[ 2w_{i(kh)} = \sum_{k \neq i} \sum_{h \neq i} w_{ik} w_{ih} \]
\[ w_i = \sum_{j \neq i} w_{ij} \]
\[ m_4 = \sum_{i=1}^{n} \frac{(x_i - \bar{x})^4}{n} \]

The conclusions in the hypothesis test are:

a. \( H_0 \) is rejected if \( |Z_{\text{value}}| < Z_{\alpha/2} \), where \( Z_{\alpha/2} = 1.96 \), meaning there is spatial autocorrelation for malaria cases in North Sumatra Province.

b. \( H_1 \) is rejected if \( |Z_{\text{value}}| > Z_{\alpha/2} \), where \( Z_{\alpha/2} = 1.96 \), meaning there is no spatial autocorrelation for malaria cases in North Sumatra Province.
Spatial autocorrelation analysis in this study was conducted using GeoDa software. Univariate analysis of Moran's Index was conducted to determine the spatial autocorrelation of Malaria in North Sumatra Province in 2018-2022. The results of the Moran's Index Global analysis produce Moran's Scatterplot, Moran's index value (I), Moran's I expectation value (E[I]), and Z-value. The results of the Global Moran Index analysis will be presented in the analysis results table.

RESULT AND DISCUSSION
Malaria Case
Malaria transmission can be facilitated by poor or slum housing (Budiman, 2007). Healthy homes must meet the requirements of Minister of Health Decree No. 829/MENKES/SK/VII/1999, including good building materials. First, building materials should not be made of materials that can release materials that can harm health. In addition, these materials should not be a place for the growth and development of pathogenic microorganisms (Suparto, 2015). Some housing variables that must be considered in physiological needs are water, disposal of human waste, garbage, and wastewater, ventilation, roof, walls, and floors (Evierni et al., 2012). Below is a graph of malaria cases in North Sumatra Province from 2018 to 2022.

![Graph of Malaria Cases in North Sumatra Province in 2018-2022](image)

Based on the graph above for 5 years (2018-2022), overall North Sumatra Province has 11,193 malaria cases. In 2018, there were 1,300 malaria cases that occurred in North Sumatra Province. Then in 2019 malaria cases decreased from the previous year, namely to 1,124 cases, then fell again in 2020 to 1,011 cases, in 2021 malaria cases experienced a fairly high increase, namely to 2,625 cases, and rose again in 2022 to 5,133. The highest case occurred in 2022 with 5,133 cases and the lowest number of malaria cases occurred in 2020, which was 1,011 cases (Kemenkes RI, 2014).

<table>
<thead>
<tr>
<th>Malaria Case</th>
<th>District/City (%)</th>
<th>District/City (%)</th>
<th>District/City (%)</th>
<th>District/City (%)</th>
<th>District/City (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>15 (45.46%)</td>
<td>16 (48.49%)</td>
<td>18 (%54.54)</td>
<td>15 (%45.46)</td>
<td>12 (36.37%)</td>
</tr>
<tr>
<td>1-705</td>
<td>18 (54.54%)</td>
<td>17 (51.51%)</td>
<td>15 (45.46%)</td>
<td>16 (48.49%)</td>
<td>18 (54.54%)</td>
</tr>
<tr>
<td>706-1410</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
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It can be seen in table 1, in 2018, there were 15 districts / cities whose areas were free from malaria, and as many as 18 districts / cities where the number of malaria cases was in the 1-705 case category. Then in 2019, as many as 16 districts / cities were free from malaria, and as many as 17 districts / cities were in the 1-705 case category. In 2020, there are 18 districts/cities that are free from malaria, and as many as 15 districts/cities are in the category of 1,411-2,116 cases. For 2021, there are 15 districts/cities free from malaria, 16 in the 1-705 case category, and 2 districts/cities in the 706-1,410 case category. Meanwhile, in 2022, there are 12 districts/cities free from malaria, 18 in the 1-705 case category, 2 districts/cities in the 706-1,410 case category, and 1 district/city in the 1,411-2,116 case category.

Global Spatial Autocorrelation Analysis of Malaria Cases
Spatial autocorrelation occurs due to inter-regional interaction or a measure of the similarity of objects in a space (distance, time, and region). This interaction describes the condition that the value of observations in region i is influenced by the value of observations in the surrounding region. If a variable exhibits a consistent pattern in its distribution, it implies the presence of spatial autocorrelation. The presence of spatial autocorrelation suggests that the attribute's value in a specific area is connected to the value of the same attribute in nearby or neighboring areas (et al., 2016).

The results of this analysis will show which areas have spatial autocorrelation and find patterns of spatial distribution of malaria in North Sumatra Province. This study uses a spatial weighting matrix with the inverse-distance method or a matrix that measures the intensity of the relationship between malaria cases between districts / cities. The inverse-distance method is a weighting matrix that takes into account the distance between one district / city and another district / city. The following table shows the number of malaria cases found in North Sumatra Province from 2018 to 2022.

<table>
<thead>
<tr>
<th>Tahun</th>
<th>Indeks Moran[I]</th>
<th>E[I]</th>
<th>Z-value</th>
<th>P-value</th>
<th>Pola Sebaran</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>0.013</td>
<td>-0.0312</td>
<td>0.297</td>
<td>0.35</td>
<td>Clustered</td>
</tr>
<tr>
<td>2019</td>
<td>0.025</td>
<td>-0.0312</td>
<td>0.628</td>
<td>0.25</td>
<td>Clustered</td>
</tr>
<tr>
<td>2020</td>
<td>0.025</td>
<td>-0.0312</td>
<td>0.0617</td>
<td>0.22</td>
<td>Clustered</td>
</tr>
<tr>
<td>2021</td>
<td>0.129</td>
<td>-0.0312</td>
<td>1.9608</td>
<td>0.05</td>
<td>Clustered</td>
</tr>
<tr>
<td>2022</td>
<td>0.148</td>
<td>-0.0312</td>
<td>2.6642</td>
<td>0.02</td>
<td>Clustered</td>
</tr>
</tbody>
</table>

Based on the results of the Moran index in table 4.3 above, an area can be said to have global spatial autocorrelation if the value of $|Z_{\text{value}}| > Z_{\alpha/2}$, where $Z_{\alpha/2}$ with a significant level of $\alpha = 5\%$ is 1.96 so that $H_0$ is rejected. So, there is significantly positive spatial autocorrelation ($0 < I \leq 1$) in 2021 and 2022, which means that there is a relationship between districts/cities and the pattern of distribution of cases that occurs is clustered ($I < E[I]$). Whereas in 2018-2020, it shows that there is no global spatial autocorrelation [$Z_{\text{value}}| < Z_{\alpha/2}$ where $Z_{\alpha/2}$ with a significant level of $\alpha = 5\%$ is 1.96, so $H_1$ is rejected. In addition, the Moran index value is greater than the expected value of Moran ($I > E[I]$), this means that malaria cases in North Sumatra Province in 2018-2020 tend to have a clustered pattern. In this case, there is no one definite reason that...
can explain why there is no spatial autocorrelation in the distribution of malaria cases, because it can be influenced by several complex factors, such as differences in malaria eradication efforts, variability in environmental conditions, or differences in the level of exposure to vector mosquitoes that cause random variations in malaria cases throughout the region, reducing the possibility of an autocorrelation pattern.

**Local Spatial Autocorrelation Analysis of Malaria Cases**

Local autocorrelation analysis was conducted using the Local Indicator of Spatial Autocorrelation (LISA) test to determine the category of clustering and the tendency of spatial relationship patterns in local areas. The resulting values can be used to identify Hot Spot and Cold Spot areas. Hot Spot is a term that describes districts/cities that have a high number of malaria cases near districts/cities that have a high number of malaria cases. Cold Spot describes districts with a low number of malaria cases adjacent to districts with a low number of malaria cases.

The results of the local spatial autocorrelation analysis for malaria cases in North Sumatra Province in 2018-2022 where there are 4 categories of malaria cases between districts/cities, namely High-High, Low-High, Low-Low, and High-Low. The HH (High-High) cluster from 2018 to 2022 was detected in only 2 districts, namely Asahan Regency in 2021-2022, and also Batubara Regency in 2022. Whereas in 2018-2020 none of the districts/cities were in this cluster. In addition, for areas with a low number of malaria cases but adjacent to areas with a high number of malaria cases (Low-High), which are prone to malaria transmission, there is 1 city that has been consistent for 5 years, namely Tanjung Balai (2018 - 2022) and another district/city that has been in the LH (Low-High) cluster for 2 years is Tebing Tinggi City (2021-2022).

Cold Spot (areas that have a low number of malaria cases and are adjacent to areas that are also low) or what is known as the LL (Low-Low) cluster consistently occurred for 3 years in Central Tapanuli District (2020-2022). Whereas in 2019 none of the districts/cities were in this cluster. The only district that is included in the HL (High-Low) cluster, which is an area with a high number of malaria cases but adjacent to an area with a low number of malaria cases, is Central Tapanuli District (2018). Meanwhile, in 2019-2022, none of the districts/cities were included in this cluster.

**CONCLUSION**

For 5 years (2018-2022), North Sumatra Province had a total of 11,193 malaria cases. In 2018, 1,300 malaria cases occurred in North Sumatra Province. Then in 2019 malaria cases decreased from the previous year, namely to 1,124 cases, then fell again in 2020 to 1,011 cases, in 2021 malaria cases experienced a fairly high increase, namely to 2,625 cases, and rose again in 2022 to 5,133. The highest case occurred in 2022 with 5,133 cases and the lowest number of malaria cases occurred in 2020, which was 1,011 cases.

For Univariate Autocorrelation Analysis, globally there is positive spatial autocorrelation ($0 < I \leq 1$) in 2021 and 2022, where $|Z_{value}| > Z_{α/2}$ with a significant level of $α = 5\%$ which is 1.96 so that $H_0$ is rejected, which means that there is a relationship between districts/cities. In 2018-2020, it shows that there is no global spatial autocorrelation $|Z_{value}| < Z_{α/2}$ with a significant level of $α = 5\%$, which is 1.96 so $H_1$ is rejected. In addition, the obtained Moran index value is greater than the expected value of Moran ($I > E[I]$), this means that malaria cases in North Sumatra Province in 2018-2020 tend to have a clustered pattern. The results of the LISA analysis in 2018 - 2022 different clusters were identified for each year but during the
observation time Hot Spot occurred in Asahan Regency (2021-2022) and Batubara Regency (2022) while Cold Spot was South Tapanuli Regency for 3 years (2020-2022).

Researchers suggest that government, to plan a suitable program to eradicate and control malaria cases. It is also expected that this research can also be a reference to find out which areas should be prioritized or focused on in handling the spread of malaria cases. because the distribution pattern of malaria cases formed in North Sumatra Province is clustered. In addition to the government, the community should be more aware of hygiene and apply healthy living behaviors to prevent malaria. It is also good to understand the factors that can cause malaria, and if there are symptoms of malaria immediately check themselves to a health facility so that the incidence of malaria can be minimized, especially in North Sumatra. It is hoped that this research can provide information for future research. Future researchers can also use other variables that may have more influence on the spread of malaria cases that have not been covered in this study.

REFERENCE
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