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Distribution of Spread and Characteristics of Confirmed Covid-19 based on Spatial Autocorrelation in Manado

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Abstract

Covid-19 is a collection of viruses that attack the respiratory system. This virus spread quickly and spread to other regions in China and most countries in the world, including Indonesia. North Sulawesi Province, especially Manado City is one of the cities in Indonesia that has been affected by Covid-19. The highest confirmed Covid-19 cases in Manado City are in the Malalayang, Mapanget, and Wanea villages which are geographically not adjacent/neighboring. This study aims to analyze the spatial distribution of Covid-19 cases and their characteristics. This study uses significant data on Covid-19 cases in every village in Manado City, where there are 86 villages (Malalayang Satu Barat Village and Malalayang Satu Timur Village combined), and the focus of this research is on the confirmed variables, with the latest data update is October 21, 2021. The effect of covid-19 between observation locations is accomplished using Moran's I, and the weighting matrix used is the Euclidean distance matrix. The Moran's Index provides an overview of the spatial relevance of the Covid-19 case data in every village in Manado City and specifically the spatial attachment of every village will be explained by the Local Moran's I value (LISA). The results of this study found that there is a spatial autocorrelation found using the Euclidean distance matrix. A spatial correlogram of 30 meters is used as the maximum geographical distance limit for being infected with Covid-19. The Moran's Index value of the Covid-19 case in Manado City is 0.348, meaning that there is a positive autocorrelation between the villages. There are thirteen villages that affect the spread of Covid-19 in Manado City, namely Malalayang Satu Timur dan Barat, Malalayang Satu, Winangun Satu, Kleak, Karombasan Utara, Ranotana Weru, Bumi Nyiur, Pakowa, Tinkulu, Taas, Paal Empat, Tikala Baru, and Paniki Dua.

Keywords: Manado City, Covid-19, Euclidean distance, Moran's I, Lisa Moran.

1. Introduction

The Covid-19 pandemic has hit almost all countries in the world and has damaged the health system, economy, and society. Recently, the world is facing a stronger second wave of Covid-19 transmission and a new variant of Covid-19 mutation, although some countries have gradually recovered from the first wave, they still need to pay more attention to the potential for the second wave of attacks by (Rendana, et, al., 2021). The case of Covid-19 in Indonesia is also increasingly worrying. This can be seen from active cases and the death rate is still increasing. Data compiled by the government until Thursday, October 21, 2021, at 12:20 WITA, there were 8897 confirmed cases and 290 deaths. Therefore, we need an analysis of spatial data using the spatial autocorrelation method to analyze the spatial distribution of Covid-19 cases and their characteristics in Manado City.

Prasetyo et al. in 2012 define spatial autocorrelation as a correlation analysis between regions (space) from observations in the form of spatial patterns (patterns of distance, time, and region) (Prasetyo, et, al., 2013). The criteria for the occurrence of the spatial autocorrelation phenomenon is in terms of the distribution of the value of an observation variable following a certain variable pattern systematically[2].

Spatial autocorrelation with the Covid-19 research object has been studied by Rendana et al. in 2021 using the Global Moran Index in South Sumatra Province, Indonesia (Rendana, et, al., 2021). The spatial correlation characteristics of Covid-19 cases in South Sumatra Province show a random distribution. The spatial correlation characteristic as measured by the Global Moran Index found an increase of about 0.09 units in the second wave compared to the first wave, meaning that the degree of clustering is higher than the first wave, and the spatial distribution of COVID-19 cases is characterized by a decentralized expansion trend. Spatial autocorrelation with the Covid-19 research object has also been investigated the hot spot spatial analysis method (Getis Ord Gi*) in Tomohon City, North Sulawesi Province, Indonesia (Rotinsulu & Sulistyo, 2021). According to the research that has been accomplished, villages with Hot Spot status in every research village are directly adjacent to and form a cluster pattern. This shows that there is a spatial correlation pattern in the spread of COVID-19 in Tomohon City. Spatial autocorrelation with the Covid-19 research object has also been studied by Ginting et al. in 2020 using the Moran's Global Index and LISA (Local Indicators of Spatial Autocorrelation) spatial analysis methods in DKI Jakarta Province, Indonesia in March-July 2020 (Rahardja, et, al., 2022). According to the research that has been accomplished, it is concluded that the spread of Covid-19 cases has covered a large number of urban villages in DKI Jakarta, with hotspots detected in various areas. Spatial autocorrelation with the Covid-19 research object has also been studied by Bekti et al. in 2021, using the method of modeling spatial areas on Java Island, Indonesia. Based on the research that has been done, it is concluded that daily and cumulative positive cases until 30 September 2020 have no significant effect on inflation in September (α=5%) (Liu, et al., 2020). Meanwhile, population density significantly affects the number of Covid-19 cases. Covid-19 has been the Geographically Weighted Regression (GWR) method, which is the development of local linear regression between observation areas (Marhamah & Jaya, 2020). Based on the results of the analysis that has been accomplished, it is concluded that modeling the number of Covid-19 cases in West Java locally through GWR has a higher coefficient of determination than modeling globally through linear regression. The spatial autocorrelation as also been investigated (Hassan, et al., 2021), the reasearch is about spatial autocorrelation measurement of land prices uses a covariance function to describe the spatial dependence and it can be identified as a geographic distance on the correlogram. Based on the research that has been done, it is concluded that the moran index can be used to determine the strength of the land price autocorrelation that occurs at a distance = 2091.3510 meters with a composition model of bessel base p = 2 and a gaussian-type function. At this optimal distance, it can be said that two locations in manado with identical attributes will have similar prices if they are adjacent to each other rather than if they are far apart (larger than 2091.3510 m) (Astuti, et, al. 2019; Weku, et al., 2019).

According to the background, this study focuses on the spread of the Covid-19 phenomenon in Manado. The focus of this research is on the confirmed variable. Through the research variables above, an analysis of the spatial autocorrelation or spatial connectivity of the spread of Covid-19 between villages in Manado City was accomplished, using the Moran Index and Local Indicator of Spatial Association (LISA) methods. The weighting matrix used is the Euclidean distance matrix. Euclidean distance is used as a spatial weighting because Euclidean distance has a high level of accuracy and is very suitable for the spread of disease, in this case, namely Covid-19. The Local Indicator of Spatial Association (LISA) is used to describe specifically the attachment of every village in Manado City.

2. Research Methodology

2.1. Literature Review

Based on the Epidemiological Indicators, the epidemiological indicator variables that will be the focus of the research is a variable of confirmed Covid-19, which is a person who has tested positive for the Covid-19 virus as evidenced by the investigation RT-PCR laboratory.

Caraka, et al., (2021) define distance weight as one of the definitions of the Euclidean matrix. The elements of the distance weight matrix are defined as:

$$W_{ij}^{(\ell)} = \begin{cases} \dfrac{\frac{1}{1+d_{ij}^{(\ell)}}}{\sum_{j=1}^{n}\frac{1}{1+d_{ij}^{(\ell)}}}, & j \text{ is the neighbor of } i \text{ on the-}\ell \\ 0, & \text{other} \end{cases} \tag{1}$$

$$d_{ij} = \sqrt{(x_i - x_j)^2 - (y_i - y_j)^2}$$

where d_{ij} represents the Euclidean distance between location *i* and location *j*.

The Moran index is a measure of global autocorrelation which is an extension of the Pearson correlation coefficient and is denoted by I Cliff and Ord in 1973, Cliff and Ord in 1981. Moran index is a technique in spatial analysis to calculate spatial relationships that occur in space by Gittleman and Kot in 1990.

Moran's I measure whether the variables x and y are correlated in one variable, for example, x *(x_i and x_j)* where *i j*, *i*=1,2,…, n_j=1,2,...,*n* with a lot of data of *n*, then the formula for the Moran's Index is in equation (2).

$$I = \frac{\sum_{f=1}^{n}\sum_{f=1}^{n} wij(x_i-\bar{x})(x_j-\bar{x})}{\sum_{f=1}^{n}(x_i-\bar{x})^2} \tag{2}$$

where *I* is the value of Moran's I, *n* is the number of locations of the incident, x_i is the value at the location I, x_j is the value at location *j*, $\bar{X}$ is the average number of variables, and W_{ij} is an element in the weighting between regions *i* and *j*.

Soltani & Askari, (2017) explains the value of this index ranges from -1 to 1. A value of $-1 \leq I < 0$ indicates a negative spatial autocorrelation, while a value of $0 < I \leq 1$ indicates a positive spatial autocorrelation.

Identification of spatial patterns using the index value criteria I, if I > E(I), then it has a clustered pattern and I < E(I) has a diffuse pattern. E(I) is the expected value of I formulated E(I) = -1/(n- 1) (Lee & Wong, 2001).

Hypothesis testing on a parameter I can be done as follows.

$H_0 : I = 0$ (no spatial autocorrelation)

$H_1 : I \neq 0$ (there is a spatial autocorrelation)

$$Z_{count} = \frac{I - E(I)}{\sqrt{var(I)}} \quad (3)$$

where I is the estimated Moran's I, which is the Moran Index test statistic value, E(I) is the expected value of the Moran's I, and var(I) is the variance value of the Moran's I.

$$var(I) = \frac{n^2 S_1 - nS_2 + 3S_0^2}{(n^2-1)S_0^2} \quad (4)$$

With

$$S_0 = \sum_{i-1}^{n} \sum_{j=1}^{n} w_{ij}$$

$$S_1 = \frac{1}{2} \sum_{i-1}^{n} \sum_{j=1}^{n} (w_{ij} + w_{ij})^2$$

$$S_2 = \sum_{i-1}^{n} (w_i + w_j)^2$$

$$w_i = \sum_{i=1}^{n} w_{ij}, w_i = \sum_{j=1}^{n} w_{ji}$$

this test will reject the initial hypothesis if the value of $|Z_{count}| > Z_{(\alpha/2)}$ while rejecting H_0 if value *P- value* < α by (Soltani & Askari, 2017).

Global spatial autocorrelation, in this case, is that the Moran index does not provide information on spatial patterns in certain areas. Therefore, information on the trend of spatial relationships in every location with LISA is needed. Anselin in 1995 defines LISA as a statistic that meets the following two criteria (Anselin, 1988).

1) The LISA value of every region can be used to indicate the existence of a significant spatial relationship grouping of the same value around the area.
2) The sum of the LISA scores for all regions is proportional to the Moran index value.

Caraka, et al., (2021) explain the index of LISA is as follows:

$$I_i = \frac{z_i}{m_2} \sum_{j=1}^{n} w_{ij} z_j \quad (5)$$

with:

$$z_i = (x_i - \bar{x})$$

$$z_j = (x_j - \bar{x})$$

$$m_2 = \sum_{i=1}^{n} \frac{(x_i - \bar{x}}{n-1}$$

testing of parameter I_i can be done as follows (Soltani & Askari, 2017).

$H_0 : I = 0$ (no spatial autocorrelation).

$H_1: I \neq 0$ (there is a spatial autocorrelation).

Test statistics:

$$Z_{(i)count} = \frac{I_i - E(I_i)}{\sqrt{var(I_i)}} \quad (6)$$

I_i is the LISA index, $Z_{(i)count}$ is the statistical value of the LISA index test, $E_{(Ii)}$ is the expected value of the LISA index, $var_{(Ii)}$ is the variance value of the LISA index.

$$E(I_i) = \frac{-w_i}{(n-1)} \quad (7)$$

$$var(I_i) = w_i^{(2)} \frac{(n - \frac{m_4}{m_2^2})}{(n-1)} + 2w_{i(kh)} \frac{(\frac{2m_4}{m_2^2} - n)}{(n-1)(n-2)} - \frac{w_i^2}{(n-1)^2} \quad (8)$$

with:

$$w_i^{(2)} = \sum_{j \neq i} w_{ij}^2, i \neq j \; 2w_{i(kh)} = \sum_{k \neq i} \sum_{h \neq i} w_{ik} w_{ih} \quad (7)$$

$$w_i = \sum_{j \neq i} w_{ij,} \; i \neq j m_4 = \sum_{i=1}^{n} \frac{(x_i - \bar{x})^2}{n-1} \qquad (8)$$

this test will reject the initial hypothesis if the value of Z_{count} lies at $|Z_{count}| > Z_{(\alpha / 2)}$ or P-value < α.

2.2.1. Moran's Scatterplot

In Moran's scatterplot graph, the horizontal axis on Moran's scatterplot shows the average value of observations at a location and the vertical axis shows the average value of observations (standardized) from locations neighboring the location in question (Lee & Wong, 2001). More details can be seen in Figure 1.

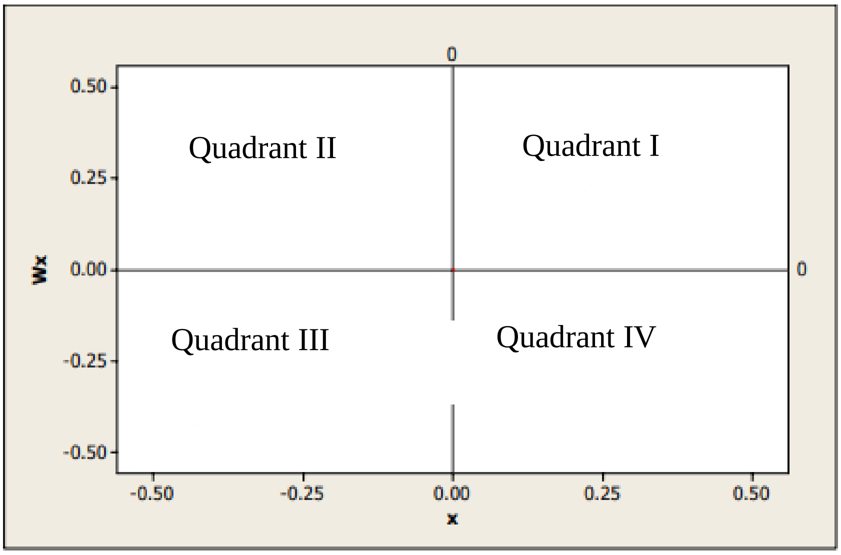

Figure 1. Moran's Scatterplot

Moran's Scatterplot is divided into 4 quadrants. Quadrant I (located at the top right) is called High-High (HH), indicating an area that has a high observation value surrounded by an area that has a high observation value. Quadrant II (located at the top left) is called Low-High (LH), indicating an area with low observations but surrounded by areas with high observation values. Quadrant III (located at the bottom left) is called Low-Low (LL), indicating an area with low observation values and surrounded by areas with low observation values. Quadrant IV (located at the bottom right) is called High-Low (HL), indicating an area with high observation values surrounded by areas with low observation values by (Abdulhafedh, 2017).

Spatial Autocorrelation (SA) is a correlation analysis between regions (spaces) of observations in the form of spatial patterns (patterns of distance, time, and region). Criteria for the occurrence of spatial autocorrelation This phenomenon occurs if the distribution of the value of an observation variable follows a certain pattern systematically.

In the spread of Covid-19 cases, spatial autocorrelation will be used to find out spatial patterns based on Covid-19 data in every village in Manado City. By using the Local indicator of spatial association (LISA) method, it will determine the areas that are included in the low-low, low-high, high-low, high-high categories, so that spatial patterns between villages will be known. According to Covid-19 data in every village in Manado City.

2.2.2. Study Area

According to The Supreme Audit Agency of the Republic of Indonesia data, the total population in Manado is estimated (based on January 2014) to be 430,790. The area of Manado City consists of land area and archipelagic area with a total area of 15,726 ha. The archipelago includes Bunaken island, Manado Tua Island, and Siladen island. Administratively, Manado City is divided into 11 sub-districts and 87 seven villages. Manado City is located at the northern tip of Sulawesi Island and is the largest city in North Sulawesi as well as the capital city of North Sulawesi Province. Geographically, it is located between 1º 25′ 88″ – 1º 39′ 50″ North Latitude and 124º 47′ 00″ – 124º 56′ 00″ East Longitude (Towoliu & Takaendengan, 2015).

Figure 2. North Sulawesi in Indonesia Map

Figure 3. Manado City on North Sulawesi Map

2.2.Method of Research

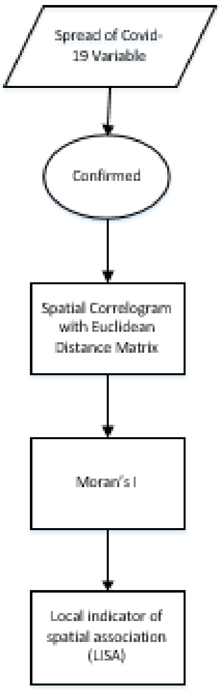

Figure 4. Research Steps Flowchart

This study has several steps as shown in Figure 4. In the first step, the Covid-19 variable is data on people who are confirmed to be Covid-19, according to the Manado City Government's Covid-19 Information and Coordination website (https://covid19.manadokota.go.id/) with the last update Thursday, October 21, 2021, in every village in Manado City it is entered into the database table using the GeoDa software. In the second stage, the Euclidean distance matrix is calculated to determine the relationship between locations in one spatial lag, and a spatial correlogram is made. Furthermore, spatial autocorrelation analysis was accomplished based on confirmed variables between regions using the Moran Index method. Finally, an analysis was accomplished using the Local Indicator of Spatial Autocorrelation (LISA), by looking at the Low-Low, Low-High, High-Low, and High-High regions.

3. Results And Discussion

3.1. Euclidean Distance Matrix

Table 1. Euclidean Matrix Threshold Value

Property	Value
Type	threshold
symmetry	symmetric
file	mdc_desa1.gwt
Id variable	ID
distance metric	Euclidean
distance vars	centroids
distance unit	unspecified
threshold value	0.0312018
#Observations	86
min neighbors	1
max neighbors	34
mean neighbors	17.28
median neighbors	18.00
% non-zero	20.09%

Table 1 shows the threshold value of the Euclidean distance matrix from the Covid-19 case data in Manado City is 0.03, meaning that every person who is within 0.03 kilometers or 30 meters from every village that is included in the high-high area in the LISA map, can be infected with Covid-19.

3.2.Spatial Correlogram

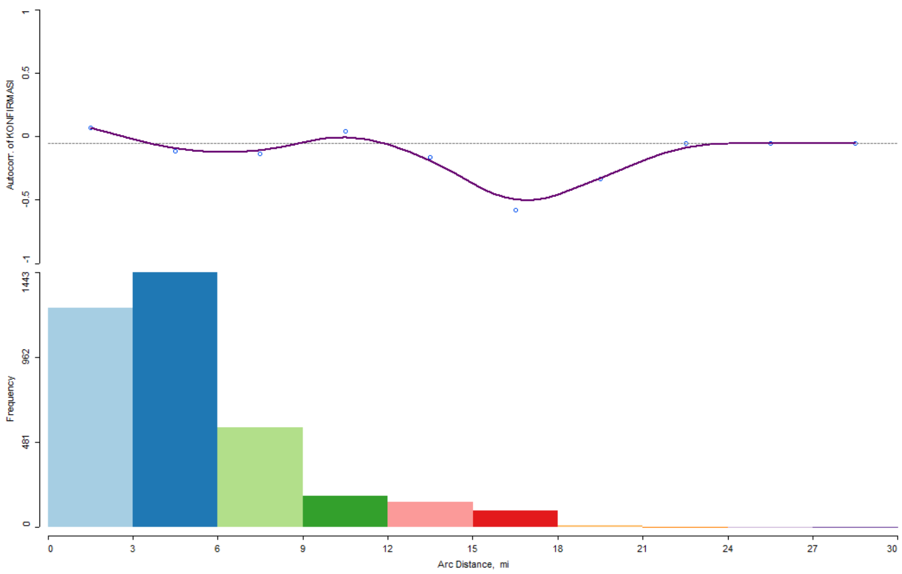

Figure 5. Spatial Correlogram

Figure 5 shows the spatial correlogram of Covid-19 confirmed data in Manado City. Based on the correlogram above, it can be concluded that the geographical distance of 30 meters is the maximum geographical distance limit for being infected with Covid-19 in Manado City.

3.3.Moran's I

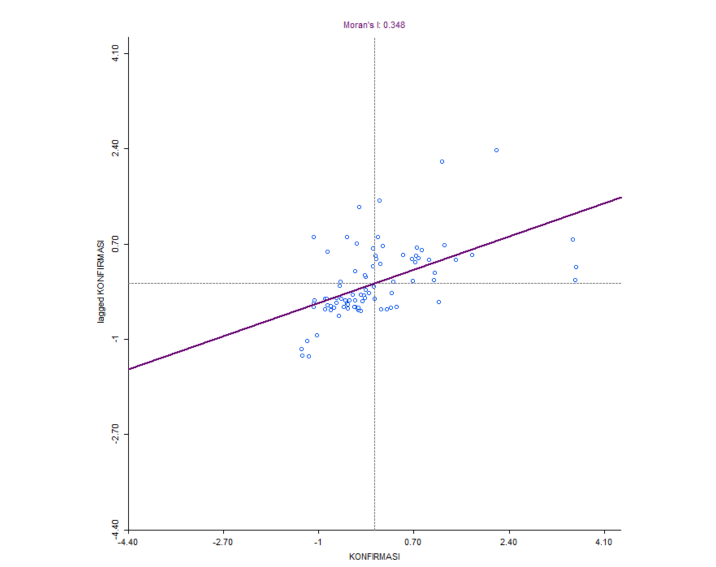

Figure 6. Moran's I Value

It is known that if the Moran's I value is in the range -1 ≤ I < 0 then the spatial autocorrelation that occurs is negative spatial autocorrelation, and if the Moran I value is in the range 0 < I ≤ -1 then the spatial autocorrelation that occurs is positive spatial autocorrelation, whereas if the Moran index value shows zero or I = 0, then there is no spatial autocorrelation. Based on the results of the spatial autocorrelation test with Moran's I in the Covid-19 case using the variable data on the number of confirmed Covid-19 people in Manado City, it was found that Global Moran's Index I = 0.348 (positive value), where I was in the range 0 < I ≤ -1, indicating the existence of autocorrelation or positive spatial patterns that gather and have the same characteristics at adjacent locations in every village in Manado City.

3.4.Local Indicator of Spatial Autocorrelation (LISA)

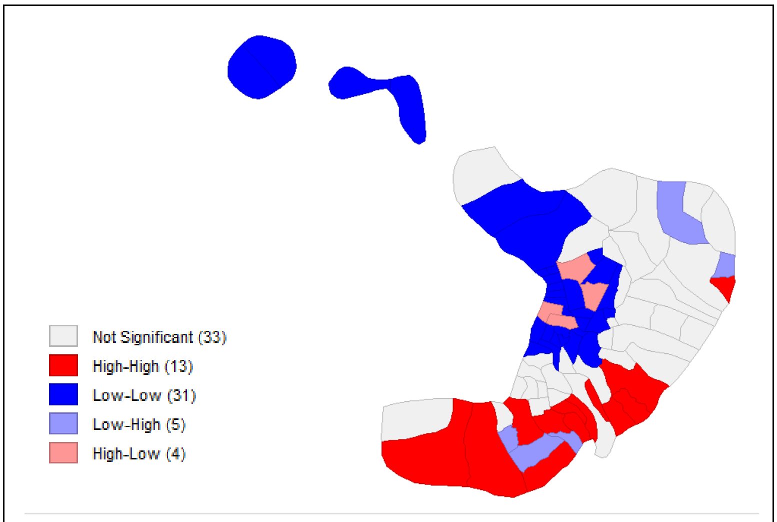

Figure 7. LISA map

Figure 7 shows the LISA map from data on the results of Covid-19 cases in Manado City. It was found that 13 (thirteen) villages were included in the High-High area, namely Malalayang Satu Barat dan Malalayang Satu Timur, Malalayang Satu, Winangun Satu, Kleak, Karombasan Utara, Ranotana Weru, Bumi Nyiur, Pakowa, Tingkulu, Taas, Paal Empat, Tikala Baru, dan Paniki Dua. 31 (thirty-one) villages which are included in the Low-Low area, namely Manado Tua Satu, Manado Tua Dua, Alung Banua, Bunaken, Meras, Molas, Tumumpa Dua, Tumumpa Satu, Mahawu, Maasing, Singkil Dua, Kombos Barat, Bitungkarangria, Sindulang Dua, Sindulang Satu, Kampung Islam, Istiqlal, Wawonasa, Ketang Baru, Ternate Tanjung, Titiwungen Utara, Wenang Selatan, Wenang Utara, Mahakeret Timur, Mahakeret Barat, Bumi Beringin, Lawang Irung, Tikala Kumaraka, Komo Luar, Tikala Ares, dan Karame. 5 (five) villages which are included in the Low-High area, Kima Atas, Paniki Satu, Karombasan Selatan, Winangun Dua, dan Batukota.4 (four) villages that are included in the High-Low area, namely Tuminting, Singkil Satu , Calaca, and Pinaesaan.

3.4.1. High-High Area

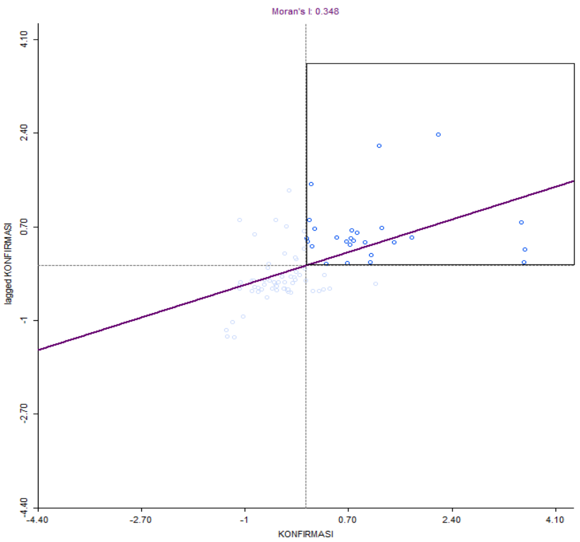

Figure 8. Moran's Scatterplot (Quadrant I)

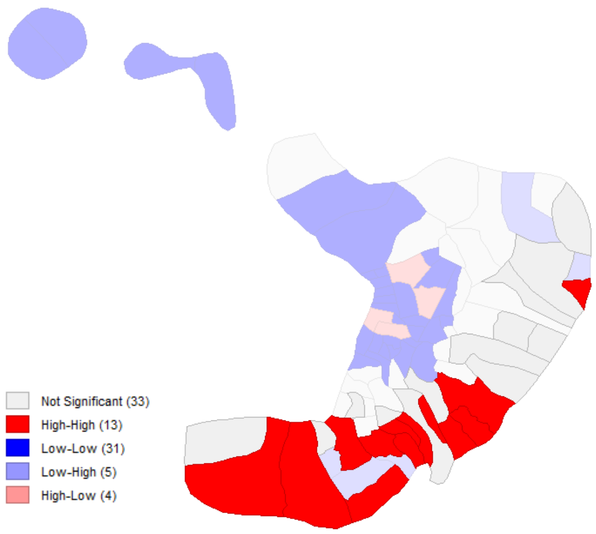

Figure 9. High-High Area

Quadrant I (High – High), shows locations that have high observation values surrounded by locations that have high observation values. The thirteen villages included in quadrant I are Malalayang Satu Barat and Malalayang Satu Timur, Malalayang Satu, Winangun Satu, Kleak, Karombasan Utara, Ranotana Weru, Bumi Nyiur, Pakowa, Tinkulu, Taas, Paal Empatt, Tikala Baru, and Paniki Dua. These thirteen villages have influenced the spread of Covid-19 in Manado City and everyone who is within 0.03 km or 30 m of these thirteen villages can be infected with Covid-19.

3.4.2. Low-Low Area

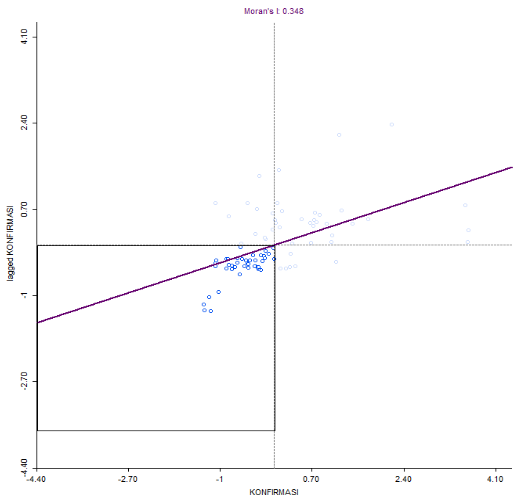

Figure 10. Moran's scatterplot (Quadrant III)

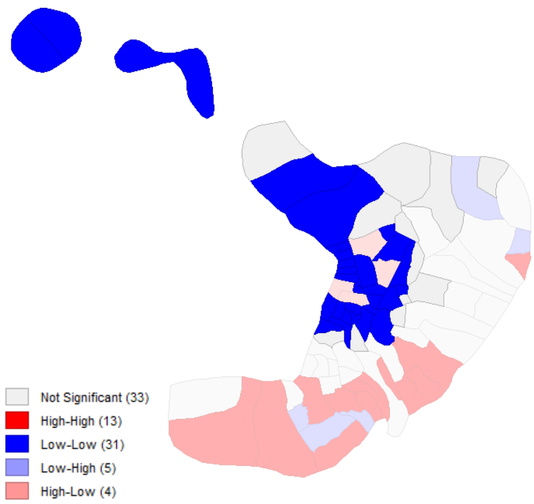

Figure 11. Low-Low Area

Quadrant III (Low – Low), shows locations that have low observation values surrounded by locations that have low observation values. The 31 (thirty-one) villages included in quadrant II are Manado Tua Satu, Manado Tua Dua, Alung Banua, Bunaken, Meras, Molas, Tumumpa Dua, Tumumpa Satu, Mahawu, Maasing, Singkil Dua, Kombos Barat, Bitungkarangria, Sindulang Dua, Sindulang Satu, Kampung Islam, Istiqlal, Wawonasa, Ketang Baru, Ternate Tanjung, Titiwungen Utara, Wenang Selatan, Wenang Utara, Mahakeret Timur, Mahakeret Barat, Bumi Beringin, Lawang Irung, Tikala Kumaraka, Komo Luar, Tikala Ares, dan Karame. These thirty-one villages do not affect the spread of Covid-19 in Manado City.

4. Conclusion

According to research that has been accomplished, the Moran's I value from the data on the results of Covid-19 cases in Manado City is 0.348, which means that there is a positive spatial autocorrelation or pattern that clumps together and has similar characteristics in adjacent locations in every village in Manado City. The threshold value of the Euclidean distance matrix from the Covid-19 case data in Manado City is 0.03 km or 30 m, and the geographical distance used for the spatial correlogram is 30 meters as the maximum geographical distance limit for being infected with Covid-19. This shows that everyone who is within 0.03 km or 30 m of every village included in the high-high area in the LISA map, which are Malalayang Satu Barat and Malalayang Satu Timur, Malalayang Satu, Winangun Satu, Kleak, Karombasan Utara, Ranotana Weru, Bumi Nyiur, Pakowa, Tingkulu, Taas, Paal Empat, Tikala Baru, and Paniki Dua could be infected with Covid-19 and that the thirteen villages affected the spread of Covid-19 in Manado City. Thirty-one villages were included in the Low-low area on the LISA map, which are Manado Tua Satu, Manado Tua Dua, Alung Banua, Bunaken, Meras, Molas, Tumumpa Dua, Tumumpa Satu, Mahawu, Maasing, Singkil 2, Kombos Barat, Bitungkarangria, Sindulang Dua, Sindulang Satu, Kampung Islam, Istiqlal, Wawonasa, Ketang Baru, Ternate Tanjung, Titiwungen Utara, Wenang Selatan, Wenang Utara, Mahakeret Timur, Mahakeret Barat, Bumi Beringin, Lawang Irung, Tikala Kumaraka, Komo Luar, Tikala Ares, dan Karame, showing that the thirty-one villages did not affect the spread of Covid-19 in Manado City.

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