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A Comparison of Weights Matrices on Computation of Dengue Spatial Autocorrelation

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Abstract. Spatial autocorrelation is one of spatial analysis to identify patterns of relationship or correlation between locations. This method is very important to get information on the dispersal patterns characteristic of a region and linkages between locations. In this study, it applied on the incidence of Dengue Hemorrhagic Fever (DHF) in 17 sub districts in Sleman, Daerah Istimewa Yogyakarta Province. The link among location indicated by a spatial weight matrix. It describe the structure of neighbouring and reflects the spatial influence. According to the spatial data, type of weighting matrix can be divided into two types: point type (distance) and the neighbourhood area (contiguity). Selection weighting function is one determinant of the results of the spatial analysis. This study use queen contiguity based on first order neighbour weights, queen contiguity based on second order neighbour weights, and inverse distance weights. Queen contiguity first order and inverse distance weights shows that there is the significance spatial autocorrelation in DHF, but not by queen contiguity second order. Queen contiguity first and second order compute 68 and 86 neighbour list

1. Introduction
Spatial analysis is a method that describes how geographically distributed phenomenon and how it compares with other phenomena. The spatial pattern can be shown with spatial autocorrelation. Spatial autocorrelation is the assessment of the correlation between observations on a variable. If the observations $X_1, X_2, ..., X_n$ shows the dependencies of space, then the data is said to be spatially auto correlated. So that spatial autocorrelation is used to analyze the spatial pattern of the spread of point locations to distinguish the location and attributes, or specific variables

In spatial analysis, it need weighting to show the neighboring among locations. This weighting is expressed in a spatial weighting matrix, namely $\mathbf{W}$. This weighting is expressed in a spatial weighting matrix, namely $\mathbf{W}$. This matrix gives an important role in any analysis of spatial data, because it shows the location, neighborhoods, and the relationship about distance among locations nearby. Selection of the type of matrix is also a major concern in spatial analysis. In the assessment of the spatial weighting, [1] states that the election of a weighted matrix to be done specifically and arranged convenience or convention. Specifications of the weighting matrix represent the information and intensity of the spatial effect of a unit space locations in the geographic system.

Reference [2] state that adjacency relationships, distance relationships and comprehensive factors relationships are summarized to characterize the definitions of spatial weight matrix. According to the spatial data, type of weighting matrix can be divided into two types: point type (distance) and the neighborhood area (contiguity). Reference [3] indicate that the selection weighting function is one determinant of the results of the spatial analysis. The distance weighting matrix involve an element of distance between the locations whose value is continuous in building the weighting matrix, so that each location will receive weighted according to that distance. Meanwhile, contiguity weighting involve an
element of area or neighborhoods. The location that neighboring directly shows the higher spatial dependency than the locations far apart.

The diversity of spatial data and methods are causing the importance of selecting the appropriate weighting matrix. In most applications, the weight matrix is more likely to be based on the distance between units, or simply contiguity ([4],[5]). Research [6] use this type of distance weighting to the analysis of ICT indicators using Geographically Weighted Regression. Research[7] use four types of contiguity weighting function to calculate Moran's I. Research[2] states that the selection of weighting matrix will effect on a parameter estimation in spatial modelling. Furthermore,[8] states that the ways of weight matrix will effect on spatial autocorrelation analysis, especially the value of Moran’s I greatly.

The study compared the type of contiguity and distance weighting in the analysis of spatial autocorrelation. The case study used is the incidence of dengue fever in Sleman, Yogyakarta, Indonesia. Selection of cases is based on the goal to identifying exposures of public health concern based on spatial epidemiology. As research [9] which use spatial autocorrelation for analysis the dengue vector populations. Reference [10] which analysis the examination of dengue fever in Guayaquil, Ecuador. The results of this research was Moran’s I value shows the high spatial autocorrelation and suggest a higher possibility of infection in places with already infected people.

Along with the development of spatial autocorrelation method for spatial analysis in various fields, on the other hand, the computer as a computing tool is also experiencing rapid development software. This research also make application development in R which easy to use and speed up the time to complete a job mainly related to the spatial analysis. This application is in plug-in form which use R language that available as free software and provides a wide variety of statistical. This plug-in provides three method of spatial autocorrelation: Moran’s I, Geary’s, and Local Indicator of Spatial Autocorrelation (LISA), with three types of weights matrices: Queen Contiguity by first order neighbor, Queen Contiguity by second order neighbor, and distance weighted.

2. Research Methodology

This research compute spatial weight matrix in three types of weighted: 1) queen contiguity based on first order neighbour weights, 2) queen contiguity based on second order neighbour weights, and 3) inverse distance weights. The next steps is use those weight to compute spatial autocorrelation by Moran’s I, Geary’s C, and LISA. This analysis will demonstrate the spatial autocorrelation in each weight. The results of the study is about: 1) the neighbour list in each weight matrices, 2) the significance of the results of autocorrelation in any type of spatial autocorrelation method, and 3) a comparison method.

The calculations are performed using the application program that has been developed, in the form of plug-in package R. The development of computer applications aimed at assisting the spatial autocorrelation in each weight. It was done in some steps: the design of a computer program with the waterfall model, designing systems and interface, implementation and unit testing, and test of the system operational. The designing interface was done in Deducer R which compatible with RJava. Deducer is a package R which provide an intuitive graphical user interface (GUI) for R [11]. It works when used with the Java based R GUI JGR. This application also was formed into package R. It was built by RStudio and Rtools programs.

![Figure 1. Location of Study](image-url)
The data used in this research is the secondary data about the number of occurrences of Dengue Hemorrhagic Fever (DHF) in 17 subdistricts in Sleman (see Figure 1). The data was obtained from Sleman District Health Office in 2010 - 2015. The names of 17 sub-district respectively: 1. Moyudan, 2. Minggir, 3. Seyegan, 4. Godean, 5. Gamping, 6. Mlati, 7. Depok, 8. Berbah, 9. Prambanan, 10. Kalasan, 11. Ngemplak, 12. Ngaglik, 13. Sleman, 14. Tempel, 15. Turi, 16. Pakem, 17. Cangkringan.

2.1. Spatial Autocorrelation

Spatial pattern analysis is an analysis that explains how geographic phenomena distributed and how it compares with other phenomena. It also explains how the relationship between geographic objects and comparing the object pattern in a location with object pattern found in other locations. Some form of spatial patterns are clustered, dispersed, and random. The forms of these patterns can also be tested by the method of spatial autocorrelation.

If there is a systematic pattern in the deployment of a variable, then there is spatial autocorrelation. The existence of spatial autocorrelation indicates that the attribute values in specific areas related to the attribute values in other areas that are neighboring. Reference [12] also explained that the spatial autocorrelation refers to a pattern in which the observations are derived from the locations adjacent sites tend to have the same value.

This study uses spatial autocorrelation test Morans’ I, Geary’s C, and LISA. Moran’s I (Index) is used to measure global spatial autocorrelation among location. The formula as in equation (1).

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

with \( n \) is the number of sample size, \( x_i \) and \( x_j \) are the value of observed variable at the location \( i \) and \( j \). \( \bar{x} \) is the average of the \( n \) observed variable. \( w_{ij} \) is the element of spatial weight matrix \( W \). Moran’s Index value is between \(-1 \) and \( 1 \). The positive value (near \( +1 \)) indicates clustering, while negative value (near \( -1 \)) indicates dispersion ([12], [13]). To evaluate the statistical significance test, it use the null hypothesis that there is no spatial autocorrelation among locations. Reject the null hypothesis if \( |Z| > Z_{a/2} \), which \( Z= (I-E(I))/\sqrt{\text{Var}(I)} \) and \( Z_{a/2} \) derived form normal standard distribution.

Geary’s coefficient (Geary’s C) is the second method which commonly used in spatial autocorrelation. The formula as in equation (2).

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

The value of Geary’s C lies between \( 0 \) and \( 2 \). It is negatively related to Moran’s I, which the values less than one indicate increasing positive spatial autocorrelation and the values greater than one indicate increasing negative spatial autocorrelation [14]. As in Moran’s I test, the null hypothesis that there is no spatial autocorrelation among locations. Reject the null hypothesis if \( |Z| > Z_{a/2} \), which \( Z= (C-E(C))/\sqrt{\text{Var}(C)} \).

Moran’s I and Geary’s C used to identify the global autocorrelation, whereas Local Indicator of Spatial Autocorrelation (LISA) is Moran local. The motivation of LISA was to decompose global autocorrelation into the contribution of individual observation ([14], [15]). It evaluate the spatial autocorrelation or clustering in those individual units by calculating local Moran’s I for each location and evaluating the statistical significance for each \( I_i \). The formula as in equation (3).

\[ I_i = z_i \sum_{j=1}^{n} w_{ij} z_j \]

where \( z_i \) is the standardize of observed variable.
2.2. Spatial Weights Matrix

A spatial weights matrix is an $n \times n$ positive symmetric matrix $W$, as in equation (4). The element of these matrix is $w_{ij}$ at location $i, j$ for $n$ locations. It play an important role in describing the structure of neighbouring or spatial structure among location. It typically reflects the spatial influence of location $j$ on location $i$ or conversely. In matrix $W$, every unit area is described as rows and columns. As example, the value of $w_{12}$ or $w_{23}$ shows the weighting between the first and second locations. The location which is close to the certain locations tend to have large $w_{ij}$, while the location which far from each other tend to have small $w_{ij}$.

$$W = \begin{bmatrix} w_{11} & w_{12} & w_{13} & \cdots & w_{1n} \\ w_{21} & w_{22} & w_{23} & \cdots & w_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ w_{n1} & w_{n2} & w_{n3} & \cdots & w_{nn} \end{bmatrix} \quad (4)$$

Matrix $W$ have some characteristic: 1) all diagonal elements of $w_{ij}$ is 0, because it is assumed that locations is not adjacent to the unit itself; 2) It is a symmetric matrix where $w_{ij} = w_{ji}$, which basically describes the interrelationships of spatial relation; 3) row matrix indicates how a location spatially associated with other regions. Therefore, the total values in a row $i$ is the total neighbors that are owned by the location $i$. There are many ways to define the weights, including contiguity weights, distance weights, and other weights (Zhou and Lin, 2008). The simplest form of weights is binary weight where $w_{ij} = 1$ for neighbouring locations $i$ and $j$, otherwise, $w_{ij} = 0$.

Contiguity weights illustrates the relative location of a unit of spatial data with other locations based on boundaries area or neighborhood list. Research [4] states the type of contiguity weights, such as linier contiguity, rook contiguity, bishop contiguity, and queen contiguity. This research use queen contiguity matrix, which create the neighborhood list based on edges corner. The element of spatial weight $w_{ij}=1$ shows that the location $i$ and $j$ are share an edge and/or a corner. Otherwise, $w_{ij}=0$ shows that the location $i$ and $j$ don’t share edge and/or a corner each other.

The spatial weights have been discussed is the type of first order neighbour weights. This study also use higher order neighbour weight, which constructs a spatial weight matrix of order $n$ based on the spatial neighbour relationship between locations. It assumed that the value of a unit is not only affected by the immediately contiguous units, but also the second until $n$ order contiguous units. The element $w_{ij}=1$ if location $j$ is adjacent to the neighbours of order $n-1$ of location $i$, and is 0 otherwise. As example for second order neighbours, as locations that are neighbours to the first order neighbour[5], the element $w_{ij}=1$ if location $j$ is adjacent to the first order neighbours of location $i$, and is 0 otherwise.

The weight matrices also can approach by Row Standardization as inequation (5).

$$w_{ij}^* = \frac{w_{ij}}{\sum_{j=1}^{n} w_{ij}} \quad (5)$$

There are many variants or modification in the build spatial weight. The choice of the method is also based on the assumptions about the nature phenomena, the characteristics of regions, socio-economic condition, the availability of public facilities, or others. Reference [16] was study about spatial weights matrix in diffusion of housing demand. In economic study, the choice of appropriate spatial weights also a central component of spatial models, which may or may not correspond to reality. In some cases, the contiguity weight would fail to capture a potentially significant relationship. As example of areas consisting of islands. According to the administrative boundaries, those islands are neighboring. However, based on polygon in map, they don’t share edge and/or a corner each other.

In endemic disease study, especially in dengue cases, the spatial relationship among locations not only can describe by neighbouring based on share edge and/or a corner, but also how the extent to which the disease is transmitted or spread. According to this reasons, this study also use distance weight. The distance is obtained from the calculation of the distance between the point latitude and
longitude [3]. So, each location will have weighted according to the distance to other locations. The distance location \( i \) and \( j \) were calculated by Euclidean distance as in equation (6).

\[
d_{ij} = \sqrt{(u_i - u_j)^2 + (v_i - v_j)^2}
\]

(6)

where \( u_i, v_i \) are the geographic coordinates longitude-latitude in location \( i \) and \( u_j, v_j \) are the geographic coordinates longitude-latitude in location \( j \).

Many kinds of distance weight are k-Nearest Neighbor, radial distance, inverse distance, exponential distance, and double distance weights. This study use inverse distance weights, which the formula as in equation (7) [17].

\[
w_{ij} = \frac{1}{d_{ij}^\alpha}
\]

(7)

where \( \alpha \) represent the distance friction coefficient, generally \( \alpha = 1 \) or \( \alpha = 2 \).

3. Results and Discussion

The results presented in this paper is about the characteristics of the spread of the incidence of Dengue Hemorrhagic Fever (DHF) in Sleman and an overview of the distribution pattern of DHF in 2014-2015. Furthermore, calculating weighted, spatial autocorrelation test, and compare the results in each weighting. All of these measures is done using the application program that has been built.

3.1. Spatial Pattern of DHF

Spatial pattern of incidence of dengue in the Sleman District used to make the priority areas need to be considered to suppress the spread of dengue incidence. According to the Data Center and Epidemiological Surveillance by Ministry of Health, incidence of dengue region can be categorized in the high (more than 55 in 100,000 population), medium (21-55 in 100,000 population) and low incidence (less than 20 in 100,000 population).

Based on Figure 2 can be seen that the incidence rate (IR) of DHF in 2014-2015 included in the category of low, medium and high. Area with a high incidence is Gamping, the area with the incidence being is Godean, Mlati, and Kalasan Sub Districts. The area with a medium incidence is the Godean, Ngaglik, Ngemplak, Berbah, and Prambanan Sub Districts, and the others is in category low incidence. These characteristics indicate that the incidence of relatively high DBF located in the southern part of Sleman. In addition, the sub-districts are also close to each other. This is shows the spatial pattern. It also occurs in 2015.

3.2. Weighting Calculation

Creation of spatial weights matrix was done by ‘Autocorrelation Test’ package which build in Deducer and RStudio. Run the syntax library(Autocorrelation Test and menu menu Autocorrelation
Test, so spatial analysis menu will appear as in Figure 3. By this application programs, users can analyze the autocorrelation test in three methods (Moran’s I, Geary’s C, and LISA) and three spatial weight (queen contiguity based on first order neighbor weights, queen contiguity based on second order neighbour weights, and inverse distance weights). The data used is in form data frame and shape file (.shp). The data frame contains the main variable in row and column to be tested. The shape file contains the geospatial data formats which used to get the neighboring and coordinate. This application programs is development from previous research [18].

![Autocorrelation Test in Deducer](Image)

**Figure 3.** Autocorrelation Test in Deducer

![Characteristics of weights list object](Image)

**Figure 4.** Characteristic of weight list

Figure 4 illustrate the queen contiguity based on first order neighbor weights. There were 17 regions (sub districts) and 68 neighbor list. This weighting matrix is formed into a weight matrix as shown in Figure 5. Queen contiguity based on second order neighbor weights and inverse distance is presented in Figure 6 and Figure 7.

![Queen contiguity based on first order neighbour weights](Image)

**Figure 5.** Queen contiguity based on first order neighbour weights

![Queen contiguity based on second order neighbour weights](Image)

**Figure 6.** Queen contiguity based on second order neighbour weights
Based on the Figure 5, can be seen that the sub-district with the highest number of neighbors is the Mlati and Ngaglik. Mlati has six neighbors which means that the incidence of dengue in this location affects and/or was affected by 6 that neighboring. Ngaglik also has six neighbors. Location that has smallest neighbors is Moyudan, Limestone, Prambanan and Cangkringan. The value in the matrix is $w_{ij}$ is calculated by Equation (4). 

Queen contiguity second order in Figure 6 produce different regions of neighborhood. There were 17 regions (sub districts) and 86 neighbor list. Through weighting queen contiguity first order, Moyudon has only two neighboring list (Minggir and Godean). While, using queen contiguity second order, Moyudon has 4 neighboring list (Seyegan, Gamping, Mlati, and Tempel). This is because Seyegan and Tempel are share edge and/or a corner with Minggir, also Gamping, Mlati are share edge and/or a corner with Godean.

Inverse distance weighting matrix in Figure 7 is calculated based on the Euclidean distance which defined as the shortest straight line between two points. It describes the value of the inverse of the distance from each of the sub districts. If two locations have great distance, they will produce small value of weighting. If two locations are close, they will produce high value of weighting. The value in the matrix is $w_{ij}$ is calculated by Equation (6).

3.3. Spatial Autocorrelation

Table 1 shows the results of spatial autocorrelation test. It provides information that using weighted queen contiguity first order and inverse distance indicated that a significant spatial autocorrelation, both on the method of Moran's I and Geary's C. This is shown by the value $|Z| > 1.96$ or $P_{\text{value}} < 0.05$. The existence of spatial autocorrelation shows that there were dependence in incidence of dengue among sub among locations. While, the test using a weighted queen contiguity second order shows that there is no spatial autocorrelation.

Pattern of spatial autocorrelation (use Moran’s I) in the queen contiguity first order is the incidence DHF which spatially clustered. As example DHF in 2014, there are 6 sub districts located in the High-High group (Gamping, Depok, Berbah, Prambanan, Kalasan, and Ngemplak). The locations in this group has a high DHF which surrounded by locations that have high DHF. The second group is Low-Low group which contains 8 sub districts (Moyudon, Minggir, Seyegan, Sleman, Tempel, Turi, Pakem, and Cangkringan). The definition of this group is the location that has a lower DHF surrounded by location that have lower DHF. There are three sub districts in High-Low group (Godean, Mlati, and Ngaglik). The definition of this group is that the location that have high DHF surrounded by location that have lower DHF. Figure 8 shows a comparison of LISA test with 3 types of weighting. It can be seen that by weighting queen contiguity first order and inverse distance, there are several locations that have significant spatial autocorrelation at $\alpha = 5\%$ and $\alpha = 10\%$. 

Figure 7. Inverse Distance weights
Table 1. Spatial Autocorrelation Test

| Year | I | Expectation, and Z | Queen Contiguity first order | Queen Contiguity second order | Inverse Distance |
|------|---|--------------------|-----------------------------|-----------------------------|-----------------|
|      |   |                    | Moran’s I                   |                             |                 |
| 2014 | I | 0.4882             | -0.1348                     | 0.4217                      |                 |
|      | E(I)| -0.0625           | -0.0625                     | -0.0625                     |                 |
|      | [Z]| 3.29*              | 0.59                        |                             |                 |
| 2015 | I | 0.4262             | -0.195                      | 0.3879                      |                 |
|      | E(I)| -0.0625           | -0.0625                     | -0.0625                     |                 |
|      | [Z]| 2.92*              | 0.59                        |                             | P value = 0.01*|
|      | Geary’s C |                    |                             |                             |                 |
| 2014 | C | 0.4518             | 1.0615                      | 0.5995                      |                 |
|      | E(C)| 1                 | 1                           | 1                           |                 |
|      | [Z]| 3.47*              | 0.42                        |                             | P value = 0.03*|
| 2015 | C | 0.4728             | 1.1285                      | 0.61                        |                 |
|      | E(C)| 1                 | 1                           | 1                           |                 |
|      | [Z]| 3.34*              | 0.89                        |                             | P value = 0.05*|

Note: *) Significance at α=5%

Figure 8. The Results of LISA test

4. Concussion

A spatial weights matrix, W, have element $w_{ij}$ at location $i, j$ for $n$ locations. It describe the structure of neighbouring or spatial structure among location and reflects the spatial influence of location $j$ on location $i$ or conversely. There are many types of weighting based on the shape of the area and its spatial structure. Different types of weighting will create the different spatial autocorrelation. In this research, queen contiguity based on first order neighbour weights compute 68 neighbour list and shows the significance spatial autocorrelation on DHF of Sleman District. Queen contiguity based on second order neighbour weights give the different results. It compute 86 neighbour list and shows the non-significance spatial autocorrelation. Inverse distance weights show that all locations adjacent each other based on Euclidean distance. It shows that there is a significance spatial autocorrelation.
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References
[1] Anselin L and Griffith D A 1988. Do spatial effects really matter in regression analysis?. Pap. Reg. Sci. 65(1) 11–34.
[2] Wang Z, Liang H Y, and Zhou Q 2013. Model for Effect of Spatial Weighted Matrix on Spatial Autocorrelation. International Journal of Applied Mathematics and Statistics. 44(14).431–445.
[3] Fotheringham A S, Brunsdon C, and Charlton M 2003 Geographically Weighted Regression: The Analysis of Spatially Varying Relationships (New York: John Wiley & Sons).
[4] Anselin L 2001 Spatial Econometrics (Dallas : University of Texas)
[5] LeSage J P and Pace R 2009 An introduction to spatial econometrics, 1st ed (Boca Raton: Taylor and Francis)
[6] Bekti R D, Andiyono, and Irwansyah E 2014. Mapping of Illiteracy and ICT Indicators using Geographically Weighted Regression. J. Math. Stat. 10 (2).130–138
[7] Chen Y 2012. On the Four Types of Weight Functions for Spatial Contiguity Matrix. Lett. Spat. Resour. Sci. 5 (2). 65–72.
[8] Chen J and Jiang J 2010. Analysis for spatial autocorrelation for point objects based on line buffer. Proceeding Accuracy 2010 Symp. Leic. UK. 20.
[9] Azil A H, Bruce D, and Williams C R 2014 Determining the spatial autocorrelation of dengue vector populations: influences of mosquito sampling method, covariables, and vector control. J. Vector Ecol. 39(1). 153–163
[10] Castillo K C, Körbl B, Stewart A, Gonzalez J F, and Ponce F 2011 Application of spatial analysis to the examination of dengue fever in Guayaquil. Procedia Environ. Sci. 7, 188–193
[11] Fellows I 2012 Deducer: a data analysis GUI for R. Journal of statistical Software. J. Stat. Softw. 49(8).1–15
[12] Lee J and Wong D W 2001 Statistical analysis with ArcView GIS (New York : John Wiley & Sons).
[13] Cliff A D and Ord J K 1988 Spatial autocorrelation, vol. 5. (London: Pion)
[14] Fischer M. M.andGetisA 2009 Handbook of applied spatial analysis: software tools, methods and applications. (New York: Springer Science & Business Media)
[15] Anselin L 1995. Local indicators of spatial association—LISA. Geogr. Anal. 27(2). 93–115.
[16] Bhattacharjee A and Jensen-Butler C 2006. Estimation of spatial weights matrix, with an application to diffusion in housing demand. Cent. Res. Ind. Enterp. Finance Firm Discuss. 519
[17] Zhou X and Lin H 2008 Spatial weights matrix. Encyclopedia of GIS. (US: Springer)
[18] Tanty H, Bekti R D, and Irwansyah E 2014. Package Plug-In R untukPemetaanAutokorelasiSpasialpadaKualitas Air,” presented at the Seminar NasionalAplikasiSains&Teknologi (SNAST) 2014, IST AKPRIND Yogyakarta, C269–C274.