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Spatial Distribution Analysis of Dengue Incidence in Makassar, Indonesia

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ABSTRACT

Makassar is one of the major cities in South Sulawesi where the incidence of Dengue Hemorrhagic Fever (DHF) is still quite high. Since dengue cases vary from one place to another, the spatial and time component must also be taken into consideration. In this study, a spatial analysis was applied in order to map the spatial distribution of dengue cases in Makassar. Moran's I statistics were used to assess the global autocorrelation of dengue incidence using queen contiguity with row-standardized weight matrix method. The results indicated that the distribution of dengue cases in Makassar for all five years was spatially random. The Local Indicator of Spatial Association (LISA) was designed to detect spatial autocorrelation at a local scale. The results showed that Biringkanaya tended to be the central location of the transmission of dengue fever. Manggala, Makassar, and Tamalanrea were areas potentially prone to be infected by dengue fever.

Keywords: Dengue fever, Spatial Analysis, Global Moran's I, LISA.

Mathematics Subject Classification: 62J12, 62G99

1. INTRODUCTION

Epidemic dengue is a major public health problem in several countries including Indonesia (WHO, 2009). Makassar is part of Indonesia where the number of people with Dengue Hemorrhagic Fever (DHF) in the city increased sharply from 2012 to 2013. The high number of dengue cases throughout 2013 was due to an erratic weather change, in particular the turning of the dry season to the rainy season (Umar, 2014). Given the high number of dengue cases in the city of Makassar, the research needs to be done related to the disease. The spread of dengue fever varies from one place to another, so that the space component must also be considered. Since dengue cases vary from one place to another, the spatial and time components must also be taken into consideration (Rosli, Asmahani, Naim, and Harsuzilawati, 2010). Spatial-temporal interaction among health events is an important component for epidemiological and public health surveillance (Nakhapakorn and Jirakajohnkool, 2006). In health research, spatial analysis is used to detect and quantify the patterns of disease distribution that may offer an insight into a disease's epidemiology (Rosli, Asmahani, Mohammad Naim, and Harsuzilawati, 2010).

In this study the spatial autocorrelation was applied to map the spatial distribution of dengue cases in Makassar. The spatial autocorrelation can be used to identify the spatial relationships between regions calculated globally and locally. Moran's I and Geary's c can be regarded as global measures of spatial autocorrelation because one statistic or value is derived for the entire study area, describing the overall spatial relationship of all the area units. However, there is no reason to believe that any spatial process is homogeneous within the distribution itself. The magnitude of spatial autocorrelation can vary by locations, and thus a distribution or a spatial pattern can be spatially heterogeneous. To describe the spatial heterogeneity of spatial autocorrelation, we have to rely on measures that can detect spatial autocorrelation at a local scale. The Local Indicator of Spatial Association (LISA) is designed for this purpose (Lee, 2001). The pattern of spatial spread of dengue fever has been studied in several areas, such as Surabaya (Arrowiyah and Sutikno, 2010), Bogor (Praja, 2013), Sukoharjo (Puspitasari and Susanto, 2011), Semarang (Faiz, Rahmawati, Safitri, 2013), and Makassar (Maria, Ishak, and Selomo, 2013). However, the studies of the spatial distribution patterns of dengue fever in Makassar by using global and local Moran are not yet thoroughly explored. Hence, in this study we aimed to examine the spatial pattern of DHF disease in Makassar both globally and locally.

2. MATERIAL AND METHODS

2.1. Study Area

Makassar is located between 119º25' East Longitude and 5º8' South Latitude bounded by Maros Regency at the North and the East, Gowa Regency at the South, and Makassar Strait at the West. The area of Makassar is 175.77 square km which includes 14 districts (Central Bureau of Statistics, 2010). The map of Makassar South Sulawesi can be seen in Figure 1.

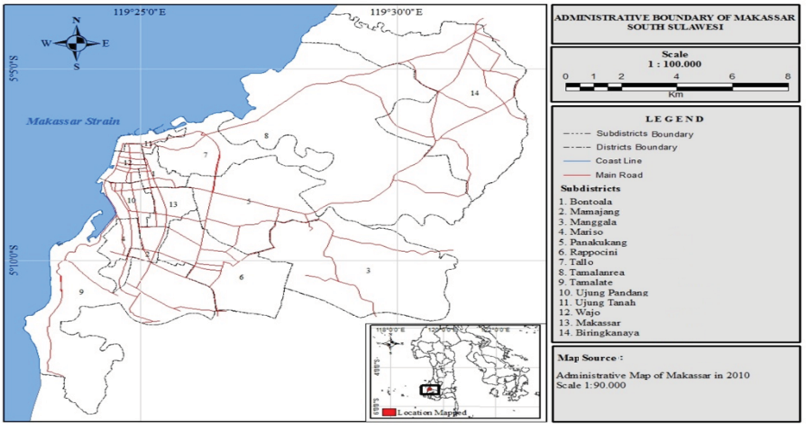

Figure 1. Map of Makassar

2.2. Data Collection

Dengue case incidence data were obtained from the Health Office of Makassar. The DHF incidences were recorded over a five-year period from 2009 to 2013 at the 14 sub-districts.

2.3. Global Indexes of Spatial Autocorrelation

A global index of spatial autocorrelation provides a summary over the entire study area of the level of spatial similarity observed among neighbouring observations. The goal is to summarize the degree to which similar observations tend to occur near each other. Since global indexes are by definition summaries over the study area, most applications of global indexes of spatial correlation in the assessment of disease pattern result in tests of clustering rather than test to detect individual clusters

(Waller and Gotway, 2004). There are two common global indexes of spatial autocorrelation, that is, Moran's I and Geary's c. Moran's I can be defined simply as

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(X_i-\bar{X})(X_j-\bar{X})}{\sum_{i=1}^{n}(X_i-\bar{X})^2},$$

where *n* is the number of cases, X_i and X_j denote the observed values at location *i* and *j*, $\bar{X}$ is the average of the *x* values over the n locations, and W_{ij} is the spatial weight measure (Ackerman, Bartley, Bravener, D'Aguair, Janssen, Sheehy, 2010). Moran's I can be interpreted as follows: a value close to 0 indicates randomness, while a positive (negative) value indicates positive (negative) autocorrelation (Hu, Mengersen, Tong, 2010). Significance test of Moran's I can be assessed under normal approximation or randomization by making use of a row-standardized weight matrix.

Test statistic: $Z(I) = \frac{I-E(I)}{\sqrt{var(I)}}$ where $E(I) = -\frac{1}{n-1}$, $var(I) = \frac{n^2 S_1 - nS_2 + 3S_0^2}{(n^2-1)S_0^2} - [E(I)]^2$ with

$$S_0 = \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij},\ S_1 = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}(W_{ij}+W_{ji})^2,\ S_2 = \sum_{i=1}^{n}(W_{i\cdot}+W_{\cdot i})^2,\ W_{i\cdot} = \sum_{j=1}^{n} W_{ij};\ W_{\cdot i} = \sum_{j=1}^{n} W_{ji}$$

2.4. Spatial Proximity Matrices

There are at least two common methods to define a spatial relationship: the rook's case and the queen's case. We adopt the queen's case, in which all the surrounding area units can be identified as neighbors of *X* as long as they touch each other even at a point. With different ways of defining neighbors, different matrices can be constructed to capture the spatial relationship among geographic features (Lee, 2001). The (*i,j*)th element of a spatial proximity matrix W, denoted w_{ij}, quantifies the spatial dependence between regions *i* and *j*, and collectively, the w_{ij} defines a neighborhood structure over the entire area. We may want to adjust for the total number of neighbors in each region and employ a *row standardized matrix* or the *stochastic matrix* where we divide each w_{ij} by the sum of neighbor weights for region *i* giving a matrix W_{std}, where $w_{std,ij} = \frac{w_{ij}}{\sum_{j=1}^{N} w_{ij}}$. If region *i* has four neighbors, each receives weight ¼ (Waller and Gotway,2004).

2.5. Local Indicators of Spatial Association (LISA)

While global spatial autocorrelation analysis aims at summarizing the strength of spatial dependencies by a single statistic, LISA focuses on heterogeneity of spatial association over space. The local analysis is based on the Local Moran Statistics, visualized in the form of significance and cluster maps (Anselin L, Syabri I, Kho). The LISA statistics and LISA cluster maps were calculated using GeoDa. Types of local spatial association can be seen in Table 1.

Table 1. Types of local spatial association

			Spatially lagged geo-referenced variable (Lx)
		High	Low
Geo-referenced variable (X)	High	Quadrant I: HH	Quadrant IV: HL
	Low	Quadrant II: LH	Quadrant III: LL

The four quadrants in Table 1 correspond to the four types of spatial association. The lower left (LL) and upper right (HH) quadrants indicate spatial clustering of similar values: low values (that is, less than the mean) in the lower left and high values in the upper right. The upper left (LH) and lower right (HL) quadrants indicate spatial association of dissimilar values: low values surrounded by high neighboring values for the former and high values surrounded by low values for the latter (Anselin, 2009). Note that the magnitude of Moran's I as such does not indicate significance, nor are the statistics directly comparable across weights and variables (Anselin, 2003).

3. RESULTS

3.1. Descriptive Analysis

The dengue case data were recorded at the sub district level over a five-year period (2009-2013) which reported 256, 185, 85, 35, 276 DHF cases in 2009, 2010, 2011, 2012 and 2013 respectively in Makassar. Figure 2 shows the number of dengue cases for each sub-district in Makassar. It can be clearly seen from the figure that the highest dengue cases over the past five years occurred in 2009 (256 cases), namely the sub-district Rappocini (68 cases) followed by the Panakkukang sub-district (38 cases). From 2010 to 2012 the number of dengue cases in Makassar experienced a drastic decline to only 35 cases. However, in 2013, the figure rose sharply to 276 dengue cases. According to the head of Makassar Health Office, the high number of dengue cases throughout 2013 was due to an erratic weather change (Umar, 2014).

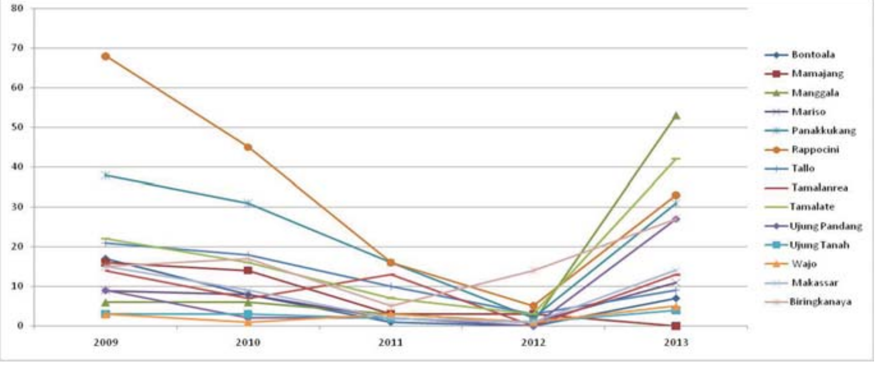

Figure 2. Number of Dengue Cases from 2009 to 2013

3.2. Spatial Autocorrelation

Makassar has 14 sub-districts, so the size of contiguity matrix is 14 × 14. The contiguity matrix describes the number of neighbors in each district in Makassar. Panakkukang has the greatest number of neighbors (6), while Biringkanaya has the least number of neighbors (1). Moran's index and Z-score results using excel, GeoDa, and ArcGIS show relatively similar value with a difference of only 0.01. The values of Global Moran,s I and Z-Score that are computed for a row-standardized spatial weight matrix based on first-order contiguity using ArcGIS can be seen in Table 2 and Figure 3.

Table 2. Moran's I and Z-score using ArcGIS.

	2009	2010	2011	2012	2013
Moran's I	0.04	0.08	0.11	-0.15	0.12
Z-score	0.91	1.05	1.1	-0.69	1.2

Based on Table 2, Z-score values are less than $Z_{1-\alpha/2} = Z_{0.975} = 1.96$ with α=0.05 for all years. This indicates that the null hypothesis stating no spatial autocorrelation (spatial randomness) is accepted.

Overall, it indicates that there is no relationship between the locations of the observations in terms of disease outbreaks of dengue fever in Makassar.

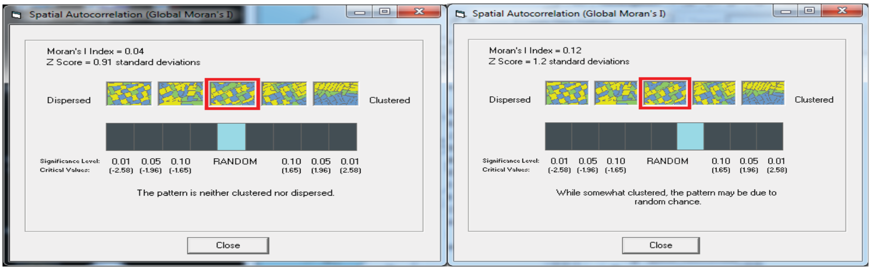

Figure 3: Results of Global Moran's I for dengue cases in 2009 and 2013 using ArcGis

The results from the Figure 3 indicated that the distribution of dengue cases in Makassar in 2009 and 2013 were spatially random with Moran's I 0.04 and 0.12 respectively.

3.3. LISA Cluster Map and Moran Scatter plot

The result of LISA cluster map and Moran scatter plot of dengue incidence for several years only can be seen in Figure 4. It has been found that there were 3 sub-districts (Manggala, Panakkukang, and Makassar) of which LISA indices were significant at α=0.05 in 2009. This means that there is a spatial relationship between the sub-districts and the surrounding sub-districts. Panakkukang was in the High-High quadrant, while Manggala and Makassar were in Low-High quadrant in 2009. Similarly, in 2010, there were 3 sub-districts (Manggala, Rappocini, and Wajo) of which LISA indices were significant at α=0.05. Rappocini is in High-High quadrant, Manggala is in Low-High quadrant, while Wajo was in Low-Low quadrant. Further, in 2011 there were 3 sub-districts (Manggala, Ujung Pandang and Wajo) with significant LISA indices at α=0.05. Manggala was in Low-High quadrant, while Wajo and Ujung Pandang were in Low-Low quadrant. In 2012, there were only two districts (Tamalanrea and Biringkanaya) of which LISA indices were significant at α=0.05. Tamalanrea was in Low-High quadrant while Biringkanaya was in High-Low quadrant. In 2013, no sub-districts had significant LISA index at α=0.05.

Biringkanaya was in High-Low quadrant in 2012, meaning that the number of DHF patients in this area was big, but surrounding sub-districts had small number of DHF patients. It implies that Biringkanaya is potential to make its neighboring sub-districts prone to outbreaks of dengue disease. Manggala and Tamalanrea which were in Low-High quadrant means that the number of patients in this area was small but the surrounding sub-districts had big number of DHF patients. It can be claimed that Manggala and Tamalanrea were potentially vulnerable to the spread of dengue disease from their surrounding areas.

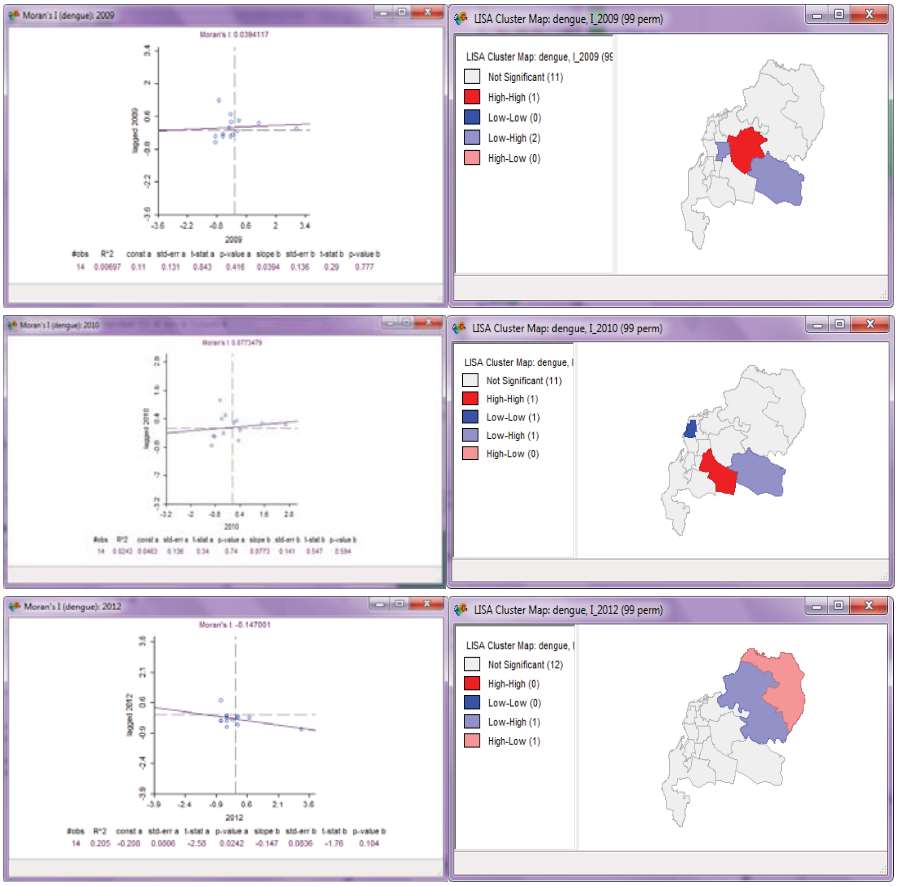

Figure 4: Moran's I and LISA map using GeoDa in 2009, 2010, and 2012

4. CONCLUSION

In general, it can be concluded that Panakkukang and Rappocini need to be prioritized in terms of decreasing the number of dengue fever incidences. Biringkanaya tends to be a central location of the DHF spread, so it should be prioritized in terms of controlling the spread of dengue disease. Manggala and Tamalanrea are potentially vulnerable to the spread of dengue disease from their surrounding areas with a great number of DHF cases.

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