Geographical Mapping of Dengue Fever Incidence 2012-2016 in Makassar, Indonesia

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Abstract. To present the geographical map of Dengue fever (DF) in Makassar city, Indonesia, we used the registered DF data to compute the relative risk (RR) of DF in different areas of Makassar city, Indonesia, for a five-year period (from 2012 to 2016). This paper aim to identify the the spatial distribution of DF occurrence to provide the map of risk area in Makassar City through the geographical map. To estimate RR for DF in Makassar City, Indonesia, the Besag York Mollie (BYM) model was proposed. The Bayesian estimates of DF relative risk were utilized for geographical mapping of DF. The results of the present study reveals that DF is still a serious health problem in Makassar city, Indonesia. The distribution of high and low risk areas of DF occurrences for all sub-districts in Makassar City can be identified in the risk geographical map to allow the better allocation and risk assessment.

1. Introduction

One of the infectious diseases that can cause death is dengue fever (DF). This disease is generally transmitted by the Aedes Aegypti mosquito infected with the Dengue virus. The level (stage) of DF disease is 2, namely early stage and advanced stage [1]. What distinguishes these two stages is the absence of plasma leakage from cells in blood vessels [2]. In advanced stage DF disease plasma leakage occurs, which is commonly referred to as Dengue Hemorrhagic Fever (DHF) disease while patients with early stage DF disease have not experienced this.

According to [3], aedes mosquitoes can only breed in tropical regions with temperatures above 16℃ and at altitudes less than 1,000 meters above sea level. Topographically, the city of Makassar has temperatures ranging between 26.2℃ and 29.8℃ and located at between 1- 25 meters above sea level (city mks 1). Therefore, the city of Makassar is an area frequented by aedes mosquitoes to breed, then many cases of DF disease in the city occur. Tthe rainfall rate in Makassar city ranges from an average of 2729 mm with the number of rainy days ranging from an average of 144 days [4].

Relative risk analysis of the spread of DF disease in the city of Makassar needs to be done to see which is sub-districts in the Makassar city are at high risk of developing DF disease. This is very closely related to national development problems, especially in the Makassar city, South Sulawesi, because one of the basic capital in the implementation of development is a good health community.

Determination of the relative risk value for the spread of DF disease has been carried out by using the Standardized Morbidity Ratio (SMR) model [5]. In that model, the number of cases of DF is seen as data on counts, not as a random variable. Meanwhile, [6] used the Poisson Gamma and the Besag, York, and Mollie (BYM) models to estimate the relative risk of the three stages of DF. In this study, the relative risk value of the spread of DF disease will be calculated using a method based on the BYM model. Under this model, disease mapping assumes that the number of people with DF disease is a Poisson

random variable [7]. With this BYM model, the risk level of DF disease every year for each sub-district in Makassar city can be determined. Therefore, this paper aims to identify the risk area of DF in Makassar city through the geographical map. In the first section, the paper presents BYM model. Then, the application and the result of the study is presented in the next section. The conclusion is presented at the last.

2. Material and Methods

2.1 Dengue Disease and Its Situation in Makassar

In this paper, the observed count DF data for 14 sub-districts in Makassar, Indonesia, from 2011 to 2016 was used. This data was provided by the Board of Health of Makassar. The map of Makassar city is displayed in Figure 1. Sub-district of Rappocini had the highest total of DF cases, 158 cases, followed by Manggala with 116 cases. Ujung tanah, Wajo and Ujung Pandang are the only three sub-districts had less than 20 cases. These can be seen in Figure 2.

2.2. Besag-York-Mollie (BYM) Model

The relative risks with Bayesian approach was introduced by [8]. Then, [9] was developed to a fully Bayesian and it is commonly known as the BYM model. This model can be used to map the disease and it used hierarchical Bayesian spatial model [10].

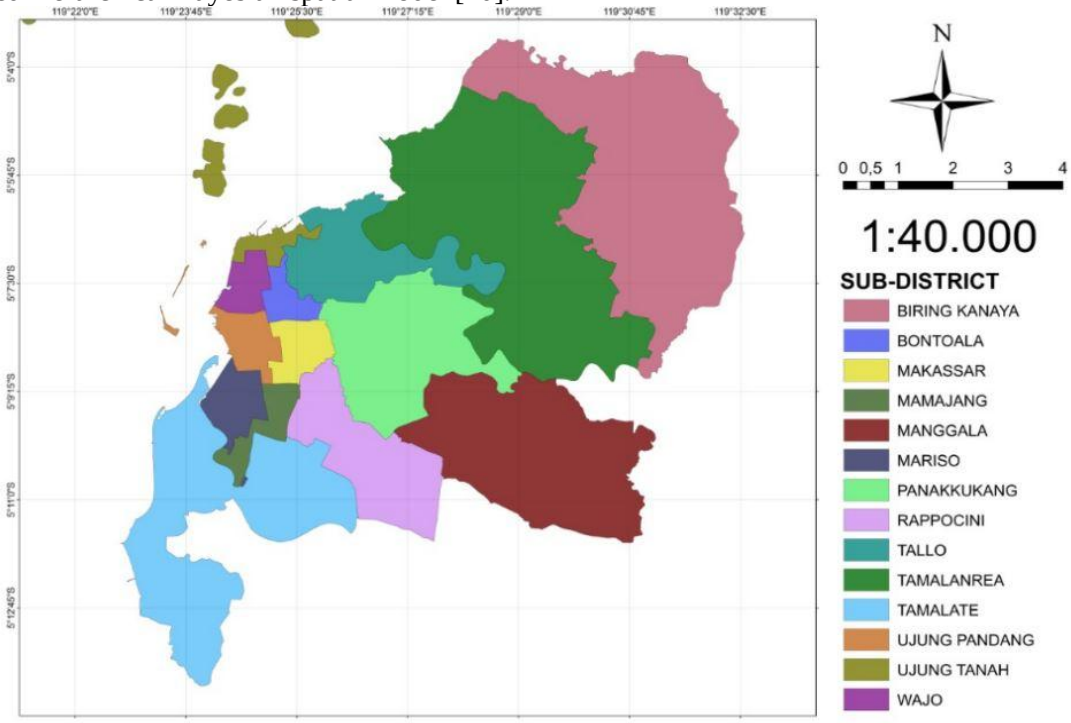

Figure 1. The map of Makassar city with all sub-districrs in South Sulawesi, Indonesia

BYM model was used to estimate the relative risk (RR). To do it, random effects and spatially structured heterogeneity is incorporated into the log-linear model. Random effects are the correlated heterogeneity that is unstructured. This effects need to be inserted in order to find the smoothing of RR at the level global and local.

If the observed number of DF cases in area *I*, called y_i and assumed to follow a Poisson distribution, then it can be written as follows:

$$y_i \sim \text{Poisson}\ (e_i\ \theta_i\ ),$$

where $e_i\ \theta_i$ is the mean of Poisson distribution. The expected number of cases in the i^{th} geographic unit

is denoted by e_i. Meanwhile, the unknown relative risk in area *i* that is θ_i. This θ_i is need to be estimated. There are three componens of the variability of the log relative risk log θ_i. It can be written as log θ_i =α+u_i +v_i, where an overall level of the relative risk, called α. The correlated heterogeneity or spatial random effect is denoted by u_i and the uncorrelated heterogeneity was represented by random effect v_i.

Before applying the Bayesian modelling, the prior distribution for each components needs to be specified. The prior of uncorrelated heterogeneity, v_i does not depend on geographic location and it follows a normal distribution, with zero mean and a common variance τ_v^2 (precision parameter) as follows:

$$v_i \sim N(0, \tau_v^2)$$

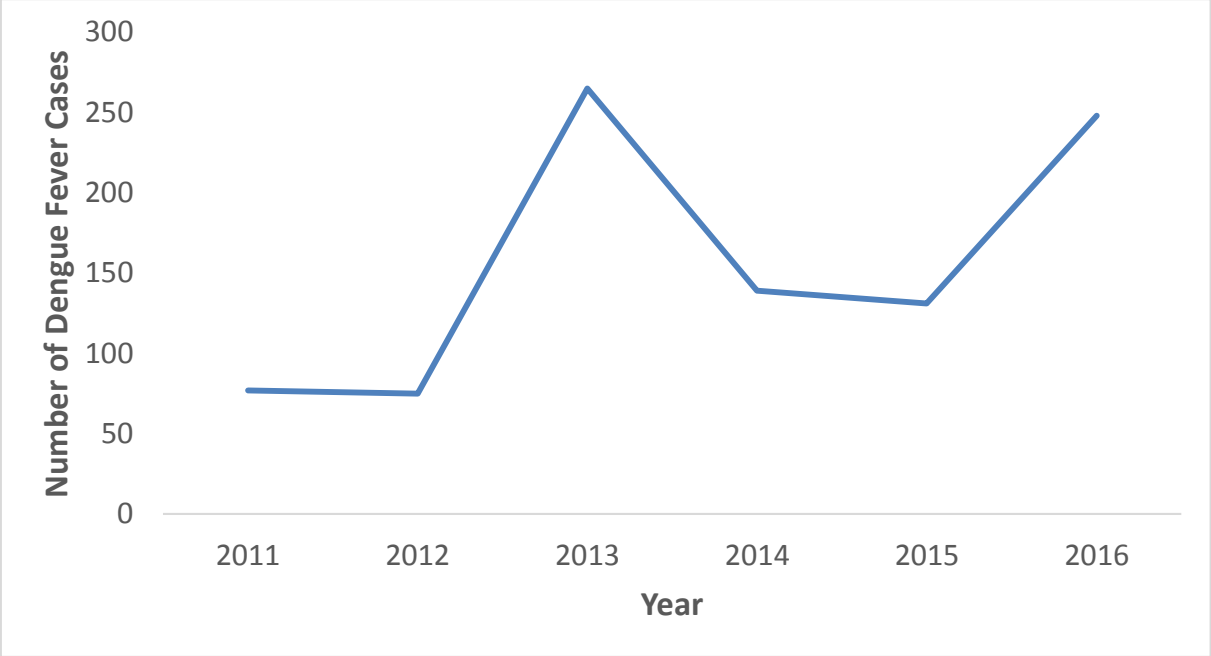

Figure 2. Total Number of DF Cases from 2011 to 2016 in All Sub-districrs in Makassar, Indonesia

The spatially structured heterogeneity is used for the clustering component. It means that when the risk in any area is estimated, the neighbouring areas is need to be considered. Lastly, the average value of its neighbouring areas influenced by a value of a parameter in one area is need to be fitted. This average value is called as the conditional autoregressive (CAR). In this spatial structure model, there is an additional variability, that is a conditional variance that depends on the number of neighbours. This is can be written as:

$$[u_i | u_j, i \neq j, \tau_u^2] \sim N(\bar{u}_i, \tau_i^2),$$

where $\bar{u}_i$ is the areas bordering area *i*, that is $\bar{u}_i = \frac{1}{\sum_j \omega_{ij}} \sum_j u_j \omega_{ij}$ and $\tau_i^2 = \frac{\tau_u^2}{\sum_j \omega_{ij}}$, where the relationship between the area *i* and *j* can be presented as ω_{ij}. As $\omega_{ij} = 1$ and *i*, *j* are adjacent, then the first order binary weighthing occurs. Meanwhile, $\omega_{ij} = 0$ then *i*, *j* are not adjacent. When the other u_j has a weighted average and $i \neq j$ is the prior mean of each u_i, then, the amount of variability of random effects v and u is controlled by the precision parameter τ_v^2 and τ_u^2.

The prior distributions for each precision parameters τ_v^2 and τ_u^2 need to be specified as well. If there are not prior estimation for precisions of the random effects, a large variance is considered. The prior distribution for τ_v^2 and τ_u^2 is the less informative and are followed by gamma distributions, respectively

[11]. In this case, the prior information is dominated by the likelihood data. As a result, the inference of relative risks is influenced by the prior minimumly.

To estimate the relative risk of the DF disease in Makassar city, the model of BYM was then be used. In this model, the Markov Chain Monte Carlo (MCMC) methods is implemented. The model for each data set including the weights was fitted using R version 3.3.3. In this paper, the relative risk of DF disease was categorised based on the number of cases, the five different levels of risks used to categorize the relative risk values were very low, low, medium, high and very high with the intervals of (<0.5, [0.5-1.0), [1.0-1.5), [1.5-2.0) and >2.0), respectively. The darkest shade in the map showing the area is in very high risk and the lightest shade region is considered as very low risk area [12].

3. Results

In this section, the result of relative risk estimation based on the application of Besag-York- Mollie (BYM) model which was applied on the observed number cases of DF disease transmission in Makassar, Indonesia is displays in the form of graphs, table and maps. Figure 3 depicts the time series plot of DF disease based on the number of cases for each sub-district in Makassar, Indonesia from 2011 to 2016. From the plot, Manggala had the highest number of cases. Among these years, most of the cases were above 1for all sub-district. However, the number of cases in Ujung tanah is zero for 2014 and increased again in 2015 with 2 cases. While for Wajo, Bontoala, and Ujung tanah, most had less than 10 cases throughout the years.

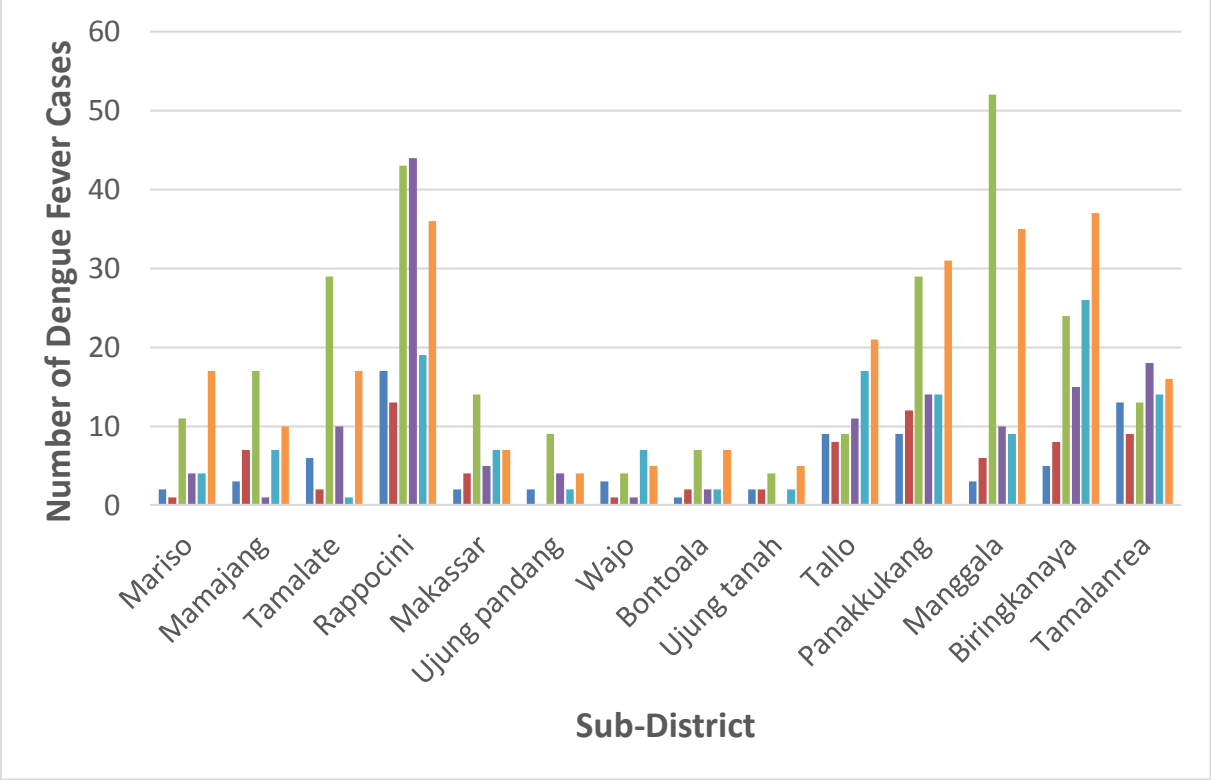

Figure 3. Time Series Plot based on Number of Cases for Each Sub-district in Makassar, Indonesia from 2011 to 2016.

Tabel 1. Relative risk of DF disease for each sub-district in Makassar city, 2011 to 2016.

Sub-district	Relative risk					
	2011	2012	2013	2014	2015	2016
Ujung Tanah	0.9895666	0.9964079	0.7715359	0.4733532	0.8303137	0.9374488
Ujung Pandang	1.0207386	0.9909359	1.1693975	1.1588194	0.9901662	0.9700467
Bontoala	0.9719477	0.9975187	0.8135825	0.6156551	0.8286892	0.9510518
Mariso	0.9762723	0.9780361	1.0278355	0.7864179	0.8603418	1.1001221
Makassar	0.964145	1.0038125	0.9741512	0.7147738	0.9581804	0.9041086
Mamajang	0.9949323	1.0272643	1.2995752	0.5103333	1.050105	0.9817329
Wajo	1.0366089	0.9961071	0.8711148	0.6730201	1.4514642	0.9780208
Manggala	0.9587311	1.0114916	1.9197258	0.8148877	0.8821492	1.1533659
Tamalate	0.9534338	0.9523744	0.9125008	0.6248958	0.4962983	0.8517659
Panakukkang	1.0216283	1.0363048	1.0403053	0.9672972	1.0350458	1.0642859
Tamalanrea	1.1286118	1.0358617	0.7506715	1.5090788	1.2269703	0.9784727
Tallo	1.0303018	1.01267	0.5493764	0.84027	1.2046229	0.97006
Rappocini	1.1286118	1.0342938	1.3905733	2.5542036	1.1310579	1.0796329
Biring Kanaya	0.9363576	1.0012052	1.6761441	0.8280359	1.13393381	1.0396603

Table 1 presented the estimated relative risk based on BYM model for DF disease in all sub-districts of Makassar city in year 2011 to 2016. According to Table 1, Rappocini had the highest relative risk (above 2) in 2014. Manggala almost had relative risks above 2 in 2013 and Biring kanaya had high relative risk in 2014. These indicated that people live in these states are more likely to be infected by Dengue fever disease compared to people in overall population. However, in 2014 and 2015, Ujung tanah and Tamalate had the very low relative risk of dengue fever. These mean that people in these states are less likely to contract with dengue fever disease compared to people in overall population.

Based on the results of relative risk estimation based on the application of Besag-York- Mollie (BYM) model in Table 1, the risk map is constructed. The DF risk maps cluster and identify the regions with different levels of risks displays in Figure 4. This figure depicts that Manggala sub-district were in very high risk for infective DF cases in 2013 and 2016. The figure also showed Tamalanrea as a high risk area in 2011, followed by Rappocini as a medium risk and Panakukang, Tallo, Ujung Tanah and Wajo as a low risk area. Other states were considered as very low risk areas in 2011. The sub-districts Panakukang, Rappocine and Wajo reached a very high risk for infective DF cases in 2012, 2014 and 2015, respectively. From the map, interestingly, Tamalate sub-district have a low risk for infective DF cases during 2011-2016. Because of the total number of population in every sub-district are different in the calculation of expected cases, then Figures 4 give different levels of risks result as well.

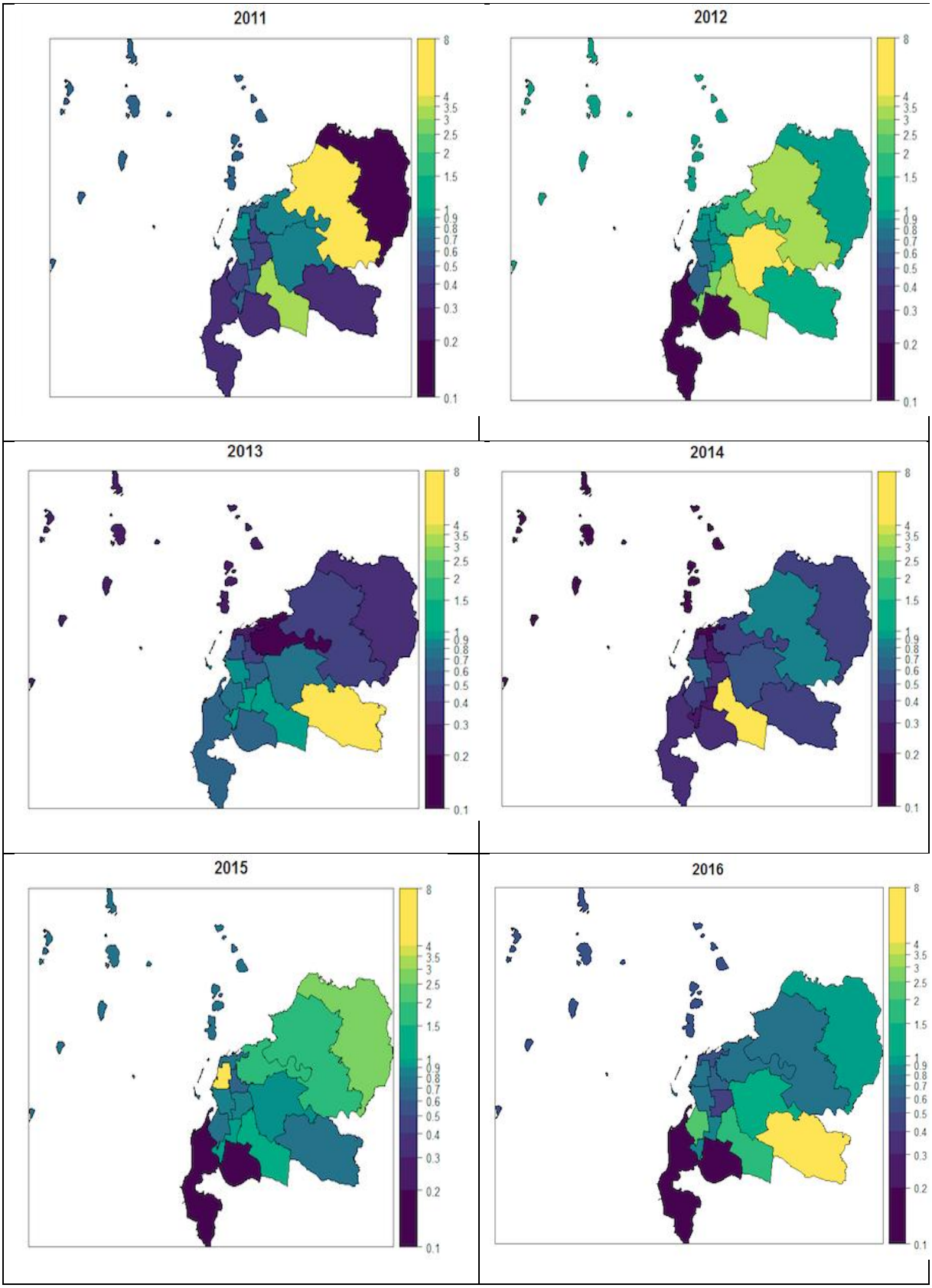

Figure 4. Risk Map for DF based on BYM Model for Year 2011 to 2016 in Makassar city, Indonesia.

4. Conclusion and Future Works

In this paper, BYM was used to estimate the relative risk of DF disease. In the risk geographical map, the distribution of high and low risk areas of DF occurrences for all sub-districts in Makassar City can be identified in order to allow the better allocation and risk assessment. The sub-districts which is vulnerable to the transmission of DF in Makassar, suggesting these sub-districts need to be pay more attention by both the city government and local communities. The BYM model can be easily applied in public health. Nevertheless, further improvement must be done to improve the current model and or compared to the others methods to increase the accuracy of the risk map. It could be made for more detailed comparisons by including more confounding factors.

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