Prediction of DHF disease spreading patterns using inverse distances weighted (IDW), ordinary and universal kriging

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Abstract. Dengue hemorrhagic disease, is a disease caused by the Dengue virus of the Flavivirus genus Flaviviridae family. Indonesia is the country with the highest case of dengue in Southeast Asia. In addition to mosquitoes as vectors and humans as hosts, other environmental and social factors are also the cause of widespread dengue fever. To prevent the occurrence of the epidemic of the disease, fast and accurate action is required. Rapid and accurate action can be taken, if there is appropriate information support on the occurrence of the epidemic. Therefore, a complete and accurate information on the spread pattern of endemic areas is necessary, so that precautions can be done as early as possible. The information on dispersal patterns can be obtained by various methods, which are based on empirical and theoretical considerations. One of the methods used is based on the estimated number of infected patients in a region based on spatial and time. The first step of this research is conducted by predicting the number of DHF patients in 2016 until 2018 based on 2010 to 2015 data using GSTAR (1, 1). In the second phase, the distribution pattern prediction of dengue disease area is conducted. Furthermore, based on the characteristics of DHF epidemic trends, i.e. down, stable or rising, the analysis of distribution patterns of dengue fever distribution areas with IDW and Kriging (ordinary and universal Kriging) were conducted in this study. The difference between IDW and Kriging, is the initial process that underlies the prediction process. Based on the experimental results, it is known that the dispersion pattern of epidemic areas of dengue disease with IDW and Ordinary Kriging is similar in the period of time.

1. Introduction
Dengue disease or Dengue Hemorrhagic Fever (DHF), is a disease caused by the Dengue virus of the Flavivirus genus Flaviviridae family. DHF is transmitted to humans through the bite of Aedes mosquitoes that have been infected with dengue virus. DHF is commonly found in tropical and subtropical regions. WHO data indicated that ASIA ranks first in terms of the number of DHF patients each year. While Indonesia is the country with the highest case of dengue in Southeast Asia [11].

In Indonesia, for the last 41 years, from 1968 to 2009, there has been an increasing number of dengue endemic provinces and cities, from 2 provinces increasing to 32 provinces with an increase rate about 97%, and from 2 cities increasing to 382 cities with an increase rate about 77%. In addition, there was also an increase in the number of dengue cases, in 1968 only 58 cases to 158,912 cases in 2009 [11].

Some cases of dengue fever cause high mortality. The high number of deaths is caused by several factors including delayed medical treatment and low public awareness of prevention. Many people are not aware of the existence of this disease, one of them caused by the lack of information about the
spread of disease they get. The availability of information about the spread of dengue disease area, will make it easier for public health office to know areas that have great potential for dengue fever. So, that preventive actions can be done earlier to the society and the death rate due to dengue fever in a region can decreased.

Several studies related to DHF have been conducted by some researchers but still not focused on the spread of DHF in a region [5], [6], [8], [15]. Although studies in dengue fever which consider spatial factors have been carried out by a number of researchers but the approach used has not used a spatial analysis approach [13], [16], whereas Puspitasari and Irwan [12] indicate that there is spatial influence in the spread of this DHF. Based on this result, the focus of this research is to determine the pattern of dissemination Disease dengue in a region appropriately using spatial analysis approach.

The reason we use three methods of spatial analysis, namely IDW, Ordinary Kriging (OK) and Universal Kriging (UK) to describe the pattern of dengue fever spread, is based on the characteristic pattern of increasing the number of dengue cases, that is decreasing, increasing the number of cases or tend to remain from year to year. The pattern is in accordance with the characteristics of the method used, namely the possibility of distribution pattern is stationary or there is a trend up or down. The formulation of the problem presented in this paper are

- How is the pattern of the spread of dengue fever area in the city of Bandung in 2016 until 2018, considering West Java is the sixth order based on the number of cases
- How the implementation of science data in solving this problem, given the availability of information about the pattern of the spread of dengue fever areas for the coming years
- There are many methods used to create a regional dispersion pattern map, in this paper will examine the implementation of three interpolation methods in spatial analysis used for mapmaking ie IDW, OK, and UK, since data on the number of cases per region is spatial data and number patterns the case varies

It is expected that the results of this study can obtained a clear picture of the pattern of the spread of DHF in each village in the city of Bandung until 2018. So, that the parties concerned can immediately take a policy to address the spread of a very significant in some villages in the city of Bandung.

2. Related works

Dengue disease in Indonesia is a contagious disease that is still a national problem in the field of health. This is because the patient number of this disease tends to increase and more widely spread. Research to obtain the relation between dengue disease with climate factor, which includes temperature, wind speed, humidity, and rainfall in Padang city done by Mangguang [8]. From the result of the research, it can be concluded that there is no significant correlation between climate factor and DHF incidence.

Puspitasari and Irwan [12], conducted a study that aims to analyze the pattern of dengue fever dispersion spatially. Spatial linkages in dengue fever dispersion are measured through spatial autocorrelation using the Moran index. The pattern of dengue fever dispersion are examined using ANN (Average Nearest Neighbor), while mapping of areas with high risk dengue fever dispersion is done by using the Kernel density estimation. The study showed that there is spatial autocorrelation in the dengue dispersion and the study also show pattern type of dengue fever occurrence is clustered pattern. Furthermore, the Kernel density estimation can show mapping of areas with high risk dengue fever dispersion.

In other research, Latifah N et. al [10] presents infectious disease data in the form of maps to know the dispersion pattern and its relation to environmental conditions, and also determine the level of vulnerability. The distribution pattern of infectious diseases have in common characteristic, which has a diffuse pattern with random grouping level. Most of the parameters relating to environmental conditions didn’t have a significant linkage to the spread of DHF. The risk of transmission in some areas of Semarang city based on qualitative analysis show that 25% areas are classified as very high risk level and 25% other areas are classified as high risk level.
Similar research is also conducted by Dom C. N., et al. [5] using temporal-spatial to determine the severity and magnitude of outbreak transmission. Spatial models are used to determine high risk of dengue fever spread, which is done by measuring three characteristics of temporal risk, namely frequency, duration and intensity. Meanwhile Rosa et al. [13] examined the temporal and spatial distribution of dengue fever by considering factors such as dengue coefficient, viral location index, population density and income level. The results showed that the main risk area of transmission of this disease is the city center, where the population has the highest income. Spatial analysis used for DHF notification is plotting census data such as age, sex, population, income, and number of cases with gradient maps. The results obtained are graphs and gradient maps, which are used as DBD disease notification, so they can be integrated with vector control programs that transmit disease.

Dom C. N., et al. [6] analyzed the pattern of dengue dispersion monthly that included spatial deployment and hotspot identification. Estimates were performed using Nearest Neighboring Averages (ANN) and Kernel Density (KD), to assess spatial spread of dengue cases and detect dengue hotspots. The results suggest that spatial patterns for dengue cases over a 5-year period is a clustered spatial (with a value R, 1) based on monthly frequency data.

Arrowiyah [2], examined the description and map of the spread of DHF incidence in the period 2006-2009, and compared the two analyzes produced by the moran’s index method I with Geary’s C. From this study it was found that the results released by the moran’s index were more sensitive than Geary’s. In addition, in this research can produce classification of disease incidence rate in Surabaya City. As for not yet done in this study is the use of distance weights in identifying patterns of spread of dengue disease in the city of Surabaya.

While the research that specifically discuss about the comparison of methods between IDW and kriging, has been done by Setianto A, et al., [14]. In the research said that the technique used for better selection of methods, not only on performance type and data concentration, but also on implementation for various spatial issues. Based on the methodology used, the IDW pattern on its surface display is smoother and sharper than the kriging. Similarly from surface analysis factors, the IDW method is more accurate than kriging, since the presence of minor surfaces and less than maximal displays is useful as a surface-surface interpretation force. While the pattern of kriging shows the breadth of the observed area so that interpolation is less accurate.

Based on the research that has been done by researcher above, hence we do research by making map of pattern of spreading area of DHF disease in Bandung City, taking into account the weight of distance, and then compare between IDW method with kriging method by using statistical test.

3. Methodology

The data used in this study is the number of DHF disease patients in 152 villages in the city of Bandung from 2010 to 2015 obtained from the health department of Bandung. Prediction of disease spread pattern is done through 2 stages, first is to predict the number of patients per year using GSTAR and continued by predicting of dengue fever pattern dispersion area using IDW and Kriging Interpolation.

3.1. Prediction number of DHF patients per year

The prediction of the DHF patients number is done to determine the number of DHF patients for each urban village in the region of Bandung from 2016 - 2018. The method used is GSTAR, by taking into account the spatial and time. GSTAR is one of the models used in the prediction of time series data and location. In the GSTAR models, parameter changes at each location forming a diagonal matrix with parameter \( \phi_{10}^{(1)} \) and \( \phi_{11}^{(1)} \). Borovkova et al, [3], the GSTAR model (1: 1) for the number of DHF patients at each location \( i = 1, \ldots, N \) and time \( (t) \) can be seen in equation (1),

\[
\hat{Z}_i(t) = \phi_{10}^{(1)}Z_i(t - 1) + \phi_{11}^{(1)}\sum_j W_{ij}Z_j(t - 1) + \epsilon_i(t)
\]  

(1)
3.2. Prediction of DHF disease spread pattern

After the prediction model in 2016 until 2018 was obtained, the next step is formation a spatial model based on prediction data. The purpose of this spatial modeling is to obtain an area dispersion model of dengue fever. Spatial models used in this research are IDW and Kriging interpolation. Based on the characteristic pattern of the number of sufferers, then the appropriate Kriging interpolation method used is Ordinary Kriging and Universal Kriging. In IDW method it is assumed that each point has local influence decreases with distance. The points have closer distance to the location estimation, would be given greater weight. Case number estimation at position \( S_0 \) using IDW method by Watson et al, [7] can be seen in equation (2)

\[
\hat{Z}(S_0) = \frac{\sum_{i=1}^{n} Z(S_i) \cdot d_{i0}^p}{\sum_{i=1}^{n} d_{i0}^p}
\]

Where \( \hat{Z}(S_0) \) the estimated value at the point \( S_0 \), \( S_0 \) is location estimation, \( n \) is the number of nearest neighbors, \( Z(S_i) \) is case number of the sample location, with \( i = 1, 2, ..., n \), \( d \) is the distance from the sample location \( S_i \) to location predictions \( S_0 \) and \( p \) is the exponent that determines the value of the weight for each prediction.

While the case number estimate at point \( S_0 \) for Ordinary Kriging and Universal Kriging is obtained from Amstrong, [1] and expressed by equation (3)

\[
\hat{Z}(S_0) = \sum_{i=1}^{n} \lambda_i Z(S_i)
\]

Where \( \lambda_i \) is weight value of i-th data, \( Z(S_i) \) is value of the number of dengue fever patients in each village, and \( n \) is number of samples in the estimation process.

In Universal Kriging [17], function \( f \) of the coordinate \( s \), which is considered as deterministic, because they were known to each domain location. Random function \( Z(s) \) is composed of a deterministic component \( m(s) \) and \( Y(s) \) is stationary random function of second order. Formula of \( Z(s) \) can be seen in equation (4)

\[
Z(s) = m(s) + Y(s)
\]

It is assumed that \( Y(s) \) is a second order stationary with mean is equal zero and covariance function \( C(h) \), so

\[
E[Z(s)] = m(s)
\]

[17] assumed that drift \( m(s) \) can be represented as a linear combination of deterministic function \( f_1 \) with coefficients \( \alpha_l \) (not zero)

\[
m(s) = \sum_{l=0}^{L} \alpha_l f_1(s)
\]

Where function \( f_0(s) \) is defined as constant and have value is 1, then equation of Kriging is presented by [17] as linear combination \( Z = \sum_{\alpha=1}^{n} w_{\alpha} Z(s_{\alpha}) \), So \( \sum_{l=0}^{L} \alpha_l (f_1(s_0) - \sum_{\alpha=1}^{n} w_{\alpha} f_1(s_{\alpha})) = 0 \) and if \( \alpha_1 \) not zero, then value of \( w_{\alpha} \) is

\[
\sum_{\alpha=1}^{n} w_{\alpha} f_1(s_{\alpha}) = f_1(s_0) \quad \text{for} \quad l = 0, ..., L.
\]

Equation (7) is referred to as universal condition. While for constant function \( f_0(s) \), \( t \) the condition is expressed as \( \sum_{\alpha=1}^{n} w_{\alpha}=1 \). By using Lagrange parameter \( \mu_l \) and minimizing, [16] will obtain Universal Kriging (UK) system equation:

\[
\begin{cases}
\sum_{\beta=1}^{n} w_{\beta} C(s_\alpha - s_\beta) - \sum_{l=0}^{L} \mu_l f_1(s_\alpha) = C(s_\alpha - s_0) & \text{for} \ a = 1, ..., n \\
\sum_{\beta=1}^{n} w_{\beta} f_1(s_\beta) = f_1(s_0) & \text{for} \ l = 0, ..., L
\end{cases}
\]

Equation (8) can be expressed in matrix in equation (9)

\[
\begin{pmatrix}
C \\
F
\end{pmatrix}
= 

\begin{pmatrix}
\mu_l \\
-\mu_l
\end{pmatrix}
\begin{pmatrix}
f_1 \\
f_0
\end{pmatrix}
\]

\[
\begin{pmatrix}
\mu_l \\
-\mu_l
\end{pmatrix}
\begin{pmatrix}
f_1 \\
f_0
\end{pmatrix}
\]

\[
\begin{pmatrix}
C \\
F
\end{pmatrix}
= 

\begin{pmatrix}
f_1 \\
f_0
\end{pmatrix}
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\begin{pmatrix}
\mu_l \\
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\end{pmatrix}
\begin{pmatrix}
f_1 \\
f_0
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\[
\begin{pmatrix}
C \\
F
\end{pmatrix}
= 

\begin{pmatrix}
f_1 \\
f_0
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\begin{pmatrix}
\mu_l \\
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\begin{pmatrix}
f_1 \\
f_0
\end{pmatrix}
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\begin{pmatrix}
C \\
F
\end{pmatrix}
= 

\begin{pmatrix}
f_1 \\
f_0
\end{pmatrix}
\]

\[
\begin{pmatrix}
\mu_l \\
-\mu_l
\end{pmatrix}
\begin{pmatrix}
f_1 \\
f_0
\end{pmatrix}
\]
Where $F = \{f_0, \ldots, f_L\}$ and $F$ is a collection of linear function stating coordinate location. $Y(s)$ is stationary random function of 2-th order, $(x, y)$ is a location coordinate, $w$ is weight factor for point $i$, $\mu$ is lagrange multiplier used to minimize the possibility of estimation error, and $\alpha$ is the trend local coefficient [17].

3.3. Determining the appropriate model

The predicted results accuracy of dengue fever dispersion with either IDW or Kriging will depend on the appropriate of the selected model. Determining the right model is based on the results of the validation and verification using a statistical measure of RMSE (Root Mean Square Error). In the selection of optimum weight on IDW and best variogram for Kriging, residual analysis was performed between observation data and estimation data using the RMSE criteria. RMSE is the root of MSE (Mean Square Error). While The MSE formula can be seen in equation 10, [9]

$$\text{MSE} = \frac{1}{n} \sum_{i=1}^{n} (\hat{Z}(S_0) - Z(S_i))^2$$

(10)

Where $\hat{Z}(S_0)$ = estimation value and $Z(S_i)$ = actual / observation value of $i$-th data. The smaller the value of RMSE, then the selection of models and predicted results will be better. It shows how close the observation data to the predicted value.

4. Design of system

The interpolation process to predict the dispersion pattern of dengue disease areas, with IDW and kriging methods (Ordinary and Universal Kriging) is described in Figures 1 and 2. And the interpolation process steps are described as follows

4.1. Input of sample data

User input sample data, ie spatial data contains data on the number of cases of DBD and the parameters required during the calculation process.

4.2. Preprocessing sample data

If there is missing sample data from the regular pattern, then the missing sample value does not need to be interpolated by taking its mean value or replacing it with a zero value

4.3. Interpolation process

4.3.1. IDW

Local/ global interpolation

Deterministic interpolation techniques can be divided into two groups: global interpolation and local interpolation. The global technique calculates the predictions using all the data sets whereas the local technique calculates the prediction of the size points that exist within the neighborhoods area, ie smaller spatial areas within larger study areas.

After determining the interpolation technique, then calculate the predicted value using Inverse Distance Weighted (IDW) method of formula 2.

4.3.2. Kriging methoda (Ordinary and Universal Kriging)

4.3.2.1. Experimental semivariogram calculations.

An experimental semivariogram was used to determine the possibility of anisotropy. The semivariogram is calculated in various directions. When each direction gives the same periodic value is isotropic, meaning semivariogram depends only on distance, $h$. If the semivariogram depends on the distance, $h$, and direction $\theta$, then it is called anisotopic. To investigate anisotropic is usually selected at least four directions.

4.3.2.2. Fitting of theoretical semivariogram model.

After the experimental semivariogram model is plotted, the fitting results of the experimental semivariogram plot with the theoretical semivariogram.
Then select the theoretical semivariogram model, input range, sill, and nugget values based on the experimental semivariogram obtained.

4.3.2.3. Validation of theoretical semivariogram model. After the theoretical semivariogram model is obtained, then the validation process of theoretical semivariogram model. Model validation is the testing process of the selected model with respect to the smallest RMSE value.

4.3.2.4. Estimated number of dengue cases by kriging method. After the theoretical semivariogram model is valid, then the model is used to estimate the number of dengue cases with ordinary kriging and universal kriging.

4.3.2.5. Kriging interpolation. After the estimation process, kriging interpolation is done by mapping on the contour map.

4.4. Implementation

At this stage of implementation, in addition to data on the number of cases of dengue fever, it takes some other inputs ie spatial data or location information in the form of coordinates of both geographic coordinates (latitude and longitude), XYZ coordinates, including datum and projection information, conversion to Universal Transverse Mercator format (UTM) into meters. In its implementation to the software, it takes a shapefile file of urban village of Bandung, which consists of vector data of an attribute. Vector data is the shape of the earth that is represented into a set of lines, dots, and areas.
5. Result and discussion

5.1. Prediction of Distribution Pattern Using IDW

Inverse distance weighted (IDW) is a deterministic spatial interpolation method, using exact calculations. In this case, the deterministic interpolation technique used is the local interpolation. Prediction calculations are taken from the points size is within the neighborhoods, in a smaller spatial area, and in the larger study area. After the interpolation is done, then the predicted value is calculated by Inverse Distance Weighted (IDW). Table 1 contains the RMSE values for the three predicted values ranging (p=1, p=1.5, and p=2) with a minimum of neighborhoods is 10. The sample data is taken from 2010 to 2015.

Table 1. RMSE value of IDW from 2010 to 2015

| Year | P = 1 | P = 1.5 | P = 2 |
|------|-------|---------|-------|
| 2010 | 17.17 | 22.38   | 17.89 |
| 2011 | 19.54 | 19.81   | 20.41 |
| 2012 | 22.81 | 23.33   | 24.19 |
| 2013 | 28.54 | 29.00   | 29.94 |
| 2014 | 14.39 | 14.41   | 14.65 |
| 2015 | 16.71 | 16.75   | 15.98 |

Table 2. Estimation value of RMSE from 2016 to 2018

| Year | P = 1 | P = 1.5 | P = 2 |
|------|-------|---------|-------|
| 2016 | 18.56 | 18.86   | 18.99 |
| 2017 | 9.53  | 9.68    | 9.97  |
| 2018 | 20.91 | 21.25   | 21.87 |

Based on Table 1 and Table 2, it can be concluded that the smallest RMSE values obtained when the value of p = 1. Hence for p values used in IDW interpolation is 1. The results of the regional dispersion patterns resulting from the IDW interpolation based on sample data from 2010 to 2015 can be seen in Figure 2.
Figure 2. The region dispersion patterns of DHF diseases at (a) 2010, (b) 2011, (c) 2012, (d) 2013, (e) 2014, and (f) 2015 using IDW

By considering the pattern of DHF spread in the Figure 2, it can be informed that the number of DHF patients in the northern region of Bandung from 2010 until 2013 tended to constant around 70 to 105 and decreased from 2014 and 2015 around 40 to 50. At the western region of Bandung, the pattern of distribution tends to decrease from 2010 to 2014 around the number 30. Then in 2015, the number of patients of dengue disease tends to fall again but not significant to below 23. While the number of patients in the southern, central part and east region of Bandung, starting in 2011 tends to rise then constant at around 105 in 2013. The number of patients is decreased in 2014 and 2015 at a rate of about 40 to 60 per year. In contrast to other region of Bandung, in middle region of Bandung since 2010 until 2011, the number of patients around 25, in 2012 to 2015 tends to constant not exceeding 30.

While the pattern of spread of dengue disease territories of the data predicted results, using GSTAR for 2016 and 2018 can be seen in Figure 3.

Figure 3. The region dispersion patterns of DHF diseases at (a) 2016, (b) 2017, and (c) 2018 using IDW
Based on the area spread pattern of dengue disease from GSTAR prediction data from 2016 to 2017, it shows that for the north and south region of Bandung tends to fall, but in 2018 rose to 94. Similarly, the pattern in the western, central and eastern region of Bandung, distribution patterns tend to fall in 2017, but rose in 2018.

5.2. Prediction of distribution pattern using kriging

Unlike the IDW method, before the Kriging interpolation method is implemented, a semivariogram measurement is computed first, to determine the most suitable theoretical semivariogram model. The theoretical semivariogram model is then used as an input model on Kriging interpolation. In this study, it is only used three options semivariogram theoretical models, namely Spherical, Exponential and Gaussian. Determination of the best theoretical semivariogram model is based on the smallest RMSE value. Table 3 presented RMSE values of each model semivariogram theoretical for data preprocessing and data predicted results GSTAR from 2010 to 2015 and from 2016 to 2018, where the shading cells in the table show the model used in the Kriging process.

| Year | Ordinary Kriging | Universal Kriging |
|------|------------------|-------------------|
|      | Eksp | Gaus | Sph | Eksp | Gaus | Sph |
| 201  | 18.0 | 17.57 | 17.3 | 17.65 | 17.7 | 17.4 |
| 0    | 3    | 4    | 3   | 7    |      |      |
| 201  | 20.2 | 20.01 | 19.7 | 20.31 | 21.2 | 20.4 |
| 1    | 4    | 5    | 1   | 5    |      |      |
| 201  | 23.9 | 23.25 | 23.4 | 23.76 | 24.5 | 24.2 |
| 2    | 6    |      | 3   | 1    |      |      |
| 201  | 29.0 | 28.29 | 28.4 | 28.57 | 28.7 | 28.4 |
| 3    |      | 9    | 4   |      |      |      |
| 201  | 14.3 | 14.44 | 14.3 | 15.25 | 15.1 | 15.2 |
| 4    | 8    | 5    | 1   | 1    |      |      |
| 201  | 15.8 | 16.15 | 15.7 | 15.82 | 16.4 | 15.8 |
| 5    | 1    | 4    | 2   | 4    |      |      |
| 201  | 19.2 | 18.97 | 18.9 | 19.08 | 19.1 | 19.1 |
| 6    | 5    | 6    | 9   | 1    |      |      |
| 201  | 9.85 | 9.70 | 9.67 | 9.81 | 9.89 | 9.90 |
| 7    |      |      |      |      |      |      |
| 201  | 21.7 | 21.26 | 21.3 | 22.39 | 22.1 | 23.0 |
| 8    | 1    | 4    | 6   | 6    |      |      |

The spread pattern of dengue disease area generated using Ordinary Kriging interpolation is presented in Figure 4.
Figure 4. The region dispersion patterns of DHF diseases at (a) 2010, (b) 2011, (c) 2012, (d) 2013, (e) 2014, and (f) 2015 using Ordinary Kriging.

Figure 4 shows that the number of DHF patients in the northern region of Bandung in 2010 about 32 to 70 people, then decreased in 2011, 2014 and 2015 under 50. Although in 2012 and 2013 had risen to reach 70 people. In the southern region of Bandung there is an increase from 2011 to 2015 with the number of patients reached 114 people. This condition extends to the eastern region of Bandung in 2012, but then becomes stable in subsequent years under 23. While in the western and central region of Bandung tend to have a constant pattern that is under 23 patients per year.

While the pattern of spread of dengue disease area predicted results using Ordinary Kriging interpolation GSTAR from 2016 to 2018 are presented in Figure 5.

Figure 5. The region dispersion patterns of DHF diseases at (a) 2016, (b) 2017 and (c) 2018 using Ordinary Kriging.
Based on Figure 5, it appears that the number of patients in the northern region of Bandung in 2017 decreased significantly to below 26, compared to number of patients in 2016 which reached 50. But in 2018, it is predicted this number will increase drastically reaches 94. In the south region of Bandung from 2016 to 2018, the pattern tends to be constant with the number of DHF patients per year ranged from 50 to 73. The condition is also not much different than the eastern region of Bandung in 2017 and 2018. Like the results obtained with IDW, on western and central region of Bandung from 2016 to 2018 are predicted to tend to be below 26.

While the spread pattern of dengue disease territory acquired from Universal Kriging interpolation can be seen in the Figure 6.

![Figure 6](image.jpg)

**Figure 6.** The region dispersion patterns of DHF diseases at (a) 2010, (b) 2011, (c) 2012, (d) 2013, (e) 2014, and (f) 2015 using Universal Kriging

Figure 6 shows that DHF patients in the northern part of Bandung in 2010 around 70, then tends to rise to 103 in 2011 to 2013. Then from 2013 to 2015 has decreased below 30. In the southern part of Bandung, the number of patients from 2011 to 2015 tends to increase to 80 per year, where previously in 2010 under 23 patients with DHF. While the number of patient in western and central part of Bandung tend to be constant under 30, from 2010 until 2015. Similarly, the pattern on the eastern city of Bandung, there is an increase in the number of patients about 30% in 2012.

The spread pattern prediction of dengue disease by using GSTAR, and Universal Kriging interpolation from 2016 to 2018 can be seen in Figure 7.
Figure 7. The region dispersion patterns of DHF diseases at (a) 2016, (b) 2017 and (c) 2018 using Universal Kriging

Based on the spread pattern of dengue disease area as seen in Figure 7, it is estimated until the end of 2016, the number of patients in most areas of Bandung city is low, that is below 35, even patient number in the western and central part of Bandung, the number is lower around 18. This condition tends to decline steadily in 2017 in all areas of Bandung. But in 2018, it is estimated that the average increase again reaches 94, even some villages in the northern part of Bandung reaches 173 patients per year.

5.3. Test of compare of IDW and kriging methods

To find out which method gives the best predicted results from the three methods used by comparison of RMSE values. Tables 4 and 5 contain the RMSE values of each method for preprocessing data from 2010 to 2015 and predicted results with GSTAR for 2016 through 2018.

| Year | RMSE | IDW | Ordinary Kriging | Universal Kriging |
|------|------|-----|------------------|-------------------|
| 2010 | 17.17| 17.34| 17.47            |                   |
| 2011 | 19.54| 19.75| 20.31            |                   |
| 2012 | 22.81| 23.25| 23.76            |                   |
| 2013 | 28.54| 28.29| 28.43            |                   |
| 2014 | 14.39| 14.35| 15.11            |                   |
| 2015 | 15.98| 15.74| 15.82            |                   |

| Year | RMSE | IDW | Ordinary Kriging | Universal Kriging |
|------|------|-----|------------------|-------------------|
| 2016 | 18.56| 18.96| 19.08            |                   |
| 2017 | 9.53 | 9.67 | 9.81             |                   |
To compare the three methods used above, based on the RMSE values obtained from each method from 2010 to 2018, we will use the t-Student test. While the data used as input on the t-Student test is the value of the RMSE. The test results obtained are presented in Table 6.

| Table 6. t-Student Testing |
|-----------------------------|
| **test** | **Value of t calculated** | **T value on t-student table** | **Conclusion** |
| IDW vs OK | 0.34 | 2.14 | IDW & OK is not different significantly |
| IDW vs UK | 2.09 | 2.14 | IDW & UK is not different significantly |
| OK vs UK | 3.92 | 2.14 | OK & UK is different significantly |

In table 6, ie on the line IDW vs OK and IDW vs UK, it appears that the value of t calculated is smaller than the t value on t-student table. So it can be concluded that the IDW method does not differ significantly with kriging method (OK and UK). While on the line OK vs UK, it appears that the value of t calculated is greater than t value on t-student table, which means that Ordinary Kriging method is significantly different with universal kriging method. Based on the test results, it can be concluded that in this study, the IDW method is not influenced by the characteristic data, while the method of Ordinary Kriging and Universal Kriging is very sensitive to the characteristics of data that is stationary or there is a trend.

Based on the test with t-student statistics on the three methods, presented in table 6, the results showed that the pattern of the spread of dengue disease area, produced by IDW method did not differ significantly with kriging method. But precisely the method of ordinary kriging with universal kriging method gives significantly different results on the pattern of the spread of dengue disease area in the city of Bandung. And based on the results of the above research, the prediction results obtained from the IDW and kriging methods are not much different. The pattern of the spread of dengue fever in Bandung until 2018, still has the same pattern that is the increase in the number of cases is quite large occurred in the city of Bandung in the north and south.

For the researcher, the future research plan that will be conducted, based on the above results, will examine the factors that influence the spread of dengue fever in the region mentioned above by using Genetic Algorithm. While the proposals submitted to the government of Bandung, associated with the results of this study, the government of Bandung, especially the Department of Health should be as early as possible to disseminate about the spread of dengue fever and how the management of this disease to urban villages in the northern and southern Bandung.

6. Conclusion
Based on the above results and discussion can take several conclusions as follows
- In general, the pattern of the spread of dengue disease area in northern and southern Bandung changed significantly i.e. from 2010 to 2015 tends to fall. The pattern will still occur until 2017, but the number of people with DHF will rise in 2018. In the western, central and east region of Bandung is relatively constant until the year 2018.
• Implementation of the three-spatial interpolation method combined with GSTAR to predict the dispersion pattern of dengue disease in Bandung area, give information that IDW and Kriging methods did not differ significantly, but Ordinary Kriging and Universal Kriging method give different result.

• IDW method is not influenced by the characteristic data, while the method of Ordinary Kriging and Universal Kriging is very sensitive to the characteristics of data that is stationary or there is a trend.

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