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Mapping The Number Of Dengue Fever Cases In West Sumatera Using Spatial Regression Analysis

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Abstract – Dengue Hemorrhagic Fever (DHF) is a disease caused by the dengue virus and transmitted from Aedes spp. DHF is one of the health problems faced by all countries in the world. One country that has a high number of dengue cases is Indonesia, so it is necessary to make efforts to reduce this problem. The purpose of this study was to determine the factors that influence the spread of the number of DHF cases by considering the spatial relationship using Spatial Regression Analysis. The data used in this study are secondary data obtained from the Health Profile of West Sumatra Province in 2020 and West Sumatra Province in Figures in 2020. The results of the study using Spatial Regression Analysis obtained a regression model, namely the SAR Model which shows the factors that influence the number of DHF cases. namely percentage of healthy latrine ownership, percentage of the total population, population density, percentage of poor people, and area height.

Keywords – Dengue hemorrhagic fever, Spatial Regression Analysis, SAR Model

I. Introduction

Health is an important problem faced by countries in the world today. One of the health problems that have not been resolved until now because the vaccine has not been found is Dengue Fever. This disease is caused by the dengue virus [1]. The virus is transmitted from the Aedes spp mosquito, which is the fastest-growing in the world, causing nearly 390 million people to be infected every year. This virus is found in tropical and subtropical areas or countries around the equator. This virus has become an enemy for countries in the world. About 75% of the world's dengue virus attacked the Asia Pacific in 2004-2010 [2]. One of the countries affected by the dengue virus is Indonesia.

Indonesia is the 2nd country in the world that has the largest dengue cases. Indonesia has experienced this dengue problem for the last 50 years [2]. DHF was first discovered in Surabaya City in 1968, as many as 58 people were infected and 24 of them died, with a mortality rate (AK) reaching 41.3%. Since then this disease has spread throughout Indonesia [3]. In 2015 the number of dengue cases reached 126,675 cases. One of the provinces that were included in the top 10 of the number of dengue cases in 2019 was West Sumatra. The number of Cases in West Sumatra Province in 2018 was 2203 cases [4]. In 2019, the number of dengue cases increased to 2,235 [5]. The high number of dengue cases in West Sumatra is a health problem that must be faced by the local government. In dealing with this case, the local government needs to analyze what is the cause of the occurrence of dengue cases caused by the dengue virus. According to [4] there are several causes for the spread of dengue cases, namely high population mobility, urban area development, climate change, population density, and other epidemiological factors. According to [6], several factors that affect the number of DHF cases include the number of hospitals, the number of pondok bersalin desa/polindes (village maternity hut), population density, the percentage of clean and healthy living households (PHBS), the percentage of healthy houses, the percentage of the population to access to safe drinking water, the percentage of quality water free of bacteria, fungi and chemicals, number of protected water facilities, and number of rainwater storage facilities.

Efforts made by the government have not yielded good results, seen from the increase in the number of dengue cases in 2019. The high number of dengue cases is fairly high, so it is necessary to handle the factors that cause dengue cases. The number of cases of DHF is different in every Regency/City in West Sumatra Province, seen from the population density, regional potential, health facilities, and other background things. So judging from the opinions of previous studies and some of the sources described above and adjusting to the situation in the Province of West Sumatra, the factors that affect the number of dengue cases is the percentage of healthy latrine ownership, area, percentage of the population, population density, percentage of poor people. and area height. So it is necessary to make efforts to overcome the number of cases of DHF by looking at the factors that influence it.

If no efforts are made or efforts are made inappropriately, it will result in high cases of DHF and can cause death [7]. Therefore, researchers are interested in knowing the distribution pattern of DHF cases or the spatial pattern of DHF cases and analyzing what factors influence the number of DHF cases in West Sumatra. The method chosen by the researcher is spatial regression analysis because DHF cases are related to regional aspects.

II. Material

Spatial regression analysis is a regression used to determine the causal factors based on considerations of spatial or location aspects. The problem of this research is to find the pattern of distribution of data on the number of dengue cases in West Sumatra using spatial regression analysis based on the factors that influence the number of dengue cases in West Sumatra in 2019. The Spatial Regression Analysis is an analysis used to see the influence between the dependent variable and the independent variable by considering the location or spatial relationship [8]. In general, the form of spatial regression can be seen as follows.

$$y = \rho W y + X\beta + u \quad (1)$$

$$u = \lambda W u + \varepsilon$$

$$\varepsilon \sim N(0, \sigma^2 I)$$

β: The regression parameter coefficient vector measuring $(p+1)\times 1$

ρ: Spatial lag parameter coefficient

λ: Spatial error autoregression coefficient with value $|\lambda|<1$

u: Error vector which is assumed to contain autocorrelation of size $n\times 1$

W: Spatial weighting matrix of size $n\times n$

y: The dependent variable vector size $n\times 1$

The spatial weighting matrix is a matrix depiction that describes the relationship between the proximity of the observer area measuring $n\times n$ which has the symbol W, where n is the number of locations observed. In general, the form of the spatial weighting matrix can be seen as follows.

$$W = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1n} \\ w_{21} & w_{22} & \cdots & w_{2n} \\ \cdots & \cdots & \ddots & \vdots \\ w_{31} & w_{32} & \cdots & w_{nn} \end{bmatrix} \quad (2)$$

A spatial autocorrelation test is a correlation between variables itself based on space or location. A spatial autocorrelation test can be done as a statistical test using Moran's Index. In general, the form of Moran's Index can be seen as follows [9].

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{s^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \quad (3)$$

n: the number of observations

y_i: observed value at location *i*

y_j: observed value at location *j*

$\bar{y}$: average of the i-th observation values from n locations

w_{ij}: spatial weighting matrix element jth row i-th column

The spatial effect test was used to determine the effect of heteroscedasticity and spatial dependence effect. The spatial heteroscedasticity effect test is an effect that is used to show the diversity between locations using the Breusch-Pagan test. The hypothesis and statistics of the Breusch-Pagan test can be seen as follows.

$$BP = \frac{1}{2} f^T Z(Z^T Z)^{-1} Z^T f \sim \chi^2_P \qquad (4)$$

with the element vector, *f* can be seen as follows.

$$f_i = \left(\frac{e_i^2}{\sigma^2} - 1\right) \qquad (5)$$

e_i^2 : error for i-th observation

Z: matrix of size *nx(p+1)* which contains standardized vector (*z*) for each observation.

With the test criteria, Reject H_0, $BP > \chi^2_{\alpha,(P-1)}$, where p is the number of regression parameters.

The spatial dependence effect test occurs due to the dependence in the regional data from Tobler's law. Testing the effect of spatial dependence can be done using the Lagrange Multiplier test statistic. The Lagrange Multiplier test is used to select the appropriate spatial regression model [10]. The Lagrange Multiplier test consists of two tests, namely a test for lag and a test for errors. In general, the form of the Lagrange Multiplier test for Lag can be seen as follows.

$$LM = \frac{\left[\frac{\varepsilon' W y}{\frac{\varepsilon' \varepsilon}{n}}\right]^2}{D} \qquad (6)$$

$$D = \left[\frac{(WX\hat{\beta})'(I - X(X'X)^{-1}X')((WX\hat{\beta})}{\hat{\sigma}^2}\right] + tr(W'W + WW) \qquad (7)$$

The Lagrange Multiplier Test for Error has the following general form [8].

$$LM = \frac{\left[\frac{\varepsilon' W \varepsilon}{\varepsilon' \varepsilon / n}\right]^2}{tr(W^2 + W'W)} \qquad (8)$$

The spatial regression parameter significance test was used to determine the feasibility of the regression coefficients in the model. Testing the significance of the spatial regression parameters can be done with the following test statistics.

$$Z_{hitung} = \frac{\hat{\theta}}{s.b_{\hat{\theta}}} \qquad (9)$$

with:

θ = parameter of spatial regression $(\beta,\ \lambda, or\ \rho)$

The selection of the best model is used to test which model is better than several spatial regression models such as the SAR, the SEM and the SARMA models. We used an AIC test to find the best model. In general, the statistics of the AIC test can be seen as follows.

$$AIC = 2n log_{\varepsilon}(\hat{\sigma}) + n log_{\varepsilon}(2\pi) + n + tr(\boldsymbol{L}) \qquad (10)$$

A model with the smallest AIC will be the best model of spatial regression.

III. METHODS

The data used in this study were taken by the Health Office of West Sumatra Province in 2020. The variables used in this study were the percentage of the number of dengue cases (Y), the percentage of healthy latrine ownership (X1), the area (X2), Percentage of Total Population (X3), Population Density (X4), Percentage of Poor Population (X5), and Altitude Area (X6). The following can be seen the structure of the data that will be used in the study.

TABLE 1. Structure of Data

District/City	Y	X_1	X_2	…	X_6
A_1	y_1	$x_{1.1}$	$x_{1.2}$	…	$x_{1.6}$
A_2	y_2	$x_{2.1}$	$x_{2.2}$	…	$x_{2.6}$
A_3	y_3	$x_{3.1}$	$x_{3.2}$	…	$x_{3.6}$
…	…	…	…	…	…
A_{19}	y_{19}	$x_{19.1}$	$x_{19.2}$	…	$x_{19.6}$

The A_i indicating the object of research, namely the Regency/City in the Province of West Sumatra. While y_{ij} and x_{ij} are the values of the i-th observation object and the j-th variable.

The research used a software ArcGIS 10.3 and GeoDa applications. The steps of spatial regression analysis can be seen as follows.

1. Exploration of data on the number of cases of Dengue Hemorrhagic Fever (DHF) in West Sumatra Province year 2019.
2. Form a spatial weighting matrix (W) with equation (2).
3. Test the spatial autocorrelation of the data on the number of DHF cases with equation (3).
4. The spatial effect test, namely the spatial heterogeneity effect test using the Breusch-Pagan test with equation (4) and the spatial dependence effect test (spatial dependence) using the Lagrange Multiplier test with equation (6).
5. Form a spatial regression model based on the Lagrange Multiplier Test.
6. Test the significance of the parameters of the spatial regression model with equation (9).
7. Selection of the best model with the smallest Akaike's Information Criterion (AIC) value with equation (10).
8. Interpretation of models and conclusion.

IV. RESULTS AND DISCUSSION

Spatial regression analysis was used to see the influence between independent variables that affected the number of DHF cases in West Sumatra Province in 2019 by considering the area or spatial (district/city). This study will show the number of occurrences of each variable which are grouped into 3 categories, namely high, medium and low. This is done to make it easier to describe the research variables. Mapping of the variables used in the study can be seen as follows.

Based on Figure 1, it can be said that the percentage of the number of DHF cases that are in the red category at intervals of 8.73-19.11 is the Padang City area. Regions that are in the yellow color category at intervals of 3.81-8.72 are the Kab. Agam, Kab. Padang Pariaman, Kab. Pasaman, Kab. West Pasaman, Kab. South Coast, Kab. Solok, Kab. Tanah Datar, Bukittinggi City, Payakumbuh City, and Sawahlunto City. While those in the green color category at intervals of 1.16-3.80 are the Kab. Dhamasraya, Kab. Mentawai Islands, Kab. 50 Koto, Kab. Sijunjung, Kab. South Solok, Padang Panjang City. Pariaman City, and Solok City

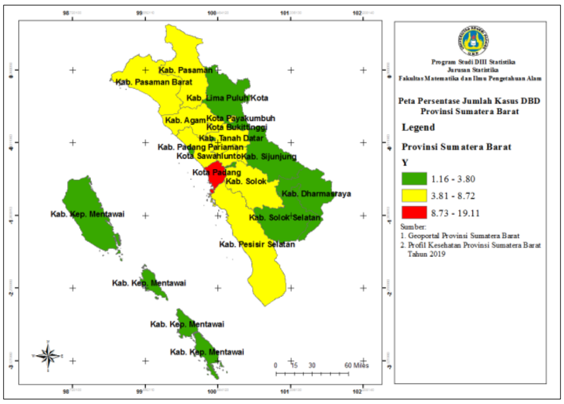

Fig 1. Map of Distribution of Number of DHF Cases by District/City in West Sumatra in 2019

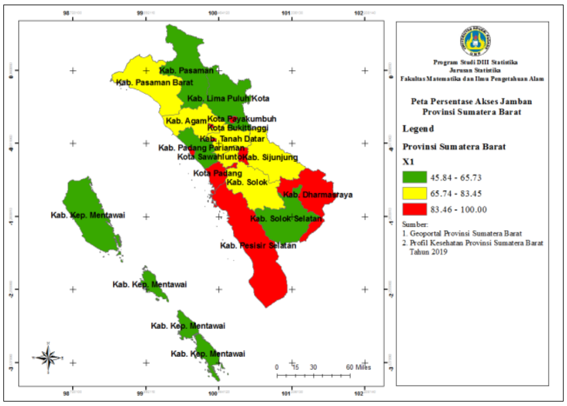

Fig 2. Map of Distribution of Healthy Latrine Ownership Percentage in West Sumatra Year 2020

Based on Figure 2, it can be said that the percentage of healthy latrine ownership in the red category at intervals of 83.46-100.00, namely the Kab. Dhamasraya, Kab. South Coast, Bukittinggi City, Padang City, Padang Panjang City, Pariaman City, Payakumbuh City, Lunto Sawah City, and Solok City. Regions that are in the yellow color category at intervals of 65.74-83.45 are the Kab. Agam, Kab. West Pasaman, Kab. Sijunjung, Kab. Solok and Kab. Flat Land. While those in the green color category at intervals of 45.84-65.73, namely the Kab. Mentawai Islands, Kab. Fifty Koto, Kab. Padang Pariaman, Kab. Pasaman and Kab. South Solok.

Based on Figure 3, it can be said that the area in the red category at intervals of 3130.81-6011.35 (Km^2) is the Kab. Pasaman, Kab. West Pasaman, Kab. 50 Koto, Kab. Solok, Kab. South Solok, Kab. South Coast and Kab. Mentawai Islands. Areas that are in the yellow color category at intervals of 694.97-3130.80 (Km^2) are the Kab. Agam, Tanah Datar Regency, Kab. Padang Pariaman, Kab. Sijunjung and Kab. Dhamasraya. While those in the green color category at intervals of 23.00-694.96 (Km^2) are Pariaman City, Padang Panjang City, Bukittinggi City, Payakumbuh City, Sawahlunto City, Solok City and Padang City.

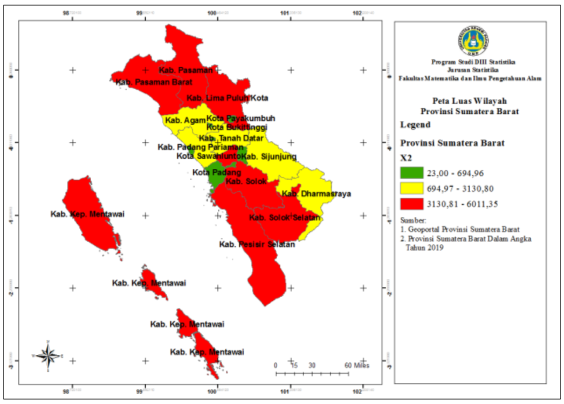

Fig 3. Area Map in West Sumatra Province in 2019

Based on Figure 4, it can be said that the percentage of the population in the red category at intervals of 9.04-17.48 is the area of Padang City. Areas that are in the yellow color category at intervals of 4.56-9.03 are the Kab. Pasaman, Kab. West Pasaman, Kab. Agam, Kab. Fifty Koto, Kab. Padang Pariaman, Kab. Tanah Datar, Kab. Solok and Kab. South Coast. While those in the green color category at intervals of 0.99-4.55 are Bukittinggi City, Payakumbuh City, Pariaman City, Padang Panjang City, Solok City, Sawah Lunto City, Kab. Sijunjung, Kab. Dhamasraya, Kab. South Solok and Kab. Mentawai Islands.

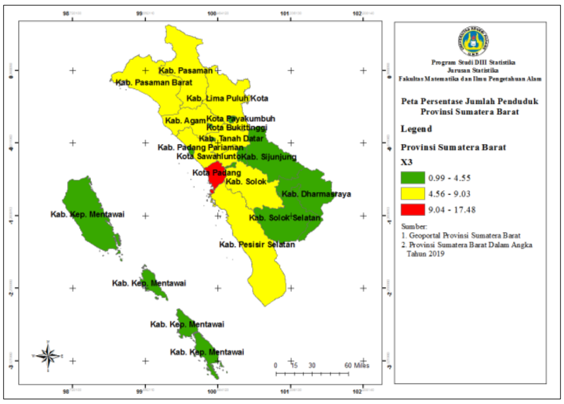

Fig 4. Map of the Distribution of the Percentage of the Total Population in West Sumatra Province in 2019

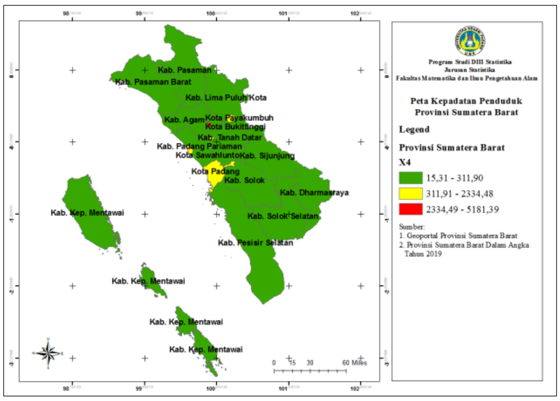

Fig 5. Population Density Distribution Map in West Sumatra Province in 2019

Based on Figure 5, it can be said that the population density in the red category at intervals from 2334.49 to 5181.39 is the area of Bukittinggi City. Areas that are in the yellow color category at intervals of 311.91-2334.48 are the areas of Padang Panjang City, Pariaman City, Payakumbuh City, Padang City and Solok City. While those in the green color category at intervals of 15.31-311.90, namely Kab. Agam, Kab. Fifty Koto, Kab. Padang Pariaman, Kab. Pasaman, Kab. West Pasaman, Kab. Tanah Datar, Lunto Sawah City, Kab. Solok, Kab. Sijunjung, Kab. Dhamasraya, Kab. South Solok, Kab. South Coast and Kab. Mentawai Islands.

Based on Figure 6, it can be said that the percentage of poor people who are in the red category at an interval of 7.99-14.43, namely the Kab. Mentawai Islands. Regions that are in the yellow color category at intervals of 4.77-7.98 are the Kab. Pasaman, Kab. West Pasaman, Kab. Fifty Koto, Kab. Agam, Kab. Padang Pariaman, Padang Panjang City, Kab. Solok, Kab. Sijunjung, Kab. Dhamasraya, Kab. South Solok, Kab. South Coast and Payakumbuh City. While those in the green color category at intervals of 2.17-4.76 are Kota Pariaman, Kab. Tanah Datar, Lunto Sawah City, Solok City, Bukittinggi City and Padang City.

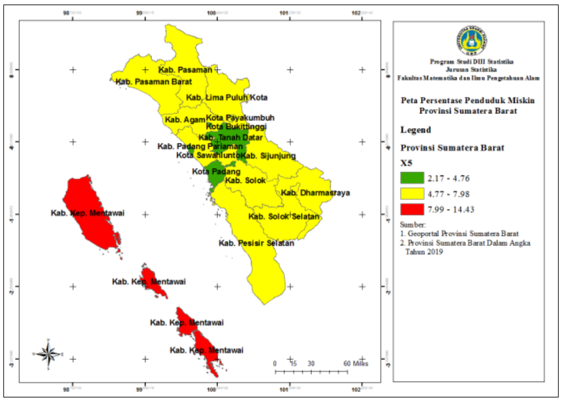

Fig 6. Map of the Distribution of the Percentage of the Poor in West Sumatra Province in 2019

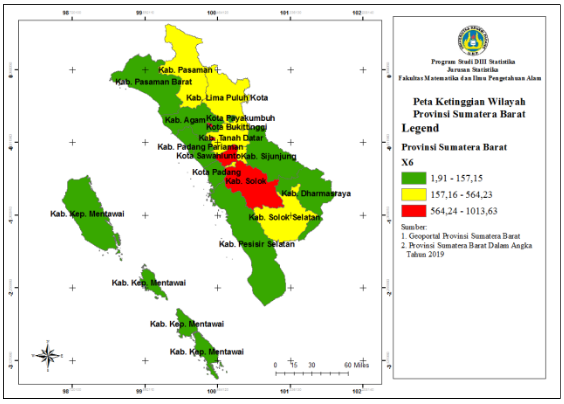

Fig 7. Map of Regional Altitude Distribution in West Sumatra Province in 2019

Based on Figure 7, it can be said that the height of the area in the red category at intervals of 564.24-1013.63 (masl)1 is the Kab. Solok, Bukittinggi City and Padang Panjang City. The areas in the yellow color category at intervals of 157.16-564.23(masl)1 are the Kab. Fifty Koto, Kab. Pasaman, Kab. South Solok, Kab. Tanah Datar, Lunto Sawah City and Solok City. While those in the green color category at intervals of 1.91-157.15 (mdpl)1 are the City of Pariaman, Kab. Mentawai Islands, Kab. West Pasaman, Kab. Agam, Payakumbuh City, Kab. Padang Pariaman, Kab. Sijunjung, Kab. Dhamasraya, Kab. South Coast and Padang City.

Spatial autocorrelation test or spatial dependence test was carried out using Moran's Index statistics. The statistical results for the Moran's Index statistical test can be seen as follows.

TABLE 2. Moran's Index Output Results and Decisions

Variable		Moran's Index	Decision
Symbol	Description		
Y	percentage of the number of dengue cases	-0.044	$I > E_N(I)$
X_1	the percentage of healthy latrine ownership	-0.112	$I < E_N(I)$
X_2	the area	0.160	$I > E_N(I)$
X_3	Percentage of Total Population	-0.119	$I < E_N(I)$
X_4	Population Density	-0.022	$I > E_N(I)$
X_5	Percentage of Poor Population	-0.032	$I > E_N(I)$
X_6	Altitude Area	-0.221	$I < E_N(I)$

With,

$$E_N(I) = -\frac{1}{n-1} = -\frac{1}{19-1} = -0.056$$

Based on the output results and the value of $E_N(I)$ above, it can be said that the decision $I<E_N(I)$ has a negative meaning that the autocorrelation value is negative with the data pattern being spread out, while for the decision $I>E_N(I)$ it means that the autocorrelation value is positive with the data pattern

The output results of the Breusch-Pagan test can be seen as follows.

TABLE 3. Output *Breusch-Pagan*

Statistik Uji	df	Nilai	P_Value
Breusch-Pagan Test	6	5.6738	0.46070

Based on the output results above, it can be said that the Breusch-Pagan Test value is 5.6738 with $\boldsymbol{\chi^2_{0,15;5-1} = 8.1152}$ and P-Value is 0.46070 with $\boldsymbol{\alpha = 0.15}$, which means it does not reject H0. So it can be said that there is spatial homogeneity, meaning that there are similarities between the observed regions.

The results of the Lagrange Multiplier Test can be seen as follows.

TABLE 4. Result of *Lagrange Multiplier*

Statistik Uji	df	Value	P_Value
Lagrange Multiplier(Lag)	1	2,1259	0,14482
Lagrange Multiplier (error)	1	1,3109	0,25223

Based on the output results above, it can be said that the P_Value value of the Lagrange Multiplier (Lag) of 0.14482 is smaller than $\alpha = 0{,}15$ which means Reject H0. Likewise, the Lagrange Multiplier (Lag) value of 2.1259 is greater than $\chi^2_{0,15(1)} = 2.0723$, which means Reject H0. So it can be said that there is a spatial dependence effect on Lag, so the modeling is continued by using the Spatial Autoregressive Model (SAR). Based on the Lagrange Multiplier test, it can be seen that in the case of Dengue Hemorrhagic Fever (DHF) in West Sumatra Province, there is a spatial effect in Lag.

Spatial Autoregressive Model (SAR) is a model that combines a linear regression model with the spatial time difference (lag) on the dependent variable using cross-section data. Parameter estimation can be done using Maximum Likelihood Estimation (MLE). The following shows the general model of SAR.

$$y = \rho W_1 y + X\beta + \varepsilon$$

$$\varepsilon \sim N(0, \sigma^2 I)$$

The results of the estimation of the SAR model parameters can be seen as follows.

TABLE 5. Estimation of SAR Model

Variable	Coefisien
ρ	-0.25410
Constanta	14.3597
X_1	-0.09696
X_2	-0.00008
X_3	0.80777
X_4	0.00137
X_5	-0.66819
X_6	-0.00248

Based on the output above, we can write the SAR model equation as follows.

$$\hat{y}_i = 14.3597 - 0.25410\boldsymbol{W}u - 0.09696X_1 - 0.00008X_2 + 0.80777X_3 + 0.00137X_4 - 0.66819X_5 - 0.00248X_6$$

The results of the significance of the SAR model parameters can be seen as follows.

TABLE 6. Signifikant test of Parameter SAR Model

Variable	Z_Value	P_Value
ρ	-1.55653	0.11958
Konstanta	3.35651	0.00079
X_1	-2.74973	0.00596
X_2	-0.21250	0.83172
X_3	8.47601	0.00000
X_4	2.98194	0.00286
X_5	-2.11352	0.03456
X_6	-1.77543	0.07583

Based on the table above, it can be said that judging from the P-Value and $\boldsymbol{\alpha = 0.15}$, the independent variables that have a real influence (regression coefficients are suitable for use by the model) are, X1, X3, X4, X5, and X6. Then we reduce the independent variable so that all independent variables that affect the dependent variable are obtained. The results of the estimation of the SAR model parameters can be seen as follows.

TABLE 7. Estimation of SAR Model Parameters

Variabel	Koefisien	Z_Value	P_Value
ρ	-0.26553	-1.63755	0.10152
Konstanta	14.612	3.50882	0.00045
X_1	-0.09734	-2.76215	0.00574
X_3	0.80260	8.83206	0.00000
X_4	0.00142	3.71814	0.00020
X_5	-0.72045	-3.37883	0.00073
X_6	-0.00256	-1.91523	0.05546

Based on the table above, it can be said that all independent variables and has a significant effect (regression coefficient is suitable for use by the model). The equation of the SAR model obtained can be seen as follows.

$$\hat{y}_i = 14.612 - 0.26553Wu - 0.09734X_1 + 0.80260X_3 + 0.00142X_4 - 0.72045X_5 - 0.00256X_6$$

The SAR model is obtained with several combinations of variables, then the best model is selected by looking at the smallest AIC value. The AIC value can be seen as follows.

Table 8. Values of R^2 and AIC

Variable	R^2	AIC
Y, X_3, X_4, X_5, X_6	0.790283	87.1447
Y, X_1, X_3, X_4, X_5	0.822269	84.0526
Y, X_1, X_3, X_4, X_5, X_6	0.850583	82.709

Based on the table above, the best SAR model is obtained, namely with the largest $R^2 = 0.850583$ and the smallest AIC value = 82.709, so that the SAR model is obtained as follows.

$$\hat{y}_i = 14.612 - 0.26553Wu - 0.09734X_1 + 0.80260X_3 + 0.00142X_4 - 0.72045X_5 - 0.00256X_6$$

Based on the model equation obtained above, the coefficient is obtained which significantly indicates that if an area is surrounded by neighbors, it will reduce the Percentage of the Number of DHF Cases in each region by 0.26553. Furthermore, from the above equation, it is found that the percentage of the population and population density has a positive effect on the addition of the Percentage of the Number of DHF cases in West Sumatra Province. Meanwhile, the percentage of healthy latrine ownership, the percentage of poor people, and the height of the area have a negative influence on the percentage of the number of dengue cases in West Sumatra Province.

V. CONCLUSION

The SAR model in this study is based on the R^2 and AIC values, which are 0.850583 and 82.709, respectively, which can be used to explain the number of dengue cases in each district/city in West Sumatra in 2019. This study concludes that the factors affecting affect the number of DHF cases, namely the percentage of healthy latrine ownership, the percentage of the population, population density, the percentage of poor people, and the height of the area.

The researcher suggests that it is necessary to do testing and research in this study because there has been no visible influence between regions on the number of DHF cases by District/City in West Sumatra in 2019. Researchers suggest adding variables or changing some variables by looking at them from another point of view. Researchers hope this research can be useful to reduce the number of dengue cases in West Sumatra in the future.

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