Identification of Factors that Influence Stunting Cases in South Sulawesi using Geographically Weighted Regression Modeling

Siswanto[1*], Mirna[2], Muhammad Yusran[3], Ummul Auliyah Syam[4] and Alya Safira Irtiqa Miolo[5]

[*]*Department of Statistics, Hasanuddin University, Makassar, Indonesia, 90245*
Email address: [1]siswanto@unhas.ac.id, [2]mirna67469@gmail.com,
[3]uccank.mhmmadyusran@gmail.com, [4]ummulsyam08@gmail.com, [5]alyairtiqa@gmail.com

Abstract

In Indonesia, nearly seven million children under five are stunted and throughout the world, Indonesia is the country with the fifth-highest stunting prevalence. South Sulawesi ranks fourth with a high stunting potential in Indonesia. Stunting is caused by multi-dimensional factors and not only due to malnutrition experienced by pregnant women and children under five. In more detail, several factors that cause stunting are the effects of poor care, the lack of household/family access to nutritious food, and the lack of access to clean water and sanitation. In addition to maternal characteristics and parenting, the problem of stunting is also influenced by environmental factors and geographical conditions (population density, climatic conditions, and inadequate sanitation) so the spatial analysis is important to do in overcoming this problem. In spatial data, often observations at a location (space) depend on observations at other locations that are nearby (neighboring). By using Geographically Weighted Regression (GWR) obtained variables that affect the prevalence of stunting in South Sulawesi Province, including the percentage of babies receiving vitamin A intake, the percentage of babies receiving exclusive breastfeeding, the percentage of babies receiving health care, the percentage of malnourished children under five, the percentage short toddlers, the percentage of infants receiving DPT-HB-Hib, Measles and BCG immunizations. R^2 for the GWR model is 81.32% and based on variables that are significant to the prevalence of stunting in South Sulawesi Province, three clusters are formed.

Keywords: children, geographically weighted regression, stunting

1. INTRODUCTION

Future Indonesian children must be healthy, intelligent, creative, and productive. If children are born healthy, grow well, and supported by quality education, Indonesian children will become the generation that supports the success of nation-building. Conversely, if children are born and grow in situations of chronic malnutrition, they will become stunted children. Dwarf (stunting) in children reflects the condition of growth failure in children under five (Under 5 years) due to chronic malnutrition, so the child becomes too short for his age. Chronic malnutrition occurs from the baby in the womb until the age of two years [6, 10]. Thus, the first 1000 days of life should receive special attention because it determines a person's level of physical growth, intelligence, and productivity in the future [10].

Siswanto, Mirna, Muhammad Yusran, Ummul Auliyah Syam and Alya Safira Irtiqa Miolo

In Indonesia, around 30.8% (nearly 7 million) of children under five experience stunting, and throughout the world, Indonesia is the country with the fifth-highest stunting prevalence [1]. South Sulawesi ranks 4th with a high stunting potential in Indonesia, after East Nusa Tenggara, West Nusa Tenggara, and Southeast Sulawesi, namely Baduta (Babies under Two Years) reaching 29.9 percent with the category 17.1 percent short and 12.8 percent very short, while toddlers 30.1 percent. Toddler who has stunted will have a level of intelligence is not optimal, making children more vulnerable to disease and in the future can be at risk of decreasing levels of productivity. In the end, stunting will be able to inhibit economic growth, increase poverty, and widen inequality [2].

Stunting is caused by multi-dimensional factors and not only due to malnutrition experienced by pregnant women and children under five. In more detail, several factors that cause stunting are the effects of poor care, the lack of household/family access to nutritious food, and the lack of access to clean water and sanitation [2]. In addition to maternal characteristics and parenting, the problem of stunting is also influenced by environmental factors and geographical conditions (population density, climatic conditions, and inadequate sanitation) so the spatial analysis is important to do in overcoming this problem. In spatial data, often observations at a location depend on observations at other locations that are nearby (neighboring).

Geographically Weighted Regression (GWR) is one solution that can be used to form a regression analysis but is local for each location of observation. GWR is part of spatial analysis with weighting based on the position or distance of one observation location from another observation location [3]. The result of this analysis is an equation model whose parameter values apply only at each observation location and differ from other locations.

Previous research conducted by Sukarsa and Kencana [12] compared the multiple linear regression model with GWR to model pneumonia in East Java Province with the results obtained from the GWR analysis that the value of the total squared error of the GWR model was smaller than the sum of the squares of errors of the multiple linear regression model. This means that the GWR model is more feasible to describe pneumonia cases that occurred in East Java in 2016. Mahdy [9] modeled the number of COVID-19 cases in West Java using GWR from the study, it was found that locally the GWR model has a higher coefficient of determination than modeling globally linear regression.

Based on previous research, it is known that the problems studied are more focused on infectious diseases that occur in Indonesia, there has been no research related to the prevalence of stunting in Indonesia in general and South Sulawesi in particular. Based on this description, researchers are interested in analyzing the factors that influence the prevalence of stunting in South Sulawesi Province.

2. METHODOLOGY

2.1 Data Source

The data used in this study are secondary data from the publication of the Ministry of Health of the Republic of Indonesia with the title Health Profile of the Province of South Sulawesi in 2013 [4] and Health Profile of the Province of South Sulawesi in 2018 [5] Because health publication data is collected every five years, the data used are from 2013 and 2018. Table 1 shows the response variables and explanatory variables used in this study.

Table 1. Response and explanatory variables

Notation	Variables	Definition
Y	Stunting Prevalence	Prevalence of stunting in each regency/city in South Sulawesi Province.
X_1	Coverage of Vitamin a Giving	The number of babies receiving vitamin A multiplied

Siswanto, Mirna, Muhammad Yusran, Ummul Auliyah Syam and Alya Safira Irtiqa Miolo

Notation	Variables	Definition
	to Infants (6-11 Months) in 2013	by 100 per number of babies per district/city in South Sulawesi Province in 2013.
X_2	Coverage of Vitamin a Giving to Infants (6-59 Months) in 2018	The number of babies receiving vitamin A multiplied by 100 per number of babies per district/city in South Sulawesi Province in 2018.
X_3	Given Exclusive breastfeeding baby in 2013	The number of babies breastfed is multiplied by 100 per number of newborns per district/city in South Sulawesi Province in 2013.
X_4	Baby Health Care Coverage	The number of babies receiving health services is multiplied by 100 per number of babies per district/city in South Sulawesi Province in 2013.
X_5	Malnutrition Toddler in 2018	Number of childhood malnutrition and multiplied by 100 per number of infants (0-59 months) in each district/city in South Sulawesi Province in 2013.
X_6	Basic immunization Full Year 2013	The number of infants having complete basic immunization is multiplied by 100 per number of babies per district/city in South Sulawesi Province in 2018.
X_7	Skinny Toddler in 2018	The number of thin children under five times 100 per number of children (0-59 months) per district/city in South Sulawesi Province in 2018.
X_8	DPT3-HB-Hib3 Immunization in 2013	The number of babies immunized for DPT 3-HB-Hib 3 times 100 per number of babies per district/city in South Sulawesi Province in 2018.
X_9	Measles Immunization in 2013	The number of babies immunized against Measles is multiplied by 100 per number of babies per district/city in South Sulawesi Province in 2018.
X_{10}	BCG Immunization for 2013	The number of babies immunized with BCG is 100 times the number of babies per district/city in South Sulawesi Province in 2018.

2.2 Research Methods

The Geographically Weighted Regression models a dependent variable y via a linear function of a set of p independent variables, $x_1, x_2,..., x_p$. The regression equation can be expressed as:

$$y_i = \beta_{i0} + \sum_{k=1}^{p} \beta_{ik} x_{ik} + \varepsilon_i \tag{1}$$

where y_i is the dependent variable, β_{ik} and x_{ik} are the parameters and observed values of the independent variable $k(k = 1, ..., p)$ for observation i, ε_i is the error term for observation i, and the subscript i is the spatial location of the observation $i = 1, ..., n$ which is generally assumed to be normally distributed with zero mean and constant variance $\varepsilon_i \sim N(0, \sigma^2)$.

In GWR model, the equation parameters for each observation location different from other locations so each location has their own regression model, which can be expressed as follow [7, 8]:

$$y_i = \beta_0(u_i, v_i) + \sum \beta_k(u_i, v_i) x_{ik} + \varepsilon_i \tag{2}$$

where y_i is the dependent variable, β_{ik} and x_{ik} are the parameters and observed values of the independent variable k for observation i, (u_i, v_i) the co-ordinate location of i and ε_i is the error term for observation i [7].

The steps of data analysis carried out in this study are as follows:

1. Conduct spatial influence testing using the Breusch-Pagan Test.
   a) Testing hypotesis
      $H_0 : \sigma_1^2 = \sigma_2^2 = \cdots = \sigma_n^2 = \sigma^2$ (There is no spatial heterogeneity)
      $H_1 : \sigma_i^2 = \sigma^2$ (There is spatial heterogeneity)
      $i = 1, 2, \ldots, n$
   b) Statistics test

   $$BP = \left(\frac{1}{2}\right) f'Z'(Z'Z)^{-1}Zf \sim \chi_{(p)}^2$$

   with vector elements f, $f_i = \left(\frac{e_i^2}{\sigma^2} - 1\right)$

   and

   e_i^2 : Least square error for the i-th observation
   σ^2 : Error variance e_i^2
   Z : matrix of size $n \times (p+1)$ contains a vector that has been standardized (z) for each location, and k is the number of predictor variables.

   c) Critical area
      The decision criterion is to reject H_0 if $BP > \chi_{(\alpha,p)}^2$ it can be concluded that there is spatial heterogeneity.

2. Calculate the Euclidean distance between points of observation location based on geographical position (longitude and latitude).

3. Determine the optimum bandwidth (h) for all observation locations using cross-validation (CV). One method used to determine the optimum bandwidth is the CV method and can be mathematically written as follows [8].

$$CV(h) = \sum_{i=1}^{n}(y_i - \hat{y}_{\neq i}(h)) \tag{3}$$

   with $\hat{y}_{\neq i}(h)$ is the estimated value y_i on the observation at the location (u_i, v_i) is removed from the estimation process. To get the optimal value of h, it is obtained from h which produces a minimum CV value.

4. Calculating the weighting matrix by substituting the optimum euclidean distance and bandwidth (h) values in the adaptive Gaussian kernel weighting function.
   The kernel function is used to estimate parameters in the GWR model if the distance function is a continuous and monotonous downward function [11]. In this study using the Gaussian kernel function.

$$W_{ij}(u_i, v_i) = \exp\left(-\frac{1}{2}\left(\frac{d_{ij}}{h}\right)^2\right) \tag{4}$$

5. Estimating the parameters of the GWR model using WLS.

6. Test the parameters of the GWR model by conducting simultaneous tests and partial parameter testing for each location.

7. Determine the GWR model

8. Conduct goodness of fit tests for the GWR model based on the adaptive Gaussian kernel weighting of R^2. The Goodness of Fit test is performed by calculating the coefficient of determination (R^2) of the GWR model. The R^2 value of GWR is obtained by the following mathematical equation [8]:

$$R^2(u_i, v_i) = \frac{JKR_W}{JKT_W} = \frac{\sum_{j=1}^{p} w_{ij}(\hat{y}_j - \bar{y})}{\sum_{j=1}^{p} w_{ij}(y_j - \bar{y})^2} \tag{5}$$

Siswanto, Mirna, Muhammad Yusran, Ummul Auliyah Syam and Alya Safira Irtiqa Miolo

3. RESULT AND DISCUSSION

3.1 Spatial Heterogeneity

Spatial heterogeneity is shown by differences from one location to another. One of the characteristics of spatial data, especially spatial analysis with a point approach is that there is a spatial heterogeneity or variance in the variants in each location. This spatial heterogeneity test can be done using the Breusch-Pagan test statistics with the hypothesis testing procedure as follows.

a) Testing Hypotesis

$H_0 : \sigma_1^2 = \sigma_2^2 = \cdots = \sigma_{24}^2 = \sigma^2$ (There is no spatial heterogeneity)

$H_1 : \sigma_i^2 = \sigma^2$ (There is spatial heterogeneity)

$i = 1, 2, \dots, 24$

b) Statistics test

$$BP = \left(\frac{1}{2}\right) f'Z'(Z'Z)^{-1}Zf = 17.773$$

c) Critical area

Because $BP = 17.773 > \chi^2_{(0.1;10)}$ P-value $= 0.059 < \alpha = 0.1$ then reject H_0.

d) Conclusion

It can be said that there is spatial heterogeneity or diversity between the locations of each variable in the stunting data. Therefore, the regression modeling used is appropriate for locations, in this case using GWR.

3.2 Weighting Matrix

The initial step in the analysis of the GWR model is determining the weighting matrix. The weighting matrix used is the adaptive gaussian kernel weighting, each weighting requires the optimum bandwidth value. Determination of optimum bandwidth value (h) for all districts/cities is obtained based on the minimum CV value. The bandwidth value (h) obtained is then substituted into each weighting to be used in forming the weighting matrix. Determination of optimum bandwidth (h) with CV criteria obtained h value of 0.625 with a minimum CV value of 3891.969. The optimum bandwidth value is used to get weighting in each district/city.

The weighting matrix at the location (u_i, v_i) is a diagonal matrix $W(u_i, v_i)$, so we obtained 24 weighting matrices for poverty data in South Sulawesi Province. Weighting matrix calculations can be written as follows:

$$W_{ij}(u_i, v_i) = exp\left(-\frac{1}{2}\left(\frac{d_{ij}}{h}\right)^2\right)$$

$$W(u_i, v_i) = \begin{bmatrix} w_{1,1} & w_{1,2} & \cdots & w_{1,24} \\ w_{2,1} & w_{2,2} & \cdots & w_{2,24} \\ \vdots & \vdots & \ddots & \vdots \\ w_{24,1} & w_{24,2} & \cdots & w_{24,24} \end{bmatrix}$$

$$W(u_i, v_i) = \begin{bmatrix} exp\left[-\frac{1}{2}\left(\frac{d_{1,1}}{h}\right)^2\right] & exp\left[-\frac{1}{2}\left(\frac{d_{1,2}}{h}\right)^2\right] & \cdots & exp\left[-\frac{1}{2}\left(\frac{d_{1,24}}{h}\right)^2\right] \\ exp\left[-\frac{1}{2}\left(\frac{d_{2,1}}{h}\right)^2\right] & exp\left[-\frac{1}{2}\left(\frac{d_{2,2}}{h}\right)^2\right] & \cdots & exp\left[-\frac{1}{2}\left(\frac{d_{2,24}}{h}\right)^2\right] \\ \vdots & \vdots & \ddots & \vdots \\ exp\left[-\frac{1}{2}\left(\frac{d_{24,1}}{h}\right)^2\right] & exp\left[-\frac{1}{2}\left(\frac{d_{24,2}}{h}\right)^2\right] & \cdots & exp\left[-\frac{1}{2}\left(\frac{d_{24,24}}{h}\right)^2\right] \end{bmatrix}$$

Siswanto, Mirna, Muhammad Yusran, Ummul Auliyah Syam and Alya Safira Irtiqa Miolo

$$W(u_i, v_i) = \begin{bmatrix} 1 & 0.7219 & \cdots & 0.0007 \\ 0.7219 & 1 & \cdots & 0.0088 \\ \vdots & \vdots & \ddots & \vdots \\ 0.0007 & 0.0088 & \cdots & 1 \end{bmatrix}$$

3.3 Simultaneous Test of GWR Model

Simultaneous parameter testing aims to test the effect of variable X on the variable Y. From Table 2, the value of F_{score} 1.407 is obtained, while the value of $F_{table} = 1$. Based on the following hypothesis testing steps, a conclusion can be obtained.

a) Testing hypotesis
$H_0 : \beta_1(u_i, v_i) = \beta_2(u_i, v_i) = \cdots = \beta_{10}(u_i, v_i) = 0$ (There is no influence of geographical factors on the model)
$H_1 : \beta_j(u_i, v_i) \neq 0$ (There is an influence of geographical factors on the model)
With $i = 1, 2, \ldots, 24$ and $j = 1, 2, \ldots, 10$.

b) Statistics test
$F = 1.407$

c) Critical area
Reject H$_0$ if $F_{score} > F_{table}$

d) Decision
Because the value $F_{score} = 1.407 > F_{table} = 1$, then reject H_0

e) Conclusion
It can be said that all explanatory variables in this study simultaneously influenced the prevalence of stunting at a significance level of 0.1. in other words, the percentage of infants aged 6-11 months who received vitamin A, the percentage of infants aged 6-59 months who received vitamin A, the percentage of infants who received exclusive breastfeeding, the percentage of infants who received health services, the percentage of malnourished children under five, the percentage of infants received complete basic immunization, the percentage of underweight toddlers, the percentage of babies who received the DPT-HB-Hib immunization, the percentage of babies who received measles immunization, the percentage of babies who received the BCG immunization together significantly affected the stunting prevalence.

Table 2. Analysis of Variance

Source	Degrees of Freedom	Sum of Square	Mean of Square	F$_{score}$
OLS Residuals	11	434.450	39.495	
GWR Improvement	4	173.330	41.596	
GWR Residuals	9	261.120	29.562	1.407

Based on Table 2 for statistical comparison between the 2 models, it can be seen from the sum of square of the GWR residuals, which is 261.120, which is smaller than the OLS residuals of 434.450. Therefore, it is believed that the computational accuracy of the GWR model is better than the OLS model. As two types of statistical models, the GWR model provides a better performance to analyze the factors that influence the prevalence of stunting in South Sulawesi. These results are consistent with the conclusions of previous studies [13].

3.4 Partial Test of GWR Model

The partial testing of parameters one by on (each parameter $\beta_k(u_i, v_i)$) aims to determine the parameters that affect the response. The explanatory variables that influence the prevalence of stunting in the Province of South Sulawesi are presented in Table 3.

Table 3. Significant level GWR regression coefficients variables with t test in each region

District/city	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
Selayar	**-3.291**	**-3.834**	**2.760**	**3.006**	**3.063**	**3.185**	**-3.538**	-2.202	2.024	1.667
Bulukumba	**-3.413**	**-3.723**	**2.877**	**3.025**	**2.900**	**2.676**	**-3.619**	-2.070	1.970	1.462
Bantaeng	**-3.440**	**-3.743**	**2.892**	**3.023**	**2.914**	**3.145**	**-3.640**	-2.068	1.974	1.441
Jeneponto	**-3.504**	**-3.756**	**2.934**	**3.023**	**2.911**	**2.922**	**-3.692**	-2.045	1.976	1.376
Takalar	**-3.576**	**-3.749**	**2.981**	**3.030**	**2.885**	**2.806**	**-3.753**	-2.016	1.981	1.303
Gowa	**-3.555**	**-3.715**	**2.967**	**3.034**	**2.855**	**2.846**	**-3.735**	-2.007	1.973	1.310
Sinjai	**-3.479**	**-3.686**	**2.926**	**3.042**	**2.837**	**2.741**	**-3.674**	-2.029	1.973	1.380
Maros	**-3.682**	**-3.750**	**3.050**	**3.106**	**2.849**	**2.651**	**-3.851**	-2.063	2.088	1.291
Pangkep	**-3.736**	**-3.740**	**3.077**	**3.151**	**2.827**	**2.457**	**-3.883**	-2.103	2.151	1.298
Barru	**-3.538**	**-3.908**	**3.065**	**3.185**	**2.967**	**2.245**	**-3.675**	**-2.443**	**2.404**	1.711
Bone	**-2.696**	**-4.037**	**2.172**	**2.676**	**3.829**	**2.273**	**-3.197**	**-3.020**	**2.673**	**2.589**
Soppeng	**-3.414**	**-3.959**	**2.989**	**3.145**	**3.071**	**2.187**	**-3.600**	**-2.540**	**2.464**	1.874
Wajo	**-3.065**	**-4.106**	**2.681**	**2.922**	**3.439**	**2.148**	**-3.388**	**-2.822**	**2.614**	**2.282**
Sidrap	**-2.908**	**-4.110**	**2.509**	**2.806**	**3.586**	**2.664**	**-3.296**	**-2.923**	**2.657**	**2.422**
Pinrang	**-3.012**	**-4.085**	**2.619**	**2.846**	**3.501**	**2.760**	**-3.336**	**-2.864**	**2.620**	**2.307**
Enrekang	**-2.848**	**-4.056**	**2.457**	**2.741**	**3.603**	**2.877**	**-3.231**	**-2.956**	**2.667**	**2.447**
Luwu	**-2.670**	**-4.041**	**2.245**	**2.651**	**3.736**	**2.892**	**-3.153**	**-3.039**	**2.711**	**2.604**
Tana Toraja	**-2.685**	**-3.980**	**2.273**	**2.627**	**3.705**	**2.934**	**-3.121**	**-3.035**	**2.703**	**2.564**
North Luwu	**-2.693**	**-4.022**	**2.187**	**2.664**	**3.815**	**2.981**	**-3.181**	**-3.027**	**2.684**	**2.586**
East Luwu	**-2.692**	**-4.090**	**2.148**	**2.706**	**3.837**	**2.967**	**-3.231**	**-3.001**	**2.646**	**2.605**
North Toraja	**-2.700**	**-4.033**	**2.356**	**2.574**	**3.409**	**2.926**	**-3.086**	**-2.772**	**2.323**	2.017
Makassar	**-3.675**	**-3.744**	**3.039**	**3.060**	**2.857**	**3.050**	**-3.843**	**3.603**	**2.877**	**-3.231**
Parepare	**-3.182**	**-4.027**	**2.820**	**2.952**	**3.267**	**3.815**	**-3.405**	**-2.739**	**2.560**	2.117
Palopo	**-2.659**	**-4.022**	**2.203**	**2.641**	**3.776**	**3.837**	**-3.149**	**-3.045**	**2.707**	**2.611**

Bold= significant variable

Based on table 3, the results show that the Coverage of Vitamin A variable Giving to Infants (6-11 Months) in 2013 (X_1), Coverage of Vitamin a Giving to Infants (6-59 Months) in 2018 (X_2), Given Exclusive breastfeeding baby in 2013 (X_3), Baby Health Care Coverage (X_4), Malnutrition Toddler in 2018 (X_5), Basic Immunization Full Year 2013 (X_6), and Skinny Toddler in 2018 (X_7) have significant regression coefficients in all districts/cities. For the DPT3-HB-Hib3 Immunization in 2013 (X_8), Measles Immunization in 2013 (X_9) and BCG Immunization for 2013 (X_{10}) variables are only significant in several districts/cities, this means that the South Sulawesi government must pay attention to the areas of Selayar, Bulukumba, Bantaeng, Jeneponto, Takalar, Gowa, Sinjai, Maros, Pangkep, North Toraja, Barru and Pare-Pare in terms of providing DPT3-HB-Hib3, Measles and BCG immunizations. Table 3 shows the variables that are significant for stunting cases in each district/city in South Sulawesi Province, if made in the form of a map it will form into three clusters.

Figure 1. Map of regional clusters based on significant variables

Based on Figure 1, there are three clusters formed based on significant variables. The yellow cluster 1 consists of North Toraja, Barru, Soppeng and Pare-Pare with significant variables being X_1 to X_9. For cluster 2, the green color consists of Bone, Wajo, Sidrap, Pinrang, Enrekang, Luwu, Tana Toraja, East Luwu, North Luwu, Makassar and Palopo with all significant variables. Meanwhile, the blue cluster 3 consists of Selayar, Bulukumba, Bantaeng, Jeneponto, Takalar, Gowa, Sinjai, Maros, and Pangkep with significant variables being X_1 to X_7. With the mapping of the factors that influence the prevalence of stunting, it is hoped that the South Sulawesi government will be able to provide assistance to families in the first thousand days of life and provide nutrition intervention packages for children and pregnant women, by reducing stunting as an investment for a better future.

3.5 Goodness of Fit Model GWR

Some criteria used to see the accuracy of the model are by looking at the value of the coefficient of determination (R^2) and the value of the Akaike Information Criterion (AIC). R^2 value means how much influence is given from a significant explanatory variable on the response variable. R^2 obtained is 0.8132 which means that overall, the model obtained can explain 81.32% the spatial effect of vitamin A in 6-11 months, vitamin A in 6-59 months, exclusive breastfeeding, baby health services, cases of malnutrition, cases of underweight toddlers, as well as DPT-HB-Hib3, Measles and BCG immunization against stunting prevalence. The remaining 18.68% is explained by other variables outside the model.

4. CONCLUSION

Based on the results of the study concluded that the variables that affect the prevalence of stunting in South Sulawesi Province, among others, the percentage of babies who received vitamin A intake, the percentage of babies who received exclusive breastfeeding, the percentage of babies who received health services, the percentage of malnourished children under five, the percentage of short toddlers, the percentage of infants receiving DPT-HB-Hib, Measles and BCG immunizations. The GWR model, $\mathbf{R^2}$ is obtained by 81.32% and forms three clusters based on variables that are significant to the prevalence of stunting in South Sulawesi Province.

ACKNOWLEDGEMENT

REFERENCES

[1]   Aidi, N.M., Fitrah, E., and Siswanto., 2018. Analysis of Factors Affecting the Number of Poor People in Indonesia Using Geographycally Weighted Regression. *International Journal Scientific Research in Science Engineering Technology (IJSRSET)*, Vol.4, No.4, 1538-1553.

[2]   Badan Perencanaan dan Pembangunan Nasional. 2018. Pedoman Pelaksanaan Intervensi Penurunan Stunting Terintegrasi di Kabupaten/Kota. Jakarta (ID): BAPPENAS.

[3]   Chasco, C., García, R. and Vicens, O., 2007. Modeling spatial variations in household disposable income with geographically weighted regression. MPRA Paper No. 1682.

[4]   Dinas Kesehatan Profinsi Sulawesi Selatan. 2013. Profil Kesehatan Provinsi Sulawesi Selatan. Makassar.

[5]   Dinas Kesehatan Profinsi Sulawesi Selatan. 2018. Profil Kesehatan Provinsi Sulawesi Selatan. Makassar.

[6]   Fotheringham, A.S., Brunsdon, C. and Charlton, M. 2003. *Geographically weighted regression: the analysis of spatially varying relationships*. John Wiley & Sons.

[7]   Gwarda, K.L. 2018. Geographically Weighted Regression in the Analysis of Unemployment in Poland. *International Journal of Geo-Information*. Vol. 7. No. 17, 1-16.

[8]   Leong, Y.Y. and Yue, J.C. 2017. A Modifiaction to Geographically Weighted Regression. *International Journal of Health Geographics*. Vol. 16, No. 11, 1-18.

[9]   Mahdy, I. F., 2020. Pemodelan Jumlah Kasus Covid-19 Di Jawa Barat Menggunakan Geographically Weighted Regression. *In Seminar Nasional Official Statistics*, Vol. 2020, No. 1, 138-145.

[10]   Kementerian Kesehatan Republik Indonesia. 2019. Riset Kesehatan Dasar Dalam Angka (RISKESDAS 2018) Provinsi Sulawesi Selatan. Jakarta (ID): Lembaga Penerbitan Badan Litbangkes.

[11]   Picauly, I. and Toy, S.M., 2013. Analisis Determinan Dan Pengaruh Stunting Terhadap Prestasi Belajar Anak Sekolah Di Kupang Dan Sumba Timur, NTT. *Jurnal gizi dan pangan*, Vol.8, No.1, 55-62.

[12]   Sukarsa, I. K. G., and Kencana, I. P. E. N., 2019. Penerapan Metode Geographically Weighted Regression (GWR) Pada Kasus Penyakit Pneumonia Di Provinsi Jawa Timur. *E-Jurnal Matematika*, Vol. 8, No.1, 27-34.

[13]   Zhao, H., Ren, Z., and Tan, J., 2018. The spatial patterns of land surface temperature and its impact factors: spatial non-stationarity and scale effects based on a geographically-weighted regression model. *Sustainability*, Vol. 10, No. 7, 2242.