International Journal of Mosquito Research

ISSN: **2348-5906**
CODEN: **IJMRK2**
IJMR 2025; 12(2): 19-24

https://www.dipterajournal.com
Received: 11-01-2025
Accepted: 17-02-2025

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Geographically weighted regression (GWR) analysis of factors related to dengue Hemorrhagic fever in central java province, Indonesia

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DOI: https://www.doi.org/10.22271/23487941.2025.v12.i2a.830

Abstract
The Incidence Rate of DHF in Central Java Province in 2022 increased threefold. Each region has different conditions, it will be difficult to analyze only using global regression analysis. This research aims to analyze the spatial of risk factors associated with DHF cases in Central Java Province. This method used is GWR (Geographically Weighted Regression). The data used are secondary data based on data from the 2023 Indonesian Health Survey and Central Java Statistics Agency. The results show that the GWR model is better than the multiple linear regression model. The R^2 value of the GWR model (99.8%) is greater than the R^2 of linear regression model (84%). Significant factors in local regression are education, nutritional status, mosquito nest eradication practices, residential density, population density, and rainfall. The conclusion is mosquito nest eradication practices, education and nutritional status are the most influential factors of DHF in Central Java Province.

Keywords: Geographically weighted regression, dengue hemorrhagic fever, factor analysis

Introduction
Infectious diseases remain a major health problem in many countries, including Indonesia. One of the most significant infectious diseases is Dengue Hemorrhagic Fever (DHF), caused by the dengue virus and transmitted by the *Aedes aegypti* mosquito [1]. This disease is primarily found in tropical and subtropical regions, including Indonesia, and can cause a wide range of symptoms, from high fever, headache, and muscle pain to severe complications such as Dengue Shock Syndrome (DSS), which can lead to death [2].

Indonesia faces a substantial burden due to DHF, reflected in the increasing number of cases reported annually. In 2022, Indonesia reported over 143,000 DHF cases and 1,237 deaths, marking a significant increase compared to the previous year. Central Java Province is one of the regions with the highest incidence rate (IR) of DHF, with 35.55 cases per 100,000 population in 2022, far exceeding the national target of IR ≤10 per 100,000 population. The case fatality rate (CFR) for DHF in Central Java Province was also the highest in Indonesia, the fatal impact of DHF in the region remains considerable [3].

Several factors influence the transmission of DHF, including education level, nutritional status, the practice of mosquito nest eradication, housing density, and environmental conditions that support mosquito breeding [4]. Previous studies have shown that higher education levels are associated with increased knowledge of DHF prevention, while poor nutritional status increases susceptibility to dengue infections [5]. High population density, particularly in urban areas, is directly linked to increased disease transmission, as *Aedes aegypti* mosquitoes have limited flight range and are more likely to transmit the virus between individuals in densely populated environments. Additionally, poor environmental sanitation and rainy seasons create breeding grounds for mosquitoes, further exacerbating the incidence of DHF [6].

Although various prevention strategies have been implemented through national policies such as the National Dengue Prevention and Control Strategy 2021-2025, provinces like Central

Java still face challenges in reducing the incidence and mortality rates associated with DHF. Therefore, further research is needed to identify the risk factors associated with DHF occurrence using a spatial approach [7].

In reality, between one location and another location have different conditions so that data between observations will be difficult to analyze using linear regression analysis. Regional conditions can also affect research, both from geographical factors, or other factors [8]. Differences in regional conditions cause spatial data diversity. Ignoring the diversity of spatial data in the regression model will result in model incompatibility. Spatial diversity causes linear regression analysis to be less able to explain the phenomena that occur. Therefore, GWR (Geographically Weighted Regression) analysis is needed, which is a local regression technique that allows model parameters to vary at each location [9].

This research aims to analyze the spatial of risk factors associated with DHF cases in Central Java Province using GWR analysis. The GWR model is built from a point approach method, based on the position of the longitude and latitude coordinates. The parameters for the regression model at each location will produce different values [10]. GWR can accommodate spatial effects so that it can better explain the relationship between response variables and predictors. The GWR method is a method that can be used to form a local regression analysis for each location [11]. The findings from this study are expected to provide more detailed information to formulate more effective, evidence-based prevention strategies and support targeted policy-making to control DHF in regions with high incidence rates, such as Central Java Province.

Methods

This type of research is cross-sectional using data from the 2023 Indonesian Health Survey obtained from the Health Development Policy Agency and the Central Java Statistics Agency. The data used are secondary data in the form of education data, nutritional status, mosquito nest eradication practices, housing density in communities with Dengue Fever and data on population density, altitude and rainfall. The number of research samples was 301 cases. The unit of analysis was 35 districts/cities in Central Java Province. In this study, the inclusion criteria included all samples suffering from Dengue Fever during the past year in Central Java Province based on data from the 2023 Indonesian Health Survey.

This research uses the GWR method. GWR (Geographically Weighted Regression) is used to explore the relationship between spatial or geographical variables by considering the coordinate points of the region. GWR focuses more on local variations in the relationship between variables in each city, not just the global relationship that is uniform throughout the region. Before the GWR test is carried out, a multicollinearity test is carried out first, the process carried out in the first Geographically Weighted Regression (GWR) modeling is to determine the distance between one observation location and another based on the longitude and latitude of each district/city in Central Java. Then continued with the calculation of the weighting for each observation location using the fixed Gaussian kernel.

Results and Discussions

3.1 Respondent Characteristics

Table 1: Characteristics of Dengue Hemorrhagic Fever Cases in Central Java Province Based on the 2023 Indonesian Health Survey

Variable	Frequency	Percent (%)
Sex		
Male	137	45,5
Female	164	54,5
Age		
<15 years old	100	33,2
≥15 years old	201	66,8
Education		
Low Education	217	72,1
Higher Education	84	27,9
Nutritional Status		
Normal	111	36,9
Abnormal	190	63.1

Based on sex characteristics, it shows that cases of Dengue Fever in Central Java Province in 2023 based on the Indonesian Health Survey, were mostly suffered by females (54.5%) compared to males (33.2%). Cases of DHF in Central Java Province in 2023 based on the Indonesian Health Survey were mostly in those over 15 years of age (66.8%) compared to those under 15 years of age (33.2%). The average age of DHF sufferers is 30.32 years, with the youngest age being 4 months and the oldest age being 85 years. Meanwhile, according to education and nutritional status, cases of Dengue Fever were mostly experienced by respondents with low education (72.1%) and abnormal nutritional status (63.1%).

3.2 Geographically Weighted Regression Analysis

To determine the performance of the model, it can be seen from the R^2 and Residual Sum of Square (RSS) values. This value is used to evaluate the quality of the regression model. R^2 measures how well the independent variables in a model explain the variation of the dependent variable.

Table 2: Performance of Global Model and GWR

Model	R^2	RSS
Global Regression	0,84	78,89
GWR	0,998	1,05

Based on Table 2, it is known that the R^2 value in the global regression model is 0.84 while the GWR model is 0.998. This shows a higher performance of the GWR model. The RSS value of the global regression model is 78.89 while the GWR model is 1.05. Based on the comparison between RSS from the global and local regression models (GWR), the GWR model shows better performance in predicting data values. This shows that the GWR model is better at explaining the diversity of DHF cases in Central Java province.

The results of global regression modeling with Geographically Weighted Regression (GWR) are as follows. These are three of the seven variables that are significant in the t-test.

Table 3: Global Regression Results

Variabel	Estimate	Standard Error	t (Est/SE)
Intercept	-0,846365	1,466191	-0,577254
Low Education	0,433279	0,240027	1,805129
Poor Nutritional Status	0,397647	0,205189	1,937952
Poor Mosquito Nest Eradication Practices	0,610609	0,220727	2,766357

Based on the regression results in Table 3, the following regression equation can be seen.

$$y = -0{,}846365 + 0{,}433279\chi_1 + 0{,}397647\chi_2 + 0{,}610609\chi_3$$

The coefficient of the education variable is positive (0.433), this shows that every increase of one unit of low education will result in an increase in DHF cases of 0,433 units assuming other variables remain constant. It can be concluded that education has a positive effect on DHF cases. The coefficient of the nutritional status variable is positive (0.397), this shows that every increase of one unit of poor nutritional status will result in an increase in DHF cases of 0.397 units assuming other variables remain constant. It can be concluded that nutritional status has a positive effect on DHF cases. The coefficient of the mosquito nest eradication practices variable is positive (0.61), this shows that every increase of one unit of poor mosquito nest eradication practices will result in an increase in DHF cases of 0,61 units assuming other variables remain constant. It can be concluded that mosquito nest eradication practices have a positive effect on DHF cases.

Based on seven variables used to measure the magnitude of influence on DHF cases in Central Java, the Global Regression results showed that mosquito nest eradication practices practices, low education, and poor nutritional status were significant variables. The most influential factor on DHF cases in Central Java was the practice of mosquito nest eradication because it obtained a constant of 061.

Local regression modeling using Geographically Weighted Regression (GWR) with a fixed Gaussian kernel weighting function produces different models for each district in Central Java Province. The following is a description of the variables analyzed.

X1 = Low Education
X2 = Poor Nutritional Status
X3 = Poor Mosquito Nest Eradication Practices
X4 = Residential Density
X5 = Population Density
X6 = Area Altitude
X7 = Rainfall

The following are significant variables in the GWR model in each district/city in Central Java Province.

Table 4: Significant Variables in the GWR Model

Regency/City	Significant Variables
Grobogan, Jepara, Magelang City, Kudus, Magelang Regency, Sragen, Sukoharjo, Wonogiri	χ_1
Salatiga City	χ_1, χ_2
Semarang Regency	χ_1, χ_2, χ_4
Batang, Kendal, Temanggung	χ_3
Demak	χ_1, χ_4
Semarang City	χ_4
Karanganyar	χ_1, χ_5
Wonosobo	χ_5
Boyolali, Klaten, Surakarta City	χ_1, χ_7

In the GWR model with the Gaussian fixed kernel weighting function, the most significant variable in the model is the low education variable (X1) which occurs in 15 regencies/cities, namely Grobogan, Jepara, Magelang City, Kudus, Magelang Regency, Sragen, Sukoharjo, Wonogiri, Salatiga City, Semarang Regency, Demak, Karanganyar, Boyolali, Klaten, and Surakarta City. The poor nutritional status variable (X2) is significant in 2 regencies/cities, namely Salatiga City and Semarang Regency. The poor mosquito nest eradication practices variable (X3) is significant in 3 regencies/cities, namely Batang, Kendal, and Temanggung. The residential density variable (X4) is significant in 3 regencies/cities, namely Demak, Semarang City and Semarang Regency. The population density variable (X5) is significant in 2 regencies, namely Karanganyar and Wonosobo. Meanwhile, the regional altitude variable (X6) is not significant in the GWR model in regencies/cities in Central Java. The rainfall variable (X7) is significant in 3 districts/cities, namely Boyolali, Klaten, and Surakarta City.

The Geographically Weighted Regression (GWR) model of DHF cases in Central Java based on the 2023 Indonesian Health Survey data can be written as follows.

Overall, the GWR model formed for X1 has a positive value, meaning that the higher the low education rate in an area, the higher the dengue fever cases in that area. Variable X2 also has a positive value, meaning that the higher the malnutrition, the higher the dengue fever cases in that area. Variable X3 has a positive value, meaning that the higher the poor mosquito nest eradication practices in an area, the higher the dengue fever cases in that area. All variables X4 also have positive values, meaning that the higher the density of unqualified housing, the higher the dengue fever cases in that area. Variable X5 has a positive value, meaning that the higher the population density in an area, the higher the dengue fever cases in that area. Likewise, variable X7 has a positive value, meaning that the higher the rainfall in an area, the higher the dengue fever cases in that area.

Table 5: GWR Model for Each Regency/City in Central Java Province

Regency/City	GWR Model
Banjarnegara	-
Banyumas	-
Batang	$\hat{y} = 1{,}022245 + 1{,}039709\chi_3$
Blora	-
Brebes	-
Cilacap	-
Demak	$\hat{y} = -5{,}397026 + 1{,}875585\chi_1 + 5{,}765174\chi_4$
Grobogan	$\hat{y} = -3{,}916456 + 1{,}47491\chi_1$
Jepara	$\hat{y} = -13{,}025175 + 3{,}470453\chi_1$
Boyolali	$\hat{y} = -3{,}308217 + 0{,}959496\chi_1 + 0{,}001242\chi_7$
Karanganyar	$\hat{y} = -0{,}347681 + 1{,}176643\chi_1 + 0{,}000556\chi_5$
Kebumen	-
Kendal	$\hat{y} = 6{,}355125 + 1{,}984739\chi_3$
Klaten	$\hat{y} = -2{,}403178 + 1{,}099076\chi_1 + 0{,}001291\chi_7$
Magelang City	$\hat{y} = 0{,}640485 + 0{,}865895\chi_1$
Pekalongan City	-
Salatiga City	$\hat{y} = -3{,}30335 + 1{,}042266\chi_1 + 2{,}148593\chi_2$
Semarang City	$\hat{y} = -2{,}2791484 + 6{,}099247\chi_4$
Surakarta City	$\hat{y} = -1{,}503143 + 1{,}160768\chi_1 + 0{,}001516\chi_7$
Tegal City	-
Kudus	$\hat{y} = -15{,}886803 + 3{,}855515\chi_1$
Magelang	$\hat{y} = 0{,}119986 + 0{,}913069\chi_1$
Pati	-
Pekalongan	-
Pemalang	-
Purbalingga	-
Purworejo	-
Rembang	-
Semarang	$\hat{y} = -3{,}437561 + 1{,}074872\chi_1 + 0{,}303897\chi_2 + 2{,}537142\chi_4$
Sragen	$\hat{y} = -0{,}73472 + 1{,}066382\chi_1$
Sukoharjo	$\hat{y} = -1{,}231169 + 1{,}266985\chi_1$
Tegal	-
Temanggung	$\hat{y} = 6{,}544874 + 1{,}321503\chi_3$
Wonogiri	$\hat{y} = 3{,}080985 + 1{,}626801\chi_1$
Wonosobo	$\hat{y} = 2{,}535918 + 0{,}000582\chi_5$

Region That Need Attention Regarding Dengue Hemorrhagic Fever in Central Java

Low education has a dominant positive correlation with the number of DHF cases, meaning that in almost every district in Central Java, low education has a positive correlation with the number of DHF cases. There are outliers that have large positive coefficient values in Pati, Kudus, Jepara, and Rembang, which have coefficient values of 4.62; 3.86; 3.47; and 3.28 respectively. The four districts are close to each other and are located in the northern coastal area of Central Java. It can be concluded that improving the quality of education needs to be prioritized in this area.

Malnutrition has a fairly positive correlation with the number of DHF cases, meaning in some districts in Central Java. There are outliers that have large positive coefficient values on the malnutrition variable in Pati, Blora, Kudus, Rembang, and Jepara, which have coefficient values of 2.0; 1.32; 1.28; 1.32; and 1.2. The five districts are close to each other and are located in the northeastern part of Central Java. It can be concluded that improving nutritional quality needs to be prioritized in this area.

Poor mosquito nest eradication practices have a fairly positive correlation with the number of DHF cases, meaning in some districts in Central Java. There are outliers that have large positive coefficient values on the variable of poor mosquito nest eradication practices in Blora and Kendal, which have coefficient values of 2.7 and 2.0, respectively. Both districts are located in the eastern and northern coastal areas of Central Java. It can be concluded that improving mosquito nest eradication practices needs to be prioritized in these areas.

Residential density factor, the districts with the highest coefficient values are Semarang City, Demak, and Kendal with values of 6.10; 5.77; and 2.93. The three districts are close to each other and are located in the northern coastal area of Central Java. It can be concluded that increasing the quality of qualified residential density needs to be prioritized in this area.

Risk Factors That Need Intervention in Central Java

In local regression, education factor was significant in 15 regencies/cities, namely Grobogan, Jepara, Magelang City, Kudus, Magelang Regency, Sragen, Sukoharjo, Wonogiri, Salatiga City, Semarang Regency, Demak, Karanganyar, Boyolali, Klaten, and Surakarta City. In this study, there were 72.1% of dengue cases in Central Java who had low education. Good education will create a society that has good knowledge because knowledge can shape a person's actions. Low education can increase the risk of dengue cases due to limited knowledge, awareness, and skills in preventing and managing existing risk factors. Therefore, it is important to carry out more effective educational interventions, which are adjusted to the level of community understanding, as well as

expanding access to health information to groups with low levels of education. Appropriate education can help increase public awareness to take better dengue prevention measures. In Marwanty's research, the multivariate results showed that the interaction between low education levels would increase the risk of dengue fever by 2.87 times [12]. In Sari's research, almost all visitors who made efforts to prevent dengue fever had higher and secondary education. This is because in higher and secondary education there will be high knowledge about efforts to prevent dengue fever [5].

The poor nutritional status factor is significant in 2 regencies/cities, namely Salatiga City and Semarang Regency. Nutritional status is related to cases of Dengue Hemorrhagic Fever (DHF). Respondents with poor nutritional status can increase the incidence of DHF. Respondents with poor/less nutrition are more susceptible to transmission and infection of the dengue virus. Devi Yanuar Permatasari *et al*. (2015) obtained research results that there is a clear relationship between nutritional status and the degree of dengue infection. It was also found that respondents with poor/less nutritional status have a 9.474 times greater risk of contracting DHF. Overweight/obese nutritional status is 5.482 times more at risk of increasing the severity of DHF compared to good nutritional status [13]. Children with poor nutritional status are susceptible to dengue virus infection because low cellular immunity causes immunological memory and immune responses that have not yet fully developed, minimal formation of specific antibodies (CD4+ and CD8+ T-helper cells) causes interferon (IFN) production by macrophages to be unable to inhibit replication and spread of infection to cells that have not been affected [14]. In addition, antibodies to the DEN virus in the body will form antibody dependent enlacement (ADE) which increases infection and virus replication. In excess nutrition is a condition of abnormality or excess accumulation of fat in adipose tissue. Overnutrition is not only a condition with excess fat deposits, but also the distribution of fat throughout the body. Adipose tissue produces and secretes various bioactive molecules, called apecytokines, including adinopectin, leptin, and resistance. Adinopectin has a potent inflammatory effect. In excess nutritional status, there is a decrease in adinopectin, making it easier for an inflammatory response to occur. This occurs because nutritional status can affect the body's immune system [15].

The factor of poor mosquito nest eradication practices is significant in 3 districts/cities, namely Batang, Kendal, and Temanggung. Mosquito Nest Eradication Practices are related to cases of Dengue Hemorrhagic Fever (DHF). Research by Jumiati *et al*. (2015) found that respondents who did not carry out good mosquito nest eradication practices had a risk of contracting DHF 3.25 times higher than respondents who carried out good mosquito nest eradication practices. The lower the mosquito nest eradication behavior, the more the housing environment will support vector development and the higher the risk of DHF infection [14]. Research by Lirin Novitasari *et al*. (2018) found that in the group of cases with poor mosquito nest eradication practices, the risk factors for DHF were 3.986 times higher compared to the group that often carried out mosquito nest eradication practices. The more environments that support the development of larvae, the more mosquitoes will be and make it easier for humans and *Aedes* mosquitoes to come into contact, so that they have a high risk of being infected with dengue fever [16]. According to Yuslita's research (2023), there was a significant relationship between the use of larvicide powder and the use of mosquito repellent with the incidence of dengue fever in Pasar Muaradua Village, Muaradua Health Center Work Area in 2023 [17].

Conclusions

Based on this research, it can be concluded that the results of the Geographically Weighted Regression (GWR) regression are the best model for modeling DHF cases in Central Java Province compared to global regression. Low education, poor nutritional status, and mosquito nest eradication practices are the most influential factors and positive correlation to DHF cases in Central Java Province. The higher the number of low education, poor nutrition, and poor mosquito nest eradication practices, the more DHF cases will increase in Central Java Province.

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