Jurnal Kesehatan
Manarang

Jurnal Kesehatan Manarang, 12(1), April 2025, pp. 01-08
ISSN 2528-5602 (Online), ISSN 2443-3861 (Print)
doi: https://doi.org/10.33490/jkm.v12i1.2009

MODELING OF INFLUENTIAL FACTORS ON DENGUE FEVER INCIDENCE IN INDONESIA USING THE MULTIVARIATE ADAPTIVE REGRESSION SPLINE METHOD: A CASE STUDY IN EAST JAVA PROVINCE

Ardi Kurniawan✉, **Nabila Shafa Aflaha**, **Sabrina Salsa Oktavia**
Departement of Mathematics, Faculty of Science and Technology, Universitas Airlangga

ARTICLE INFO

Article history

Submitted : 2025-04-23
Revised : 2026-03-12
Accepted : 2026-04-12

Keywords:

Dengue Hemorrhagic Fever; sanitation; mosquito control; Multivariate Adaptive Regression Splines (MARS)

ABSTRACT

Indonesia, as a tropical country, continues to face mosquito-borne diseases, particularly Dengue Fever (DF), transmitted by the *Aedes aegypti* mosquito. This disease remains a significant public health issue, with fluctuating but generally high incidence rates across various regions. MARS (Multivariate Adaptive Regression Splines) is a non-parametric regression method that is adaptive in modeling non-linear relationships between dependent and independent variables and is capable of capturing interactions among independent variables. The best MARS model is one that has the lowest Generalized Cross Validation (GCV) and Mean Square Error (MSE) values. This study employs a quantitative approach using secondary data obtained from the 2023 Indonesia Health Survey Report. The MARS model for Dengue Fever prevalence in Indonesia is as follows: Y = 0.522 + 0.157 × BF1 – 0.046 × BF3 + 0.272 × BF8 + 0.038 × BF10 – 0.018 × BF12. The proportion of households without trash bins is the most influential factor affecting Dengue Fever prevalence in Indonesia, with an importance level of 100%. This is followed by the proportion of households not implementing mosquito control efforts, with an importance level of 37.811%, and the proportion of households without handwashing facilities, with an importance level of 35.669%. By inserting the Basis Function values into the model equation, it was concluded that the Dengue Fever prevalence in East Java Province (Y = 0.3881) is lower compared to the national prevalence in Indonesia (Y = 0.522) because variables X3 and X5 have lower values.

ABSTRAK

Indonesia sebagai negara tropis masih dihadapkan pada penyakit yang ditularkan oleh nyamuk *Aedes aegypti* yaitu Demam Berdarah Dengue (DBD). Penyakit ini menjadi masalah kesehatan yang signifikan dengan angka kejadian yang fluktuatif namun cenderung tinggi di berbagai wilayah. MARS merupakan metode regresi non-parametrik yang adaptif dalam pemodelan hubungan non-linear antara variabel dependen dan independen, serta mampu menangkap interaksi antar variabel independent. Model MARS terbaik adalah model yang memiliki nilai *Generalized Cross Validation* (GCV) dan nilai *Mean Square Error* (MSE) minimum. Jenis penelitian ini menggunakan metode kuantitatif dengan data sekunder yang diperoleh dari publikasi Laporan Survei Kesehatan Indonesia 2023. Pemodelan MARS pada prevalensi Demam Berdarah Dengue di Indonesia adalah $Y = 0{,}522 + 0{,}157 \times BF_1 – 0{,}046 \times BF_3 + 0{,}272 \times BF_8 + 0{,}038 \times BF_{10} – 0{,}018 \times BF_{12}$. Proporsi rumah tangga tidak memiliki tempat sampah menjadi faktor yang paling berpengaruh terhadap prevalensi Demam Berdarah Dengue di Indonesia dengan tingkat kepentingan 100%. Kemudian diikuti oleh proporsi rumah tangga tidak menerapkan upaya pemberantasan nyamuk dengan tingkat kepentingan 37,811% dan proporsi rumah tangga tidak memiliki fasilitas cuci tangan dengan Tingkat kepentingan 35,669%. dengan memasukkan nilai Basis Function ke dalam persamaan model, didapatkan kesimpulan bahwa Prevalensi Demam Berdarah Dengue di Provinsi Jawa Timur yaitu Y = 0,3881 lebih rendah jika dibandingkan dengan Prevalensi Demam Berdarah Dengue di Indonesia yaitu Y = 0,522 karena variabel X_3 dan X_5 memiliki nilai lebih rendah.

Kata Kunci:

Demam Berdarah Dengue; Sanitasi; Pemberantasan Nyamuk; Multivariate Adaptive Regression Splines (MARS)

✉ ***Corresponding Author:***
Ardi Kurniawan
Email: ardi-k@fst.unair.ac.id

INTRODUCTION

Indonesia, as a tropical country, is still faced with serious challenges related to Dengue Hemorrhagic Fever (DHF). The disease, transmitted by the *Aedes aegypti* mosquito, remains a significant public health problem with fluctuating incidence rates but tends to be high in various regions (Harapan et al., 2019). According to data from the Ministry of Health, in 2023 there were more than 130,000 cases of dengue fever with a Case Fatality Rate (CFR) of 0.7% (Indonesia Health Profile, 2023). In East Java Province, the number of dengue cases in 2023 reached 7,235, with an incidence rate of 17.96 per 100,000 people and 65 deaths (CFR = 0.9%). This figure shows that East Java bears a significant burden of dengue, even though cases nationwide are decreasing. The spread of dengue disease is inseparable from various environmental factors and community behavior, such as environmental sanitation, availability of clean water, waste management, and mosquito prevention (WHO, 2023).

Dengue is recognized as one of the fastest-growing mosquito-borne diseases in the world. The World Health Organization estimates that around 390 million dengue infections occur each year globally, with approximately 96 million cases manifesting clinically (Bhatt et al., 2013). The rapid increase in dengue incidence over the past decades has been closely associated with urbanization, population growth, globalization, and climate variability that facilitate the expansion of mosquito habitats and virus transmission (Brady et al., 2012). In tropical countries such as Indonesia, warm temperatures and high humidity provide ideal environmental conditions for the breeding and survival of *Aedes aegypti*, thereby increasing the potential for dengue outbreaks (Morin et al., 2013).

Dengue prevention and control are mainly aimed at reducing vector populations through efforts to *eradicate mosquito nests* (PSN) by draining, closing, and recycling water reservoirs (Indonesia Health Profile, 2023). Other preventive measures include the use of insecticides as mosquito repellent (Almeida et al., 2022), planting mosquito repellent plants (El Raheim Mohammed Donia et al., 2012), and keeping larvae-eating fish (Vanlerberghe et al., 2011). International studies have also demonstrated the effectiveness of community-based and technology-based interventions, such as the use of *Wolbachia-infected* mosquitoes (Utarini et al., 2021), climate prediction-based control approaches (Morin et al., 2013), and risk mapping using GIS technology (Leta et al., 2018). Various research efforts have been carried out to identify factors that contribute significantly to the prevalence of dengue. However, understanding the determinants of dengue transmission remains challenging due to the complex interactions among environmental, behavioral, and climatic factors (Messina et al., 2014).

Environmental sanitation and household infrastructure also play a crucial role in determining dengue transmission risk. Poor waste management, inadequate sanitation facilities, and the presence of open water containers can create breeding sites for mosquitoes and increase vector density in residential areas (Gubler, 2011). Several studies have shown that communities with limited access to sanitation and proper waste disposal systems tend to have higher risks of vector-borne diseases, including dengue fever (Troyo et al., 2009). Therefore, understanding how environmental sanitation factors interact with community behavior is essential in developing effective dengue prevention strategies.

In addition to environmental and sanitation factors, behavioral practices within households significantly influence mosquito breeding and disease transmission. Preventive actions such as regular elimination of stagnant water, proper waste management, and the consistent implementation of mosquito control programs have been proven to reduce vector populations and dengue incidence (Erlanger et al., 2008). However, the relationship between these factors is often complex and may involve non-linear patterns and interactions among multiple determinants. Consequently, advanced statistical and machine learning approaches are increasingly required to capture these complex relationships and provide more accurate insights into the determinants of dengue transmission (Messina et al., 2014).

In addressing this challenge, this study uses Multivariate Adaptive Regression Splines (MARS), an adaptive regression technique that is able to model non-linear relationships and identify the main predictors of dengue prevalence in Indonesia. MARS is an adaptive non-parametric regression method for modeling non-linear relationships between dependent and independent variables, and is able to capture interactions between independent variables (Rosenblatt, 1991).

The selection of the Multivariate Adaptive Regression Splines (MARS) model was carried out using *a stepwise* method consisting of *forward* and *backward* stages. *Forward* is done to get the function with the maximum number of bases. In the *backward* stage, one base function will be selected and output that base if the contribution to the model is small. The *backward* process will continue until no base function can be removed (Park et al., 2017). Compared to conventional statistical approaches, MARS offers several advantages in modeling complex epidemiological data. Traditional regression models often require assumptions such as linearity, normality, and predefined interaction structures, which may not adequately represent the complex relationships among environmental and behavioral factors associated with disease transmission (Hastie, 2009). MARS addresses these limitations by automatically selecting relevant variables, identifying interaction effects, and constructing flexible piecewise regression functions known as basis functions (James et al., 2013).

The best MARS models are those that have a minimum *Generalized Cross Validation* (GCV) value (Bekar Adiguzel & Cengiz, 2023). The GCV value is obtained from the sum of the squared residuals that have been corrected by the squares of the factors, such as the number of base functions, interactions, and the number of observations (Sriningsih et al., 2023). *Mean Square Error* (MSE) is the average square error between the actual value and the forecast value. MSE is also used as a criterion in MARS modeling, where the lower the MSE value, the better the model produced (Sabancı & Cengiz, 2022).

This study examines five independent variables related to environmental sanitation and mosquito control efforts: the proportion of households without access to defecation facilities, wastewater disposal systems, garbage containers, handwashing facilities, and mosquito eradication practices. Using the MARS method, this study aims to analyze the relationship between these factors and dengue prevalence across 38 provinces in Indonesia and identify potential interactions among them. The findings are expected to provide insights for policymakers in developing more targeted dengue prevention and control strategies in Indonesia.

METHOD

Research Design

This type of research uses a quantitative method that aims to measure and analyze the relationships between variables objectively through the collection of numerical data and the application of statistical techniques. This approach was chosen because it allows for systematic and measurable testing of hypotheses, so that it can provide generalizable results.

Data Collection

The data used in this study are secondary data, where data are obtained or collected by researchers from existing sources. The variables used consist of a dependent variable, namely the prevalence of Dengue Hemorrhagic Fever in 38 provinces in Indonesia in 2023, with five independent variables that are suspected to be influencing factors, including the proportion of households that do not have access to defecation facilities, the proportion of households that do not have a wastewater disposal site, the proportion of households that do not have a garbage can, the proportion of households that do not have handwashing facilities, and the proportion of households that do not implement mosquito eradication efforts. The data for this research were obtained from the publication of the 2023 Indonesian Health Survey Report.

Data Analysis and Processing

The initial stage of data analysis was carried out by calculating descriptive statistics for each variable. Furthermore, the analysis was conducted using the MARS method. To obtain the MARS model, the maximum number of Basis Functions (BF), Maximum Interactions (MI), and Minimum Observations (MO) were first determined. To obtain the best model, experiments were carried out on combinations of BF, MI, and MO so that the MARS model with a minimum GCV value and a maximum R-Square value was obtained.

RESEARCH RESULT

Descriptive Statistics

The characteristics of the incidence of Dengue Hemorrhagic Fever in Indonesia and the factors that are suspected to influence it can be presented in the form of descriptive statistics as presented in Table 1 below.

Table 1 Characteristics of Dengue Fever Incidence in Indonesia and the Suspected Influencing Factors

Variable	N	Mean	Min	Max
Y	38	0.72	0.26	3.90
X1	38	4.18	0.20	23.50
X2	38	24.17	0.30	70.90
X3	38	11.52	2.40	40.50
X4	38	20.37	2.30	62.00
X5	38	80.61	68.30	91.00

Table 1 show the following results :

1. The average prevalence of Dengue Hemorrhagic Fever in Indonesia (Y) is 0.72% with a minimum prevalence of 0.26% in Gorontalo Province and a maximum prevalence of 3.90% in Central Papua Province.
2. The average proportion of households that do not have access to defecation facilities in Indonesia (X_1) is 4.18% with a minimum proportion of 0.20% in DKI Jakarta Province and a maximum proportion of 23.50% in Papua Mountainous Province.
3. The average proportion of households that do not have a wastewater disposal site in Indonesia (X_2) is 24.17% with a minimum proportion of 0.30% in DKI Jakarta Province and a maximum proportion of 70.90% in East Nusa Tenggara Province.
4. The average proportion of households that do not have a garbage can in Indonesia (X_3) is 11.52% with a minimum proportion of 2.40% in Yogyakarta Province and a maximum proportion of 40.50% in Central Papua Province.
5. The average proportion of households that do not have handwashing facilities in Indonesia (X_4) is 20.37% with a minimum proportion of 2.30% in Bali Province and a maximum proportion of 62.00% in Mountainous Papua Province.
6. The average proportion of households that do not implement mosquito eradication efforts in Indonesia (X_5) is 80.61% with a minimum proportion of 68.30% in Papua Province and a maximum proportion of 91.00% in Riau Islands Province.

MARS Analysis

After conducting the experimental stage on the combination of BF, MI, and MO, the best MARS model results were the combination of BF = 15, MO = 2, with MI = 2 and 3. The GCV value for the best MARS model is 0.054 and R-Square is 0.866 and the shape of the model is as shown in the following equation:

$$Y = 0.522 + 0.157 \times BF_1 - 0.046 \times BF_3 + 0.272 \times BF_8 + 0.038 \times BF_{10} - 0.018 \times BF_{12}$$

with,

$BF_1 = \max(0, X_3 - 18.20)$;
$BF_2 = \max(0, 18.20 - X_3)$;
$BF_3 = \max(0, X_4 - 36.30)$;
$BF_7 = \max(0, X_5 - 75.70)$;
$BF_8 = \max(0, 75.70 - X_5)$;
$BF_{10} = \max(0, 5.50 - X_3) \times BF_7$;
$BF_{12} = \max(0, 76.30 - X_5) \times BF_2$;

The results of interpretation on each *Base Function* (BF) in the MARS model are as follows:

1. $BF_1 = \max(0; X_3 - 18.20)$

   With a coefficient value of 0.157, it shows that for every increase in BF_1 by one unit, the prevalence of dengue in every province in Indonesia will increase by 0.157%. BF_1 will have an impact on the prevalence of Dengue Hemorrhagic Fever in Indonesia (Y) when the value of the proportion of households that do not have a garbage can (X_3) is more than 18.20%. On the other hand, if $X_3 \leq$

18.20%, then it has no effect on Y.

2. $BF_3 = \max(0; X_4 - 36.30)$

With a coefficient value of -0.046, it shows that for every increase in BF_3 by one unit, the prevalence of dengue in every province in Indonesia will decrease by 0.046%. BF_3 will have an impact on the prevalence of Dengue Hemorrhagic Fever in Indonesia (Y) when the value of the proportion of households that do not have handwashing facilities (X_4) is more than 36.30%. On the other hand, if $X4 \leq 36.30\%$, then it has no effect on Y.

3. $BF_8 = \max(0; 75.70 - X_5)$

With a coefficient value of 0.272, it shows that for every increase in BF_8 by one unit, the prevalence of dengue in every province in Indonesia will increase by 0.272%. BF_8 will have an impact on the prevalence of Dengue Hemorrhagic Fever in Indonesia (Y) when the proportion of households that do not implement mosquito eradication efforts (X5) is less than 75.70%. Conversely, if $X4 \geq 75.70\%$, then it has no effect on Y.

4. $BF_{10} = \max(0; 5.50 - X_3) \times BF_7$

$BF_7 = \max(0; X_5 - 75.70)$

$BF_{10} = \max(0; 5.50 - X_3) \times \max(0; X_5 - 75.70)$

With a coefficient value of 0.038, it shows that for every increase in BF_{10} by one unit, the prevalence of dengue in every province in Indonesia will increase by 0.038%. BF_{10} will have an impact on the prevalence of Dengue Hemorrhagic Fever in Indonesia (Y) when the value of the proportion of households that do not have garbage cans (X_3) is less than 5.50% and the value of the proportion of households that do not implement mosquito eradication efforts (X_5) is more than 75.70%. When few households do not have garbage cans (good hygiene conditions), but many households do not implement mosquito eradication, it shows a positive interaction with the prevalence of dengue in Indonesia. This means that the lack of mosquito eradication efforts can still increase the risk of dengue even though hygiene conditions are more maintained.

5. $BF_{12} = \max(0; 76.30 - X_5) \times BF_2$

$BF_2 = \max(0; 18.20 - X_3)$

$BF_{12} = \max(0; 76.30 - X_5) \times \max(0; 18.20 - X_3)$

With a coefficient value of -0.018, it shows that for every increase in BF_{12} by one unit, the prevalence of dengue in every province in Indonesia will decrease by 0.018%. BF_{12} will have an impact on the prevalence of Dengue Hemorrhagic Fever in Indonesia (Y) when the proportion of households that do not implement mosquito eradication efforts (X_5) is less than 76.30% and the proportion of households that do not have a garbage can (X_3) is less than 18.20%. This means that the better the hygiene conditions and mosquito eradication efforts, the lower the risk of dengue.

Furthermore, from the MARS model, it can be seen that there are three predictor variables that are included in the model, namely variables (X_3), (X_4), and (X_5). To see the extent to which these variables affect the formation of the MARS model, it can be seen in the following Table 2.

Table 2 Importance Level of Predictor Variables

Variable	Importance Level
Lack of Trash Disposal Facility (X_3)	100.000%
Not Implementing Mosquito Eradication Efforts (X_5)	37.811%
Lack of Handwashing Facilities (X_4)	35.669%
Lack of Access to Toilet Facilities (X_1)	0.000%
Lack of Wastewater Disposal Facility (X_2)	0.000%

Based on **Table 2,** it can be seen that the variable not having a garbage can (X3) is the most important variable in the MARS model with a 100% importance level, followed by the variable not implementing mosquito eradication efforts (X5) with an importance level of 37.811%. In third place, the variable not having handwashing facilities (X4) has an importance level of 35.669%. Meanwhile, in the fourth and fifth positions, there are variables that do not have access to defecation facilities (X1) and do not have a wastewater disposal site (X2), which do not have an importance level (0%) because they have been represented by the previous three variables.

DISCUSSION

In this study, the MARS model is applied to data from East Java Province. This analysis aims to identify the extent to which environmental factors and household behavior influence the incidence rate of Dengue Hemorrhagic Fever in East Java Province. For the data from East Java Province, the values of each variable are X1 = 3.60, X2 = 18.70, X3 = 5.80, X4 = 10.20, and X5 = 75.70. Based on the calculation results, the values obtained are BF1 = 0, BF2 = 12.4, BF3 = 0, BF7 = 0, BF8 = 0, BF10 = 0, BF12 = 7.44.

Continuing by substituting the Basis Function values into the model equation, the result is Y = 0.522 + 0.157 × (0) – 0.046 × (0) + 0.272 × (0) + 0.038 × (0) – 0.018 × (7.44) = 0.3881. From this modeling result, it can be concluded that the prevalence of Dengue Hemorrhagic Fever in East Java Province, with Y = 0.3881, is lower compared to the prevalence in Indonesia, which is Y = 0.522. The main factor contributing to this decline is BF12, which is influenced by variables X3 and X5 having lower values. This indicates that East Java Province has effective waste disposal efforts and more frequent mosquito eradication within households, significantly helping to reduce dengue fever cases.

The interpretation of Y, which represents the prevalence of Dengue Hemorrhagic Fever, is calculated based on a combination of variables X3, X4, and X5. It shows a difference from the actual value obtained from the 2023 SKI Report for East Java Province, which is 0.49. This discrepancy is due to other factors such as rainfall, temperature, population density, or urbanization rates. However, this modeling remains useful for identifying general patterns of dengue fever risk factors but does not replace direct observational data.

CONCLUSION AND SUGESTION

The modeling of Dengue Fever prevalence in Indonesia using the Multivariate Adaptive Regression Splines (MARS) method is as follows: Y = 0.522 + 0.157 × BF1 – 0.046 × BF3 + 0.272 × BF8 + 0.038 × BF10 – 0.018 × BF12. The proportion of households without a trash disposal facility is the most influential factor affecting Dengue Fever prevalence in Indonesia, with an importance level of 100%. This is followed by the proportion of households not implementing mosquito eradication efforts, with an importance level of 37.811%, and the proportion of households without handwashing facilities, with an importance level of 35.669%.

For the example used in the MARS modeling application, data from East Java Province were used, with the result obtained being Y = 0.522 + 0.157 × (0) – 0.046 × (0) + 0.272 × (0) + 0.038 × (0) – 0.018 × (7.44) = 0.3881. The main factor contributing to this reduction is BF12, which is influenced by variables X3 and X5 that have lower values. This indicates that East Java Province has effective waste disposal efforts and more frequent mosquito control implemented within households, which significantly helps reduce dengue fever cases.

Modeling the prevalence of Dengue Hemorrhagic Fever in Indonesia using the MARS method may produce results that differ from actual values due to various influencing factors such as rainfall, temperature, population density, and urbanization. Nevertheless, this modeling remains useful for identifying general patterns of dengue risk factors. The findings of this study are expected to provide insights and recommendations for the government, particularly the Ministry of Health, to strengthen public awareness and prevention efforts. Future studies are encouraged to incorporate additional variables and improved methodologies to enhance the accuracy of dengue prevalence modeling in Indonesia.

By identifying the best modeling approach for the prevalence of Dengue Fever in Indonesia across 38 provinces using the Multivariate Adaptive Regression Splines (MARS) method, this study is expected to provide suggestions and recommendations to the government, particularly the Ministry of Health, to continue educating the public about the factors that cause Dengue Fever. For future research, this study can be improved by employing a more refined methodological approach, so that the modeling results for Dengue Fever prevalence in Indonesia become more accurate.

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