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Model Prediction of Incident Dengue Fever Based on Climate Factors with Multivariate Adaptive Regression Spline Longitudinal

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ABSTRACT

Climate change impact on the possibility of improvement of incident that continuously from vector borne disease. Dengue fever is one of the infectious diseases due to poor environmental conditions. Dengue fever is a condition of the emergence of incident pain or death by epidemiologis on a region in a specific period of time. The purpose of this research is to predict what variables that have a role in influencing the incident dengue fever. The results of the study showed that with the approach of MARS longitudinal, that the case of dengue fever from 2006 until 2014 influenced by the air pressure, temperature, humidity and rainfall that many occurs on the month and year. Increase in case of dengue fever occurred in the year 2006, namely on when the rainfall between 148 mm until with 288 mm, on 2009 on at humidity more than 66 percent will occur increase of 17.839, and on know 2013 at the time when wind speed under 6.2 knot an increase of 1757.892, and on when the rainfall is more than 359.3 mm an increase of 3.294.
KEYWORDS: *Dengue Fever*, Climate Change, Longitudinal, MARS

INTRODUCTION

Dengue Fever is one of the infectious diseases due to poor environmental conditions caused by virus *dengue* through the teether mosquitoes *Aedes aegypti* and *Aedes albopictus*. The disease can cause an interruption in the blood vessels capillaries, heavy bleeding, blood clotting system until the cause of death.

The spread of the dengue fever disease can be caused by high population mobility, the development of urban areas, climate change, urbanisation, etc. The diversity of climate change can affect a wide spectrum of infectious diseases, either directly or indirectly [1]. Climate change causes changes rainfall, temperature, air humidity and wind direction so that affect the reproduction of vectors of diseases such as the mosquito *aedes*, *malaria*, etc. [2]. High rainfall will cause the temperature of the environment become low and air humidity to high. On the condition the multiplication of mosquitoes *aedes* will increase so that need to be monitored the increase in many cases dengue fever.

In Indonesia, dengue fever often causes of extraordinary events and plague. The extraordinary events are a condition of the emergence or increased incidents of pain or death by epidemiologis on a region in a specific period of time. In 2013, patients with dengue fever which spread all over the country by 112511 cases, while in the year 2014, cases DB decline of 100347 cases with death as much as 907 people [3].

The province of East Java, in 2014 was recorded as the third highest province for many cases of death due to DB, namely as many as 107 cases. Based on the data obtained from 2006 until 2014, cases DB in Surabaya City always occupies the highest number of good for many patients and many cases of death compared with other districts in East Java Province. In 2013, in Surabaya City there are 2.196 DB patients with cases of death as much as 15 people. Later in the year 2014, a decline namely there are 816 patients and 17 cases of death [4].

According to [5], some of the factors that affect the spread of the disease dengue fever is the parent factor (host), the environment and factors pathogens (virus). The parent factor regarding the vulnerability of the human body and immunity against disease, while environmental factors regarding the geographical (height from the surface of the sea rainfall, wind, humidity, seasons), demographic conditions (density, mobility behavior, customs, social economy population) [6]. The factor pathogens regarding the type and density of mosquitoes as vectors of penular disease. Climate factors have an important role to rising disease Dengue Fever namely, air temperature and humidity rainfall. Changes in the air temperature and the availability of water is the main determinan perkembang of scattered and spread of mosquitoes Dengue Fever [7]. The predictors variables to incident dengue fever more than one variable and interact with each other and the pattern of the relationship between the response variable with are variable predictors not yet known and used *Multivariate Adaptive Regression Splines* (MARS) [8][9].

Research related to MARS, [10] using Bootstrap in MARS for the classification of MARS, [11] modeling villages left behind in West Java. While data modeling longitudinal, [12][13][14][15] and [17] investigate assessment and inference longitudinal observation in the case of linier and linier multivariate regression model.

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With the increasing case of dengue fever from year to year, then researchers want to predict what variables that have a role in influencing the incident dengue fever with the MARS longitudinal approach, so with know a factors that act against the incident Dengue Fever is expected to be used as a reference for the prevention and control of a case of dengue fever.

METHODOLOGY

Dengue fever and climate data is a secondary data obtained from the Health Office [4] and the Central Statistics Agency [18]. Climate data is the result of observation, the Meteorology and Geophysics Agency Juanda station. Case dengue fever and climate data that is used is the data per month from January 2006 until December 2014. Many cases of dengue fever in Surabaya City as a response variable, while the climate as predictors variables. In this research, factors that become attention is geographically environmental factors include air humidity (%), air pressure (mbs), temperature *(°C)*, the duration of the flashes sun (%), Rainfall (mm), and the wind speed (knot).

A case of dengue once again comes can be described according to the following concepts.

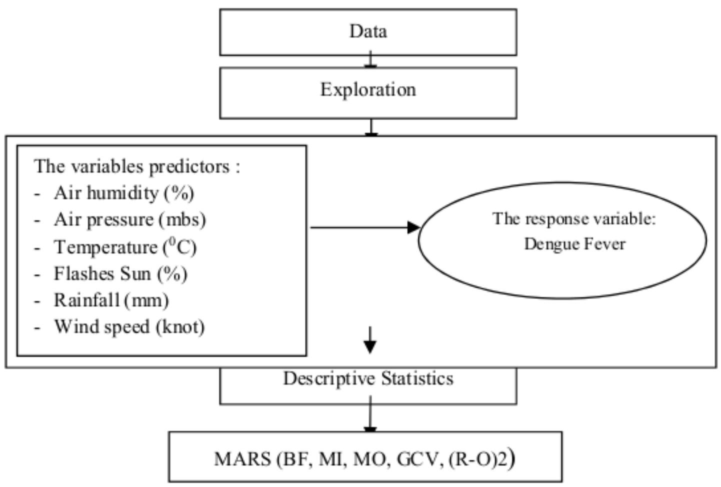

Figure 1. Modeling flow MARS on Incident Dengue Fever

MARS implement stepwise forwad/backward selection strategy. Determine the model of MARS is optimal among the other models is by selecting the model that has the lowest GCV value. MARS can find location and the number of the required knot through the stepwise procedure [8][9]. Forward stepwise done to get the function with the number of maximum base function with minimize Average Sum of Square Residual (ASR). backward stepwise parsimony done model, aims to select the function of the base is produced from the forward stepwise to minimize the value of GCV [9][10].

The minimum GCV function is defined as:

$$GCV^*(M) = \frac{ASR}{[1-\frac{C(M)^*}{n}]^2} = \frac{\frac{1}{n}\sum_{i=1}^{n}[y_i-\hat{f}_K(x_i)]^2}{[1-\frac{C(M)^*}{n}]^2}$$

The general model of MARS equation can be written as follows[9]

$$\boldsymbol{f(x) = \alpha_0 + \sum_{m=1}^{M} \alpha_m \prod_{k=1}^{K_m} [s_{km} \cdot (x_{v(k,m)} - t_{km})]_+ + \varepsilon_i}$$

Where,

$\boldsymbol{\alpha_0}$ = function of the parent basis (constant basis function),
$\boldsymbol{\alpha_m}$ = coefficient from the basis function to-*m*,
M = maximum basis function (non-constant basis function),
K_m = degrees of interaction,
$\boldsymbol{s_{km}}$ = worth 1 if data is located to the right of the *knot point*, or worth -1 if data is located at the left of the *knot point*,
$\boldsymbol{x_{v(k,m)}}$ = variables predictors
$\boldsymbol{t_{km}}$ = the value of the *knot* from the variables predictors $x_{v(k,m)}$.

RESULTS AND DISCUSSION

Description of this research includes the mean and standard deviation from each of the research variables. Now in detail is presented in the following table.

Table 1. The value of the Mean and Standard deviation of variables Research

Mean Deviation Standard	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
Many cases of dengue fever (Y)	348.75	267.83	180.75	175.00	281.58	92.33	90.92	183.00	68.00	187.57
	308.78	180.91	127.52	112.95	169.14	68.11	54.85	176.68	31.34	136.69
Humidity (%) (X1)	76.60	73.63	76.58	75.92	79.33	76.67	77.17	79.17	75.67	76.75
	7.31	14.780	5.97	6.50	2.8	4.96	5.71	7.37	6.19	6.84
The air pressure (MBS) (X2)	1010.89	1010.38	1010.30	1010.58	1009.97	1010.13	1010.53	1010.18	1011.05	1010.44
	1.79	1.1169	1.29	1.24	1.20	1.67	1.62	1.28	1.23	1.38
Temperature (0C) (X3)	27.41	27.9	27.43	27.72	27.82	27.30	27.24	27.72	28.03	27.62
	1.16	0.82	0.85	0.92	0.41	0.85	1.29	0.89	0.99	0.91
Flashes Sun (%) (X4)	77.78	72.48	70.25	75.88	61.72	69.08	72.03	61.78	71.08	70.23
	19.32	21.28	21.81	16.99	19.75	22.86	24.13	19.91	23.52	21.06
Rainfall (mm) (X5)	185.19	126.28	125.24	210.58	241.25	149.09	115.79	189.17	165.08	167.52
	259.96	160.81	129.80	259.35	169.97	136.69	129.51	155.78	149.04	172.32
Wind speed (knot) (X6)	6.08	7.77	7.32	6.57	6.58	7.22	7.28	7.05	7.31	7.02
	2.22	0.88	1.73	1.12	0.62	0.77	0.81	0.77	0.93	1.09

Table 1 shows that the average number of cases of dengue fever of 188 cases, most happened in 2006 and least in the year 2014. The moisture provides value by an average of 76.75 %, most high occurred in 2010 at 79.33% and most a low in 2007 of 73.63%. The air pressure provides value by an average of 1010.44 MBS, most high occurred in the year 2014 at 1011.05 and least 2011 of 1010.13 mbs. Temperature gives the value of the average 27.62^{0}C, most high occurred in the year 2014 by 28.03^{0}C and least 2012 in 27.24^{0}C. Flashes sun provides value by an average of 70.23 %, most high occurred in the year 2006 at 77.78 % and least 2010 at 61.72%. The rainfall provides value by an average of 167.52 mm, most high occurred in 2010 by 241.25 mm and least 2012 in 115.79 mbs. Wind speed provides value by an average of 7.02 knot, most high occurred in the year of 2007 of 7.77 knot and most low of 2006 6.08 knot. This indicates integrators said from 2006 until 2014 have high humidity, so mosquitoes become more active and often bite so that improve the transmission of dengue fever, and is supported by the temperature optimum enough for the growth of mosquitoes.

The election of the best model obtained with how to compare the value of GCV and $(R\text{-}O)^2$. The value of the smallest GCV and values $(R\text{-}O)^2$ largest is the best model. The comparison is done on the various number of basis functions (BF), maximum interaction (MI) and minimum observation (MO). All possible model that has been obtained of trail a best model with the criteria model that has the value of the smallest GCV and $(R\text{-}O)^2$. The best model on the BF=32, MI=2 and MO=1 with GCV = 10188.593 and $(R\text{-}O)^2$ = 0.937 is as follows:

$$\begin{aligned} Y = 445.418 &- 38.016\,BF1 - 88.975\,BF2 + 168.396\,BF4 - 45.224\,BF5 - 34.492\,BF10 + 0.154\,BF15 \\ &+ 62.422\,BF17 - 227.208\,BF23 - 170.263\,BF24 + 207.082\,BF26 - 236.272\,BF28 \\ &+ 25.557\,BF30 - 15.021\,BF32 \end{aligned} \quad (1)$$

with

BF1 = max(0, MONTH - 3)
BF2 = max(0, 3 - MONTH)
BF4 = max(0, 2008 – YEAR)
BF5 = max(0, MONTH - 9) *BF4
BF9 = max(0, X3 - 28.000)
BF10 = max(0, 28.000 - X3)
BF15 = max(0, X5 - 20.800) * BF4
BF17 = max(0, X1 - 77.000) * BF9
BF23 = max(0, 5 - MONTH) * BF9
BF24 = max(0, YEAR - 2010)
BF25 = max(0, 2010 - YEAR)
BF26 = max(0, YEAR - 2011)
BF28 = max(0, YEAR - 2013)
BF30 = max(0, MONTH - 3) *BF28
BF32 = max(0, X2 - 1006.900) * BF25.

The above equation can be interpreted that a case of dengue fever after March occurred decline of 38.016, and before the March occurred decline of 88.975. Increase in case of dengue fever occurs before the year 2008 168.396, after 2010 of 170.263, then after 2011 until 2013 of 207.082, and then a drop in the case of dengue fever after 2013 of 236.272. A case of dengue fever after the ninth month and before the year 2008 will happen decline of 45.224, while the case of dengue fever after the 3 month and after 2013 will be an increase of 25.557. The case of dengue fever on when the rainfall is above 20.8 mm and before the year 2008 will be an increase of 0.154. The case of dengue fever on when the temperature (X3) under 28^{0}C occurs a decline of 34.492. The case of dengue fever at the moisture (X1) above77% and temperatures (X3) above 28^{0}C an increase of 62.422. The case of dengue fever before the month of May and temperatures (X3) above 28^{0}C occurs a decline of 227.208. The Case of dengue fever on when the air pressure (X2) more than 1006.9 mbs and before 2010 occurred decline of 15.021.

This shows that the air humidity above 77% affect the age of mosquitoes and can be vectors, because enough time for the movement of the virus from the stomach to the saliva glands. So that will improve a case of dengue fever.air pressure is closely related with temperature, the lower the temperature of an place, then the air pressure will be more. This will also affect the survival of mosquitoes. The air pressure (X2) more than 1006.9 mbs and before the year 2010 is a high air pressure, so mosquitoes will not be able to survive, this result in a decline a case of dengue fever, especially before 2010.

Temperature (X3) above 28^{0}C will slow the growth of mosquitoes, so that result in a decline a case of dengue fever. Rain can affect the life of mosquitoes in two ways that is causing the rising air humidity and add the brood. Every 1 mm rainfall increase the density of mosquitoes 1 tail, but if the rainfall in the 1 weeks of 140 mm, then the larvae will be swept away and die, so that the density of mosquitoes decreases. The high rainfall will increase the number of the place of the multiplication of mosquitoes natural. The waste dry waste like old bottles, cans, and leaves that allows collect the rain water is the preferred brood place to spawn the mosquito *Aedes aegypti*. rainfall above 20.8 mm and before the year 2008 will be an increase of 0.154.

The wind can affect on a flight and the spread of mosquitoes. If the wind speed 11-14 m/seconds or 25-31 miles/hour, will impede the airlines mosquitoes. Wind speed on when the sun rises and sets a time fly lice to in or out of the house where this affects the number of contacts between men with mosquitoes.

Table 2. The Best Model a Case of Dengue Fever various BF, MI, MO Based GCV and $(R\text{-}O)^2$

Year	**GCV**	**$(R\text{-}O)^2$**	**Prediction Model**
2006	31971.759	0.957	Y = 119.396 - 4.387 * BF1 + 4.424 * BF3; BF1 = max(0, X5 - 288.200) BF3 = max(0, X5 - 147.900)
2007	35704.230	0.705	Y = 267.833
2008	17742.174	0.687	Y = 180.750
2009	4743.063	0.972	Y = 32.959 + 17.839 * BF1 - 0.166 * BF2; BF1 = max(0, X1 - 66,000) BF2 = max(0, X5 + .923067E-05)
2010	31211.596	0.751	Y = 281.583
2011	3076.851	0.985	Y = 246.708 - 98.809*BF1 - 330.497*BF2 - 39.623*BF3 - 1,995*BF4; BF1 = max(0, X3 – 26.800) BF2 = max(0, 26.800 - X3) BF3 = max(0, X4 – 92.000) BF4 = max(0, 92.000-- X4)
2012	3076.745	0.843	Y = 112.944 - 8.260 * BF2 BF2 = max(0, 78,000 - X1)
2013	18726.932	0.897	Y = + 94.922 1757.892 * BF2 + 3.294 * BF3; BF2 = max(0, 6,200 - X6) BF3 = max(0, X5 - 359.300)
2014	820.333	0.949	Y = 94.873 - 4.204 * BF2 - 3.552 * BF4; BF2 = max(0, 77,000 - X1) BF4 = max(0, 54,000 - X4)

Table 2 shows the best model on each year based on the smallest GCV criteria and $(R\text{-}O)^2$. The model of the case of dengue fever in 2006, incident dengue fever influenced by factor rainfall, on when rainfall (X5) more from 288.2 mm will occur 4.387 decline and at the time of rainfall (X5) more from 147.9mm to 288.2 mm will be an increase of 4.424. In 2007, 2008 and 2010 model of a case of dengue fever each constant of 267.833, 80.750 and 281.583. The model of the case of dengue fever 2009 influenced by moisture factor (X1) and rainfall (X5), at humidity (X1) more than 66 percent will occur increase of 17.839 and when the rainfall (X5) occurs a decline of 0.166. The year 2011, the model of the case of dengue fever was influenced by temperature factor (X3) and flashes of the sun (X4), on when the temperature (X3) more than 26.8^{0}C will happen decline of 98.809, on when the temperature (X3) less than 26.8^{0}C will happen decline of 330.497, at flashes of the sun (X4) more than 92 percent will happen decline of 39.623 and on when the flashes of the sun (X4) less than 92% will happen decline of 1,995. The model of the case of dengue fever 2012, influenced by factor moisture on when the moisture less than 78 % occurs a decline of 8.26. 2013, model a case of dengue fever was influenced by wind speed (X6) and rainfall (X5), on when the wind speed under 6.2 knot an increase of 1757.892, and on when the rainfall is more than 359.3 mm an increase of 3.294. The model of the case of dengue fever the year 2014, influenced by moisture factor (X1) and flashes of the sun (X4), at humidity (X1) less than 77 percent will happen decline of 4.204 and on when the flashes of the sun (X5) less than 54 percent decline of 3.552.

Flashes of the sun affect the entire climate components such as temperature rainfall, and the air pressure. The longer the duration of the flashes of the sun, then the temperature will go up while the rainfall and the air pressure will drop. Mosquitoes prefer a shady and not be exposed to direct sunlight.

CONCLUSION

1. The Model that describes the relationship of factors that affect the case of dengue fever in Surabaya City with the method of Mars is model on the criteria BF=32, MI=2 and MO=1 with GCV = 10188.593 and $(R\text{-}0)^2$ of 0.937. Case of incident dengue fever from 2006 until 2014 influence by air pressure (mbs), temperature (^{0}C), Humidity (%), Rainfall (mm) that many occurred on the month and year.

2. Increase in case of dengue fever occurred in the year 2006, namely on when the rainfall between 148 mm until with 288 mm, on 2009 on at humidity (X1) more than 66 percent will occur increase of 17.839, and on know 2013 at the time when wind speed under 6.2 knot an increase of 1757.892, and on when the rainfall is more than 359.3 mm an increase of 3.294.
3. Decline in case of dengue fever occurred in 2011, namely on when the temperature (X3) more than 26.8^0C will happen decline of 98.809, on when the temperature (X3) less than 26.8^0C will happen decline of 330.497, at flashes of the Sun (X4) more than 92 percent will happen decline of 39.623 and on when the flashes of the Sun (X4) less than 92% will happen decline of 1,995, and in the year 2014, namely on when the humidity (X1) less than 77% will happen decline of 4.204 and on when the flashes of the sun (X5) less than 54% decline of 3.552

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