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Prediction Model of Dengue Hemorrhagic Fever Incidence Using Climatic Factors in Kabupaten Gorontalo

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Abstrak

Kasus demam berdarah termasuk kedalam salah satu masalah yang dihadapi oleh seluruh negara ASEAN, sehingga status wilayahnya telah ditetapkan menjadi hiperendemik dalam 10 tahun terakhir. Global warming diprediksikan dapat mengakibatkan peningkatan suhu rata-rata permukaan bumi sebesar 2,0 ºC hingga 4,5 ºC ditahun 2100, yang akan berdampak langsung pada penyakit yang diakibatkan oleh vektor. Penelitian ini bertujuan mengkaji hubungan faktor iklim terhadap kejadian demam berdarah dan mencari model prediksi kejadian demam berdarah di Kabupaten Gorontalo. Data penelitian menggunakan data sekunder dari tahun 2012 – 2016, yang meliputi data iklim (suhu rata-rata, lama penyinaran, curah hujan, hari hujan, dan rata-rata kecepatan angin) perbulan yang diperoleh dari Badan Meteorologi dan Geofisika (BMKG) Kelas II Gorontalo dan data kejadian demam berdarah merupakan data insidens perbulan yang diperoleh dari dari Dinas Kesehatan Kabupaten Gorontalo. Berdasarkan nilai determinant values (R^2) dari lima model yang dihasilkan diperoleh nilai sebesar 13,4 % dengan p value = 0,004 dan persamaan regresi linear dengan menggunakan metode backward diperoleh nilai persamaan y = 42,948 + (0,686 × 130,48) yang hasilnya 132,54. sehingga diperkirakan jumlah kasus demam berdarah di Kabupaten Gorontalo dalam setahun mencapai 132 kasus. Selain faktor iklim, meningkatnya angka kasus kejadian demam berdarah dapat pula disebabkan oleh urbanisasi, kepadatan penduduk, tingginya mobilisasi penduduk, perilaku masyarakat, keberadaan dan kualitas fasilitas serta layanan kesehatan yang diperoleh oleh masyarakat. Alangkah baiknya perlu dilakukan improvisasi baik pada saat perencanaan program pencegahan dan penerapannya. Serta mendesain program pencegahan dan pengendalian penyakit berbasis spasial yang menganalisis seluruh parameter iklim, demografi, dan lingkungan yang menjadi penyebab tingginya angka kejadian demam berdarah

Abstract

All countries of ASEAN member agree that dengue fever is one of the major problems faced by all ASEAN countries so the status of their territory has been determined to be hyperendemic in the last 10 years. Global warming is predicted to result in an increase in the average temperature of the earth's surface by 2,0^{O}C to 4,5^{O}C in 2100, which will have a direct impact on diseases caused by vectors. This study aims to examine the relationship of climate factors to the incidence of dengue fever and find a predictive model of dengue fever in Gorontalo regency. This research data used secondary data from 2012-2016, which included climate data (average temperature, irradiation time, rainfall, rainy days, and average wind speed) per month obtained from the Meteorology and Geophysics Agency (MGA) Gorontalo Class II and dengue fever incidence data were monthly incident data obtained from the Health Office Gorontalo regency. Based on the values of determinant values (R^2) of the five models that were obtained, the value is 13,4% with p value = 0,004 and the linear regression equation using the backward method. Thus, estimated number of cases of dengue fever in Gorontalo Regency in a year reached 132 cases. Besides climate factors, the increasing number of cases of dengue fever might be caused by urbanization, population density, high population mobilization, community behavior, existence and quality of facilities and health services obtained by the community. Improvisation is needed for planning prevention programs and its implementation. As well as designing spatial-based disease prevention and control program that analyzes all climate, demographic and environmental parameters that are the causes of the high incidence of dengue fever.

BACKGROUND

Dengue fever in the last three decades has become a global problem shown by the increasing number of dengue fever cases throughout the country, which have tropical and subtropical climates which generally occur in urban areas. This disease is caused by a virus of *Flaviviradae* family and spread by the *Aedes sp*. The presence of uncontrolled mosquito existence in densely populated areas is one of the supporting factors, which causes a high incidence of dengue fever every year. Therefore, the effective step used to prevent dengue fever is to break the chain of transmission of the virus thrugh vector control of the cause (WHO, 2011)

All countries of ASEAN member agree that dengue fever is one of the major problems faced by all ASEAN countries so the status of their territory has been determined to be hyperendemic in the last 10 years. The determination of ASEAN countries to become a hyperendemic region also influences the burden of the economy. One of Indonesia's closest neighboring countries, namely Malaysia every year (since 2002-2007) allocated costs with estimated expenditures reaching 133 million dollars with an average estimated expenditure (88 - 215 million dollars) for activities that include handling patients, vector control , and research and development of dengue fever control. Thailand annually (from 2000-2005) incurred costs with an estimated expenditure of 135 million dollars with an average estimated expenditure (56-264 million dollars). Both of these countries each issued different budgets to reduce dengue fever rates. Malaysia spent 41.3% of its total budget of (54.9 million Dollars) and Thailand issued 49% of its total budget (66.2 million dollars) (Lim *et al.,* 2010). Thus, according to WHO countries in Southeast Asia and the Western Pacific region have represented 75% of dengue problems globally (WHO, 2011)

Based on the results of modeling studies that had been conducted in several regions, it shows that the high incidence of dengue fever or the outbreak of dengue fever was directly affected by the rainy season and the phenomenon of *el nino* (Bhatia *et al.,* 2013). Research conducted by Promprou 2005 in Thailand had found that climate factor plays a role in the transmission cycle of dengue fever. But the role varies because it is influenced by geographical location (Bhatia *et al.,* 2013). Ecological conditions factors significantly influence the development cycle of *Aedes sp*. Low air temperature and high humidity affect the behavior of *Aedes sp* mosquito that behave *hygrophilic*. The *hygrophilic* nature of mosquito, associated with the outbreak of dengue fever is influenced by climate factors, where the mosquito lives and breeds (Bhatia *et al.,* 2013)

Temperature condition is closely related to the amount of rainfall occurring, because of its role as an evaporation rate regulator which also affects the presence of puddle. Rainfall, temperature and humidity indirectly affect the condition of the land that has to do with the condition of vegetation, which can trigger or inhibit the growth of vector populations in the environment. Based on research conducted Troyo, *et al.,* 2009 and Van Benthem *et al.,* 2005 in (Morin *et al.,* 2013) the incidence of dengue fever is closely related to the condition of vegetation, the presence of trees, the quality of occupancy, and the total used and unused area. The phenomenon of climate change can change the way humans use their land and this has an impact on increasing dengue vector population in the environment. This is in accordance with research conducted by Chang *et al*. 1997 and Vanwambeke *et al.,* 2007 (Morin *et al.,* 2013) that transfer of land function that is not suitable for use can affect the number and population of mosquito species in environment.

Global warming is predicted to result in an increase in the average temperature of the earth's surface by 2,0 ºC to 4,5 ºC in 2100, which will have a direct impact on diseases caused by vectors. Climate change caused by global warming that triggers an increase in temperature of 2,0 ºC can shorten the incubation period of the dengue virus, so the number of infectious mosquito increases and its presence in the environment will become longer. In addition, mosquito will bite humans more often because of the dehydration they experience so the contact between humans and mosquito will increase. It is estimated that 5 to 6 billion people or (50% - 60% of the world's human population) will be at risk of infected dengue fever if climate change continues to occur but the number of risky populations can be reduced to 3.5 billion or (35% of the human population) if climate change can be controlled (WHO, 2011)

Until 2015 dengue fever was a disease that threatened Gorontalo Province every year. Based on data from Ministry of Health in 2015, Gorontalo Province ranked first with the highest CFR (Case Fatality Rate) of (6,06%) and the lowest CFR (0,0%) was occupied by NTT. Although the number of IRs (Incidence Rate) for 2011-2015 did not place Gorontalo Province into five provinces with the highest Incidence Rate of DHF did not mean that dengue fever problems in Gorontalo Province had been solved. The high number of CFR is closely related to problems related to behavior, success of efforts or health promotion programs, and quality and access to health services (Kemenkes, 2016)

In the last five years Gorontalo District has been overshadowed by two diseases that have the potential for outbreaks of dengue fever and malaria. Based on data from Public Health Office Gorontalo regency in 2012-2016, district with the highest number of dengue fever cases was Limboto and Telaga Biru. The high incidence of dengue fever in the two districts was due to high population density (BPS, 2016). Population density and house distance are closely related to the incidence of dengue fever in a region. The closer the house is, the easier the dengue virus can spread from person to person living in densely populated areas (Prasetyowati, 2015)

One alternative method in the effort to control dengue fever which focuses on producing the right choice of action or policy is the modeling method. This method is designed to predict the state of the pattern of disease events and see the future impact if an alternative control action is implemented with the expectation that the outbreak control effort runs effectively and efficiently (Djafri, 2015). The use of modeling methods using climate data can be used as an early warning system model in controlling dengue fever in all endemic areas in Indonesia.

METHODS

This study used an ecological study design, which aims to examine the relationship of climate factors to the incidence of dengue fever. From the depth aspect of the analysis, this research is analytical research. The research data included secondary data collected from 2012 - 2016, the climate data used (average temperature, irradiation time, rainfall, rainy days, and average wind speed) per month obtained by Gorontalo Meteorology and Geophysics Agency (MGA) Class II. Data on dengue fever were monthly incident data obtained from Public Health Office Gorontalo regency.

Incident data and climate data were analyzed to find predictive models of dengue fever using multiple linear regression analysis. Determination of prediction models based on the results of identification of the dominant factors of the independent variables which consist of (temperature, duration of irradiation, rainfall, rainy days, and wind speed), which affects the dependent variable (dengue fever) described in a regression equation. The quality of the regression equation is determined from the value of the coefficient of determination. The value of determination determines how big the role of the independent variable is on the dependent variable determined by the value range 0-100%. The closer the value of determination to the value of 100%, the better the regression equation will be.

RESULTS AND DISCUSSION

Univariate Analysis of Climate Factors and Dengue Fever Incidents

Based on (table 1) the results of univariate analysis for climate variables and the incidence of dengue fever, the average temperature in Gorontalo Regency in 2012-2016 obtained had reached 27˚C with the highest temperature of 28,60^{0}C. For rainfall figures the highest value reaches 412 mm with an average rainfall of 130,48 mm. The highest number of rainy days reaches 25 days a month and the lowest number of rainy days is 2 days a month. The highest incidence of dengue fever is 92 cases over a period of 5 years. Climate factors such as (wind speed, temperature, irradiation time, rainfall and rainy days) affect the incidence of dengue fever in a region. However, to determine the influence of climate factors on the incidence of dengue fever, a multivariate test is needed to identify the dominant factors that influence the incidence of dengue fever.

Table 1
Univariate Analysis of Climate Variables in Gorontalo District 2012-2016

Variable	Min	Max	Mean	Std. Deviation
Wind Speed	1	6	2,70	1,17
Temperature	24,1	28,60	27,0	0,76
Irradiation Time	3,70	9,70	6,42	1,28
Rainfall	6	412	130,48	91,65
Rainy Day	2	25	14,60	6,23
DHF Incidence	0	92	12,40	18,10

Based on table 1. During 2012-2016, the average number of temperatures was 27^{0}C and the highest temperature was 28,60^{0}C in Gorontalo Regency. This temperature is ideal for *Aedes sp* mosquito to incubate eggs. According to Clement, 1992 the best temperature for larvae growth was adult mosquito was 26^{0}C - 32^{0}C, but the temperature was extreme between under 26^{0}C and above 32^{0}C would be disrupted of mosquito growth. However, the mosquito eggs hatched while temperature was 10 ˚ but the growth was immature (Boekoesoe, 2015). For average rainfall within 5 years was 130,48 mm and the highest rainfall was 412 mm. The highest number of rainfall during 5 years indicated Gorontalo regency is suitable for *Aedes* mosquito habitat. Aedes mosquito needs an average rainfall of more than 500 mm per year (Sunarno *et al.,* 2017) and it is reasonable that the highest dengue hemorrhagic fevers cases in Gorontalo regency reached 92 cases during 5 years.

Distribution of Dengue Fever Cases in 2012-2016

Cases of dengue fever in Gorontalo regency in 2012-2016 based on (figure 1) had experienced an increase at the beginning of the year; January, February and March. The highest number of Dengue Fever Cases in January occurred in 2013 with 63 cases and 2016 with 92 cases. The highest number of Dengue Fever Cases in February and March occurred in 2013 until 2016. Early 2016 was the year with the highest incidence of dengue fever with total number of 93 cases in January, 84 cases in February and 48 cases in March. However, overall the trend of dengue fever in Gorontalo regency has a noticeable decreased.

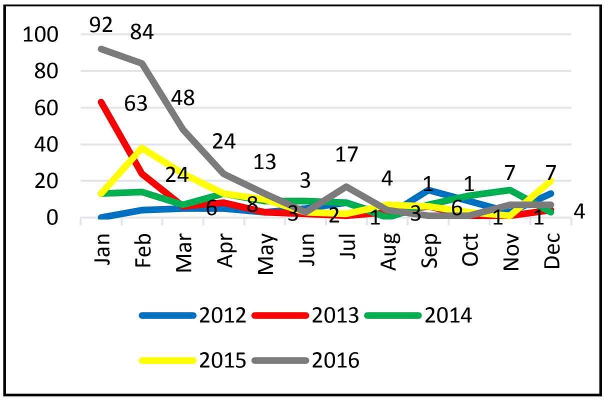

Figure 1
Monthly Distribution Cases of Dengue Fever Graph 2012-2016

Dengue hemorrhagic fever cases within 5 years based on figure 1 shows that the highest cases of dengue hemorrhagic fever found in January, February, and March. The highest rainfall in Gorontalo regency occurred in these months (BMKG, 2016). However, it is considered by the trend of dengue hemorrhagic fever cases in figure 1 that it has decreased. In addition, climatic factors increased from dengue hemorrhagic fever could cause many factors such as vector density, demography, human health behavior, quality of health service, and quality of dengue prevention and control programs (Boekoesoe, 2015)

High rainfall may cause more available breeding place, but when rainy season and dry intermittent drought have more positive for mosquito population because of the rain at that time did not cause flood. Moreover, this condition caused an optimal temperature and humidity for mosquito population to increase. Based on this description, rainfall has an influence against dengue fever incidence. (Rasmanto *et al.,* 2016)

Results of Multivariate Analysis of Climate Factors on Dengue Fever Cases

Based on (Table 2) there are five models of linear regression analysis using Backward method and the first model is obtained with R^2 value of 11,9%. In the second model, rainy day variable is excluded because the value of the p variable is greater than the other variables. Each variable with a greater p value in the model will be excluded, until the entire variable has a value of p <0,05. In the third and fourth models, variables with a significance value of p> 0,05 is excluded, so that in the fifth model left only 1 variable with a significance value of p <0,05. Determination value or R^2 value of linear regression equation in the fifth model is 13,4%, which means that there are other factors in the form of non-climatic environmental factors, behavioral factors, and the quality of control programs and health services that can affect the incidence of dengue fever in Gorontalo Regency.

The linear regression equation obtained is y = 3,760 - (0.376 × Rainfall), considering that the data analyzed is data from data transformation using the Ln function. To make it more understandable, the form of the value of the equation is changed in the form of a natural logarithm to form the original value using the Exp (x) function. So that the equation value y = 42,948 + (0.686 × 130.48) is 132,54, which means that if the average rainfall was 130,48 mm in 2017, it is estimated that the number of dengue cases in a year reached 132 cases.

Table 2
Multivariate Analysis between Climate Variables and Cases of Dengue Fever in Gorontalo Regency in 2012-2016

Model	Variable	B	Std. Error	t	*p* value	R^2
1	Constant	-4,543	14,926	-0,304	0,762	1,9%
	Wind Speed	0,542	0,386	1,401	0,167	
	Temperature	3,284	4,566	0,719	0,475	
	Irradiation Time	-1,518	1,091	-1,391	0,170	
	Rainfall	-0,545	0,219	-2,489	0,016	
	Rainy Days	0,221	0,403	0,549	0,585	
2	Constant	-1,998	14,097	-0,142	0,888	8,9%
	Wind Speed	0,537	0,384	1,398	0,168	
	Temperature	2,735	4,427	0,618	0,539	
	Irradiation Time	-1,782	0,974	-1,830	0,073	
	Rainfall	-0,475	0,177	-2,685	0,010	

Model	Variable	B	Std. Error	t	*p* value	R^2
3	Constant	6,613	2,107	3,138	0,003	8,3%
	Wind Speed	0,519	0,381	1,364	0,178	
	Irradiation	-1,615	0,930	-1,736	0,088	
	Rainfall	-0,451	0,172	-2,628	0,011	
4	Constant	6,262	2,107	2,972	0,004	5,6%
	Irradiation Time	-1,024	0,829	-1,235	0,222	
	Rainfall	-0,512	0,167	-3,072	0,003	
5	Constant	3,760	0,582	6,460	0,000	3,4%
	Rainfall	-0,376	0,126	-2,992	0,004	

Based on the results of multivariate analysis, only one variable with a p-value <0,05 and Coefficient of determination (R^2) of linear regression equation on the fifth model 13,4%. The result of the linear regression equation y = 42,948 + (0,686 × 130,48) with the result by equation 132,54. This means that when the rainfall index average 130,48 mm has an estimated number of dengue fever cases reached 132 cases in 2017.

The using of the linear regression equation to decide the predictive model based on climatic variables is the dominant influence to dengue hemorrhagic fever cases in Gorontalo Regency in 2012-2016 that obtained a rainfall is the dominant influence of dengue hemorrhagic fever cases. This variable such as wind speed, temperature, irradiation time, and rainy days were eliminated because of the p-value of these variable were not significant. Thus, the model obtained only explains the magnitude effect of rainfall on dengue fever incidence.

According the table of univariate analysis climate variable on table 1, the rainfall average is 130.48 mm for five years. It means that the rainfall average is suitable for mosquito life cycle because it less than 200 mm. This is consistent with research by (Sungkar, 2011) which states that an incidence of dengue cases usually occurred at the beginning and end of rainy season. The prevalence of vector diseases such as dengue and malaria are often associated with rainfall season and humidity (Jahja *et al.,* 2016). However, the amount of rainfall is the most important factor in climatic factors can affect dengue virus transmissions because it associated with dengue life cycle and mosquitoes and human into contact. Thus, there is a relationship between average monthly dengue cases and the average monthly amount of rainfall. Many types of research conclude that meteorological factors and environmental parameters have interacted with dengue incidence and have an interaction complexity with rainfall. Higher rainfall has been associated with dengue elsewhere in south-east Asia such as Thailand and Indonesia (Choi *et al.,* 2016)

The dengue incidence has depended with climate change because every change of climate parameter conditions may contribute to increasing dengue development stages and dengue transmission. The non-climatic factors such as urbanization, rising populations, and people mobilizations may contribute to increasing a dengue incidence (Choi *et al.,* 2016). Moreover, another factor such as behavior factors, living nearer to health facilities are important factors in dengue prevention and control (Chandren *et al.,* 2015). Based on the determination value of regression linear (R^2) result 13,4 %, it means that another factor such as behavior factors, living nearer to health facilities, dengue preventive and controlling quality and health service quality may impact to increasing dengue cases in Gorontalo Regency.

CONCLUSIONS

This study concludes that meteorological factor such as rainfall is a domain predictor in dengue fever incidence in Gorontalo regency. It shows that the highest cases of dengue hemorrhagic fever occurred in five years consistently found in January, February, and March due to the highest rainfall. Based on this situation, program prevention is needed before the peak of the rainy season that causes of dengue incidence. An outbreak of dengue fever cases is not only caused by climatic factor but also weak plan of dengue prevention and control program.

The determinant values (R^2) on the fifth model shows a rainfall also as a dominant factor incidence of dengue fever in Gorontalo regency. Nevertheless, it would be possible that there was another significant factor in the incidence of dengue fever such as demography condition. Population density, urban and settlement problems may be caused of high incidence of dengue fever suggesting that a population problem should be considered in each plan and assessment urban and settle development by government and private sector. The dengue prevention and control programs would likely efficiently worked if demographic problems, environmental condition, and more climate parameters are integrated into one system which analyzing and mapping distribution of dengue cases such a spatial-temporal system. Thus, the sophisticated early warning system model for dengue outbreak prediction can be developed and would also enable the sophisticated dengue control system to implements at local or regency rather than province and national-scale only, so that as part of concatenation system measures aimed to protecting Gorontalo regency communities health and alert to face of emerging infectious diseases and climate change.

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