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The Relationship Between Climate Factors and Dengue Hemorrhagic Fever Incidence in Sleman, Yogyakarta

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ABSTRACT
Dengue hemorrhagic fever (DHF) is a viral disease that is endemic in tropical and subtropical regions. It is spread through the bite of the Aedes mosquito. One of the factors influencing the spread of DHF is climate, which influences both vector and virus activity. The climate of a region is influenced by geographical conditions. Sleman Regency is the third-most-affected dengue-endemic area in Yogyakarta, and has various geographical and climatic conditions that may contribute to DHF incidence. This study aims to examine the relationship between climatic factors and the incidence of DHF, with the results potentially assisting in the development of an early warning system. The study was analytic observational with a cross-sectional design. Data on the incidence of DHF between 2008 and 2015, as the dependent variable, were obtained from the District Health Office. Climate data, as independent variables, were obtained from the local Meteorology, Climatology, and Geophysics Agency. The climate parameters studied were humidity, temperature, the difference between minimum and maximum temperatures, rainfall, and number of rainy days. Spearman correlation analysis was used to determine the relationship between variables. The total incidence of DHF in Sleman Regency was 4,125 from 2008 to 2015. Results showed that humidity was positively correlated with DHF ($p < 0.001$; $r = 0.458$), as were rainy days ($p < 0.001$; $r = 0.429$) and rainfall ($p < 0.001$; $r = 0.428$). Temperature was not correlated with DHF ($p = 0.407$; $r = 0.086$). The minimum-maximum temperature difference was not correlated at a statistically significant level, but had a negative direction was close to the significance threshold ($p = 0.06$; $r = -0.278$). It was concluded that the determinants of DHF in Sleman Regency are humidity, rainfall, and rainy days. As these three parameters increase, the incidence of DHF also increases.

Keywords: *rainfall, DHF, rainy day, humidity, temperature*

1. INTRODUCTION

Dengue Hemorrhagic Fever (DHF) is a serious global public health issue. This disease is caused by the dengue virus, which is a member of the genus Flavivirus and is known to have four dengue virus serotypes: DEN-1, DEN-2, DEN-3, and DEN-4. [1] Approximately 2.5 billion people in more than 100 countries are at risk of contracting dengue. Globally, it is estimated that every year 50 million to 400 million infections occur, with 500,000 cases requiring hospitalization and more than 200,000 patients dying. [2]

The vector of DHF transmission is the Aedes mosquito from the Stegomya subgenus *(Aedes aegypti)*. DHF viruses spread through vector bites. In vector mosquitoes, transsexual transmission occurs from male mosquitoes to female mosquitoes through mating and transovarial transmission from the mosquito to its offspring. [3] Geographically, *Ae. aegypti* live in both tropical and sub-tropical regions. *Aedes aegypti* is a type of African mosquito, first described in Egypt. Currently, *Ae. aegypti* has a global distribution and plays an important role in the spread of DHF. [4; 5; 6] *Ae. albopictus* is a secondary vector of DHF transmission, originating in mainland Asia. This mosquito and was first described in India. Like *Ae. aegypti*, *Ae. albopictus* has spread throughout the world and plays an important role in the spread of DHF. [6]

The cycle of DHF spread in a particular area usually follows a pattern of seasonal changes. [7] Temperature, rainfall, and humidity are known to influence the spread of DHF. [8] *Ae. aegypti* and *Ae. albopictus* mosquitoes, as DHF vectors, require water with certain conditions for egg-laying and larval development, as well as a warm, humid environment for adult mosquitoes and virus replication. [9] Climatic elements such as temperature and rainfall have been shown to affect the biophysical function of mosquitoes and their spawning grounds. High rainfall can increase the vector population by providing eggs, while temperature influences egg hatching rate, development time, and survival rate. Increasing the temperature also reduces the virus incubation time in the vector’s body. [10]

The magnitude of climatic influence on the incidence of DHF varies across regions. In urban areas of Indonesia such as Jakarta, [11] Kota Semarang, [12] and Kota Yogyakarta, [13] three climate parameters—temperature, humidity, and rainfall—affect DHF. In dry, mountainous areas such as Gunung Kidul, only humidity and rainfall affect DHF. [14] Regarding climate parameters, the number of rainy days has so far been little studied and has yielded different results in different regions. Research in South Sumatra, Indonesia, using a descriptive method, concluded that there was no relationship between the number of rainy days and the incidence of dengue fever. [15] This differs from a study in Susekat, Thailand, which showed that the number of rainy days is a risk factor for dengue fever. [16] There has been no research on the link between rainy days and DHF in Sleman Regency. It has even been shown that climatic influences differ during different transmission seasons throughout the year. [17].

The difference in the influence of climate parameters from one region to another shows that the incidence of DHF is local. The fact that DHF incidence is local has implications for how prevention is managed; this may also need to differ from one region to another. It is not yet known specifically which climate parameters are influential in Sleman Regency. This study aims to reveal the climate parameters that influence the incidence of DHF in Sleman Regency. Increased knowledge of these influential factors will be the basis for efforts to prevent DHF and develop an early warning system.

2. MATERIAL AND METHOD

This study was an analytic observational study using a cross-sectional design. The dependent variable was the incidence of DHF, namely the number of new dengue diagnoses in Sleman Regency every month during the period from 2008 to 2015. The independent variables were climate-related: humidity, rainfall, number of rainy days, temperature, and minimum-maximum (min-max) temperature differences.

In this study, climatic variables are measured monthly to map onto DHF incidence figures. “Humidity” refers to average monthly humidity. “Temperature” is the average monthly temperature, and “rainfall” is the amount of monthly rainfall. A “rainy day” is counted in this study when a minimum rainfall of 0.5 mm is collected within 24 hours. “Min-max temperature” is the difference between the highest temperature and the lowest temperature in a month, intended to represent temperature fluctuations within the relevant month.

Climate data in the form of average monthly humidity, average monthly temperature, amount of rainfall, and number of rainy days were obtained from the Climatology Station of the Meteorology, Climatology, and Geophysics Agency in the Province of Yogyakarta. Data for the min-max temperature difference was obtained by calculating the difference between the highest and lowest temperatures each month during the period from 2008 to 2015. Dengue Hemorrhagic Fever incidence data were obtained from the Sleman Regency Health Office.

Data were analyzed using SPSS software version 20. Relationships between variables were examined by using the Spearman Rank Test because the data was not normally distributed. The data were tested for normality using the Kolmogorov-Smirnov test.

3. RESULTS AND DISCUSSION

3.1. The incidence of DHF in Sleman Regency from 2008 – 2015

The incidence of Dengue Hemorrhagic Fever in the Sleman Regency in the 2008–2015 period fluctuated. In 2008 the number of events was high (765 cases), and this level recurred five years later in 2013, with 736 cases. The lowest incidence occurred in 2011, with 166 cases (Figure 1).

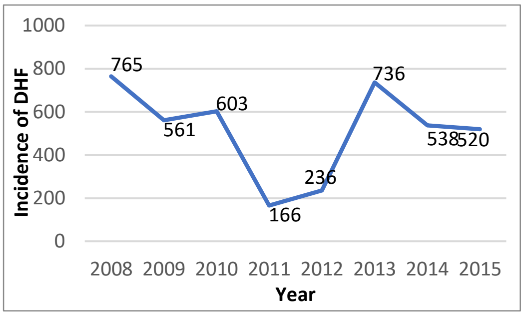

Figure 1. Fluctuations in DHF incidence in Sleman Regency, 2008-2015

Climatic factors were analyzed for correlation with the number of DHF events each month. The average climatic conditions in Sleman Regency for the whole 2008–2015 period are described in Table 1. As shown, Sleman Regency has high humidity (81.74%), warm temperatures (26.16 °C), moderate rainfall (6,487 mm), and 11.6 rainy days a month. The temperature fluctuation represented by the mean min-max temperature range was moderate (9.21 °C).

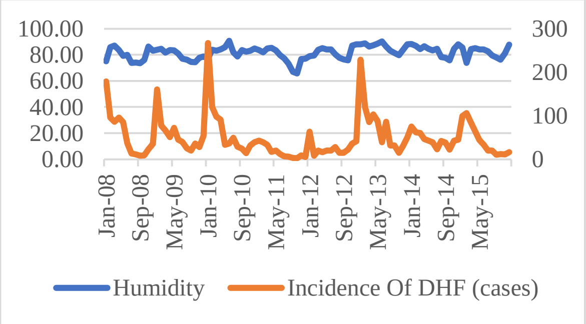

Figure 2. Average annual humidity and DHF incidence in Sleman Regency 2008-2015

Figure 2 presents a graph of average monthly humidity in the period from 2008–2015. It seems that the fluctuation pattern is similar to that of DHF incidence. Low humidity is in line with low incidences of DHF, while higher humidity is in line with higher incidences of DHF. This suggests that there may be a correlation between humidity and the incidence of DHF.

Table 1. Overview of Sleman Regency climate factors in 2008-2015

Variable	Average	Unit	Max	Min	St Dev.	Total Data
Humidity	81.74	%	90.73	65.69	4.919	96
Temperature	26.15	°C	28.8	23.72	0.831	96
Rainfall	6.487	mm	23.83	0	5.608	96
Rainy day	11.615	day	28	0	8.159	96
Min-Max Range Temperature	9.214	°C	12.71	6.12	1.103	96

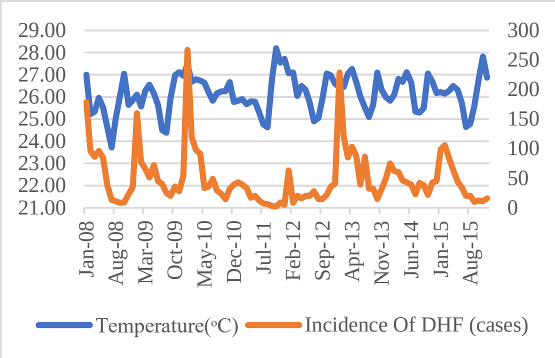

Figure 3. Average annual temperature and DHF incidence in Sleman Regency during the period 2008-2015

Figure 3 shows that there was an increase in the average monthly temperature in the period from 2008–2010 but a subsequent decrease in 2011. Subsequently, between 2011 and 2015 there was no significant temperature change. In general, the average monthly temperature in Sleman Regency did not show any significant fluctuations between 2008 and 2015. This is different from the incidence of DHF in the Sleman Regency, which does tend to fluctuate.

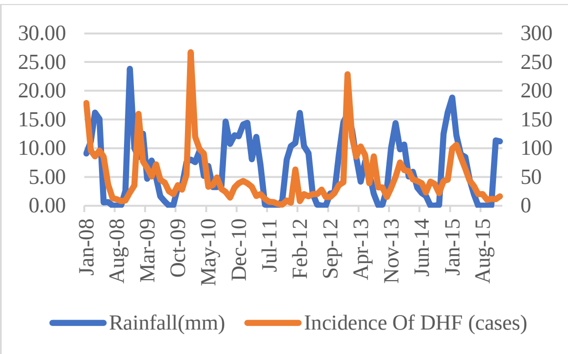

Figure 4. Average annual rainfall and DHF incidence in Sleman Regency 2008-2015

In Figure 4, it can be seen that the average annual rainfall in Sleman Regency has fluctuated, where the lowest average annual rainfall occurred in 2009 (4.6 mm) and the highest average annual rainfall occurred in 2010 (8.1 mm). Figure 4 also shows that each increase in rainfall is followed by an increase in the incidence of DHF. By the same token, decreases in rainfall are followed by a decrease in the incidence of DHF. This happens every year, except in 2015 where the rainfall increases but the incidence of dengue fever decreases.

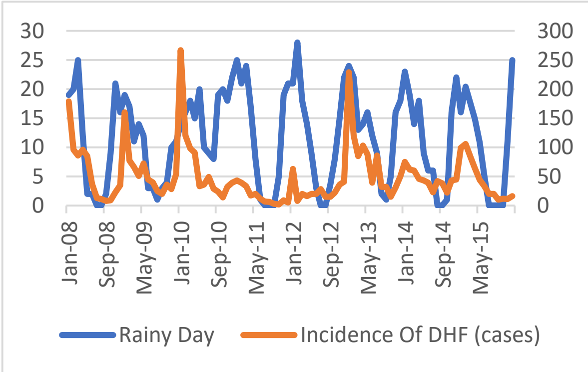

Figure 5. Average monthly rainy days and DHF incidence in Sleman Regency in 2008-2015

From Figure 5, it can be observed that that the lowest average number of monthly rainy days occurred in 2009 (9.0 days) and the highest average number of monthly rainy days occurred in 2010 (15.8 days). As with rainfall (Figure 4), each increase in the number of rainy days is followed by an increase in the incidence of DHF, and every decrease in rainy days is followed by a decrease in the incidence of DHF. This happens every year, except in 2015, where the number of rainy days increased but the incidence of DHF decreased.

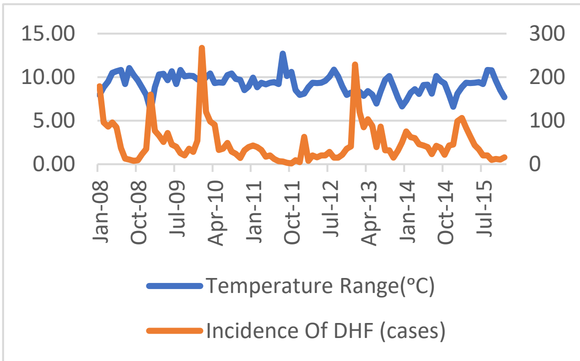

Figure 6. Annual min-max temperature range and incidence of DHF in Sleman Regency during the period 2008-2015

Figure 6 shows that the difference in min-max temperature decreased in 2011–2013 and increased in 2013–2015. The lowest average min-max temperature difference occurred in 2013 (8.2 °C). In general, the graph pattern of the difference in annual average min-max temperature tends to be the opposite of the incidence of DHF: an increase in the min-max temperature difference tends to be followed by a decrease in the incidence of DHF.

The correlations of the above-described climatic factors with the incidence of dengue cases was tested using the Spearman Rank Test. Results are shown in Table 2.

Table 2. Spearman correlation test results between climate factors and DHF events

No	Climate Factors	Value of p	Correlation Coefficient Value
1	Humidity	0.000	0.458
2	Temperature	0.407	0.086
3	Rainfall	0.000	0.428
4	Rainy days	0.000	0.429
5	Min-max difference in temperature	0.060	-0.278

In Table 2, it can be seen that the humidity p-value is 0.000 ($p < 0.05$) and the correlation coefficient (r) is 0.485, meaning that there is a positive and statistically significant relationship between humidity and the incidence of DHF. The p-value for the temperature variable is 0.407 ($p > 0.05$), meaning that there is no correlation between temperature and the incidence of DHF. The p-value for the rainfall variable is 0.000 ($p < 0.05$), with $r = 0.428$, so there is a positive and statistically significant correlation between rainfall and the incidence of DHF. The p-value for the rainy-day variable is 0.000 ($p < 0.05$) with a value of $r = 0.429$, meaning that there is a positive and statistically significant correlation between the number of rainy days and the incidence of DHF. The p-value for the temperature difference variable is 0.06 ($p > 0.05$), meaning that there is no statistically significant inverse relationship between temperature differences and the incidence of DHF; however, the correlation is close to statistical significance.

3.1.1 Humidity

This study shows that humidity has a positive correlation with DHF incidence. According to Thu *et al.* (1998) [18], Dengue virus replication in the Aedes mosquito increases under high humidity conditions in the laboratory. Humidity also affects the reproductive activity of mosquito vectors. Research by Costa *et al.* (2010) [19] and Weeraratne *et al.* (2013) [20] has shown that *Ae. aegypti* mosquitoes tend to lay more eggs in humid conditions. The number of eggs released by female mosquitoes affects the mosquito population. A higher population of mosquitoes means that DHF will spread with greater ease. According to Lega *et al* (2017) [21], the optimal humidity for *Ae. aegypti* mosquitoes is between 72% and 95% (84%), which will lead to 91%–95% survival of larvae. Environmental humidity also affects the biting activity of *Ae. aegypti* mosquitoes, which is expressed as the Man Landing Rate. Sintorini (2018) [22] showed that both increased biting activity and higher survival rate in the *Ae. aegypti* mosquito increase the effectiveness of this mosquito as a vector of dengue transmission.

3.1.2. Temperature

We did not find that temperature correlated with the incidence of DHF ($p = 0.407$). As temperature is believed to be related to mosquito density, this result is not in line with some previous laboratory studies. Costa *et al.* (2010) [19], for example, found that temperature affects the mosquito's egg-laying period. These researchers found that at an ambient temperature of 25°C, the spawning period of *Ae. aegypti* mosquitoes increases to 5 days and mosquitos produce 43% more eggs than at ambient temperatures of 35°C. Research on the *Ae. albopictus* mosquito [23] also shows that temperature is closely related to the number of adult mosquitoes ($p < 0.001$) and the mortality of adult mosquitoes ($p < 0.001$).The inconsistency of these results with previous laboratory studies may be due to the granularity of our data. Our data are monthly average temperature data, so the effect of daily temperature fluctuations is not visible. In the laboratory, temperature conditions are held stable.

3.1.3. Temperature Fluctuations

This study examined the possibility that temperature fluctuation factors may affect the incidence of DHF. However, due to the data limitations discussed above, temperature fluctuations and the incidence of DHF are shown in monthly, not daily, increments. In Table 2, it can be seen that there is no significant correlation between monthly temperature fluctuations and the incidence of DHF, but that the inverse relationship does approach significance ($p = 0.060$; $r = -0.278$). This suggests that under conditions of high temperature fluctuation, there a lower incidence of DHF may be more likely. This is in accordance with the results of several previous studies, which stated that in months with a high temperature difference there is a lower spread of the dengue virus and in months with a low temperature difference there is a greater spread of the dengue virus. [24]

Apart from affecting the incubation of the virus in the mosquito's body, daily temperature fluctuations also affect the survival of female mosquitoes. [24] The greater the temperature fluctuation, the lower the endurance of female mosquitoes, meaning that temperature fluctuations influence the transmission of the dengue virus [25] and ultimately can affect the potential for dengue outbreaks. [26]

3.1.4. Rainfall

The results indicate that rainfall has a moderate, statistically significant positive correlation with the incidence of DHF in Sleman Regency. If this measure is related to vector density, it is in line with Wee *et al.* (2013)

[27] and Valdez *et al.* (2017) [28], who found that rainfall is an important factor in providing a watery environment for aquatic mosquito eggs, larvae, and pupae.

On the other hand, excessive rainfall has a negative impact on the mosquito population. Dieng *et al*. (2012) [29] conducted a study using artificial rain, finding a positive correlation between rainfall and the number of *Ae. albopictus* larvae that floated out of a container ($p = 0.001$). Rainwater falling onto the surface of water in a container can cause larvae or pupae to be swept out, because the larvae and pupae of the Aedes mosquito have a habit of rising to the surface of the water to fetch oxygen. [30] Field and laboratory research [27;29] also showed that the highest levels of rainfall studied were found to decrease the *Ae. aegypti* and *Ae. albopictus* mosquito population.

3.1.5 Rainy day

The results of the study regarding number of rainy days showed a statistically significant positive correlation between the number of rainy days and the incidence of DHF in Sleman Regency. In this study, the term "rainy day" is used to denote 24 hours on which a station has recorded 0.5 mm or more rainfall. If the rainfall is less than 0.5 mm, then the rainy day is considered zero, but the amount is still included in the rainfall data. The number of rainy days in a month can be considered the same as the frequency of rain during a month. Research found that there was a relationship between rain [31] and the frequency of rain [32] and the abundance of adult mosquitoes of *Ae. aegypti*.

Rainy days serve to maintain the condition of puddle availability the Aedes mosquito needs to lay eggs. Containers that produce mosquitoes or eggs that emerge after rain can be lost or damaged due to evaporation, seepage, or human elimination. Having a sufficient number of rainy days plays an important role in maintaining the existence of a mosquito nest container or a place to lay eggs.

5. CONCLUSION

In Sleman Regency, humidity, rainy days, and rainfall are the climatic factors with the greatest influence on DHF incidence. The average monthly temperature has no effect, while the inverse relationship with minimim-maximum temperature difference almost reaches the significance threshold.

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