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Effect of Climate on Dengue Fever in Semarang City in 2016-2020

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Abstrak

Dengue merupakan penyakit tular nyamuk yang telah menyebar secara global dan menjadi salah satu masalah kesehatan di Indonesia. Kota Semarang merupakan salah satu daerah endemik dengue di Jawa Tengah, Indonesia. Penelitian ini merupakan penelitian deskriptif kuantitatif dengan rancangan analisis *time series*. Tujuan penelitian ini adalah untuk mengetahui pengaruh faktor iklim (curah hujan, kelembapan, suhu rata-rata) terhadap kejadian demam dengue di Kota Semarang tahun 2016-2020 pada selang waktu 0-3 bulan. Analisis bivariat dilakukan dengan menggunakan spearman's rank test. Hasil penelitian menunjukkan bahwa ada pengaruh yang signifikan antara curah hujan dengan kejadian demam dengue pada selang waktu 0-3 bulan. Kelembapan memiliki pengaruh yang signifikan terhadap kejadian demam dengue pada selang waktu 0-2 bulan. Curah hujan memiliki koefisien korelasi tertinggi pada selang waktu 1 bulan. Koefisien korelasi tertinggi antara kelembapan dan kejadian demam dengue terjadi pada selang waktu 1 bulan. Suhu rata-rata tidak memiliki pengaruh yang signifikan terhadap kejadian demam dengue. Disimpulkan curah hujan dan Kelembapan memiliki pengaruh yang bermakna terhadap kejadian demam dengue di Kota Semarang.

Abstract

Dengue is a mosquito-borne disease that has spread globally and become one of the health problems in Indonesia. Semarang City is one of the dengue endemic areas in Central Java, Indonesia. This research is a quantitative descriptive study with a time series analysis design. The purpose of this study was to determine the effect of climatic factors (rainfall, humidity, average temperature) on dengue fever in Semarang City in 2016-2020 at time lag of 0-3 months. Spearman's rank test is used in bivariate analysis. The results showed that there was a significant effect between rainfall and the incidence of dengue fever at lag of 0-3 months. Humidity has a significant effect on dengue fever at lag of 0-2 months Rainfall has the highest correlation coefficient at an interval of 1 month. The highest correlation coefficient between humidity and dengue fever incidence occurred at a lag of 1 month. The average temperature has no significant effect on the incidence of dengue fever. We concluded that rainfall and humidity have a significant effect on the dengue fever incidence in Semarang City.

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INTRODUCTION

Dengue is a mosquito-borne disease that has spread globally and become one of the health problems in Indonesia. Dengue fever has clinical manifestations in the form of high fever, body and muscle aches, nausea, vomiting, skin rashes, and fatigue (Chumpu, 2019). In general, dengue fever lasts five to seven days, during which time some patients recover, but dengue fever can also develop into a more lethal stage, namely dengue hemorrhagic fever (Chumpu, 2019). The most distinguishing between dengue hemorrhagic fever and dengue fever is not bleeding, but plasma leakage due to increased permeability of blood vessels (CDC, 2009).

Indonesia is one of the countries with the highest dengue fever burden in the world (Stanaway, 2016). For 50 years, the annual incidence rate (IR) of dengue hemorrhagic fever (DHF) in Indonesia from 1968 to 2016 increased sharply, from 0.05 cases per 100,000 people to 77.96 cases per 100,000 people (Harapan, 2019). The IR of DHF per 100,000 population in Indonesia tends to decrease from 51.5 in 2019, to 40 and 27 per 100,000 population in 2020 and 2021 respectively (Kementrian Kesehatan RI, 2021). During 2019-2021, trend of IR of DHF In Indonesia has been decreased. However, dengue still causes a morbidity and economic burden for the community. This is supported by previous study in 2019 which found that DHF still poses a large economic burden to the public payers and the people of Indonesia where the total economic burden of DHF in Indonesia is estimated at US$ 381.15 million (Nadjib, 2019). Therefore, prevention and control of dengue is one of the main priority lists for the community and policy makers.

Semarang City is one of the DHF endemic areas in Central Java, Indonesia (Dinas Kesehatan Kota Semarang, 2017). This city has an area of 373.67 km^2 with a total population growth of 0.49% in 2017. Geographically, Semarang City divided into highlands and lowlands areas. The highland is mostly used for plantations, rice fields, and forests while the lowland area is the center of government, trade, and industry activities. The IR DHF in Semarang City in 2006-2016 tends to always exceed IR DHF of Central Java and the IR DHF of Indonesia. The IR of DHF in Semarang City in 2017 was 18.14 per 100,000 population, decreased from the previous year which reached 25.22 per 100,000 population) (Dinas Kesehatan Kota Semarang, 2017). During 2016-2017, trend of IR of DHF In Semarang City has been decreased. However, a study in Semarang City in 2017 stated that Semarang City has a very high larval density and categorized as an area with a high risk of dengue infection (Martini, 2017).

Hendrik L. Blum theory explained that health status is determined by 40% environmental (physical environment, social environment, and economy), 30% behavioral factors, 10% health care factors, and 20% genetic factors (Irwan, 2017). Dengue infection have a main vector namely *Aedes aegypti*, while the secondary vector is *Aedes albopictus*. To reproduce, the dengue vector requires a comfortable and suitable environment (Azhari, 2017). One of the environmental factors that can influence the transmission of dengue fever is climate (Morin, 2013). Climate is the average weather for a long time, ranging from 25-30 years and over a relatively wide area (Winarno, 2019). Climate consists of several elements, namely rain, sun intensity, wind, temperature, and humidity.

Previous research found that meteorological factors such as temperature, rainfall, humidity, and air quality directly or indirectly affect the growth and distribution of vectors (Gui, 2022). These findings are also supported by research from Bhatia (2022) which found that temperature, rainfall, and relative humidity are the most important climatic factors associated with the transmission of dengue fever. A study in Malaysia also found that rainfall have a positive correlation with dengue cases, meanwhile wind speed have a negative correlation on dengue cases (Tosepu, 2018). Rainfall can increase breeding sites for mosquitoes which can further increase the density of mosquito (Choi, 2016). While humidity can affect the chances of mosquitoes to live (Rau, 2019). In addition, temperature affects the life cycle of mosquitoes where at temperatures of 25-30 degrees Celsius mosquitoes tend to breed optimally (Monintja, 2021).

Previous studies have examined the relationship between climate (temperature, rainfall, humidity, wind speed) and dengue hemorrhagic fever in Semarang City in 2006-2011(Wirayoga, 2014). Similar studies have also examined climatic factors (rainfall, air humidity, and air temperature) that have a relationship with DHF incidents in Semarang City in 2008-2017(Angelina, 2019). Although there are many other studies that have examined the relationship between climate factors and dengue incidence, but there have not been many studies in Indonesia that have examined the time lag of climate factors on dengue incidence. The definition of time lag is the period between one weather observation and the incidence of dengue (Sriklin, 2021). In other studies, time lag also can be defined as delayed effect of climate variable on dengue incidence (Tuladhar, 2019).

The study of the time lag aims to determine whether the increase in dengue cases is influenced by climatic factors that precede it. In addition, time lag study also can identify the most influencing preceding months period on the occurrence of dengue fever (Tuladhar, 2019). The purpose of this study is to determine the effect of climatic factors (rainfall, average temperature, humidity) and the incidence of dengue fever in Semarang City in 2016-2020 at time lags of 0-3 months.

METHOD

This research is a quantitative descriptive study with a time series analysis design. This research was conducted in Semarang City, Central Java. The population of this study were all reports of dengue fever case data and climate factor data (rainfall, humidity, average temperature) in Semarang City. While the research sample is a report of monthly cases of dengue fever and monthly climate (rainfall, air temperature, and humidity) data for 60 months (January 2016-December 2020). Data on dengue fever cases was sourced from Tunggal Dara via web page http://116.254.113.136:8080/tunggaldara/. Tunggal Dara is online source of information on dengue infection from the Semarang City Health Office. For the climatic variable, data on rainfall, humidity, and average temperature are sourced from the Semarang City Statistics Center (BPS Kota Semarang) and the Meteorology, Climatology, and Geophysical Agency (BMKG) Database Center via the web page http://dataonline.bmkg.go.id/data_iklim.

Rainfall, humidity, and average temperature data were obtained from the Central Java Climatology Station because of its location which is closer to Semarang City. The climate data obtained from BMKG is daily climate data, then the data is converted into monthly data. The units used for each variable are the person for the monthly cases of dengue fever, millimeters for the rainfall variable per month, degrees Celsius for the average air temperature variable per month, and percentage for the humidity variable per month.

Univariate analysis was carried out to describe dengue variables, rainfall, humidity, and average temperature descriptively. Bivariate analysis was carried out using the Pearson's product moment test or Spearman's Rho as an alternative test. Before conducting bivariate analysis, the normality test was carried out for each variable using the Kolmogorov-Smirnov test.

The exposure variable in this study is the climate variable. While the outcome variable is the dengue fever cases. Bivariate analysis was carried out to determine the correlation between climatic factors and dengue cases. Bivariate analysis also used to evaluate the correlations of the monthly climatic variables and monthly cases of dengue fever for time lags from 0-3 months. Time lags from 0-3 months were chosen because the previous literature explained that the average age of female *Aedes sp* mosquitoes varies from 10-35 days and even can reach 2-3 months (Goindin, 2015; Suyanto, 2011). The climatic variable of 1 month earlier was considered lag 1, while climatic variable of 2 month earlier was considered lag 2, and climatic variable of 3 month earlier was considered lag 3. Meanwhile for lag 0 is the month that corresponds to dengue fever cases. In the Pearson or Spearman correlation test, the direction and strength of the relationship can be seen by looking at the correlation coefficient value from 0.00 – 1.00 (Cahyati, 2012).

This research has passed an ethical review from the Health Research Ethics Commission (KEPK) Faculty of Sports Science, Semarang State University with the number: 546/KEPK/EC/2022.

RESULT AND DISCUSSION

The results of the univariate analysis of climatic variable and dengue fever cases shown in Table 1. From 2016 to 2020 the highest number of monthly cases of dengue fever is 788 cases. Meanwhile, the lowest number of monthly cases of dengue fever is 16 cases. The monthly average rainfall and mean temperature were 136 mm and 28.3 degrees Celsius respectively. The highest humidity in Semarang City was 88%, while the lowest humidity was 66%.

In Figure 1., it is known that the highest number of monthly cases of dengue fever occurred in March 2016 (788 cases), while the lowest number of monthly cases of dengue fever occurred in September 2017 (16 cases). From 2016-2020, the peak of dengue fever cases in Semarang City usually occurs in December-March. The number of cases tended to decrease sharply after the peak of cases but in the period February 2017 to the November 2018 the number of cases tended to decrease from the period in previous years (Figure 1.).

The highest rainfall in Semarang City occurred in January 2016 and January 2017 which amounted to 399 mm (Figure 1.). In addition, peak of rainfall usually occurs in January and February. From 2016-2020 the lowest rainfall occurred in July 2018, August 2018, and May 2018, which amounted 0 mm (rain did not occur in these months). It can be concluded that the lowest rainfall tends to occur in May-August. The average monthly rainfall in Semarang City from 2016 to 2020 is 136 mm (Table 1.).

During 2016-2020, the highest humidity occurred in February 2020 (88%), while the lowest humidity occurred in August 2019 (66.1%) (Figure 2.). From 2016-2020 the highest humidity usually occurs in February and March. In addition, the lowest humidity usually occurs in August – September. The average humidity in Semarang City is 79% (Table 1.).

Air temperature fluctuations in Semarang City can be observed in Figure 3. During 2016-2020, the highest average temperature in Semarang City occur in November 2019 (30 °C), while the lowest average temperature occurs in January and February 2017 (26 °C).

Table 1. Descriptive Statistics of Monthly Data on Climate and Dengue Cases From 2016-2020

Variable	N	Mean	Median	Minimum	Maximum
Dengue Fever	60	207	115	16	788
Rainfall (mm)	60	136	102,7	0	399
Avergae temperature (°C)	60	28,3	28,3	26	30
Humidity (%)	60	78	79	66	88

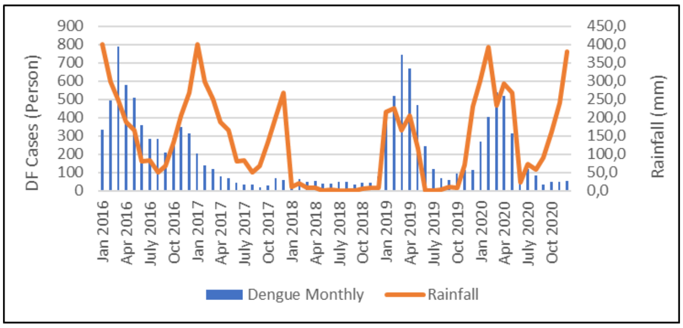

Figure 1. Graph of the Relationship Between Rainfall and DF Cases in Semarang City in 2016-2020

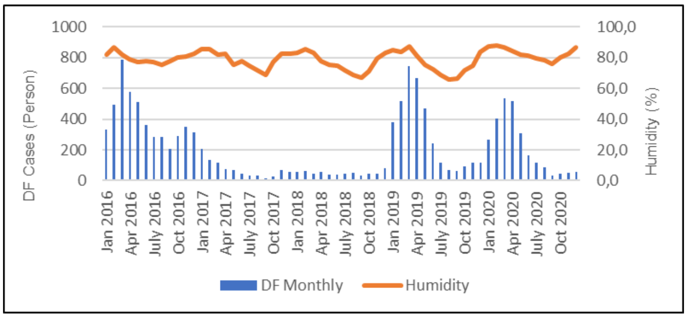

Figure 2. Graph of the Relationship Between Air Humidity and DF Cases in Semarang City in 2016-2020

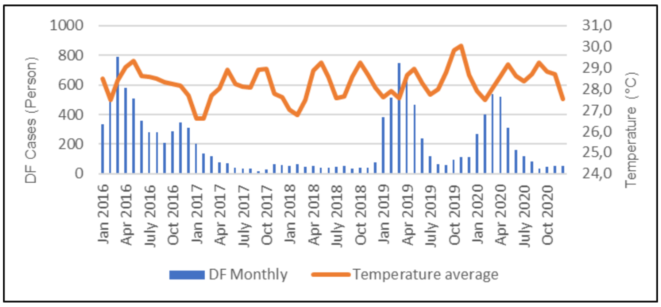

Figure 3. Graph of the Relationship Between Average Temperature and DF Cases in Semarang City in 2016-2020

The results of the bivariate analysis show that 2 of the 3 climate variables have a significant effect on dengue fever in Semarang City (Table 2.). The climate variable that has no significant effect with cases of dengue fever in all lags is the average temperature variable. In addition, in lag 3, the climate variable that has a significant effect to dengue fever cases Semarang City is the rainfall variable.

Rainfall has a significant effect with dengue fever cases at lag 0, lag 1, lag 2, and lag 3. At lag 0, rainfall has a significant effect on dengue fever with a positive direction and moderate strength where the value of r or the correlation coefficient is 0.538. The results of this correlation indicate that when rainfall increases, the number of dengue fever cases will also increase in the same month. This finding is in line with research in Southeast Sulawesi Province which states that climate factor have a positive and significant relationship on dengue hemorrhagic fever at lag 0 or in the same month (Tosepu, 2018).

Rainfall has the highest correlation coefficient at intervals of 1 month with a positive relationship (r=0.574) and moderate strength. The direction of a positive correlation indicates that when rainfall increases, dengue fever cases also tend to increase 1 month later. These findings are in line with research in Cimahi City in 2004-2013 which found that rainfall have the largest correlation coefficient on the dengue hemorrhagic fever incidence at an interval of one month (r=0.265, p-value =0.004) (Fuadiyah, 2018).

In lag 2, rainfall and dengue incidence have a positive and moderate correlation with a correlation coefficient of 0.513. These findings are in line with research in the Administrative City of Central Jakarta which found that rainfall and DHF incidence showed a positive and moderate relationship in lag 2 (Nugraha, 2021). The significant relationship between rainfall and dengue incidence in lag 2 means that if there is an increase in monthly rainfall, it will also be followed by an increase in the number of monthly dengue cases in the following 2 months.

In lag 3, rainfall and dengue incidence have a positive and weak correlation with a correlation coefficient of 0.323. These findings are in line with research in the Administrative City of Central Jakarta which found that rainfall and DHF incidence showed a positive relationship in lag 3 (r=0.357, p-value =0.0001) (Nugraha, 2021). The significant relationship between rainfall and dengue incidence in lag 3 means that if there is an increase in monthly rainfall, it will also be followed by an increase in the number of monthly dengue cases in the following 3 months.

Climatic conditions affect the incidence of dengue indirectly (Tran, 2020). In the transmission of dengue disease, rainfall affects the breeding and life cycle of mosquitoes (Rau, 2019).

Rainfall can form a breeding habitat for juvenile *Aedes* mosquitoes and furthermore lead to an increase in mosquito abundance (Choi, 2016). If the mosquito density increases, the risk of contracting dengue infection will tend to increase. This is supported by a study in Bandung City, Indonesia which found that the addition of *Aedes aegypti* can increase the risk of dengue infection by 1.8% (Faridah, 2022).

However, excessive rainfall can also reduce mosquito density. It is supported by previous study in Singapore which found that excessive rainfall significantly reduced the risk of a dengue outbreak 6 weeks after flushing (Benedum, 2018). A study in Surabaya City, Indonesia also found that rainfall can eliminate mosquito breeding sites by washing away mosquito eggs or larvae if the amount of rainfall reaches 140 mm in a week (Paramita, 2017).

The next variable that has a significant effect on the incidence of dengue fever is humidity. The variable humidity has a significant effect on dengue fever incidence at lag 0, lag 1, and lag 2. Humidity has the highest correlation coefficient on dengue fever at lag of 1 month with an r value of 0.563, the r value indicates that the relationship between humidity and the incidence of dengue fever have a positive correlation with moderate strength. These findings indicate that an increase in air humidity will be followed by an increase in dengue fever cases 1 month later.

Table 2. The Effect of Climate Factors on Dengue Fever in Semarang City, 2016-2020

Variable	Lag 0 (N=60)		Lag 1 Month (N=59)		Lag 2 Month (N=58)		Lag 3 Month (N=57)	
	r	**P-Value**	**r**	**P-Value**	**r**	**P-Value**	**r**	**P-Value**
Rainfall	0.538	<0.01*	***0.574***	<0.01*	0.513	<0.01*	0.323	0.014*
Average Temperature	-0.13	0.320	-0.16	0.22	-0.02	0.857	0.099	0.463
Humidity	0.471	<0.01*	***0.563***	<0.01*	0.471	<0.01*	0.259	0.051

Italicized and bold entry denotes the largest value of correlation coefficient and significance with *p < 0.05;

Findings in this study is in accordance with research in the Cirebon District which states that the humidity variable has a significant relationship to the incidence of dengue hemorrhagic fever at a lag of 1–2 months (Astuti, 2019).

In lag 0, humidity and dengue incidence have a positive and moderate correlation (r=0.471, p-value =<0.01). This result indicates that an increase of humidity will lead to an increase in cases of dengue fever in the same month. This finding is supported by previous studies in Nepal which found that relative humidity had a correlation on dengue incidence at a lag of 0 month (r=0.339, p-value =<0.01) (Tuladhar, 2019). Meanwhile, in lag 2 humidity and dengue incidence have a positive and moderate correlation (r=0.471, p-value =<0.01). This result indicates that an increase of humidity will lead to an increase in cases of dengue fever in the next 2 month. This finding is in line with previous research in the Administrative City of Central Jakarta which found that relative humidity has a significant relationship on DHF incidence at lag of 2 months (r=0,329, P-value =0,0001).

Based on previous studies In Jakarta, Indonesia, humidity can affect the extrinsic incubation period of mosquitoes (Sintorini, 2018). In addition, humidity can affect the density population of mosquitoes. At an appropriate humidity level, mosquitoes have a longer chance of living, conversely if the humidity level is not appropriate, it can increase the chances of mosquitoes to die (Rau, 2019). This condition can happen because the spiral on the body of an adult mosquito is always wide open so that at low humidity, the fluids in the mosquito's body can evaporate and cause the death of the mosquito (Athen, 2022). *Ae. aegypti* can survive in an environment with a humidity limit of at least 60% (Ridha, 2019). Furthermore, a study in Brazil found that when the air humidity was higher than 79%, the abundance of mosquitoes decreased (Da Cruz Ferreira, 2017). In addition, a comparative study between Semarang City and Malang City shows that there are differences in the time-lag effect of climate factors on the incidence of DHF in the two cities. This happens due to the influence of differences in environmental characteristics and social activities in each city (Fauzi, 2019)

The average temperature variable has a p-value under than 0.05 so it is considered to have no significant relationship on dengue fever in Semarang City. These findings are also in accordance with research Angelina and Windraswara (2019) who found that temperature variable have no significant relationship on dengue hemorrhagic fever in Semarang City in 2008-2017. However, the findings in this study is not in accordance with research in Manado Municipality which found that temperature have a significant relationship on the prevalence of dengue fever with an r value of −0.845 (Monintja, 2021).

This findings also not in line with previous theories which state that metabolic processes and mosquito cycles are highly dependent on temperature (Marinho, 2015). Breeding of *Aedes aegypti* mosquitoes can be affected by temperature because an increase in temperature can shorten the development time of mosquitoes from the egg phase to adult mosquitoes (Tresna, 2019). The optimum average temperature for mosquito growth is 25–30^0C (Monintja, 2021). In the pupal phase, the higher the room temperature, the number of larvae that develop into pupae tends to decrease, the number of pupae that develop will decrease as the temperature rises to ≥ 30^0C (Rahmiati, 2019).

Besides affecting the development of larvae, temperature also affects the hatching of mosquito eggs where hatching above 90% occurs in the temperature range between 22-28ºC. Meanwhile at 35ºC the hatching rate was 50%, and at 36ºC he eggs of Ae. aegypti cannot hatch (Setiyaningsih, 2014). Based on descriptive data, the average minimum, and maximum temperatures in Semarang City in 2016-2020 ranged from 26-30◦C, which means that based on theory, these temperatures can support the breeding of dengue vectors. However, the study did not find a significant relationship between average temperature and dengue fever. This can be explained by previous findings which state that the insignificant relationship between temperature and dengue caused by variations in temperature that are constant or do not fluctuate much (Rau, 2019).

CONCLUSION

Our study found that rainfall and humidity have a significant effect on dengue fever in Semarang City in 2016-2020. Rainfall has a significant effect on dengue fever at a time lag of 0,1,2,3 months. Meanwhile humidity, has a significant effect on dengue fever at a time lag of 0,1,2 months. Therefore, efforts to prevent dengue infection in Semarang City can be maximized since December to anticipate an increase in the number of dengue cases in February-March period. The weakness of this study was data analyzed per month, while to provide a clearer picture of the time lag effect of climate on dengue incidence, weekly data analysis can be carried out in future studies.

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