

The relationship between climate factors and dengue fever incidence in Jambi City, Indonesia

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Abstract

Background: Dengue is one of the major public health problems in Indonesia. Climatic conditions play an important role in influencing mosquito populations and virus transmission. A change in climate conditions can lead to alterations in mosquito biology, such as breeding lifespan, and virus replication rates, which in turn affect the incidence of human dengue cases. The aimed of this study is to analyze the relationship between climate factors and the dengue incidence by considering a lag effect of up to four months. **Methods:** This study employed a retrospective ecological time-series design. This study analysed the monthly dengue cases from January 2010 to December 2024. The data were obtained from the Jambi City Health Office. Climatic data, including minimum, maximum, and average temperature (°C), relative humidity (%), and rainfall (mm/day), were collected from the Meteorology, Climatology, and Geophysics Agency (BMKG). The data were analyzed using Spearman's correlation test with lag periods ranging from 0 to 4 months. **Results:** The results showed that maximum and average temperatures had a significant positive correlation with dengue cases at a three-month lag ($r = 0.257$; $p = 0.001$ and $r = 0.181$; $p = 0.016$, respectively). Rainfall exhibited a significant negative correlation ($r = -0.205$; $p = 0.006$). Minimum temperature and relative humidity were not significantly associated with dengue incidence. **Conclusion:** Temperature and rainfall influence dengue transmission with a three-month lag effect. These findings can support early warning systems and climate-informed dengue control programs.

Keywords: Dengue, temperature, rainfall, humidity, lag effect, jambi city

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INTRODUCTION

Dengue is a mosquito-borne infectious disease transmitted primarily by *Aedes aegypti* and *Aedes albopictus* [1]. According to WHO (2024), the global incidence of dengue has risen dramatically, from approximately 500,000 cases in 2000 to 14.1 million. Indonesia is among the countries most affected by dengue, ranking second globally after Brazil.[2] Ministry of Health of Indonesia data indicates that in 2024, only about 5% of Indonesia's 514 districts or cities were free from reported dengue cases.[3] The City of Jambi, located on Sumatra Island, is one of the regions with a relatively high dengue burden, showing a consistent upward trend in case numbers, particularly following the COVID-19 pandemic period.[4]

Environmental and climatic factors are important determinants in the dynamics of dengue transmission. Climatic factors such as air temperature, humidity, and rainfall influence the mosquito life cycle and the replication process of the dengue virus.[5] High temperatures can accelerate larval development. Elevated temperatures may also shorten the extrinsic incubation period of the virus within the mosquito's body.[6] Conversely, excessive rainfall can wash away breeding sites and reduce the vector population.[7] Meanwhile, high humidity can extend the lifespan of mosquitoes, thereby increasing the frequency of transmission.[8]

Although studies have examined the influence of climate on dengue in Indonesia, most have focused on larger urban areas [9–15]. There is limited empirical evidence on how climatic factors affect dengue incidence specifically in Jambi City, where the dynamics may differ from other regions. Additionally, the effect of climate on dengue is not always immediate. The lag between climate changes and rising dengue cases complicates understanding. This study specifically addresses the gap by analysing how climate factors relate to dengue incidence in Jambi city by considering lag effect.

METHODS

Study area

This study was conducted in Jambi City, the capital of Jambi Province. Jambi City is the most densely populated city in the province, accounting for 17.05% of the total population of Jambi Province. The city experiences two distinct seasons: the dry season (from April to October) and the rainy season (from November to March). Administratively, Jambi City is divided into 11 districts and 62 sub-districts. The city is classified as an endemic area for dengue.[16].

Design and data sources

This study employed a retrospective design using an ecological time-series study approach. Monthly dengue data from January 2010 to December 2024 were obtained from the Jambi City Health Office, while climatic data were retrieved from the official website of the Meteorology, Climatology, and Geophysics Agency (BMKG) at <https://dataonline.bmkg.go.id/dataonline-home>. The climatic variables included daily average temperature, maximum temperature, minimum temperature (°C), relative humidity (%), and rainfall (mm), which were aggregated into monthly averages for analysis. In this study, the minimum temperature was defined as the lowest air temperature recorded in a day during the observation period, averaged by month. The maximum temperature referred to the highest air temperature recorded in a day, also averaged monthly. The average temperature was calculated as the mean value of the maximum and minimum temperatures for each month. Rainfall was defined as the average daily precipitation (mm/day) obtained from daily observations and subsequently averaged monthly. Relative humidity was defined as the average

percentage of water vapor content in the air relative to the maximum capacity the air can hold, calculated from daily data and expressed as a monthly average.

Data analysis

The data in this study were analysed univariately and bivariately. The bivariate analysis utilized the Spearman correlation. The Spearman test was conducted to evaluate the correlation between climate variables and the incidence of dengue cases, given that the data were not normally distributed. The analysis utilized lag periods of 0, 1, 2, 3, and 4 months to consider potential delayed impacts of climatic conditions on dengue incidence. A p-value below 0.05 was considered statistically significant.

RESULTS

Descriptive analysis was performed to describe the characteristics of dengue case data and meteorological variables during the observation period. The spearman correlation analysis was performed to assess the correlation between climate factors and the dengue.

Table 1. Univariate results of climatic variables (temperature, humidity, and rainfall) and dengue cases in Jambi City

Variable	N	Min-Max	Mean	Median	SD	95% CI
Dengue	180	0.00-287.00	39.44	21.00	47.96	32.36-46.51
Rainfall	180	0.00-16.16	6.83	6.83	3.44	6.60-7.62
Min Temperature	180	22.65-27.00	23.71	23.68	0.47	23.64-23.78
Max Temperature	180	29.46-33.92	32.01	32.03	0.69	31.91-32.12
Average Temperature	180	25.80-28.27	27.14	27.15	0.45	27.07-27.21
Average Humidity	180	73.80-88.34	83.41	84.00	2.47	83.04-83.77

The number of dengue cases varied widely, ranging from 0 to 287 cases per month, with an average of 39.44 cases and a median of 21 cases. The relatively large standard deviation (SD = 47.96) indicates considerable fluctuations in dengue cases across observation periods. The average daily rainfall was 6.83 mm/day (SD = 3.44), ranging from 0 to 16.16 mm/day, suggesting that the study area experienced moderate to high rainfall intensity with substantial month-to-month variation. The minimum temperature ranged from 22.65°C to 27.00°C, with an average of 23.71°C, while the maximum temperature ranged from 29.46°C to 33.92°C, with an average of 32.01°C. The average daily temperature was 27.14°C, with small monthly variations (SD < 1°C), indicating relatively stable thermal conditions. The mean relative humidity was 83.41%, ranging from 73.80% to 88.34%, reflecting a humid environment conducive to the development of *Aedes aegypti* mosquitoes.

Table 2 shows varying patterns of relationships among the studied variables. The analysis across different lag periods (from lag 0 to lag 4 months) indicates that rainfall and dengue cases exhibit a consistently negative relationship throughout all lag intervals. The correlation became significant at a two-month lag ($r = -0.185$; $p = 0.014$), strengthened at a three-month lag ($r = -0.205$; $p = 0.006$), and reached its highest value at a four-month lag ($r = -0.219$; $p = 0.004$). Temperature variables demonstrated differing directions of association. Minimum temperature showed a very weak and non-significant positive correlation across all lag periods ($p > 0.05$). In contrast, maximum temperature exhibited a progressively stronger positive association at longer lag intervals, becoming significant at two months ($r = 0.178$; $p = 0.019$), three months ($r = 0.257$; $p = 0.001$), and four months ($r = 0.280$; $p < 0.001$).

Similarly, average temperature followed the same pattern, showing a significant positive correlation beginning at a three-month lag ($r=0.181$; $p=0.016$) and continuing at four months ($r=0.192$; $p=0.011$). Meanwhile, average humidity displayed a very weak and non-significant correlation with dengue cases across all lag periods.

Table 2. The relationship between climatic variables (temperature, humidity, and rainfall) and dengue incidence in Jambi City.

Variable	Lag 0 bulan (n=180)		Lag 1 (n=179)		Lag 2 (n=178)		Lag 3 (n=177)		Lag 4 (n=176)	
	r	Sig	r	Sig	r	sig	r	sig	r	sig
Rainfall	-0.109	0.145	-0.145	0.051	-0.185	*0.014	-0.205	**0.006	0.219	**0.004
Minimum Temperature	0.091	0.222	0.097	0.197	0.044	0.556	0.050	0.509	0.020	0.793
Maximum Temperature	0.092	0.218	0.08	0.912	0.178	*0.019	0.257	**0.001	0.280	***<0.001
Average Temperature	0.026	0.731	0.035	0.641	0.136	0.070	0.181	*0.016	0.192	*0.011
Average Humidity	0.083	0.269	0.030	0.694	0.004	0.955	-0.003	0.963	-0.049	0.517

Remarks: *p-value<0.05; **p-value<0.01; ***p-value<0.001

DISCUSSION

The findings of this study indicate a significant relationship between climatic factors and the incidence of dengue, particularly within a lag period of two to four months. Maximum temperature and average temperature were found to have a significant positive association with the number of dengue cases, whereas rainfall showed a significant negative association. Meanwhile, minimum temperature and relative humidity did not demonstrate any significant relationship with case numbers. Similar results of study conducted in Indonesia such as Central Java, Jakarta, and Manado also found that climatic factors were correlated with dengue incidence. [10–13]

The positive association between maximum and average temperature with dengue incidence at a three-month lag suggests that rising temperatures may contribute to an increase in dengue cases after a certain delay. Biologically, higher temperatures accelerate the life cycle of *Aedes aegypti* mosquitoes from egg to adult and shorten the extrinsic incubation period (EIP) of the dengue virus within the mosquito [17]. The virus develops more rapidly inside the mosquito at optimal temperatures of approximately 28–32°C. Furthermore, elevated temperatures enhance mosquito biting frequency and flight activity. It directly increases the likelihood of virus transmission from mosquitoes to humans. Kakarla et al. reported that the impact of temperature on case increases typically emerges after a delay of one to three months. [18–19]

In contrast, rainfall exhibited a significant negative correlation with dengue incidence, particularly at lags of three to four months. This inverse relationship may be explained by high-intensity rainfall disrupting mosquito breeding habitats. Excessive rainfall can flush away eggs and larvae from small water containers that serve as breeding sites for *Aedes aegypti*, thereby reducing vector density. [20] Conversely, very low rainfall may limit the availability of potential breeding habitats. This finding suggests that moderate rainfall levels are more conducive to mosquito proliferation compared to periods of heavy rainfall. The observed lag of two to three months indicates that the reduction in vector populations following changes in rainfall intensity requires time before being reflected in human case numbers.

Humidity biologically contributes to prolonging mosquito lifespan and increasing biting activity. [19] In this study, humidity did not show a significant relationship with dengue incidence. This may be attributed to the consistently high and stable humidity levels in the study area, which exhibit limited variability and therefore a minimal statistical effect. This findings were not in line with the study conducted by Adnyana et.al [19] in Bali where high humidity demonstrated influence on dengue incidence. Overall, this study reinforces evidence that meteorological variables exert a delayed effect (lag effect) on the transmission dynamics of dengue. The three-month lag identified in this analysis indicates that climatic conditions occurring three months prior can serve as early indicators of potential dengue outbreaks. Such information is critical for developing a climate-based early warning system, enabling health authorities to implement timely preventive and vector control measures.

CONCLUSIONS

There is a relationship between meteorological factors and the incidence of dengue with a three-month lag effect. Maximum and average temperatures are positively associated with an increase in dengue cases, whereas rainfall shows a negative association.

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DECLARATION OF ARTIFICIAL INTELLIGENCE USE

During the preparation of this work the author(s) used Chat GPT, Grammarly, and Quillbot in order to improve language, readability of the paper, interpret data, and technical writing assistance. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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