

The effect of climate variability on dengue disease in endemic areas: a study of Bandung City, Indonesia

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ABSTRACT

Dengue fever remains a significant public health issue, particularly in dengue-endemic areas such as Bandung City, Indonesia. Climatic variations have been shown to influence the transmission and incidence of dengue, emphasizing the need to analyze these relationships in endemic regions. This study aimed to analyze the relationship between climate variability and dengue incidence in Bandung City during 2021–2023 and to project trends for 2024 and 2025. An ecological study design was used, with secondary data collected from 30 sub-districts. Climate variables (temperature, humidity, rainfall, wind speed, and air pressure) and dengue incidence data were analyzed using multiple linear regression and exponential smoothing. The results showed that climatic variations collectively explained 24.5% of the variance in dengue incidence ($R^2=0.245$, $p=0.018$), with temperature ($p=0.024$, $r=0.375$) and air pressure ($p=0.015$, $r=-0.402$) being the most influential factors. Humidity, rainfall, and wind speed showed no significant individual effects. Projections indicated an increasing trend in dengue cases in 2024 and 2025, supported by preliminary data showing 1,741 cases reported in Bandung City as of March 2024. These findings confirm the relevance of climate variability as a predictor for dengue incidence. Environment-based interventions, including climate-based early warning systems, proper water reservoir management, community education, and cross-sectoral collaboration, are essential to mitigate the impact of climate variability on dengue transmission. Further research is needed to explore spatial and temporal changes in dengue transmission to improve prevention and control efforts.

Keywords:

dengue fever, climate variability, temperature, air pressure, environmental interventions

Citation:

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INTRODUCTION

The dengue virus is responsible for the highest disease burden among arboviruses, with an estimated 100 million infections occurring over the past 20 years.^{1,2} It is estimated that approximately 50% of the global population lives in areas conducive to dengue virus transmission.³ The incidence of dengue has increased 30-fold over the past five decades, and projections estimate that 2.25 billion more people will be at risk of dengue in the next five decades.⁴ The Asian region represents 70% of the global dengue disease burden. Dengue cases in South and Southeast Asia are particularly prevalent, with a significant population of 1.3 billion residing in dengue-endemic areas across 10 countries in the Southeast Asia Region. Among the 30 most dengue-endemic countries in the world, India, Indonesia, Myanmar, Sri Lanka, and Thailand are particularly noteworthy.⁵

Indonesia is one of the countries contributing the most cases of dengue fever in the world, with the incidence of the disease continuing to increase. In 2021, there were 73,518 cases (incidence rate (IR) of 27/100,000 population), and this figure rose to 143,266 cases (IR of 52.1/100,000 population) in 2022.⁶ Bandung City is a dengue endemic area with a very high incidence rate.

The incidence of dengue in Bandung City is quite fluctuating, the prevalence of dengue in 2020 was 111/100,000 population, increased to 145/100,000 population in 2021, increased again to 201/100,000 population in 2022, and decreased in 2023 to 77/100,000 population.⁷ Based on the data reported as of March 2024, Bandung City is one of the cities contributing the most dengue cases in Indonesia (1,741 cases), this number is higher than West Bandung Regency (1,422 cases), and lower than Tangerang Regency

(2,540 cases).⁸ The increasing trend of dengue fever cases can be influenced by the density of *Aedes* sp. mosquitoes in the affected area. The increase in vector density can be influenced by the presence of containers that can hold water, and the greater the number of containers, the higher the risk of contracting the dengue virus.⁹ Other factors that can encourage an increase in cases include rapid and unplanned urbanization,¹⁰ climate change,¹¹ population growth,¹² population density,¹³ population mobilization,¹⁴ and the presence of larvae.¹⁵

Bandung is a highland city with unique geographical features that influence its climate and ecology. Situated at an elevation of approximately 768 meters above sea level, Bandung experiences a moderate climate, which is distinct from the lower-lying tropical areas. This climatic condition affects the behavior of *Aedes* mosquitoes, which thrive in specific temperature and humidity ranges. Additionally, Bandung's location in the Sunda Megathrust zone makes it susceptible to various environmental factors such as rainfall patterns and seasonal temperature variations, which significantly impact the spread of dengue fever.¹⁶⁻¹⁸ Furthermore, Bandung's rapid urbanization over the past few decades has created a unique challenge for dengue control. The city's urban growth has often been unplanned, leading to increased densities of standing water, which serve as breeding sites for *Aedes* mosquitoes. The transformation of rural areas into urban centers, accompanied by population growth and increased human mobility, exacerbates the spread of dengue.^{19,20} Studies have shown that urbanization, particularly in tropical cities, often leads to a higher density of mosquito breeding sites and contributes significantly to the dynamics of vector-borne diseases such as dengue.²¹ Alterations in temperature, rainfall patterns

and humidity affect disease distribution through a number of impacts on mosquito habitats, vectors, vector activity and pathogen development within vectors.²² In addition, climate change is expected to intensify dengue outbreaks and expand the geographic spread of vectors, which are able to transmit dengue viruses from endemic to non-endemic areas.²⁰ It is known that the life cycle and population dynamics of *Aedes* spp. are strongly influenced by rainfall and temperature.^{23,24} Numerous researches on climate change and its variability have revealed that this phenomenon has a significant influence on the epidemiology of dengue fever.²⁵⁻²⁷

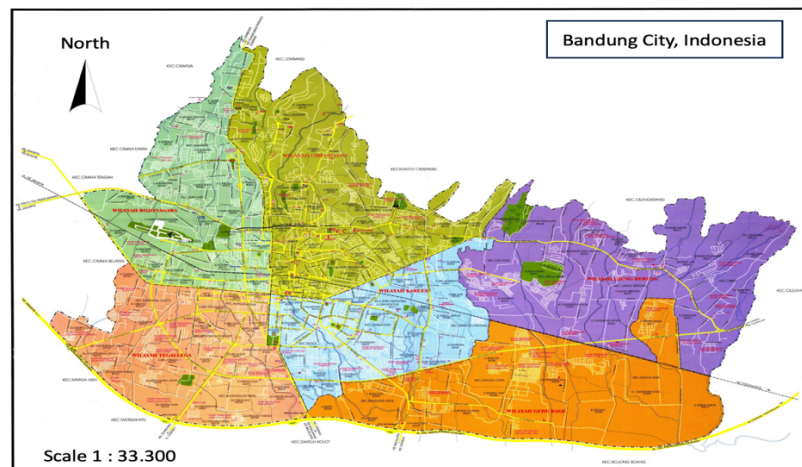
With the increasing trend of dengue fever, especially in endemic areas, there is a need to reassess climate variability in increasing dengue cases. Current treatment approaches are supportive, focusing on mitigating complications and reducing symptom severity.²⁸ There is currently a commercially available vaccine called Dengvaxia, but its use is still restricted as it may increase the risk of severe dengue fever in people with no previous history of infection.²⁹ In addition, there is a QDenga brand vaccine that has shown a promising safety record.³⁰ Although this vaccine has been licensed, its sustainability has not been demonstrated in the general population. There are no effective therapies and vaccines available, hence vector control remains the main alternative to reduce dengue fever transmission.³¹ This study integrates multiple climate parameters including rainfall, temperature, and humidity with local epidemiological data to create a more accurate predictive model for dengue incidence. By combining these variables, the study aims to forecast the impact of climate variability on dengue outbreaks, offering a more nuanced understanding of how specific climatic

factors influence the timing and intensity of dengue fever cases in Bandung. This approach provides a comprehensive framework for early warning systems and more effective disease control strategies in endemic areas. The findings from this research will be instrumental for public health authorities in developing timely and region-specific strategies for dengue prevention and control. Therefore, this study aims to forecast the number of cases and evaluate the impact of climate variability on the increase of dengue fever in endemic areas.

METHOD

Study area

This study was conducted in the city of Bandung, located in the western part of Java Island, Indonesia, at coordinates 6°55'S latitude and 107°36'E longitude (**Figure 1**). Bandung is the capital of West Java Province and covers an area of approximately 167.67 km², with a population of around 2.5 million people as of 2020. It is one of the largest and most populous cities in Indonesia and serves as a significant center for education and economic activities in the region. In terms of climate, Bandung experiences a tropical climate with two distinct seasons: the wet season and the dry season. The wet season typically occurs from November to March, while the dry season lasts from April to October. According to the Köppen climate classification, Bandung has a tropical climate with a clear dry season and significant rainfall during the wet season. The city's average annual temperature ranges between 23°C and 28°C, making it relatively cooler compared to other major cities in Indonesia.³²



Source: <https://ppdbkotabandung.wordpress.com/pustaka/peta-kota-bandung/>

Figure 1. Geographical Location of the Study Site – Bandung City, Indonesia

Data collection

This study utilized monthly dengue fever case data from January 2021 to December 2023, obtained from the Bandung City Health Office. The dataset includes a total of 36 monthly observations. The decision to use dengue cases from the years 2021 to 2023 was based on the availability of data recorded by the Bandung City Health Office at the time of this study, as well as its sufficient size for the analysis. Climate variability data for the same period (January 2021 to December 2023) was obtained from the Statistics Center Agency. Weather-related variables such as average temperature, average humidity, rainfall, wind speed, and air pressure were measured by the Meteorological and Climatological Stations using Automatic Weather Station (AWS) equipment. Bandung City hosts one Meteorology, Climatology, and Geophysics station, the Bandung Geophysical Station, which provided the relevant climate data.

Data analysis

The data were analyzed using both descriptive and inferential methods with the help of Microsoft Excel and SPSS version 28. The steps of data analysis are as follows: Descriptive Analysis: The

collected data were analyzed descriptively to provide an overview of the trends in dengue cases and climate variability in Bandung from 2021 to 2023. The dengue case data were analyzed to describe the number of cases per month for each year within the study period, allowing for the identification of fluctuations and seasonal patterns. Additionally, climate variability data, including average temperature, humidity, rainfall, wind speed, and air pressure, were averaged monthly to provide an understanding of the climatic conditions influencing the distribution of *Aedes* sp. vectors, which can cause the transmission of dengue fever.

Exponential smoothing was used to forecast the future incidence of dengue fever in Bandung City. This method is particularly suitable for time series forecasting by incorporating the most recent observations in a weighted manner. The formula used for this method is as follows:³³

$$F_{t+1} = F_t + \alpha (Y_t - F_t)$$

Description :

F_{t+1} = new forecast (for time period $t+1$)

F_t = previous forecast (for time period t)

α = smoothing constant ($0 \leq \alpha \leq 1$)

Y_t = actual number of dengue in the previous period

The new estimate is the old estimate plus a portion of the result of the error in the last period. The exponential smooth method used in this study is exponential smooth with Holt's linear trend model.

To examine the relationship between climate variability and dengue incidence, a correlation analysis was conducted to measure the strength of the linear relationship between climate variables (temperature, humidity, rainfall, wind speed, and air pressure) and the number of dengue cases. The correlation coefficient test was used to determine whether there is a positive or negative correlation between climate factors and dengue case numbers and to assess the strength of the relationship over the study period. Simple linear regression was performed to determine the effect of climate variability on dengue incidence in Bandung. In this analysis, climate variables (such as temperature, humidity, rainfall, wind speed, and air pressure) were tested simultaneously to assess the extent to which these factors could explain changes in dengue cases. Using the F distribution test

and the Coefficient of Determination (R^2), this analysis aims to measure how much climate variability influences and explains the variation in dengue incidence, providing clearer insights into the contribution of climate factors to disease spread.

Ethical clearance

This study was approved by the Health Research Ethics Committee of Bhakti Kencana University, with approval number 087/09.KEPK/UBK/VII/2023.

RESULTS

This study was conducted in Bandung City, utilizing secondary data to analyze the distribution of dengue cases from 2021 to 2023 (**Figure 1**). The incidence showed fluctuations, with the peak observed in January 2022 (1,225 cases) and the lowest in April 2023 (71 cases). The data highlights seasonal variations and provides a foundation for further analysis of potential contributing factors.

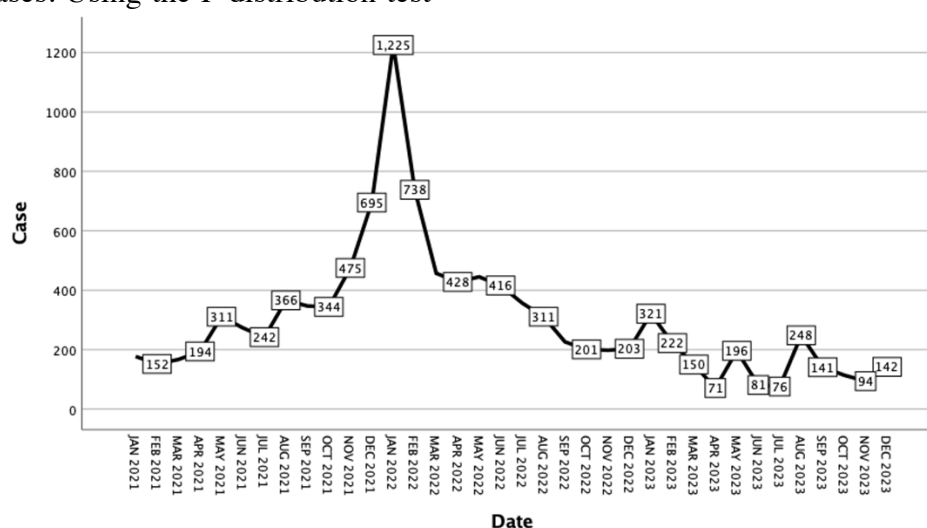


Figure 2. Distribution of Dengue Incidence in 2021-2023

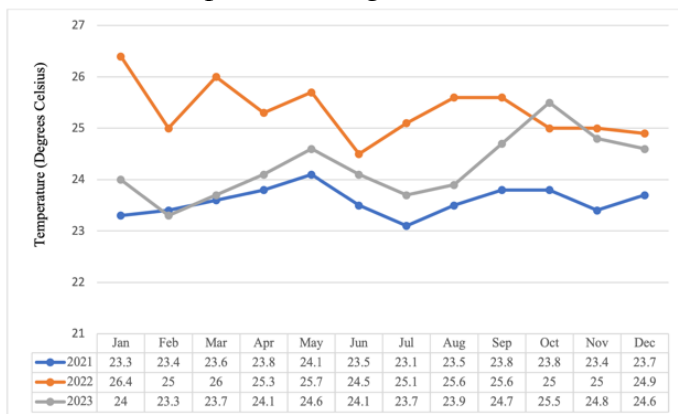
Figure 2 illustrates climate variability in Bandung City from 2021 to 2023 based on secondary data analysis. The

highest average temperature was recorded in January 2022 (26.4°C), while the lowest was in July 2021 (23.1°C). Humidity

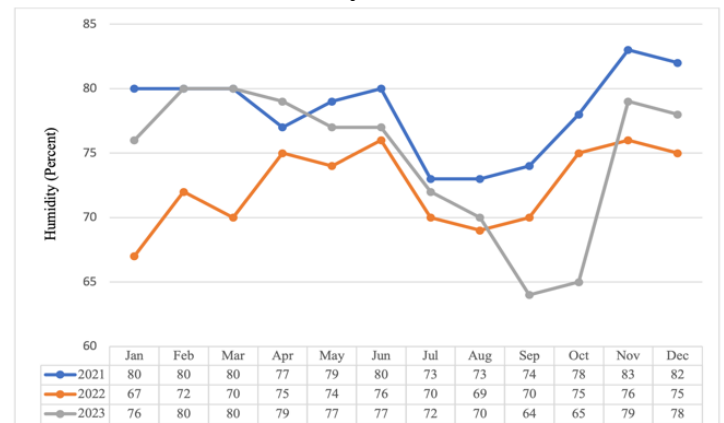
peaked in November 2021 (83%) and reached its lowest point in September 2023 (64%). Rainfall was highest in November 2021 (454.3 mm) and lowest in September 2023 (18 mm). The strongest wind speeds were observed in January–February 2021

(9 knots), whereas the lowest speeds (2 knots) occurred throughout most months in 2022 and 2023. Air pressure ranged from a maximum of 926.4 mb in October 2023 to a minimum of 921.7 mb in January 2021.

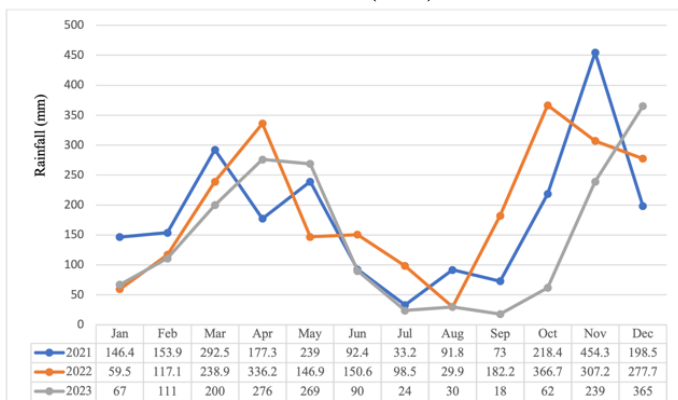
Temperature (Degrees Celsius)



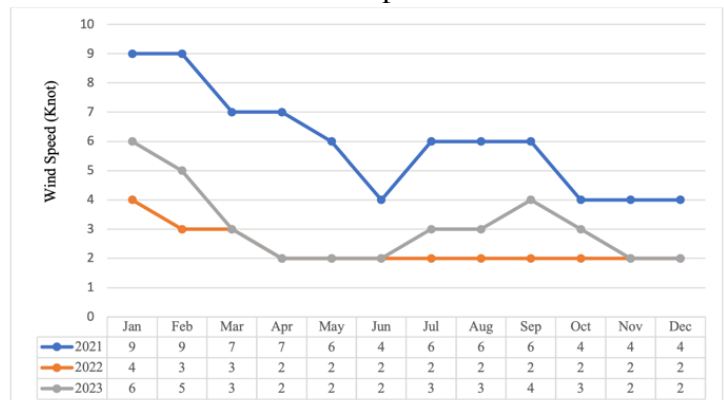
Humidity (Percent)



Rainfall (mm)



Wind speed



Air Pressure (mb)

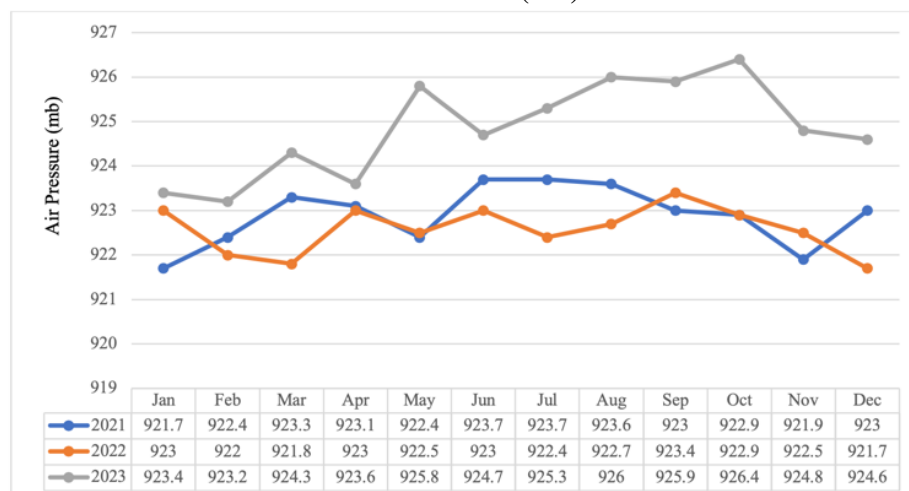


Figure 3. Distribution of Climate Variability for 2021-2023

Figure 3 presents the epidemiological trend of dengue incidence and its projected increase in 2024 and 2025 based on time-series analysis. The analysis indicates a

potential resurgence of cases, emphasizing the importance of early intervention and preventive measures to mitigate the predicted rise in dengue incidence.

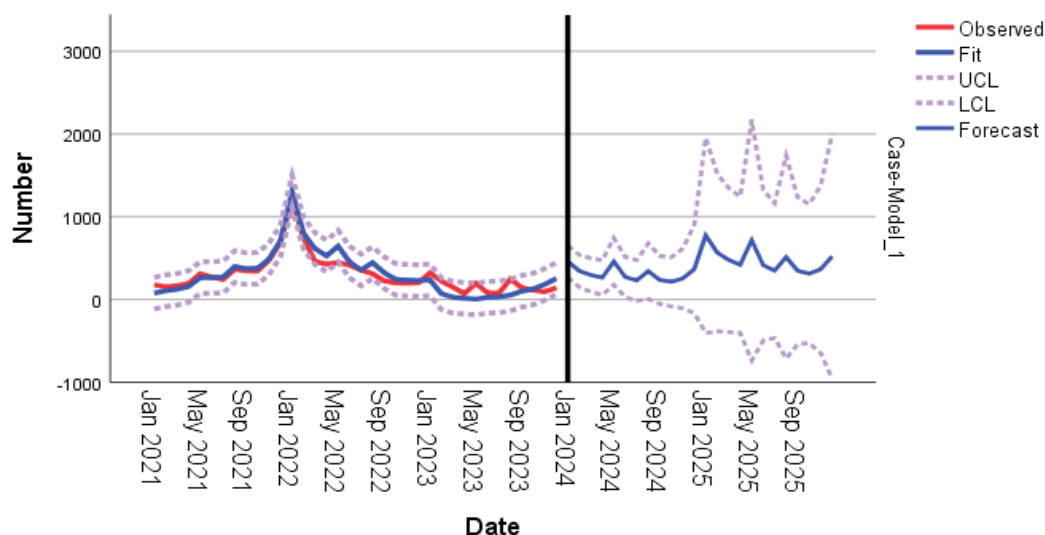


Figure 4. Epidemiologic trends of dengue incidence and case forecasting by month in 2024-2025

Table 1 summarizes the correlation analysis between climate variability and dengue incidence in Bandung City from 2021 to 2023. The analysis shows a moderate negative correlation between air pressure and dengue incidence ($p=0.015$, $r=-0.402$) and a moderate positive correlation between temperature and dengue incidence ($p=0.024$, $r=0.375$). No

significant correlations were found for humidity ($p=0.262$, $r=-0.192$), rainfall ($p=0.615$, $r=-0.087$), and wind speed ($p=0.916$, $r=-0.018$) with dengue incidence over the three-year period. These findings suggest that air pressure and temperature may play a more significant role in influencing dengue incidence compared to other climate factors.

Table 1. Correlation Analysis of Climate Variability with dengue incidence

Variable	Year	r	P value	r	P value	95% CI	
						Lower	Upper
Temperature	2021	0.218	0.497	0.375	0.024	0.053	0.626
	2022	0.560	0.059				
	2023	-0.286	0.367				
Humidity	2021	-0.097	0.765	-0.192	0.262	-0.490	0.146
	2022	-0.543	0.068				
	2023	0.026	0.936				
Rainfall	2021	0.262	0.411	-0.087	0.615	-0.404	0.249
	2022	-0.517	0.085				
	2023	-0.216	0.501				

Variable	Year	r	p value	r	p value	95% CI	
						Lower	Upper
Wind Speed	2021	-0.723	0.008				
	2022	0.909	0.001	-0.018	0.916	-0.345	0.312
	2023	0.719	0.008				
Air Pressure	2021	-0.009	0.979				
	2022	0.060	0.852	-0.402	0.015	-0.645	-
	2023	-0.210	0.512				0.085

Notes: Spearman rank test

Table 2 presents the results of the multiple linear regression analysis examining the effect of climate variability (temperature, humidity, rainfall, wind speed, and air pressure) on dengue incidence in Bandung City from 2021 to 2023. The analysis shows that climate variability variables collectively have a significant effect on dengue incidence ($F=3.267$, $p=0.018$), with an R^2 value of 0.353, indicating that 35.3% of the variation in dengue incidence can be explained by these variables. Among the individual variables, air pressure had a statistically significant negative effect on dengue incidence ($t=-2.104$, $p=0.044$), while other variables (temperature, humidity, rainfall, and wind speed) did not show significant individual effects. These findings highlight the importance of air pressure as a key factor in understanding dengue incidence.

Table 2. Multiple Linear Regression Model Between Climate Variability and Dengue Incidence

Variable	t	p value	F	p value	R Square	Adjusted R Square
(Constant)	1.897	0.068				
Temperature	1.768	0.087				
Humidity	0.540	0.594				
Rainfall	-1.367	0.182	3.267	0.018	0.353	0.245
Wind Speed	0.483	0.632				
Air Pressure	-2.104	0.044				

Notes: Multiple linear regression test

DISCUSSION

Based on trend analysis, it is projected that dengue fever will increase again in 2024 and 2025, which may be influenced by extreme weather conditions. Preliminary data from March 2024 indicate that Bandung City has already reported 1,741 dengue cases, making it one of the highest contributors to dengue cases in Indonesia during this period. Although researchers did not further analyze the specific role of climate in the future, these

findings align with previous studies suggesting that extreme weather events, such as El Niño, are expected to become more frequent, leading to an increase in dengue infections. For instance, studies in China have demonstrated that extreme temperatures and increased rainfall are strongly and positively associated with dengue outbreaks.^{34,35} These results are consistent with the increasing frequency of climate events such as El Niño, which is expected to exacerbate the frequency and intensity of dengue outbreaks worldwide,

particularly in tropical regions like Southeast Asia. These findings emphasize the importance of implementing early intervention strategies to mitigate the anticipated impacts of climate variability on dengue transmission.

The findings in this study show that there is a correlation between temperature and the incidence of dengue fever. This result is in accordance with a study in Cambodia which stated that an increase in the average maximum temperature by 1°C led to an increase in the number of dengue cases.³⁶ Similar findings were conducted in Thailand (1983-2001) and Singapore (2000-2012) where elevated temperatures were shown to increase the incidence of dengue fever.^{37,38} A study in Sri Lanka found that minimum, average, and maximum temperatures were correlated with dengue incidence.³⁹ The average temperatures in Bandung City during the 2021-2023 period were (23.6°C, 25.3°C, and 24.3°C, respectively) which is favorable for mosquito breeding. The optimum average temperature for mosquito growth is 25-30°C, while the highest or most active mosquito activity is at 29°C and the lowest activity is at 32°C.⁴⁰ A study that monitored the epidemic potential of dengue fever globally stated that the increased epidemic potential of dengue fever in subtropical and tropical areas is the temperature range between 20°C - 32°C.⁴¹

However, it is important to note that the relatively low coefficient of determination ($R^2 = 0.245$) indicates that only 24.5% of the variation in dengue incidence can be explained by climate variables. This suggests that other factors, such as socio-economic conditions, urbanization, vector control efforts, and human behavior, play significant roles in influencing dengue transmission, which were not accounted for in this model. Incorporating these variables could potentially improve the model's predictive accuracy. Further research should explore these unexamined variables, particularly

human mobility, urbanization patterns, and public health interventions, to gain a more holistic understanding of the dynamics of dengue transmission.

Humidity does not correlate with dengue incidence. This result is in line with the findings in Palu City, which stated that there was no significant correlation between humidity and dengue incidence and the air humidity in Palu City during the observation period was 64.7%-84% on average.⁴² The same finding was also made in the Talaud Islands District, where there was no correlation between humidity and dengue incidence.⁴³ Different results were found in Makassar and Manado, where there was a significant relationship between humidity and dengue prevalence, and relative humidity may be a factor that strongly influences egg development and adult population size of *Aedes aegypti*.^{44,45} The average humidity in Bandung City during the 2021-2023 period was (78.3%, 72.4%, and 74.8%, respectively), which creates a favorable environment for breeding *Aedes aegypti* mosquitoes. Findings in China showed that 74.6% humidity may increase the potential density of mosquitoes.⁴⁶ Generally, humidity levels increase mosquito survival rate and daily biting rate. Nonetheless, humidity above 79% may decrease mosquito populations due to complex interactions among climatic factors.⁴⁷ In Bandung, the average humidity was 72.4%-78.3% during the study period. Therefore, the humidity level in Bandung City is still in a condition that increases the ability to transmit dengue fever. While humidity did not show a strong correlation with dengue incidence in this study, it is still important to note its role in mosquito survival and the overall mosquito population dynamics. Future studies should include more detailed data on indoor and outdoor humidity levels to further clarify these relationships.

Rainfall does not correlate with dengue incidence. This result is in accordance with the findings in Semarang

City, where there was no correlation between rainfall and dengue incidence due to very high and long-lasting rainfall, which eliminated breeding sites of mosquito vectors.⁴⁸ Similar to the findings in Sukabumi City, there was no correlation between rainfall and dengue incidence because the public eradicated mosquito nests before the rainy season came, thus reducing mosquito breeding sites.⁴⁹ Different findings in Manado City indicated that there was a moderate correlation between rainfall and dengue incidence, as rain can increase mosquito breeding sites in the form of water storage containers so that it can become a breeding site for mosquitoes and cause an increase in dengue incidence.⁵⁰ The highest incidence of dengue occurred from December to January during the 2021-2023 period when rainfall conditions were not too high. This pattern is due to the behavior of people in Bandung City who often collect clean water during the transition period from the rainy season (December to March) to the summer season (April to June). These water storage containers, commonly found inside houses, such as bathtubs, provide ideal breeding sites for *Aedes aegypti* mosquitoes. Previous research conducted in Bandung City reported that the majority of *Aedes aegypti* larvae were found in indoor water reservoirs, particularly in bathtubs, highlighting the need for targeted vector control measures during this seasonal transition.⁵¹ Findings in Mexico showed that the frequency of larval populations was higher in households (14.1%), compared to containers found outdoors (5.1%).⁵² Meanwhile, findings in Thailand showed that the most important risk factors for the presence of *Aedes aegypti* were container type (jars and tanks), location (toilet/bathroom), and lid status (no lid).⁵³ The observed disconnection between rainfall and dengue incidence suggests that human behaviors such as water storage

might have a larger influence than rainfall alone. This highlights the importance of community education and seasonal interventions to control mosquito breeding sites.

Wind speed does not correlate with dengue incidence. This result is aligned with a study conducted in Bitung City, which reported that there was no correlation between wind speed and dengue incidence.⁵⁴ It is also in alignment with a study in Mataram, which stated that the average wind speed was between 2–2.4 knots. These wind speeds occurred in October-February and July. This condition shows that an increase in wind speed does not equal an increase in dengue cases.⁵⁵ The insignificant relationship could be due to the close proximity of houses in residential areas, so wind speed has little effect on vector dispersal. In addition, *Aedes aegypti* mosquitoes tend to stay indoors more often.⁵⁶ Wind speed at sunrise and sunset when mosquitoes fly in or out of the house determines human contact with mosquitoes. However, different results in the wind speed analysis conducted in stages, specifically in 2021, 2022, and 2023, showed a correlation. In 2021, there was a negative correlation, meaning that the lower the wind speed, the higher the incidence of dengue, with the average wind speed in 2021 being 6 knots. Meanwhile, 2022 and 2023 showed a positive correlation, meaning that the higher the wind speed, the higher the incidence of dengue, with an average wind speed of 2.3 knots and 3.1 knots, respectively. So, the researcher assumes that the wind speed that has the potential to increase the incidence of dengue is 3 knots - 6 knots. Wind speeds ranging from 11-14 m/s affect or inhibit mosquito flight. Wind speed will affect mosquito flight distance.⁵⁷ This speed will not inhibit the mosquito vector from flying, so it is sufficiently ideal for the *Aedes aegypti* mosquito vector activity.

The findings in this study show that there is a correlation between air pressure and the incidence of dengue fever. This result is aligned with research conducted in Sri Lanka, which found that air pressure has a major impact on dengue fever transmission.⁵⁸ It is also consistent with a study conducted in Bangladesh, which reported that air pressure significantly affects the spread of dengue fever.⁵⁹ Air pressure is also associated with wind speed. Wind speed is determined by the difference in air pressure between the origin and destination of the wind (as a driving factor) and the resistance of the terrain through which it passes.⁶⁰ Among other environmental factors, humidity and air pressure are well-known environmental factors in ecological studies. Both humidity and air pressure are considered as potential predictors of dengue fever.⁶¹ Air pressure, in combination with other climate factors, could be a critical component in predicting dengue outbreaks. It is important to examine these relationships further, particularly in the context of how atmospheric pressure and temperature interact to influence mosquito behavior.

Overall climate variability (temperature, humidity, rainfall, wind speed, and air pressure) was simultaneously significantly associated with dengue fever incidence. This result is in line with research conducted in Makassar which reported that all climate variables (humidity, rainfall, temperature, and wind speed) have a significant correlation with dengue fever cases. Meanwhile, humidity has a dominant correlation to dengue fever cases compared to other climatic factors⁴⁴. Similarly, a study in China found that environmental factors influencing dengue infection are relatively complex, with various factors interacting with each other in various direct or indirect ways.⁶¹

To address the projected increase in dengue cases, it is recommended that public health organizations, such as the Bandung City Health Office, collaborate with

meteorological agencies to implement climate-based early warning systems. This system could forecast periods of high transmission risk based on predicted changes in weather patterns. Additionally, water management strategies, such as encouraging the use of covered water storage containers, should be integrated into dengue control programs. Cross-sector collaboration among local governments, environmental agencies, and public health authorities is crucial to effectively manage and mitigate dengue outbreaks in Bandung.

This study has several limitations, which include: first, the data on climate variability (temperature, humidity, rainfall, wind speed, and air pressure) were not analyzed by subdistrict, so that autocorrelation between climate variability and dengue fever incidence could not be analyzed; second, this study focused on the risk of dengue fever in a static environment, without taking into account temporal and spatial changes in the dengue epidemic under dynamic environmental conditions, such as climate change. Therefore, further research should focus on the dynamic characteristics that affect the spatial pattern of dengue epidemics.

CONCLUSION

This study successfully analyzed the relationship between climatic variations and dengue incidence in Bandung City during the period 2021–2023. The results revealed that temperature and air pressure were moderately associated with dengue incidence, while humidity, rainfall, and wind speed showed no significant individual effects. Climatic variations collectively explained 24.5% of dengue incidence, suggesting that other factors also play a significant role in dengue transmission. The study also projected an increasing trend in dengue cases for 2024 and 2025, emphasizing the urgent need for interventions tailored to climatic factors. These findings highlight the importance of

incorporating climate-based strategies in public health planning to reduce dengue incidence. For future research, it is recommended to incorporate longer longitudinal datasets to improve the robustness of trend projections and capture more comprehensive patterns of dengue outbreaks. Additionally, integrating socio-economic data with climate variables could provide a more holistic understanding of the factors influencing dengue fever incidence, as demographic and socio-economic factors may interact with climatic conditions to affect disease transmission.

AUTHOR CONTRIBUTIONS

H.A.: Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft, Writing – review and editing, Supervision. D.F.: Conceptualization, Methodology, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review and editing. C.C.: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review and editing, Supervision. Y.M.U.: Resources, Project administration. R.M.N.: Software, Validation, Data curation, Formal analysis, Writing – original draft. R.P.: Visualization, Investigation, Writing – original draft, Writing – review and editing. A.S.: Formal analysis, Investigation, Validation, Writing – original draft, Writing – review and editing.

ETHICAL CONSIDERATION

The study was approved by the Health Research Ethics Committee, Bhakti Kencana University, with protocol number 087/09.KEPK/UBK/VII/2024, and the approval was granted on 10 April 2024.

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