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The Effect of Climate Factors and Larvae-Free Index on Dengue Hemorrhagic Fever: A Secondary Data Analysis of Probolinggo City, 2022–2024

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A B S T R A C T

Dengue hemorrhagic fever (DHF) cases in Probolinggo City had fluctuated over the past three years and had shown an upward trend. The number of cases increased by 45.75% in 2022, 4.48% in 2023, and 110.30% in 2024. Climatic conditions could affect the *Aedes* mosquito population, potentially increasing the incidence of DHF. This study aimed to analyze the influence of climatic factors and ABJ on DHF cases in Probolinggo City. This study used an ecological design and monthly secondary data from January 2022 to December 2024 (n = 36). Data on DHF cases and ABJ were obtained from the Probolinggo City Health Office, while climate factor data were obtained from the BMKG. Data analysis was performed using univariate, bivariate, and multivariate analyses via multiple linear regression with a significance level of 5% ($\alpha = 0.05$). There were 946 cases of DHF in Probolinggo City from 2022 to 2024, with a peak of 111 cases in May 2024. Partial analysis showed that rainfall ($p=0.643$) and wind speed ($p=0.213$) had no significant effect, whereas Humidity ($p=0.038$), temperature ($p=0.003$), and ABJ ($p=0.002$) had a significant effect on DHF cases. Multiple linear regression analysis showed that ABJ, temperature, and Humidity had a significant effect on DHF cases, with a strong correlation coefficient ($R = 0.826$) and a coefficient of determination of 68.2% ($R^2 = 0.682$), with the equation: DHF Cases = −5.512 ABJ + 16.480 Temperature + 1.696 Humidity. DHF cases in Probolinggo City fluctuated, with DHF cases significantly influenced by Humidity, temperature, and ABJ. The results of this study were used to strengthen early warning systems and DHF control planning based on climate factors and to improve ABJ in Probolinggo City.

Kasus Demam Berdarah Dengue (DBD) di Kota Probolinggo mengalami fluktuasi selama tiga tahun terakhir dan menunjukkan trend peningkatan, dari 45,75% (tahun 2022), 4,48% (2023), dan 110,30% (2024). Kondisi iklim dapat dipengaruhi populasi nyamuk *Aedes,* yang berpotensi meningkatkan kejadian DBD. Penelitian ini bertujuan untuk menganalisis pengaruh faktor iklim dan ABJ terhadap kasus DBD di Kota Probolinggo. Penelitian ini menggunakan desain ekologis dan data sekunder bulanan dari Januari 2022 hingga Desember 2024 (n = 36). Data kasus DBD dan ABJ diperoleh dari Dinas Kesehatan Kota Probolinggo, sedangkan data faktor iklim diperoleh dari BMKG. Analisis data dilakukan menggunakan analisis univariat, bivariat, dan multivariat dengan regresi linier berganda pada tingkat signifikansi 5%. Terdapat 946 kasus DBD di Kota Probolinggo dari tahun 2022 hingga 2024, dengan puncak 111 kasus pada Mei 2024. Analisis parsial menunjukkan bahwa curah hujan ($p=0,643$) dan kecepatan angin ($p=0,213$) tidak berpengaruh signifikan, sedangkan kelembapan ($p=0,038$), suhu ($p=0,003$), dan ABJ ($p=0,002$) berpengaruh signifikan terhadap kasus DBD. Analisis regresi linier berganda menunjukkan bahwa ABJ, suhu, dan kelembapan berpengaruh signifikan terhadap kasus DBD, dengan koefisien korelasi yang kuat ($R = 0,826$) dan koefisien determinasi sebesar 68,2% ($R^2 = 0,682$), dengan persamaan: Kasus DBD = −5,512 ABJ + 16,480 Suhu + 1,696 Kelembapan. Kasus DBB di Kota Probolinggo berfluktuasi, dengan kasus DBB dipengaruhi secara signifikan oleh kelembapan, suhu, dan ABJ. Hasil penelitian ini digunakan untuk memperkuat sistem peringatan dini dan perencanaan pengendalian DBB berdasarkan faktor iklim serta untuk meningkatkan ABJ di Kota Probolinggo.

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1. Introduction

Dengue Hemorrhagic Fever (DHF) is a communicable infectious disease that remains a major public health concern, particularly in tropical and subtropical regions. The *dengue* virus is transmitted through the bites of *Aedes aegypti* and *Aedes albopictus* mosquitoes that feed on human blood (Setiawan & Budi, 2023). The *Aedes aegypti* mosquito serves as the primary vector for DHF in tropical regions and has been identified in 167 countries, most of which have tropical climates. This mosquito's activity tends to be high year-round in tropical regions, particularly during the rainy season, making tropical countries like Indonesia ideal habitats for its reproduction (Ramadona & Wijayanti, 2024).

Indonesia's tropical climate supports the growth and spreads of disease vectors such as *Aedes aegypti* and *Aedes albopictus*. These two mosquito species are active nearly year-round, resulting in a continuous emergence of DHF cases with fluctuating numbers (Dewi et al., 2023). East Java Province is one of the regions in Indonesia with a relatively high number of DHF cases, and the city of Probolinggo ranked third, with fluctuating increases in DHF cases from 2022 to 2024 (East Java Health Office, 2024).

Data from the Probolinggo City Health Department shows that the incidence of DHF in 2022 was 91.6 per 100,000 residents, then rose to 95 per 100,000 residents in 2023, and saw a significant increase in 2024 to 196.3 per 100,000 residents (Probolinggo City Health Department, 2024). This increase indicates a sharp upward trend in DHF cases over the past three years.

The rise in DHF cases in Probolinggo City is also evident in the percentage increase: 45.75% in 2022, 4.48% in 2023, and a surge to 110.30% in 2024. The status of vector control is reflected in the Larvae-Free Index (ABJ) values, which remain below the national target of ≥ 95%, with an average ABJ of 88.81% in 2022, 89.80% in 2023, and 87.42% in 2024. This indicates that there is still potential for *Aedes* mosquitoes to breed in residential areas, which could increase the risk of dengue transmission (Probolinggo City Health Department, 2024).

The spread of the disease is also influenced by various factors such as the environment, climate, population, and human behavior (Saputra et al., 2023). Several factors that contribute to the increase in DHF cases include the vector population, population density, human mobility, and environmental and climatic conditions (Hamid et al., 2023). Climate factors play a significant role in determining how quickly DHF spreads, as changes in climatic conditions can affect mosquito activity and increase the risk of dengue virus transmission (Rakhmatsani & Susanna, 2024).

Climatic factors such as Rainfall, temperature, and Humidity are closely linked to the survival of dengue vectors. Rainfall can increase the availability of mosquito breeding sites; temperature affects the life cycle and biting activity of mosquitoes; and Humidity can extend the lifespan of mosquitoes and increase the frequency of bites, thereby potentially increasing the transmission of the dengue virus (Ghaisani et al., 2021). Changes in climatic factors can also affect mosquito activity and increase the risk of dengue virus transmission (Rakhmatsani & Susanna, 2024). In addition to climatic factors, areas with dense populations, poor sanitation, and limited access to health services tend to have a higher risk of dengue transmission (Hamid et al., 2023). DHF cases also often follow recurring patterns of transmission that intensify during specific periods depending on climatic and environmental conditions (Roelofs et al., 2024).

Various studies have shown that climatic factors influence the incidence of DHF and that the *Aedes aegypti* index is used as an indicator for vector control. However, no study has yet examined the simultaneous effects of climatic factors, including Rainfall, temperature, Humidity, and wind speed, and the ABJ on DHF cases in Probolinggo City using multiple linear regression analysis. This situation indicates a research gap that needs to be addressed to obtain a more comprehensive understanding of the factors influencing the incidence of DHF in Probolinggo City. Therefore, trend analysis is needed to identify patterns of increases and decreases in cases systematically. Research on the influence of climate factors and ABJ on DHF cases in Probolinggo City is expected to serve as a reference in developing more targeted, effective, and sustainable control strategies.

This study aims to examine the influence of climatic factors and ABJ on DHF cases in Probolinggo City, as well as to describe the number of DHF cases, climatic conditions (Rainfall, Humidity, air temperature, and wind speed), and ABJ values for the years 2022–2024 based on secondary data.

2. Methods

This study uses ecological studies, utilizing secondary data to analyze the influence of climate factors and ABJ on dengue fever cases in Probolinggo City based on data from the last three years (2022–2024). This study was conducted in the administrative area of Probolinggo City from August 2025 to January 2026. Data sources include the Probolinggo City Health Office for dengue fever and ABJ case data, and the Indonesian Meteorology, Climatology, and Geophysics Agency (BMKG) for climate data, including rainfall, air temperature, humidity, and wind speed.

The unit of analysis in this study is monthly data covering the period from January 2022 to December 2024 (36 months). Data on DHF cases, climate factors, and ABJ were organized by observation month, such that each month represents one observation unit. If data were available daily, they were processed into monthly data using cumulative values for Rainfall and average values for air temperature, relative Humidity, and wind speed. ABJ data were adjusted to monthly data based on reports available from the Probolinggo City Health Department. The independent variables in this study were climate factors such as Rainfall, air temperature, relative Humidity, and wind speed, as well as ABJ; conversely, the dependent variable was the number of DHF cases in Probolinggo City during 2022 – 2024.

Data processing was conducted through the stages of editing, coding, entry, and cleaning before statistical analysis was performed. Data analysis was conducted in stages: univariate analysis to describe the characteristics of each research variable; bivariate analysis to identify the relationship between each independent variable and the number of DHF cases; and multivariate analysis using multiple linear regression to analyze the simultaneous effects of climate factors and ABJ on the number of DHF cases and to identify variables with significant effects.

Statistical assumption tests were performed prior to multiple linear regression analysis, including tests for normality of residuals, multicollinearity, heteroscedasticity, autocorrelation, and linearity to ensure that the regression model met the classical assumptions. All data analysis was performed using IBM SPSS Statistics software with a significance level of 5% ($\alpha = 0.05$).

3. Results

3.1. DHF cases in Probolinggo City, 2022 – 2024

The number of DHF cases in Probolinggo City during the 2022 – 2024 period varied from year to year. The distribution of DHF cases by year is presented in Table 1. Based on these data, 223 cases of DHF were recorded in 2022, increasing to 233 cases in 2023, and surging significantly in 2024 to 490 cases. The average number of cases per month in 2022 and 2023 was 19 cases each, while in 2024 it increased to 41 cases per month. The highest number of cases occurred in May 2024 with a total of 111 cases, while the lowest number of cases was recorded in August 2023, when no cases were found (0 cases).

Table 1. DHF cases in Probolinggo City, 2022 – 2024

Year	Number of Cases	Monthly Average	Highest Number of Cases	Lowest Number of Cases
2022	223	19	February (45)	October (2)
2023	233	19	June (47)	August (0)
2024	490	41	May (111)	October (1)

Source: Probolinggo City Health Office (2022 – 2024)

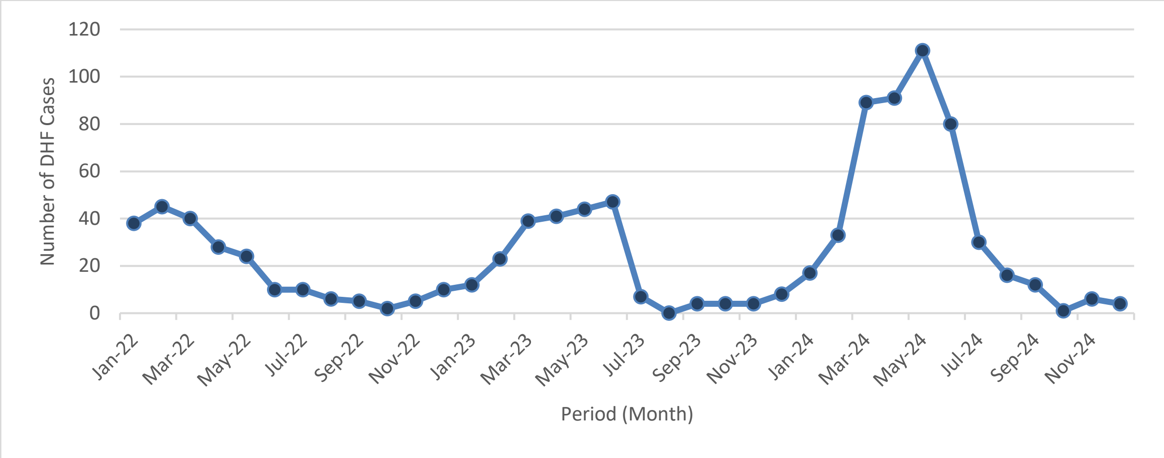

Figure 1. Distribution of DHF cases in Probolinggo City, 2022 – 2024

The Figure 1 shows the fluctuating pattern of DHF cases during the study period. DHF cases tended to increase from the beginning to the middle of the year, particularly from March through May, then declined from July through October, and rose again toward the end of the year.

3.2. Distribution of DHF Cases, Average Climate Factors, and Larvae-Free Index (ABJ)

Table 2 shows that a total of 946 DHF cases were recorded during the study period, with the highest number of cases occurring in 2024, totaling 490 cases. Meanwhile, 233 cases were recorded in 2023 and 223 cases in 2022. The average Rainfall during the study period was 10.96 mm, with the highest value recorded in 2022 at 12.42 mm and the lowest in 2023 at 9.43 mm. The average relative Humidity was 85.85%, with the highest value occurring in 2022 at 90%. During the study period, the average air temperature was 22.42°C, with the highest temperature recorded in 2024 at 22.78°C. The average wind speed was recorded at 0.49 m/s. Meanwhile, the average ABJ during the study period was 88.68%, with the highest value in 2023 at 89.8% and the lowest in 2024 at 87.42%.

Table 2. Distribution of DHF cases, average climate factors, and ABJ

Year	n (Months)	Cases	Mean Rainfall (mm)	Mean Humidity (%)	Mean Temperatur e (°C)	Mean Wind Speed (m/s)	Mean ABJ (%)
2022	12	223	12,42	90	21,76	0,54	88,81
2023	12	233	9,43	82,86	22,71	0,55	89,8
2024	12	490	11,02	84,69	22,78	0,38	87,42
2022–2024	36	946	10,96	85,85	22,42	0,49	88,68

Source: Probolinggo City Health Office and BMKG (2022 – 2024)

3.3 Assumption Tests

A normality test of the residuals was conducted to ensure that the residuals of the multiple linear regression model are normally distributed, so that the parameter estimates and significance tests can be validly interpreted. The Shapiro–Wilk test was used to test for normality because the sample size was less than 50 (N = 36). The test was conducted at a significance level (α) of 0.05, with the decision criterion based on the p-value: the residuals are considered normally distributed if the p-value is greater than 0.05. The results of the normality test show that the unstandardized residuals have a Shapiro–Wilk statistic of 0.960 with a p-value of 0.211. A p-value greater than 0.05 indicates that the regression model residuals are normally distributed; thus, the normality assumption has been met, and the multiple linear regression analysis can proceed.

Table 3. The Shapiro–Wilk test results

Variable	Shapiro–Wilk Statistic	n	*p-value*	Remarks
Unstandardized residuals	0,960	36	0,211	Normally distributed

A multicollinearity test was conducted to determine whether there was a high correlation among the independent variables in the multiple linear regression model. The test used the Tolerance and Variance Inflation Factor (VIF) values. The regression model was deemed free of multicollinearity if the Tolerance value was > 0.10 and the VIF value was < 10. The multicollinearity test results show that all independent variables have Tolerance values ranging from 0.240 to 0.906 and VIF values ranging from 1.104 to 4.161. All Tolerance values are greater than 0.10, and all VIF values are less than 10; therefore, it can be concluded that the regression model does not exhibit multicollinearity.

Table 4. The Multicollinearity test results

Variable	*Tolerance*	*VIF*	Remarks
Rainfall	0,416	2,403	No multicollinearity
Humidity	0,240	4,161	No multicollinearity
Temperature	0,517	1,935	No multicollinearity
Wind Speed	0,495	2,019	No multicollinearity
ABJ	0,906	1,104	No multicollinearity

A heteroscedasticity test was conducted to determine whether there was unequal variance in the residuals from one observation to another in the regression model. The test was conducted using the Glejser test, which involves regressing the absolute values of the residuals against the independent variables.

Table 5. The Heteroscedasticity test results

Variable	Sig.	Remarks
Rainfall	0,442	No heteroscedasticity
Humidity	0,931	No heteroscedasticity
Temperature	0,841	No heteroscedasticity
Wind Speed	0,155	No heteroscedasticity
ABJ	0,897	No heteroscedasticity

The regression model is considered free of heteroscedasticity if the significance value (Sig.) for each variable is greater than 0.05. The results of the heteroscedasticity test show that the rainfall variable has a significance value of 0.442, Humidity of 0.931, temperature of 0.841, wind speed of 0.155, and ABJ of 0.897. All significance values are greater than 0.05, so it can be concluded that the regression model does not exhibit heteroscedasticity.

An autocorrelation test was conducted to determine whether there was a correlation between the residuals of one observation and those of another observation in the regression model. The test was performed using the Durbin-Watson (DW) test. In general, a regression model is considered to be free of autocorrelation if the Durbin-Watson value falls between 1.5 and 2.5. Based on the test results, the Durbin-Watson value was 1.609. This value falls within the range of 1.5–2.5, so it can be concluded that the regression model does not exhibit autocorrelation.

Table 6. Autocorrelation test results

Statistik	Value
Durbin-Watson	1,609
Remarks	No autocorrelation

3.4. The effect of climate factors and larval index on DHF Cases

A multiple linear regression analysis was conducted to determine the effect of Rainfall, Humidity, temperature, wind speed, and ABJ on the number of DHF cases in Probolinggo City. The test results indicate that Humidity, temperature, and ABJ have a significant effect on the number of DHF cases, as their p-values are less than 0.05. Conversely, Rainfall and wind speed do not have a significant effect on the number of DHF cases, as their p-values are greater than 0.05. The beta values indicate that temperature has the greatest effect, followed by Humidity, while ABJ has a negative effect. The regression coefficients for each variable indicate either a positive or negative relationship with the number of DHF cases, as presented in Table 7.

Table 7. The Multiple Linear Regression Coefficient test results

Variable	*Coefficient B*	*Sig.*	*Beta*	*t*	*Sig.*
Constant	-22,308	275,201	-	-0,081	0,936
Rainfall	-0,298	0,636	-0,099	-0,468	0,643
Humidity	2,584	1,192	0,604	2,168	0,038
Temperature	19,389	6,073	0,607	3,193	0,003
Wind Speed	25,300	19,906	0,247	1,271	0,213
ABJ	-6,957	2,012	-0,496	-3,458	0,002

Based on the results of the partial tests, only the variables of Humidity, temperature, and ABJ showed a significant effect on the number of DHF cases. Therefore, to obtain a more parsimonious regression model consisting only of significant variables, a subsequent multiple linear regression analysis was conducted by including these three variables as predictors. The results of the final regression analysis using Humidity, temperature, and ABJ were then used to formulate the regression equation and interpret the magnitude of each variable's effect on the number of DHF cases in Probolinggo City.

The results of the multiple linear regression analysis showed that ABJ, air temperature, and Humidity are associated with the number of DHF cases in Probolinggo City. The high correlation coefficient (R) value of 0.826 indicates that the independent variables have a very strong relationship with DHF cases. The coefficient of determination (R^2) reached 0.682, meaning that the ABJ, air temperature, and humidity variables can explain 68.2% of the variation in DHF cases. Other variables outside the scope of this study influence the remaining portion. Partially, ABJ has a significant negative effect on DHF cases, while air temperature and Humidity have a significant positive effect on DHF cases.

Table 8. The Multiple Linear Regression test results

Variable	*Koefisien B*	*Sig.*	*R*	*R Square*	*Adjusted R Square*	*Std. Error of the Estimate*
ABJ	-5,512	0,000	0,826	0,682	0,653	22,528
Temperature	16,480	0,000				
Humidity	1,696	0,003				

The relationship between all independent variables and DHF cases can be summarized in a multiple linear regression equation. The resulting equation is shown below.

$$Y = -5.512 \text{ ABJ} + 16.480 \text{ Temperature} + 1.696 \text{ Humidity}$$

This equation illustrates that ABJ, temperature, and Humidity simultaneously influence DHF cases. This simultaneous relationship confirms that DHF control requires an integrated approach that addresses both environmental factors and community behavior.

4. Discussion

DHF cases in Probolinggo City from 2022 to 2024 showed a fluctuating pattern with a fairly sharp increase in 2024. This pattern indicates that dynamic factors, including environmental conditions, climatic conditions, and vector density, still influence DHF transmission in Probolinggo City. The increase in cases observed from early to mid-year also reflects a seasonal pattern commonly found in tropical and subtropical regions. According to Anas et al. (2025), DHF incidence tends to rise during periods when environmental conditions support the development of *Aedes aegypti* mosquitoes, thereby increasing the risk of contact between humans and the vector.

The fluctuating pattern observed in this study aligns with the findings of Fitri et al. (2024) in Palu City, who reported that the number of DHF cases fluctuates from year to year and tends to increase during certain months. Rubianti's (2023) study in Bima City also demonstrated month-to-month variations in DHF cases influenced by changes in the local environment and climatic conditions. These similar patterns indicate that DHF incidence in urban areas is not constant but is strongly influenced by changes in ecological conditions that support vector survival. Thus, fluctuations in DHF cases in Probolinggo City can serve as a basis for determining early warning periods and control priorities.

The distribution of climatic factors in Probolinggo City during the 2022–2024 period shows fluctuations from month to month and year to year. Rainfall exhibits a seasonal pattern, with a maximum of 34.29 mm and a minimum of 0 mm; Rainfall tends to increase at the beginning of the year and decrease toward the middle and end of the year. Humidity remains relatively high throughout most of the year, with a maximum of 95% and a minimum of 68.25%. Air temperature shows a relatively narrow range between 21.19°C and 24.43°C, while wind speed ranges from 0.06 m/s to 1.13 m/s. These conditions reflect a dynamic climatic environment that can impact the life cycle of the *Aedes* mosquito, a vector for DHF.

The increase in DHF cases is believed to be linked to climatic conditions that favor the proliferation of the *Aedes aegypti* vector. Rainfall follows a seasonal pattern, with a maximum of 34.29 mm and a minimum of 0 mm; Rainfall tends to increase at the beginning of the year and decrease toward the middle and end of the year. The average relative Humidity in Probolinggo City reached 85.85%, while the average air temperature was 22.42°C and wind speeds ranged from 0.06 m/s to 1.13 m/s. These values remain within the optimal range for the growth and development of *Aedes aegypti* mosquitoes, from the egg and larval stages through to adulthood. A study by Sapta et al. (2025) in West Lampung Regency demonstrated that Rainfall, Humidity, and temperature are significantly associated with DHF cases, with Humidity showing the strongest correlation with an increase in cases. Similar findings were reported in a study in Bandung City, which showed that climate variability can simultaneously explain part of the variation in DHF incidence, with air temperature being one of the significantly influential factors. A nationwide study by Akbar et al. (2025) also indicated that relative Humidity and Rainfall are the climate parameters most consistently associated with the DHF incidence rate across various regions of Indonesia.

An overview of entomological conditions based on the ABJ in Probolinggo City during the 2022 – 2024 period shows fluctuations, with the highest average in 2023 at 89.80% and the lowest in 2024 at 87.42%. These values remain below the national ABJ standard of ≥ 95%, indicating that larval-free conditions in Probolinggo City are not yet optimal. These findings are consistent with the study by Listianingsih (2024) in Kediri Regency, which reported that ABJ values in the study area remained below the national standard and varied from month to month.

Multiple linear regression analysis indicates that of the five variables analyzed, ABJ, air temperature, Humidity, Rainfall, and wind speed, only three variables have a significant effect on the number of DHF cases: ABJ, air temperature, and Humidity. The ABJ variable has a regression coefficient of -5.512 with a significance value of 0.000. These results indicate that a 1% increase in ABJ is estimated to reduce the number of DHF cases by 5.512, assuming all other variables remain constant. A high ABJ value reflects the success of Mosquito Breeding Site Eradication (PSN) activities in reducing *Aedes aegypti* breeding sites, thereby lowering the likelihood of *dengue* transmission. A study by Rubianti et al. (2024) in Bima City also concluded that a low ABJ is associated with an increase in *dengue* cases due to suboptimal community participation in mosquito breeding site eradication activities.

The air temperature variable has a regression coefficient of 16.480 with a significance value of 0.000. These findings indicate that every 1°C increase in air temperature is estimated to increase the number of DHF cases by 16.480. Temperatures within the optimal range accelerate the mosquito life cycle, increase biting frequency, and accelerate the development of the *dengue* virus within the mosquito's body. These conditions increase the likelihood of DHF transmission. The results of a study by Budhidharma et al. (2025) in Bekasi City also show that air temperature is one of the climatic factors contributing to the rise in DHF cases.

Air humidity showed a regression coefficient of 1.696 with a significance value of 0.003. These results indicate that a 1% increase in air humidity is estimated to increase the number of DHF cases by 1.696 cases. High Humidity can extend the lifespan of *Aedes aegypti* mosquitoes, thereby increasing the likelihood that they will survive long enough to reach their infectious stage. A longer mosquito lifespan increases the likelihood of dengue virus transmission to humans. A study by Akbar et al. (2025) also reported that relative Humidity is one of the climate parameters most consistently associated with DHF outbreaks in Indonesia.

The rainfall variable did not show a significant effect on DHF cases in Probolinggo City, with a significance value of 0.643. These results indicate that Rainfall alone cannot explain the changes in the number of DHF cases during the study period. This may be because the effect of Rainfall on DHF incidence is not immediate; rather, it requires a time lag for breeding sites to form, for larvae to develop into adult mosquitoes, and for dengue virus transmission to occur. These findings are consistent with a study by Rahmah & Adiningsih (2022) in Majene Regency, which showed that Rainfall was not associated with DHF incidence ($p=0.91$). This suggests that increased Rainfall does not always lead to an increase in DHF cases because its effect on dengue transmission is indirect and depends on the conditions of mosquito breeding sites.

The wind speed variable also did not show a significant effect on DHF cases in Probolinggo City, with a significance value of 0.213. These results indicate that wind speed cannot explain the changes in the number of DHF cases during the study period. The relatively small variation in wind speed is believed not to have sufficiently influenced the spread of *Aedes aegypti* mosquitoes or the disease transmission pattern. This finding is consistent with a study by Sandy (2024) in Jayapura Regency, which showed that wind speed was not significantly associated with DHF cases ($p = 0.515$). This is likely because the relatively low variation in wind speed has not been sufficient to affect the mobility and spread of *Aedes aegypti* mosquitoes. This may be because *Aedes aegypti* mosquitoes have limited flight capabilities, typically ranging only 50–100 meters from their breeding sites. Hence, vector spread is more influenced by the presence of breeding sites and mosquito population density than by variations in wind speed.

The relationship between the variables ABJ, air temperature, and air humidity and DHF cases is indicated by a correlation coefficient (R) of 0.826, which falls into the "very strong" category. The coefficient of determination (R^2) of 0.682 indicates that these three variables can explain 68.2% of the variation in DHF cases in Probolinggo City. In contrast, the remaining 31.8% is influenced by other factors outside the scope of this study, such as population density, community mobility, environmental sanitation, and clean and healthy living behaviors. The resulting regression equation, Y = -5.512 ABJ + 16.480 Temperature + 1.696 Humidity, confirms that increases in temperature and Humidity tend to increase the number of *DHF* cases. In contrast, an increase in ABJ helps reduce the number of DHF cases.

The findings of this study indicate that the dynamics of DHF cases are caused by the interaction of several environmental factors, including climatic conditions and vector density, as reflected by the ABJ value. Controlling DHF in Probolinggo City requires an integrated strategy combining vector control and monitoring of climatic factors. Community-based prevention efforts are a key factor in dengue control. Research by Nanda et al. (2025) shows that certain 3M Plus Mosquito Breeding Site Eradication (PSN) behaviors such as covering water storage containers, using insect repellent, and installing window screens are associated with changes in the number of dengue cases. These findings align with the study by Hamid et al. (2025), which emphasized that implementing the 3M Plus program through community service activities can increase public awareness of preventive measures against DHF. These similar results indicate that increasing community participation in 3M Plus PSN activities, strengthening epidemiological surveillance, and utilizing climate information as an early warning system are crucial steps to mitigate the risk of rising case numbers. Integrating climate data with the dengue surveillance system is expected to enhance the effectiveness of sustainable dengue prevention and control programs in Probolinggo City.

5. Conclusions

DHF cases in Probolinggo City during the 2022 – 2024 period showed fluctuating patterns from month to month and year to year, with the sharpest increase occurring from March to May 2024. Climatic factors, including Rainfall, Humidity, temperature, and wind speed, also fluctuated during the study period. The ABJ value also fluctuated and has not yet reached the national standard of ≥ 95%, indicating that mosquito larvae control has not been optimal. The analysis shows that Humidity, temperature, and ABJ have a significant effect on DHF cases in Probolinggo City. In contrast, Rainfall and wind speed do not have a significant effect, as indicated by the equation: DHF Cases = −5.512 ABJ + 16.480 temperature + 1.696 humidity. The regression model exhibits a very strong correlation (R = 0.826) and explains 68.2% of the variation in DHF cases. These findings highlight the importance of strengthening early warning systems, increasing “3M Plus” public health campaigns, and utilizing and integrating climate data with DHF surveillance to support more effective and sustainable *Ae. aegypti* control.

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