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Analysis of Climate and Environmental Risk Factors on Dengue Hemorrhagic Fever Incidence in Bogor District

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Abstract

Dengue Hemorrhagic Fever (DHF) is transmitted through the bites of *Aedes aegypti* and *Aedes albopictus* mosquitoes and remains an endemic in Bogor District. This quantitative correlation study with an ecological approach aimed to analyze how DHF incidence was influenced by climate factors, population density, Larvae Free Rate, and the area altitude factor. Secondary data were obtained from the Bogor District Health Office, Bogor District Central Bureau of Statistics, and the Meteorology, Climatology, and Geophysics Agency. The spatial analysis method was used for the area altitude factor. The results showed a significant relationship between climate factors, such as air humidity at a Time Lag of 0 months ($r = 0.394$) and the altitude factor ($r = -0.350$), and DHF incidence in the Bogor District from 2017 to 2022. Spatial data showed that DHF incidence tends to be higher in districts with lower altitudes. Therefore, the Bogor District Health Office and the community can enhance efforts to prevent and control DHF, especially during seasonal transitions and in areas with lower altitudes. Cross-sector collaboration with the Meteorology, Climatology, and Geophysics Agency is also necessary to remain vigilant during climate fluctuations.

Keywords: altitude area, climate, dengue hemorrhagic fever, Larvae Free Rate, population density

Introduction

Dengue hemorrhagic fever (DHF) is an infectious disease caused by the dengue virus, spread through female mosquitoes from the *Aedes aegypti* and *Aedes albopictus* species.¹ The DHF is the fastest-growing vector-borne disease. It is a public health problem with the potential to cause a significant number of deaths worldwide.² In the last few decades, the incidence of DHF has increased up to 30 times globally, with an estimated 50 million dengue infections occurring each year and around 2.5 billion people living in dengue-endemic countries.³

A total of 1.8 billion (>70%) of the populations at risk live in Southeast Asia and the Western Pacific.³ Indonesia ranks second among the 30 dengue-endemic countries globally, with the highest number of DHF cases.⁴ Bogor District in West Java Province had fluctuating, relatively high DHF cases each year from 2017 to 2022. In 2017, there were 276 cases, which increased to a peak of 2,220 cases in 2021 before falling slightly to 1,953 cases in 2022.⁵⁻⁶

The distribution and increase in DHF cases can be attributed to various risk factors, including the population

levels of *Aedes* mosquito vectors, dengue virus virulence, population immunity, population mobility, population density, socioeconomic status, and community behaviors that can create mosquito breeding habitats.⁷ Population density is closely related to DHF transmission. In densely populated areas, the proximity of houses allows *Aedes* mosquitoes to more easily transmit the dengue virus, as the flight range of female *Aedes* mosquitoes is around 50-100 meters.⁸ One indicator used to measure the success of mosquito eradication programs is the Larvae Free Rate (LFR), for which the national standard at $\geq 95\%$.⁹

Climate factors, such as rainfall, air temperature, and humidity, also affect the DHF incidence.¹⁰ Rainfall is particularly relevant to the life cycle of *Aedes* mosquitoes. Heavy rainfall may saturate the soil, creating numerous water puddles that serve as breeding sites for mosquitoes, thus increasing the mosquito vector density.¹¹ Increased air temperature is associated with the development of mosquito larvae and the dengue virus within them.¹² While, air humidity is closely related to the physiological processes and respiratory systems of mosquitoes. Humidity levels above 85% lead to longer mosquito lifespans.¹³

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Another environmental risk factor is the area altitude. *Aedes aegypti* mosquitoes thrive at altitudes of 0-500 meters above sea level; while, they are not well-suited to survive at altitudes greater than 1,000 meters above sea level.^{9,14} Given the relatively high number of DHF cases in Bogor District each year from 2017 to 2022, this study aimed to analyze the climate and environmental risk factors associated with DHF incidence in Bogor District from 2017 to 2022.

Method

This quantitative correlation study with an ecological approach was analyzed using time series data. Secondary data was used for disease factors, including the total number of dengue patients, dengue incidence rate (IR), and the LFR in Bogor District recorded by the Bogor District Health Office from January 2017 to December 2022. As for the environmental risk factors, climate data (air temperature, air humidity, and rainfall) was obtained from the Central Meteorology, Climatology, and Geophysics Agency; while, the population density and area altitude data were sourced from the Bogor District Central Bureau of Statistics.

Data processing was conducted in two ways. First, statistical tests through univariate analysis were used to describe the frequency distribution of variables, and bivariate analysis was used to determine the relationship between two variables using Pearson and Spearman Correlation Tests. For climate correlation tests, three analyses were conducted: climate data for the same month (Time Lag 0), climate data from one month earlier (Time Lag 1), and climate data from two months earlier (Time Lag 2) correlated with the dengue IR.

The climatic factors did not directly influence DHF incidence immediately, but rather, they affected the mosquito vector's life cycle. In the mosquito's life cycle, from egg to infective adult, a time lag can occur between climate fluctuations and the increase in DHF cases.¹⁰ The second test involved spatial analysis using ArcGIS 10.8 to determine the spatial depiction of information. In this study, spatial analysis was conducted only on the area altitude factor to depict the relationship between the area altitude and DHF incidence.

Results

Incidence Rate of Dengue Hemorrhagic Fever

The DHF incidence in Bogor District increased from 2017 to 2021, then decreased in 2022. The highest number of DHF cases was recorded in 2021, with 2,220 cases and an IR of 40.44 per 10,000 population. While, the lowest occurred in 2017, with 276 cases and an IR of 4.83 per 100,000 population (Figure 1).

Rainfall, Air Temperature, and Air Humidity

Rainfall in Bogor District showed a fluctuating trend from 2017 to 2022. The highest rainfall, 33.54 mm, occurred in April 2019. In contrast, the lowest rainfall, 4.44 mm, occurred in January 2022. The optimal rainfall for mosquitoes was below 50 mm, peaking between 15-35 mm (Figure 2).

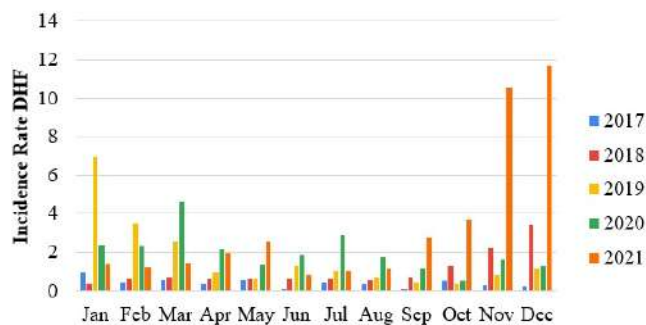


Figure 1. Overview of Dengue Hemorrhagic Fever Incidence Rate in Bogor District, 2017-2022

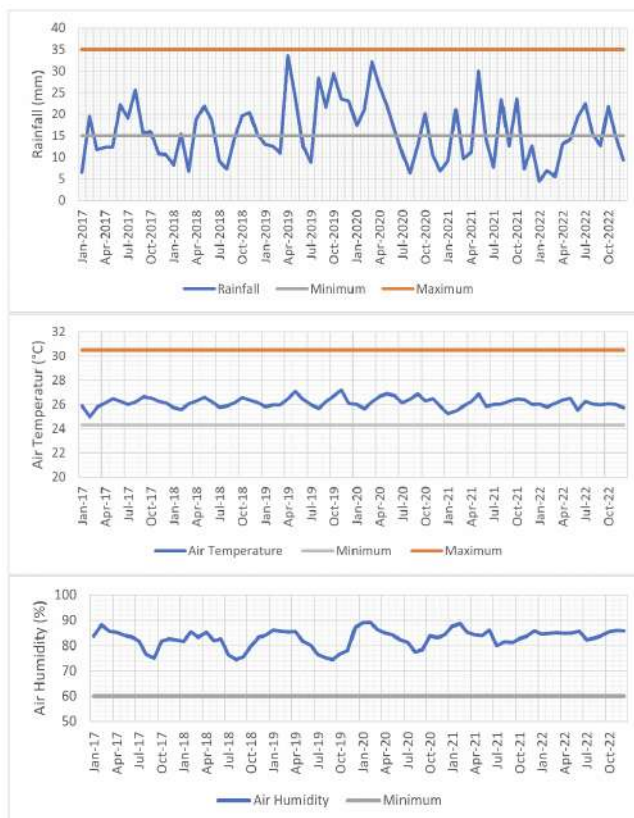


Figure 2. Monthly Distribution of Rainfall, Air Temperature, and Air Humidity in Bogor District, 2017-2022

Air temperature in Bogor District from 2017 to 2022 did not show drastic monthly changes and remained relatively stable. The air temperature falls within the optimal range for mosquito infection in range of 24.3 and 30.5°C. The highest air temperature, 27.20°C, was recorded in November 2019, while the lowest, 24.97°C, was recorded in February 2017 (Figure 2).

Air humidity in Bogor District showed a fluctuating trend from 2017 to 2022. The air humidity in Bogor District, which ranged from 70-85%, was optimal for mosquito survival (>60%). The highest air humidity, 89.21%, occurred in February 2020, and the lowest, 74.43%, occurred in September 2019 (Figure 2).

Population Density

Population density in Bogor District was assessed based on the average population density per subdistrict from 2017 to 2022. The highest population density was found in the Cijeruk, Cigombong, and Bojong Gede Subdistricts, while the lowest was in the Sukajaya Subdistrict.

Larvae Free Rate

Due to incomplete LFR data, the analysis was limited to 2019-2022. The average LFR in Bogor District from 2019 to 2022 was 93.25%. From 2019 to 2021, LFR values in Bogor District were below a national standard of ≥95%. The highest LFR value, 95%, was recorded in 2022 (Figure 3).

Area Altitude

The altitudes of the subdistricts within Bogor District vary significantly. The Cisarua Subdistrict had the highest altitude, 789 meters above sea level, while the Parung Panjang Subdistrict had the lowest altitude, 51 above sea level. Given the classification of altitude between lowland (<200 asl) and highland (>200 asl), Bogor District has

19 subdistricts in the highland (47.5%) and 21 subdistricts in the lowland (52.5%) (Figure 4).

Normality Test

The results of the normality test, using the Kolmogorov-Smirnov test, indicated that all variables from 2017 to 2022 were normally distributed (p-value>0.05), except for the air humidity variable at Time Lag 0 and the altitude variable (p-value<0.05). Normally distributed variables will be analyzed via bivariate analysis using the Pearson correlation test. While, non-normally distributed variables will be analyzed using the Spearman correlation test.

Correlation of Climate Factors, Population Density, Larvae Free Rate, and Altitude with Dengue Hemorrhagic Fever Incidence Rate in Bogor District, 2017-2022

The correlation test for climate variables was conducted using three time lag scenarios (Time Lag 0, Time Lag 1, and Time Lag 2). It was because climate factors did not directly affect DHF occurrence but instead influenced

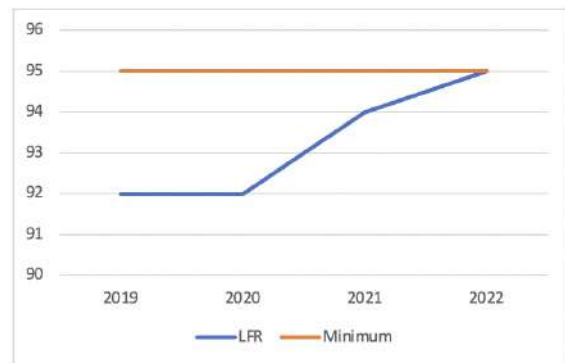


Figure 3. Distribution of Larvae Free Rate in Bogor District, 2019-2022

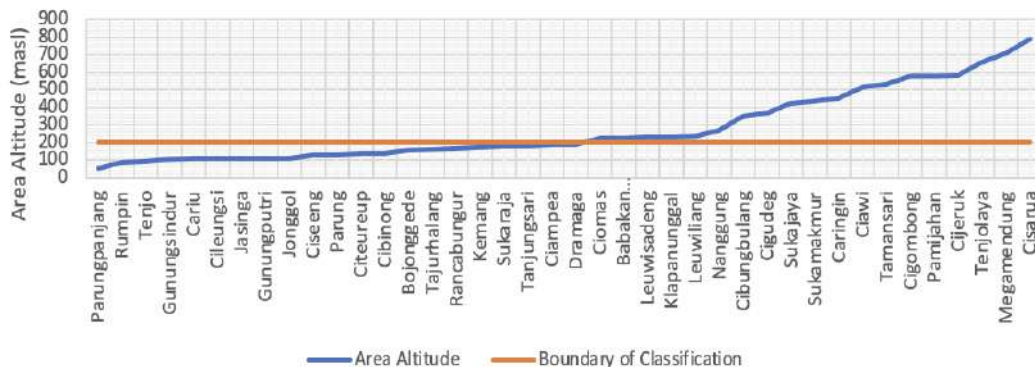


Figure 4. Distribution of Area Altitude in Bogor District in 2017-2022

the mosquito life cycle. In the mosquito life cycle, from eggs to infective adults, there may be a time lag between climate fluctuations and an increase in DHF cases; therefore, the time lag testing for climate factors needs to be considered.

The correlation test results for the three time lag scenarios of climate variables showed that only the air humidity at Time Lag 0 had a significant relationship with the DHF IR (p-value = 0.001). Additionally, the altitude variable showed a significant relationship with the DHF IR (p-value = 0.027). However, population density and the ABJ did not show significant relationships with DHF IR (p-value>0.05; p-value>0.05) (Table 1).

Map of Correlation between Area Altitude and Dengue Hemorrhagic Fever Incidence in Bogor District, 2017-2022

The correlation map showed that the area altitude significantly affected DHF occurrence. In subdistricts with lower altitudes, such as the Cibinong, Cileungsi, and Gunung Putri Subdistricts, DHF incidence tends to be higher. On the contrary, DHF incidence tended to be lower in subdistricts with higher altitudes. These results indicated that higher altitudes had lower temperatures, which led to the suboptimal and slower breeding process of *Aedes aegypti* mosquitoes, resulting in reduced dengue virus transmission. (Figure 5).

Discussion

The highest DHF IR in Bogor District was recorded in 2021 (IR = 40, 44 per 100,000 population). This condition was due to climate factors, including rainfall, air

temperature, and air humidity within the optimal range for mosquito breeding. Furthermore, in 2021, the LFR was below the national standard of <95%, indicating a high larval density. With the persistently high larval density, the risk of DHF transmission remained high.

Rainfall is an important factor in DHF transmission, as it can create containers of stagnant water, which serve as breeding sites for *Aedes aegypti* mosquitoes.¹¹ More breeding sites result in easier egg-laying for mosquitoes, leading to an increase in mosquito population and an elevated risk of DHF transmission.^{11,13} The optimal rainfall for mosquitoes is below 50 mm, peaking between 15-35 mm.^{15,16}

Rainfall can increase air humidity, prolonging the lifespan of adult mosquitoes.¹¹ However, the correlation analysis did not show a significant relationship between

Table 1. Correlation Test Results between Climate, Population Density, Larvae Free Rate, Area Altitude and Dengue Incidence

Variable	Dengue Incidence		
	Coef. Correlation (r)	p-value	
Rainfall	Time Lag 0	-0.165	0.167
	Time Lag 1	-0.145	0.228
	Time Lag 2	-0.096	0.431
Air temperature	Time Lag 0	-0.050	0.675
	Time Lag 1	-0.122	0.313
	Time Lag 2	-0.153	0.207
Air humidity	Time Lag 0	0.394	0.001*
	Time Lag 1	0.169	0.159
	Time Lag 2	0.196	0.105
Population density		-0.755	0.083
Larvae Free Rate		0.861	0.139
Area altitude		-0.350	0.027*

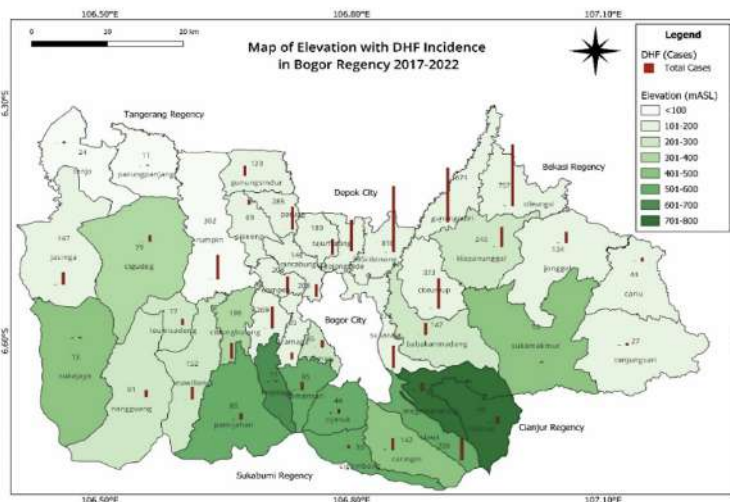


Figure 5. Correlation Map of Area Altitude with Dengue Hemorrhagic Fever in Bogor District, 2017-2022

rainfall and DHF in Bogor District from 2017 to 2022. The implementation of the “3M Plus” activities, through the actions of draining, closing, and utilizing or recycling all mosquito breeding habitats, to prevent DHF before the rainy season can also influence mosquito presence.⁹ Prolonged rainfall can eliminate mosquito breeding sites, as the mosquito larvae get carried away by the current and perish.¹⁷

Air temperature is an environmental variable that can enhance vector proliferation and reduce the time required for the dengue virus to replicate in mosquito bodies (the extrinsic incubation period of the dengue virus).¹⁸ A shortened incubation period allows the virus to replicate faster, leading to an increased viral count in mosquitoes.¹⁸ Moreover, higher temperatures promote larval development.¹⁸

The optimal air temperature range for mosquito infection is 24.3-30.5°C.¹⁵ However, the correlation analysis indicated that air temperature did not significantly correlate with the DHF IR in Bogor District from 2017 to 2022. The air temperature in Bogor District during this period ranged from 24.97°C to 27.20°C. Although these temperatures were optimal for mosquito development, it was possible that the mosquitoes were not infective.

Air humidity affects the respiratory systems and physiological processes of *Aedes aegypti* mosquitoes.¹³ The optimal humidity for mosquito survival is >60%.¹⁹ Low air humidity (<60%) shortens the lifespan of mosquitoes, as it causes the fluid in their bodies to evaporate.¹³ On the contrary, high air humidity (>85%) prolongs their lifespan.¹³

The correlation analysis between air humidity and DHF IR showed a significant relationship with moderate correlation strength and a positive correlation direction at Time Lag 0. These results indicated that higher air humidity was associated with increased DHF incidence, confirming the results of a previous study in Surabaya City.¹³ However, there was no significant correlation between Time Lag 1 or Time Lag 2 humidity and DHF IR, possibly due to other dominant factors, such as the physical environmental house conditions, including ventilation and lighting, which can influence mosquito activities. Mosquitoes prefer dark and moist places to rest and lay eggs.²⁰

Population density is a risk factor for DHF transmission.⁷ High-density settlements with low socioeconomic status have higher DHF transmission rates, given that female *Aedes* mosquitoes have a flight range of about 50-100 meters. The denser the population, the easier *Aedes* mosquitoes can transmit the dengue virus.⁸ However, the correlation analysis between population density and DHF incidence rate showed no significant relationship, consistent with a previous study in the South Minahasa

District.⁸ The lack of significant correlation may be due to the relatively small number of analyzed population data, which consisted of only six data points. Data quantity could affect the significance value of the relationship between variables.

The LFR is one indicator used to assess the presence of *Aedes* mosquitoes in an area, with the standard LFR value set at $\geq 95\%$. The LFR value in Bogor District from 2019 to 2022 was in the low category ($\leq 95\%$). Existing theories suggest that a low LFR value ($\leq 95\%$) indicates high mosquito larval density and an elevated risk of DHF transmission.^{9,13} However, the correlation analysis between the LFR value and the DHF incidence rate did not show a significant relationship. This might be due to technical errors during the reporting process, such as a less meticulous larval survey, leading to suboptimal examination of mosquito larvae. This result aligned with a study by Nuranisa, et al.²¹ The LFR value is calculated by comparing the number of houses or buildings without larvae to the total number of examined houses.⁹ The number of houses or buildings examined could also affect an area's LFR value.

Altitude is another environmental factor that can influence the proliferation of *Aedes aegypti* mosquitoes as the DHF vector.²² Area with altitudes greater than 1,000 meters above sea level did not have *Aedes aegypti* mosquitoes, resulting in low DHF transmission risk. This condition is due to altitude's impact on climate factors, such as rainfall, temperature, and humidity.²² Higher areas experienced lower temperatures due to higher rainfall and humidity. These conditions lead to sub-optimal and slower mosquito breeding, resulting in reduced dengue virus transmission.²³

The correlation analysis in this study was consistent with existing theories,^{22,23} indicating that altitude has a significant relationship with the DHF incidence rate. Moreover, the correlation had a moderate strength, with a negative correlation direction. This means that higher areas had lower DHF incidence. This correlation result was further supported by the correlation map, which showed that most DHF occurrences happen in lowland areas, aligned with a study by Tamengkel, et al.²²

Conclusion

In Bogor District, from 2017 to 2022, the highest incidence of DHF occurred in 2021, and the lowest incidence is in 2017. The DHF incidence in Bogor District is significantly influenced by climatic factors such as air humidity at Time Lag 0 and geographical factors such as area altitude. The Health Office is encouraged to collaborate and work with the Meteorology, Climatology, and Geophysics Agency to prevent increases in DHF cases during climate fluctuations. Community participation in DHF prevention and control efforts is also crucial, for instance, by

implementing the "1 House 1 Mosquito Larva Inspector" movement and "3M Plus" activities. Moreover, maintaining health and environmental cleanliness is essential to eliminate mosquito breeding sites, particularly during seasonal changes and in areas with low altitudes where people reside.

Abbreviations

DHF: Dengue Hemorrhagic Fever; LFR: Larvae Free Rate; IR: Incidence Rate.

Ethics Approval and Consent to Participate

This study has been approved by the Ethic Commission for Health Research, Faculty of Public Health, Universitas Indonesia No. Ket-612/UN2.F10.D11/PPM.00.02/2023.

Competing Interest

The authors declared that there is no significant competing financial, professional, or personal interest that might have affected the performance or presentation of the work described in this manuscript.

Availability of Data and Materials

Data and information used as study materials can be obtained from the corresponding author upon reasonable request.

Authors' Contribution

RAW is responsible for the ideas created, analysis, preparation of writings, supervising the study, writing review, and editing. TR and RAW performed formal analysis, investigation, interpretation, and writing-original draft preparation. AA and FN were subsequently involved in conceptualization, methodology, software, validation, resources, data curation, writing review, and editing. All authors have made substantial contributions to the final manuscript for publication.

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Not Applicable.

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