Association between climate fluctuations and dengue fever outbreaks in Surakarta (2023–2024)

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Abstract. Dengue fever is a persistent public health challenge in tropical regions, where climate variability influences vector dynamics and transmission. This study investigates the association between climate fluctuations and dengue outbreaks in Surakarta during 2023–2024. This study used an ecological research design with secondary data on dengue fever incidence, rainfall, air temperature and humidity from 2023 to 2024. Secondary data was obtained from the Surakarta City Statistics Centre. The Pearson statistical test was performed to assess the differences between variables. This study found that dengue fever incidence is associated with climate variables such as rainfall intensity ($p = 0.01$ and $r = 1.000$), air temperature ($p = 0.01$ and $r = 1.000$) and air humidity ($p=0.01$ and $r = 1.000$). Elevated humidity further supported vector proliferation and was significantly associated with outbreak intensity. Temperature fluctuations showed weaker but noteworthy effects on disease incidence. These findings suggest that rainfall, air temperature and air humidity are critical drivers of dengue transmission in Surakarta City. In conclusion, rainfall intensity, air temperature and air humidity are associated with dengue fever outbreaks in Surakarta City from 2023 to 2024. Early warning systems incorporating meteorological data may enhance outbreak prediction and improve public health preparedness.

1 Introduction

The dengue virus, which causes dengue fever (DF), dengue hemorrhagic fever (DHF), and dengue shock syndrome (DSS), is classified as a group B arthropod virus and is currently known as the Flavivirus genus in the Flaviviridae family. Dengue virus has four serotypes: DENV-1, DENV-2, DENV3, and DENV-4. This virus is transmitted to humans by mosquito bites from Aedes aegypti [1]. When a person infected with the dengue virus is bitten by an infectious mosquito, the virus in the blood enters the mosquito's stomach. The virus will subsequently grow and disseminate throughout the mosquito's tissues, including its salivary glands. This extrinsic incubation period lasts approximately one week, following which the mosquito can infect others. The dengue virus persists in the mosquito's body throughout its

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life, allowing it to continue spread the disease. Dengue virus can affect people of all ages at any time of year [1].

The incidence of dengue has reportedly increased globally over the past decade, increasing from 505,430 cases in 2000 to 5.2 million in 2019. Currently, dengue fever is endemic in the Americas, Southeast Asia, the Western Pacific, and Africa. Asia contributes approximately 70% of the global disease burden [2]. According to the World Health Organization (WHO), over half of the global population is at risk of getting dengue fever. This disease is most common in tropical and subtropical cities and semi-urbanized areas. More than five million cases were recorded in over 80 countries in 2023 as a result of outbreaks and an unexpected increase [3]. In 2024, 14,127,435 cases of dengue fever were reported worldwide, the most since the global dengue fever monitoring system was started in 2010. According to the WHO data, the number of cases was twice as high as in 2023 (6.8 million). Furthermore, dengue fever caused 9,508 deaths, or 0.07%, in 2024 [4].

Dengue fever is still a serious public health issue in Indonesia, which has the largest number of cases in Southeast Asia [5]. The Indonesian Ministry of Health recorded approximately 140,000 cases of dengue fever in 2023, with a 1.2% death rate. Furthermore, dengue fever mortality increased in 2024 compared to 2023 [5]. The prevalence of dengue fever in Central Java Province remains high. In 2019, Central Java Province had 1,027 dengue fever cases [6]. This statistic ranked Central Java Province fourth among ten provinces with high dengue fever rates [6]. Meanwhile, 160 cases of dengue fever were reported in Surakarta City in 2019, which was more than in 2018 [7]. As a result, the Indonesian government has identified dengue fever as a top priority disease.

According to a 2020 report from the Indonesian Ministry of Health, several factors influence the high number of dengue fever cases in Indonesia, including climate, environmental conditions, population mobility, population density, and community behaviour. Several research showed a strong link between climate and dengue disease incidence [8]. Climate change can have an impact on the breeding cycle time, behaviour, survival, and reproduction of Aedes aegypti and Aedes albopictus mosquitoes, all of which contribute to the transmission of dengue virus to humans Climate change affects temperature, humidity, and rainfall [9]. Temperature, rainfall, and relative humidity are the most critical climatic elements that influence dengue disease transmission [9]. Rainfall has a substantial impact on the life cycle of the Aedes aegypti mosquito. Prolonged rainfall increases mosquito breeding places and population, increasing the risk of female mosquitoes transmitting dengue virus to their next host. Temperature variations also have an effect on mosquito metabolism. Dengue virus typically spreads in tropical and subtropical regions [10]. The optimal temperature for mosquito growth is 25°C to 27°C. If the temperature falls below 10°C or rises over 40°C, mosquito growth ceases [10]. Furthermore, greater temperatures will impact dengue virus reproduction, the gonotrophic cycle, the incubation period, and the virus's transmission. High temperatures will raise air humidity. Optimal air humidity levels of 71.9% to 83.5% can increase mosquito survival, prolonging their life span [10]. Global climate change is complicating dengue fever management in Indonesia [10]. According to Nuraini et al. (2021), an increase in dengue fever incidence is associated with higher temperatures and rainfall. This means that weather predictions can be used to anticipate dengue fever epidemics. Understanding the association between climate and dengue fever has the potential to help address the high risk of dengue fever, strengthen public health systems, and reduce the growing burden of dengue fever [11]. Based on climate fluctuation data and dengue fever incidence data in Surakarta City, further research is required to determine the association between climatic fluctuations and dengue fever incidence. We expect that this research can serve as a reference for dengue prevention and control in Surakarta City.

2 Material and methods

This is an analytical quantitative study using an ecological study design or correlation study to investigate the association between climate fluctuations (temperature, rainfall, and humidity) and dengue fever outbreaks in Surakarta City from 2023 to 2024. This study's dependent variable is the number of dengue fever cases, and the independent variable is climate, which includes rainfall, temperature, and humidity. This investigation was carried out in September 2025. Secondary data analysis of climate variability including rainfall, temperature, humidity, and dengue fever incidence data was obtained from the Surakarta City Central Statistics Agency. This study's population consisted of all the people diagnosed with dengue fever in Surakarta City as recorded by the Surakarta City Central Statistics Agency in the years 2023-2024. This study did not use sampling because observations were made of the entire population in Surakarta City, Central Java Province. The data was analysed using univariate and bivariate analyses, and also with correlation tests. Univariate analysis is used to generate descriptive explanations. Bivariate analysis was performed to investigate the association between independent variables such as rainfall, humidity, and air temperature and the dependent variable, which is the incidence of dengue haemorrhagic fever cases in Surakarta in 2023-2024.

3 Result

3.1 Univariate analysis

3.1.1 Rainfall intensity

Based on a report from Surakarta City's Central Statistics Agency, information was acquired about rainfall fluctuations in Surakarta City from 2023 to 2024. Fig. 1 shows an increase in rainfall from 193.7 mm in 2023 to 223.3 mm in 2024. Dengue fever cases also increased by 99 people in 2023, reaching 220 in 2024.

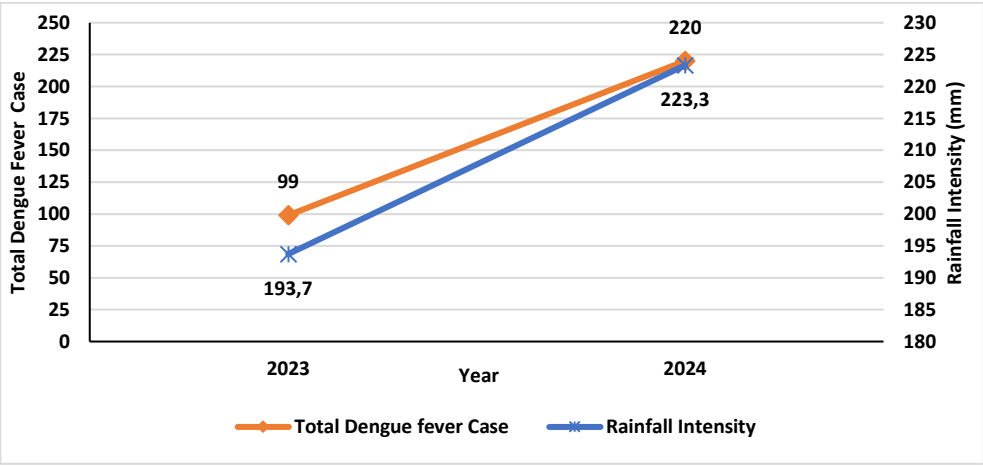

Fig. 1. Trend of dengue fever cases and rainfall intensity in 2023-2024 in Surakarta, Indonesia

3.1.2 Air temperature

The following information was acquired from the Surakarta City Central Statistics Agency on air temperature fluctuations in Surakarta City in 2023-2024. Fig. 2 illustrates how the incidence of dengue fever increased between 2023 and 2024. The average air temperature in 2023 also increased in 2024 from 27.5°C to 27.6°C.

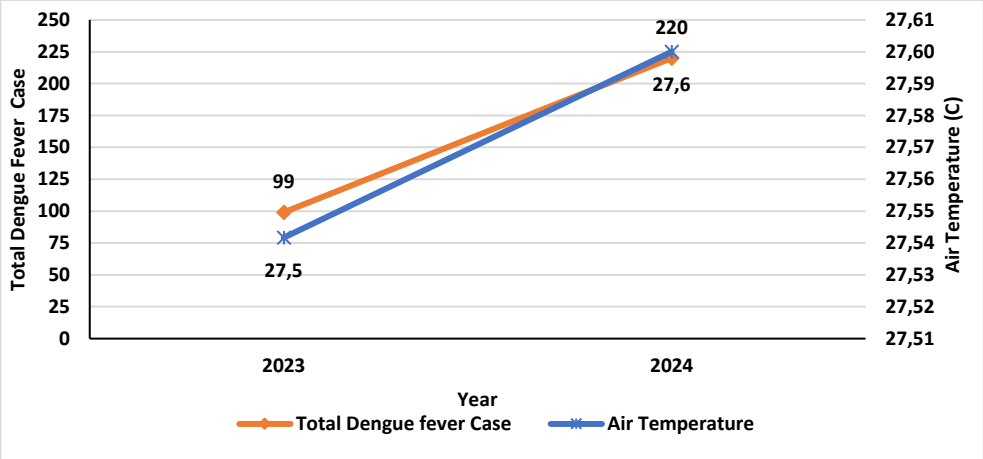

Fig. 2. Trend of dengue fever cases and air temperature in 2023-2024 in Surakarta, Indonesia

3.1.3 Air humidity

According to humidity fluctuation data from the Surakarta municipal Central Statistics Agency for 2023-2024, humidity increased from 2023 to 2024. Fig. 3 shows that the average air humidity in Surakarta was 72.8% in 2023, rising to 76.3% in 2024. Dengue fever cases increased from 99 in 2023 to 220 in 2024.

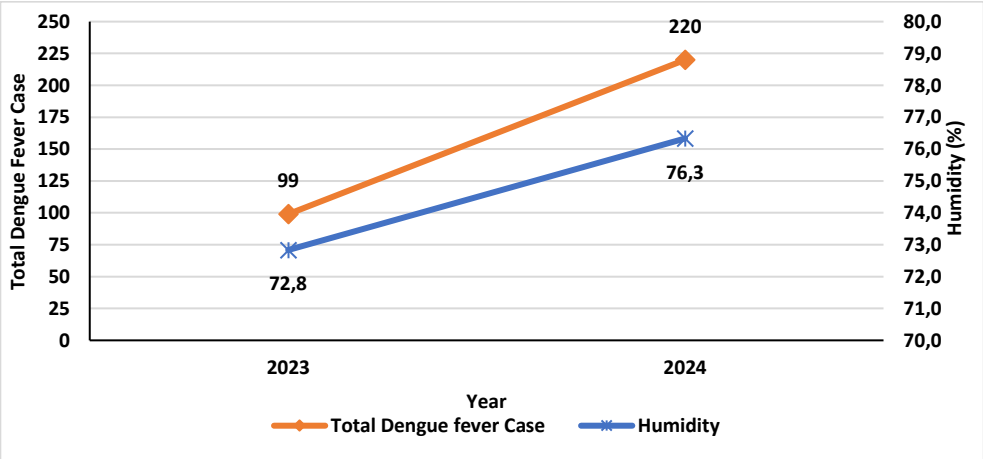

Fig. 3. Trend of dengue fever cases and humidity in 2023-2024 in Surakarta, Indonesia

3.2 Bivariate analysis

Based on the findings of the Pearson correlation test between rainfall in table 1, air temperature in table 2, and humidity in table 3 with the incidence of dengue fever in Surakarta city shows a significance value of p = 0.01. A p-value of less than 0.05 indicates a positive and significant association between rainfall, air temperature, humidity, and dengue outbreaks in Surakarta city from 2023 to 2024. This value of 1.00 from the r statistical test indicates a strong association between variables. There is a positive correlation, suggesting that the frequency of dengue fever cases increases as rainfall, temperature, and humidity rise.

Table 1. Results of Correlation Analysis between Rainfall intensity and Dengue Fever Outbreaks in Surakarta City from 2023 to 2024

Variable	Dengue fever		
	Pears. Correlation. (r)	Significant (p)	Description
Rainfall intensity – case of dengue fever	1.000	0.01	

Table 2. Results of Correlation Analysis between Air Temperature and Dengue Fever Outbreaks in Surakarta City from 2023 to 2024

Variable	Dengue fever		
	Pears. Correlation. (r)	Significant (p)	Description
Air temperature – case of dengue fever	1.000	0.01	

Table 3. Results of Correlation Analysis between Air Humidity and Dengue Fever Outbreaks in Surakarta City from 2023 to 2024

Variable	Dengue fever		
	Pears. Correlation. (r)	Significant (p)	Description
Humidity – case of dengue fever	1.000	0.01	

4 Discussion

4.1 Association between rainfall intensity and dengue fever outbreaks

Climate change is leading to an increase in dengue fever cases. Several studies have found that climatic conditions such as rainfall, temperature, and humidity influence the timing, breeding cycle, behaviour, survival, and reproduction of Aedes aegypti mosquitos, all of which contribute to the spread of the dengue virus to humans. This study showed a significant association between rainfall and dengue fever cases in Surakarta City from 2023 to 2024, with a p-value of 0.01. Annual rainfall in Surakarta City reached an average of 193.71 in 2023 and increased to 223.32 in 2024.

The findings of this study are consistent with previous studies on the relationship between dengue fever cases and rainfall by Putra et al. (2023). These findings indicate a fairly strong and positive relationship between rainfall and dengue fever cases in Malang City from 2011 to 2020 (p=0.005) [12]. According to environmental epidemiology study, rainfall is associated with dengue fever incidence. High rainfall can lead to more places to breed for

Aedes aegypti mosquitos. Increased rainfall intensity leads to more adult mosquito breeding sites and higher mosquito density. Furthermore, increased stagnant water will serve as breeding grounds for mosquitoes, leading to an increase in dengue fever incidence. Climate and the availability of breeding sites are two major influences on the Aedes aegypti population [12]. Ultimately, this will enhance the possibility of human-dengue virus vector contact.

4.2 Association between air temperature and dengue fever outbreaks

Air temperature is another climatic component that influences the Aedes aegypti mosquito's spreading and development. As a result, temperature plays an important role in the dengue virus transmission cycle. The average global temperature increased by 0.9°C during the last two decades. The Aedes aegypti mosquito's habitat has expanded significantly as temperatures increased. Current conditions allow the Aedes aegypti mosquito to survive in areas of North America and Europe that were previously unsuitable for it. In Asia, increasing minimum temperatures have increased the survival and reproductive capacity of this mosquito species in Nepal and the highlands of northern India, which were previously unsuitable for this mosquito species. Increasing temperatures are one of the most important environmental variables impacting the spread of Aedes aegypti populations worldwide [13]. Extreme temperatures can have an impact on larval development. Temperatures above 35°C slow the mosquito's physiological functions. The ideal average temperature for mosquito growth is between 25 and 30°C [10]. According to the findings of this study, the average temperature in Surakarta City was 27.5°C in 2023 and 27.6°C in 2024. This can make mosquitos live longer. Furthermore, due to their endophilic and endophagic nature, Aedes aegypti mosquitos can breed outside of their optimal living temperature. Increasing temperatures impact the intensity of female mosquitoes by decreasing the egg incubation time and accelerating the development of mosquitoes from larvae to adults, increasing the mosquito population and the risk of dengue virus transmission [5]. Increasing air temperatures also have an impact on Aedes aegypti mosquitoes' blood-sucking activities and lifespan. Female mosquitos suck blood more frequently in warmer climates [12]. Furthermore, higher temperatures can accelerate the replication of dengue virus in mosquitos [3]. Air temperature effects not just the growth of viruses in the mosquito's body, but also the spread and gonotrophic cycle [1]. With the increasing number of mosquitoes and the increasing frequency of blood feeding, it is estimated that the risk of dengue transmission will also increase.

This study's results are consistent with prior studies. Studies in Thailand and Singapore showed a relationship between temperature and the number of dengue cases [3]. A study in Manado city found a significant association ($p < 0.001$) between increased dengue fever cases and air temperature from January 2015 to December 2020 [5]. Putra and Lestari's (2023) investigation of the relationship between the incidence rate of dengue fever in Malang Regency from 2011 to 2020 and air temperature showed a relationship ($p=0.003$) and a correlation coefficient ($r=0.272$). This suggests that an increase in the incidence of dengue fever cases is accompanied by an increase in air temperature [12]. Other research suggests every 1°C increase in temperature increases the monthly incidence of dengue fever cases by 13% [1]. However, a study contradicts these results. From 2017 to 2022, correlation studies in Bogor Regency suggested that air temperature did not have a significant correlation with dengue disease incidence. During this time, air temperatures in Bogor Regency ranged between 24.97°C and 27.20°C, excellent for mosquito development. However, it is possible that these mosquitos were not infectious [15].

4.3 Association between air humidity and dengue fever outbreaks

Temperature and rainfall have a considerable influence on air humidity, a component of weather and climate. Air humidity is defined as the water vapor content of the air, which can be expressed as absolute humidity, relative humidity, or water vapor pressure deficit. Air humidity is one of several environmental elements that influence disease transmission. High humidity in the air is strongly associated with dengue fever [14]. Humidity is essential for the survival, habitat creation, and reproductive cycle of Aedes aegypti, hence directly influencing the transmission rate of the dengue virus [12]. This climate factor influences mosquito populations globally, with the greatest pronounced effect shown in tropical and subtropical areas [13]. Asian countries such as India, Bangladesh, Malaysia, and Indonesia have high humidity levels, making them suitable breeding sites for dengue vectors [13].

Air humidity affects the respiratory system and physiological functions of the Aedes aegypti mosquito. Mosquito survival requires air humidity levels of at least 60%. Low air humidity (<60%) shortens mosquito lifetime by causing fluids in their bodies to evaporate. On the other hand, high air humidity (>85%) extends their lives [15]. Furthermore, humidity increases mosquito metabolism, which leads to increased biting. Air humidity is associated with an increase in dengue fever cases because it increases the density of the dengue virus vector as well as the dengue virus's external incubation period, hence enhancing its transmission [3]. In areas with relative humidity above 75%, the vector's ability to spread dengue virus is 1.3 times more than in areas with lower humidity [13].

The findings of this study are consistent with previous studies. A quantitative discovered a significant association between humidity and dengue fever cases (p= 0,000) [12]. Correlation studies in Surabaya showed a significant association between air humidity and dengue fever incidence ($p = 0.05$, $r = 0.19$). This can be interpreted as meaning that the incidence of dengue fever rises with humidity [7].

5 Conclusion

Rainfall, temperature, and humidity are associated with dengue fever outbreaks in Surakarta, Central Java, in 2023-2024. Climate changes (rainfall, temperature, and humidity) have an impact on the emergence of dengue fever cases, but they are not absolute because they can be impacted by other factors such as community behaviour, high mobility, housing expansion, population density, and environmental conditions. As a result, more research is needed to identify other factors that influence the incidence of dengue fever. We hope that the findings of this study could potentially be used as a reference in dengue fever control.

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