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Analysis of Geographic Environmental Risk Factors Associated with Dengue Infection in Palembang City

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Abstract: This study aimed to identify the relationship between environmental factors temperature, humidity, and rainfall, and dengue infection incidence in Palembang City, with emphasis on temporal lag effects and their implications for disease surveillance and control. A quantitative descriptive study was conducted using monthly secondary data from 2021 to 2023. Time-series descriptive analysis and lag correlation methods were applied to examine both concurrent and delayed associations between the environmental variables and dengue case counts. While temperature and humidity showed no consistent concurrent association with dengue incidence, rainfall demonstrated a notable lag-1 effect, whereby increased rainfall in a given month was followed by a rise in dengue cases one month later. This temporal pattern suggests that post-rainfall accumulation of standing water may facilitate mosquito breeding and subsequently elevate transmission risk. These findings highlight the importance of incorporating temporal environmental indicators into dengue early warning systems. Integrating rainfall lag patterns into public health monitoring could support more timely and targeted prevention efforts in Palembang and comparable urban settings across Indonesia.
Keywords: Dengue infection; temperature; humidity; rainfall; Palembang City

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INTRODUCTION

Dengue hemorrhagic fever (DHF) is a disease caused by dengue virus infection and is characterized by fever, myalgia, and/or arthralgia. The disease is transmitted by the mosquito vectors Aedes aegypti and Aedes albopictus (Amelinda et al., 2022). The pathogenesis of dengue virus infection involves complex interactions between the virus, host genetics, and immune responses (Bhatt et al., 2021). Clinical manifestations include bone pain, joint pain, muscle pain, headache, and rash (W. H. Wang et al., 2020). The disease spectrum ranges from self-limiting illness to severe shock, with approximately 0.5%–5% of infections progressing to severe disease (Schaefer et al., 2022). While most mild cases recover without complications, approximately one in 20 infected individuals enters a critical phase characterized by thrombocytopenia, increased vascular permeability, and plasma leakage (Aguilar-Briseño et al., 2020).

At the global level, dengue poses an escalating public health challenge. More than 50% of the global population resides in dengue-endemic regions, which account for more than half of the global disease burden, and incidence has increased substantially over the past three to five years (World Health Organization, 2020). Dengue-related mortality rose from approximately 16,957 deaths in 1990 to 40,467 deaths in 2017, while disability-adjusted life years (DALYs) attributable to dengue reached an estimated 2,922,630 globally in 2017 — a 107.6% increase since 1990 (Zeng et al., 2021). This upward global trend is similarly reflected at the national and local levels in Indonesia. According to the 2023 Indonesian Health Profile, the national dengue incidence rate stood at 41.4 per 100,000 population, with a case fatality rate (CFR) of 0.78% (Kemenkes RI, 2024). At the provincial level, South Sumatra recorded a dengue incidence rate of 31.5 per 100,000 population with a CFR of 0.7%, and Palembang City contributed the highest number of cases among all districts and municipalities in the province (Dinkes Prov. Sumsel, 2024) — a figure consistent with the 727 dengue cases reported in the 2023 Palembang Health Profile (Dinkes Kota Palembang, 2024). These figures underscore that the global rise in dengue burden is not an abstract trend but one that is acutely felt at the local level in Palembang, reinforcing the urgency of localized, evidence-based investigation.

Understanding the drivers of this local burden requires an appropriate theoretical lens. One of the fundamental epidemiological frameworks used to describe disease causation is the classic epidemiological triad, comprising the agent, host, and environment. Disrupting interactions among these components — through vaccination, habitat modification, or reduction of host exposure — can reduce disease transmission (Oliveira et al., 2018). Applied to dengue, the triad identifies four dengue virus serotypes as the infectious agent, humans as the primary host, and environmental conditions as a critical contextual determinant. This study focuses specifically on the environmental component of the triad, examining how geographic and climatic factors shape dengue transmission dynamics in Palembang.

Environmental, climatic, geographic, socioeconomic, and sociocultural factors across different regions contribute to the predictive thresholds of dengue disease (Dalpadado et al., 2024), and previous studies have consistently demonstrated strong associations between dengue incidence and socioecological factors, including ambient temperature, rainfall, and land use (Y. Wang et al., 2025). Temperature has been positively correlated with dengue incidence in numerous studies, with an optimal range of 25°C–30°C supporting vector development, while excessively high temperatures can lead to adult mosquito mortality (Liu et al., 2023). Humidity has also been widely reported to influence dengue transmission, as increased humidity may prolong adult mosquito lifespan and shorten viral incubation periods, thereby enhancing transmission intensity (Islam et al., 2023). Rainfall duration and intensity are similarly crucial, as rainfall provides aquatic habitats for mosquito breeding and enhances vector distribution (Andhikaputra et al., 2023; Fujita et al., 2023).

Despite this growing body of evidence, studies examining the temporal effects of these environmental factors on dengue incidence at the local level remain limited in Indonesia, and particularly scarce in the context of Palembang City. Most existing research has focused on national or regional scales, leaving a critical gap in understanding how temperature, humidity, and rainfall interact with dengue transmission dynamics at the city level over time. This gap is consequential: without locally specific evidence, public health interventions risk being misaligned with the actual environmental conditions driving transmission in Palembang. Therefore, this study aimed to analyze geographic environmental risk factors — specifically temperature, humidity, and rainfall — associated with dengue infection incidence in Palembang, with a focus on their temporal effects. The findings are intended to provide an evidence base for the development of locally tailored dengue surveillance and prevention strategies, contributing to more timely and effective public health responses in the city.

METHOD

A quantitative descriptive study was conducted using secondary data from 2021 to 2023. The study population included all residents of Palembang diagnosed with dengue infection during the study period. The data used is pre-existing data that recorded and summarized by the disease prevention and control division of the Palembang Health Office in the form of reports for 2021, 2022, and 2023. The recording carried out by the Palembang Health Service comes from reports from community health centers and data collection from collaboration with all hospitals in Palembang. The summarized data are patients who were confirmed to have been diagnosed with dengue infection based on the results of a doctor's assessment. Data verification was conducted by visiting several community health centers and hospitals in Palembang. This involved reviewing patient reports of vector-borne diseases at the community health centers and medical records from hospitals that granted data access. Based on this review, the data recorded by the health office was consistent with data from community health centers and hospitals in Palembang.

Monthly dengue incidence data were obtained from the Palembang Health Office, while meteorological data (rainfall, temperature, and relative humidity) were collected from the South Sumatra Class I Climatology Station. Secondary data collection was conducted, specifically temperature, relative humidity, and rainfall. These three meteorological data sets were recorded in the Palembang region. The data were collected in detail, representing an average of one month, resulting in 12 data sets in one year. The research spanned three years, resulting in 36 meteorological data sets. Data were analyzed using descriptive statistical analysis to assess the distribution of each study variable.

The descriptive data study focused on the numerical distribution of both dengue infection incidence and meteorological variables. The descriptive study was conducted by examining the pattern of fluctuations in numerical figures in the same month and the following month, known as lag-1. The tool used for descriptive studies in this research is the chart creation feature in the Microsoft Excel application.

RESULT AND DISCUSSION

In 2021, monthly dengue cases varied substantially, with the highest number recorded in November (39 cases) and the lowest in July (4 cases). Temperature remained relatively stable throughout the year, ranging from 27.1°C to 28.2°C, while relative humidity ranged between 81% and 88%. Rainfall showed wider monthly variation, with the highest rainfall recorded in December (578.8 mm) and the lowest in June (59 mm) (Figure 1). Although temperature and humidity fluctuated only slightly, increases in dengue cases appeared to occur after periods of higher rainfall, suggesting that antecedent environmental conditions may have supported mosquito breeding before the observed rise in cases.

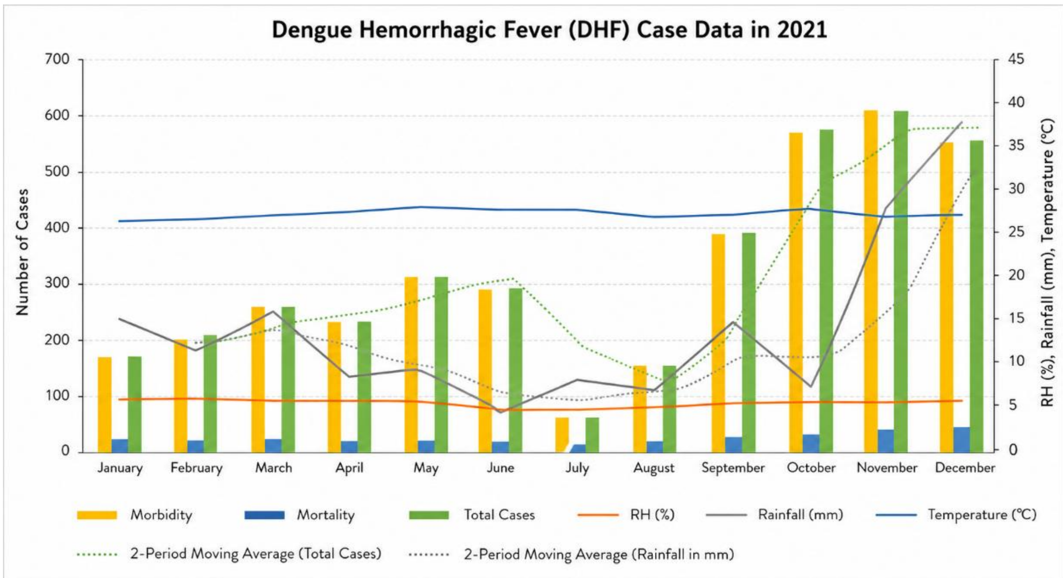

Figure 1. Distribution of dengue infection cases 2021

In 2022, the highest number of dengue cases was reported in January (108 cases), whereas the lowest was recorded in February (50 cases). Temperature ranged from 27.3°C to 28.5°C, and relative humidity varied between 80% and 88%. The highest rainfall occurred in April (398.1 mm), while the lowest rainfall was recorded in July (130 mm) (Figure 2). Despite relatively stable temperature and humidity, dengue cases were concentrated mainly in the early part of the year. This pattern, particularly in relation to rainfall in preceding months, supports the possibility that rainfall contributed to subsequent increases in dengue incidence rather than producing an immediate effect within the same month.

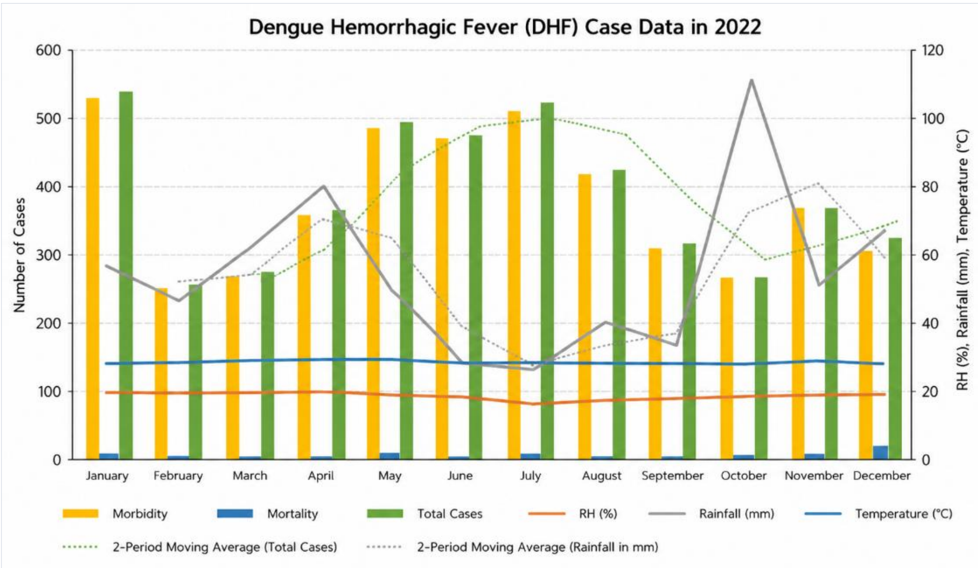

Figure 2. Distribution of dengue infection cases 2022

In 2023, the highest number of cases was observed in February and December, with 91 cases recorded in each month, while the lowest number occurred in September (38 cases). Temperature ranged from 26.9°C to 29.0°C, and relative humidity ranged from 72% to 85%. Rainfall was highest in November (32 mm) and lowest in September (3 mm) (Figure 3). The two peaks in February and December occurred after months with relatively higher rainfall, whereas the lowest case count in September coincided with a period of minimal rainfall. This pattern further supports the presence of a lag-1 relationship between rainfall and dengue incidence.

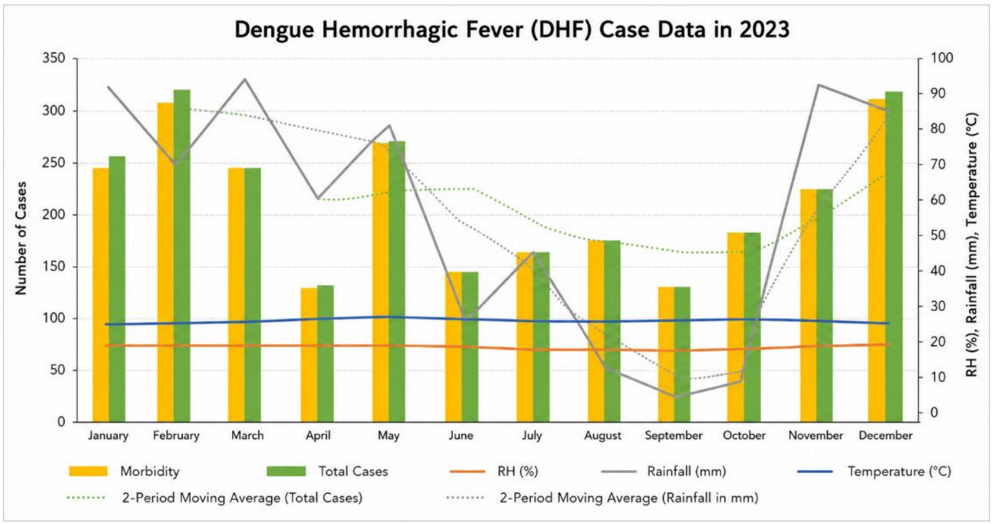

Figure 3. Distribution of dengue infection cases in 2023

Across the three-year observation period, the descriptive analysis did not show a consistent concurrent relationship between dengue incidence and either temperature or relative humidity. Rainfall also did not demonstrate a clear synchronous association with dengue cases in the same month. However, a more consistent temporal pattern was identified when rainfall was assessed with a one-month lag. In general, increases in monthly rainfall were followed by increases in dengue cases in the subsequent month (Figure 4). This lag-1 pattern is epidemiologically plausible because rainfall creates and replenishes stagnant water bodies, including puddles, uncovered containers, and drainage systems, which serve as breeding sites for *Aedes aegypti* and *Aedes albopictus*. After rainfall, mosquito eggs hatch and larvae develop into adult mosquitoes over approximately 8–14 days, depending on environmental conditions. Adult mosquitoes then require an additional extrinsic incubation period before they can transmit dengue virus to humans. Together, these biological processes explain the approximately one-month interval between increased rainfall and subsequent increases in dengue cases.

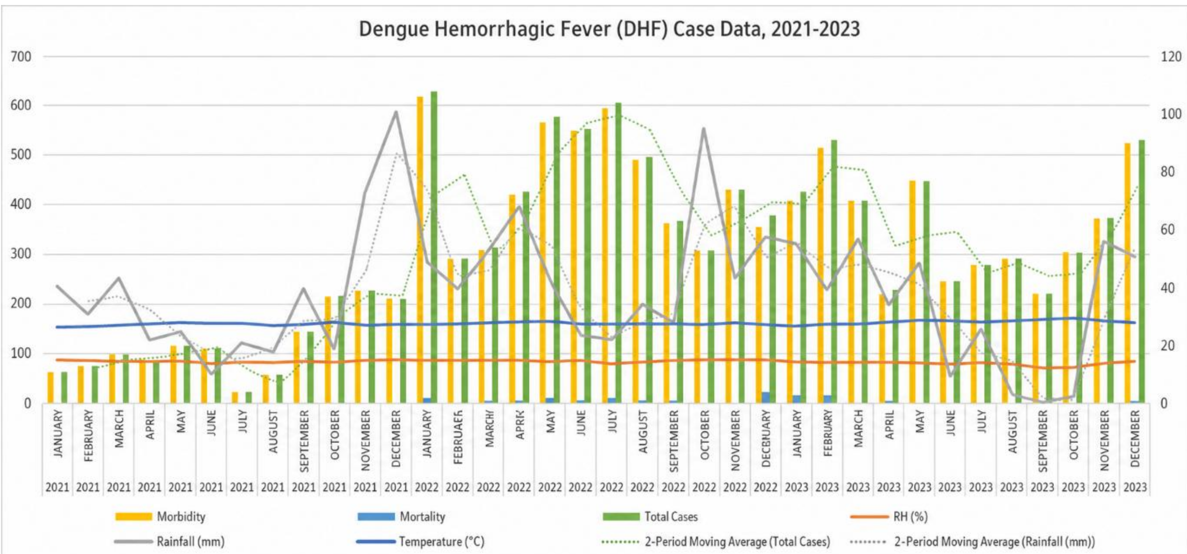

Figure 4. Distribution of dengue infection cases from 2021 to 2023

The absence of a clear association between temperature and dengue incidence is consistent with the findings of Kesetyaningsih et al. (2018) in Sleman Regency, Indonesia. From the perspective of the epidemiological triad, temperature is an environmental factor that primarily influences the vector component by affecting larval development, adult mosquito survival, biting frequency, and the extrinsic incubation period of dengue virus within mosquitoes. However, these effects are more likely to become epidemiologically visible when temperature varies substantially over time. In tropical regions such as Indonesia, where temperature remains relatively stable throughout the year, ambient temperature may not function as a major limiting or modulating factor for dengue transmission. In Palembang, temperatures generally remained within a range suitable for mosquito survival and virus replication, thereby reducing the likelihood that monthly temperature variation would independently explain changes in dengue incidence. This differs from findings in temperate or subtropical settings, where wider seasonal temperature changes may produce stronger associations between temperature and dengue transmission (Huang et al., 2021).

Relative humidity also showed no consistent association with dengue incidence. This finding is in line with Islam et al. (2023), who reported no clear relationship between dengue incidence and relative humidity during a one-year observation period. Humidity can influence dengue transmission by affecting mosquito survival, activity, and biting rates. High relative humidity may prolong mosquito longevity and increase the probability of virus transmission. However, in Palembang, relative humidity remained relatively high and stable across much of the observation period. As a result, humidity may not have varied sufficiently to generate detectable changes in vector abundance or transmission intensity. This finding contrasts with studies from Thailand, where stronger humidity effects have been reported in areas with clearer seasonal variation. Xu et al. (2019) showed that relative humidity had the strongest effect in northeastern Thailand, followed by central regions, reflecting the role of regional climatic variability. Similarly, Castro et al. (2021) reported that relative humidity and landscape-level water availability influenced dengue transmission intensity. These differences indicate that the effect of humidity on dengue is context-dependent and may be more apparent in regions where humidity varies more substantially over time and space.

Rainfall emerged as the most relevant climatic factor in this study, particularly when assessed with a one-month lag. This finding is consistent with Astuti et al. (2019), who reported a positive cross-correlation between pediatric dengue incidence and rainfall at lags of one to two months in Cirebon, with dengue cases peaking during the rainy season. Similarly, Ali et al. (2022) found that post-rainfall urban environments facilitate dengue vector breeding because stagnant water accumulates in areas with poor drainage. In the context of the epidemiological triad, rainfall is an important environmental determinant because it directly increases the availability of breeding habitats for *Aedes* mosquitoes. Rainfall creates standing water in household containers, drainage channels, and other urban structures, thereby increasing vector density and the likelihood of contact between dengue virus, mosquito vectors, and susceptible human hosts.

The lag-1 association observed in this study is biologically coherent. *Aedes aegypti* requires approximately 8.5 days to develop from egg to adult, including around 7.5 days in pre-pupal stages and one day in the pupal stage (Anoopkumar et al., 2017). After mosquito proliferation, dengue infection in humans has an intrinsic incubation period of approximately 3–14 days following viral exposure (Leowattana & Leowattana, 2021). Therefore, the cumulative period from rainfall-induced vector breeding to clinically detectable dengue cases is compatible with the one-month lag observed in this study.

These findings reinforce the usefulness of the epidemiological triad as a framework for understanding dengue transmission in tropical urban settings. Among the three climatic variables examined—temperature, relative humidity, and rainfall—rainfall was the most consistent environmental factor associated with dengue incidence. In Palembang, temperature and humidity remained relatively stable and therefore may have provided a continuously suitable background for mosquito survival rather than acting as drivers of monthly variation. In contrast, rainfall fluctuated more clearly and directly influenced the availability of mosquito breeding habitats. Thus, the observed dengue pattern appears to be driven mainly by rainfall-mediated changes in the vector component, while the agent and host components remained relatively stable during the study period.

The findings also have practical implications for dengue control in Palembang. The lag-1 effect suggests that elevated rainfall in a given month may serve as an early warning indicator for increased dengue transmission in the following month. This provides public health authorities with an opportunity to implement preventive interventions before cases rise. Such interventions may include larval source reduction, intensified fogging in high-risk areas, drainage improvement, and community-based campaigns to eliminate standing water. Integrating rainfall monitoring into local dengue surveillance systems could therefore improve the timeliness and effectiveness of dengue prevention strategies in Palembang and similar urban settings in Indonesia.

Several limitations should be acknowledged. First, the analysis was limited to a single city and a three-year observation period, which may restrict statistical power and generalisability. Future studies should include longer observation periods and multi-city or provincial designs to capture spatial heterogeneity in dengue risk across South Sumatra and other regions of Indonesia. Second, this study focused only on climatic predictors, while other components of the epidemiological triad, including population immunity, population density, human mobility, urbanisation, vector control activities, and circulating dengue serotypes, were not examined. Future research should integrate meteorological data with serotype surveillance, vector indices, and host-level data to produce a more comprehensive model of dengue transmission. Finally, future analyses should consider using non-linear distributed lag models to detect delayed, threshold-dependent, and non-linear climate effects that may not be captured by descriptive or conventional correlation-based approaches.

CONCLUSION

This study examined the association between temperature, relative humidity, rainfall, and dengue incidence in Palembang, South Sumatra, Indonesia. The findings show that rainfall was significantly and positively associated with dengue incidence at a one-month lag, indicating that increased rainfall was followed by higher dengue cases in the subsequent month. In contrast, temperature and relative humidity showed no significant association, likely because Palembang's equatorial climate keeps these variables relatively stable throughout the year. The lag-1 effect of rainfall is consistent with the biological cycle of *Aedes aegypti* and the incubation periods of dengue virus in mosquitoes and humans. Rainfall increases standing water and mosquito breeding habitats, while the combined developmental and incubation periods create a delay between rainfall and reported dengue cases. This finding suggests that rainfall can serve as an early warning indicator, providing approximately four weeks for public health authorities to strengthen vector control, larval source reduction, and entomological surveillance before case numbers rise. This study is limited by its single-city setting, restricted observation period, and the exclusion of other relevant factors such as population density, dengue serotypes, population immunity, and urban drainage conditions. Future studies using longer time-series data, multi-city comparisons, entomological and serotype information, and advanced lag-based models are needed to validate and extend these findings.

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