

Influence of climatic variations on dengue fever incidence in Eastern Thailand

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ABSTRACT

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This study explored the relationship between meteorological factors and dengue fever incidence in Eastern Thailand from 2013 to 2024. This study used secondary data from the Thai Meteorological Department and the Bureau of Epidemiology, spanning the period from 2013 to 2024. Data for seven provinces in Eastern Thailand including Chanthaburi, Chachoengsao, Chonburi, Trat, Prachinburi, Rayong, and Sa Kaeo were analyzed. Climatic variables (precipitation, relative humidity, minimum and maximum temperatures, and the number of rainy days) were obtained from the Thai Meteorological Department, while dengue fever case data were sourced from the Bureau of Epidemiology. The analysis focused on identifying the temporal associations between climate variability and dengue incidence. Stepwise multiple linear regression was applied to examine the influence of climatic factors on dengue fever, with the model accounting for variations in temperature, humidity, rainfall, and rainy days. Stepwise multiple linear regression analysis revealed that average minimum temperature, average maximum temperature, and relative humidity were significant predictors of dengue incidence. The minimum temperature had the strongest positive effect, suggesting that warmer nights promote mosquito survival and virus transmission. High daytime temperatures and humidity were found to reduce mosquito activity and breeding suitability. The model accounted for 14.2% of the variance in dengue incidence, indicating the need for further consideration of other factors like urbanization and public health interventions. These findings emphasize the importance of integrating meteorological data into early warning systems and developing climate-sensitive prevention strategies.

Keywords: dengue fever; climate variability; *Aedes aegypti*; Eastern Thailand; vector-borne disease

1. INTRODUCTION

Climate change is recognized as a global challenge that has environmental, economic, social and health impacts. Without effective strategies to address it, it could hinder sustainable development and pose threats to current

and future generations. In addition, climate variability facilitates the spread of infectious diseases such as dengue fever. Particularly in tropical and subtropical regions such as Thailand (Langkulsen et al., 2020). To address this challenge, countries, including Thailand, have ratified the Paris Agreement under the United Nations Framework

Convention on Climate Change (UNFCCC), which aims to reduce the increase in global temperatures and increase our ability to cope with the impacts of climate change. This commitment is also aligned with the Sustainable Development Goals (SDGs), particularly Goal 13: Climate Action and Goal 3: Good Health and Well-being (SDG Move, 2015).

Climate change has disrupted the balance of ecosystems and natural environments, resulting in heightened health risks, particularly among vulnerable populations such as children, the elderly, and bedridden individuals. Utilizing the “impact chain” framework allows for the identification of critical vulnerabilities and the design of effective mitigation and adaptation measures. According to the World Health Organization (2024), dengue fever reached unprecedented global levels in 2023, with over 6.5 million reported cases and approximately 6,800 deaths, followed by over 7.6 million cases, including 3.4 million confirmed cases and more than 3,000 deaths, by April 2024. As of May 2025, more than 3 million cases and 1,400 deaths have already been reported across 90 countries. Nearly 4 billion people now reside in dengue-risk areas (Centers for Disease Control and Prevention [CDC], 2025). In Thailand, dengue incidence remains high, with over 26,500 cases and 22 deaths reported by April 2024 an increase of 123% compared to the same period in 2023 (Travel Health Service, 2024). The Eastern region, including Chonburi province and Bang Lamung district (Pattaya area), has experienced localized outbreaks consistent with broader national surges (CDC, 2025).

Mosquitoes are insects that thrive in warm climates, particularly under current global warming conditions. Rising global temperatures have expanded mosquito habitats beyond traditional tropical regions into previously unsuitable areas with temperate or even cooler climates. The *Aedes albopictus* mosquito, a known vector of dengue and chikungunya viruses, has expanded its geographic range into parts of southern Europe where these diseases had not been previously reported. In Thailand, however, the primary vector of dengue is *Aedes aegypti*, although *Aedes albopictus* also contributes to transmission, particularly in rural and peri-urban areas (Sutriyawan et al., 2024). Higher temperatures have a direct effect on the mosquito life cycle, shortening the larval-adult development time, allowing mosquitoes to transmit diseases faster. In addition, high temperatures increase the mosquitoes’ blood-sucking ability, infectivity and transmission. Studies have shown that higher temperatures significantly increase the infection rate of mosquitoes and reduce the incubation period of viruses, allowing for faster transmission of mosquito-borne diseases (Delrieu et al., 2023). In Thailand, the Department of Disease Control has identified *Aedes aegypti* as the primary vector of dengue virus transmission, while *Aedes albopictus* also contributes to disease transmission in some rural and peri-urban settings (Department of Disease Control, 2025b).

This study investigated the relationship between climate change and dengue fever outbreaks over a twelve-year period, focusing on seven provinces in the eastern region of Thailand namely Chonburi, Rayong, Chanthaburi, Trat, Sa Kaeo, Prachinburi, and Chachoengsao where dengue remains endemic and incidence rates have continued to rise. In this context, climate change encompasses not only long-term trends in environmental conditions but also variations in key climate parameters and the occurrence of

climate-related anomalies, such as extreme weather events. The study specifically examined fluctuations in temperature, rainfall, relative humidity, and the number of rainy days, all of which play a critical role in mosquito ecology and the dynamics of dengue virus transmission.

According to the Department of Disease Control (2025a), annual dengue incidence in Thailand does not necessarily increase every year because disease transmission is influenced by multiple factors, including population immunity and environmental conditions. Continuous surveillance is therefore essential for effective dengue prevention and control.

The term “over time” refers to the period from 2013 to 2024, during which both climatic and epidemiological data were collected and analyzed. This time frame was selected to capture seasonal variations, interannual climate variability, and longer-term environmental shifts that may contribute to changes in dengue transmission patterns. Climatic data were obtained from the Thai Meteorological Department, while monthly dengue case data were sourced from the Bureau of Epidemiology, Ministry of Public Health. The analytical approach focused on identifying correlations and potential lag effects between climatic factors and dengue incidence, with the goal of enhancing understanding of how environmental drivers influence disease outbreaks in one of Thailand’s most vulnerable regions.

These factors have important implications for the changes in the disease spread. Moreover, the eastern region’s hot and humid climate, along with high annual rainfall, especially during the rainy season and towards the end of the year, creates favorable conditions for the proliferation of *Aedes* mosquitoes, the primary vector of the dengue virus (Zafar et al., 2025). While national-level studies have explored the relationship between climate variability and vector-borne diseases, there remains a lack of in-depth, localized research specific to the eastern region of Thailand. This region possesses unique geographical features, economic activities, and community structures that differ markedly from other parts of the country realities (Phanitchat et al., 2019). This research gap has limited the development of effective and geographically relevant disease prevention policies at the provincial or district levels, where current strategies may still rely on generalized data that do not reflect local epidemiological (Tontisirin & Anantsuksomsri, 2021).

This region possesses unique geographical features, economic activities, and community structures that differ markedly from other parts of the country. However, a significant research gap remains in understanding how these localized characteristics influence dengue transmission. This gap has limited the development of effective, context-specific disease prevention policies at the provincial or district level. In many cases, local public health strategies continue to rely on generalized national-level data or aggregated epidemiological trends, which may not accurately reflect the micro-level variations in climate conditions, vector ecology, population density, and health infrastructure within specific communities.

Such reliance on generalized data can result in inefficient resource allocation, misaligned intervention timing, and low community engagement, ultimately reducing the effectiveness of vector control programs. For instance, Wijayanti et al. (2016) highlighted how national dengue strategies in Southeast Asia often overlook localized

transmission patterns, leading to delays in outbreak response. Similarly, Gibb et al. (2023) emphasized that fine-scale climate and vector data are critical for timely prediction and early warning systems, especially in regions experiencing rapid urbanization or environmental change. Without geographically nuanced insights, public health planning risks adopting “one-size-fits-all” approaches that fail to address the unique vulnerabilities of specific districts or provinces.

Therefore, this study is of particular importance in enhancing spatial understanding specifically in terms of geographic distribution patterns, spatial clustering of cases, and environmental context of how climate change influences dengue outbreaks in the eastern region of Thailand.

2. MATERIALS AND METHODS

2.1 Research design

This study utilized meteorological data and dengue fever incidence statistics specific to the Eastern Region of Thailand. Seven provinces were selected as study sites based on their history of recurrent outbreaks and distinct climatic characteristics. To support spatial interpretation, Figure 1 presents a map delineating the region’s geographical boundaries and the locations of the selected provinces.

2.2 Research population and sample

The dataset used in this study consisted of monthly time-series data on rainfall, relative humidity, minimum and

maximum temperatures, and the number of rainy days from 2013 to 2024, obtained from the Thai Meteorological Department. Corresponding dengue fever case data for the same period were sourced from the Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health. The analysis focused specifically on data from seven provinces in the eastern region of Thailand: Chanthaburi, Chachoengsao, Chonburi, Trat, Prachinburi, Rayong, and Sa Kaeo. This comprehensive dataset allowed for the examination of temporal associations between climatic variables and dengue incidence across the study area.

All seven provinces in the eastern region of Thailand, Chanthaburi, Chachoengsao, Chonburi, Trat, Prachinburi, Rayong, and Sa Kaeo, were selected as the study area due to their documented history of persistent and recurrent dengue outbreaks, which pose significant public health challenges (Bureau of Epidemiology, 2023). These provinces also exhibit diverse climatic and ecological conditions, ranging from coastal zones and urban centers to rural and forested areas, providing a comprehensive context to study the impact of climate variability on dengue transmission (Polwiang, 2020). The geographic and socio-environmental heterogeneity across these provinces allows for analysis of spatial variations in disease dynamics and the effectiveness of local vector control strategies, making this region an ideal setting for understanding how climate factors interact with other determinants to influence dengue epidemiology (Khan et al., 2023).

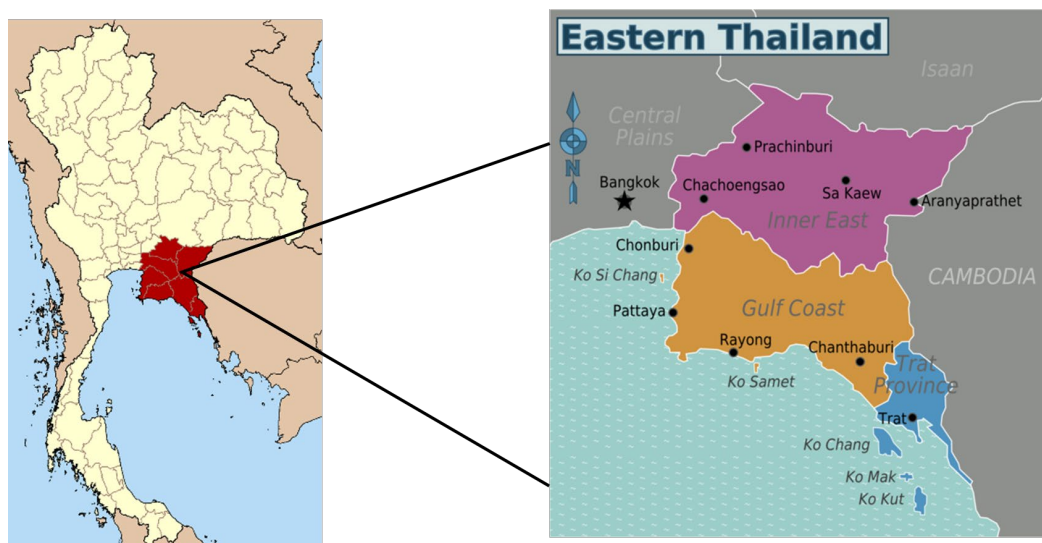


Figure 1. Map of Eastern Thailand showing the study area

Source: https://wikitravel.org/wiki/en/index.php?title=File:Eastern_thailand_regions_map.png

2.3 Data collection

Secondary data on the number of dengue fever cases and incidence rates were collected for seven provinces in the eastern region of Thailand, namely Chanthaburi, Chachoengsao, Chonburi, Trat, Prachinburi, Rayong, and Sa Kaeo, during the period from 2013 to 2024. According to the International Classification of Diseases, 10th Revision (ICD-10) codes A90 (Dengue fever [classical dengue]) and A91 (Dengue hemorrhagic fever), ensuring standardized case definitions across the dataset. These data were

obtained from the Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health, and compiled by provincial public health offices. For this study, only dengue cases considered potentially influenced by climate variability and change were included. This selection was based on temporal and spatial criteria derived from existing literature, which identifies climate-sensitive periods and regions where fluctuations in temperature, rainfall, and humidity significantly impact mosquito vector dynamics and virus transmission (Hasan et al., 2025).

Specifically, dengue case data were aligned with climatic data to focus on months and locations demonstrating known correlations with climatic anomalies, such as increased rainfall or elevated temperatures, which can create favorable conditions for *Aedes* mosquito breeding and viral replication. This approach helps isolate the subset of dengue incidence most likely affected by environmental factors, thereby strengthening the analysis of climate-disease relationships. In parallel, monthly meteorological data for the same provinces and period were obtained from the Thai Meteorological Department. The climatic variables analyzed in this study consisted of precipitation, relative humidity, minimum temperature, maximum temperature, and the number of rainy days.

2.4 Statistical analysis

Data processing involved descriptive analysis, including the calculation of mean, variance, minimum, and maximum values. This was followed by an analysis of the relationship between meteorological factors precipitation, average relative humidity, average minimum temperature, average maximum temperature, and the number of rainy days and the incidence of dengue fever with SPSS program. Precipitation was measured in millimeter (mm), temperature in degrees Celsius (°C), relative humidity in percentage (%), and the number of rainy days in days. To examine the impact of climate change-related factors on dengue fever incidence, stepwise multiple linear regression analysis was employed.

2.5 Ethical considerations

Ethical approval for the study protocol was obtained from the Ethics Committee of Sirindhorn College of Public Health, Yala, having the approval number SCPHYLIRB-2567/452. All the information obtained was anonymized, and data privacy and confidentiality were ensured (IRB/16 Dec/2024).

3. RESULTS AND DISCUSSION

3.1 Trends of dengue fever incidence in the eastern region of Thailand (2013–2024)

The incidence rate of dengue fever in the seven eastern provinces of Thailand has fluctuated annually. In 2013, 8,468 cases were reported, followed by a decrease to 3,786 cases in 2014. However, the number rose sharply to 16,097 cases in 2015, before dropping again to 3,598 in 2016 and slightly declining to 3,244 in 2017. In 2018, the number of cases increased to 7,733, continuing to rise to 13,155 in 2019, then declined to 7,024 in 2020 and dropped significantly to only 757 cases in 2021. The incidence began to rise again, reaching 3,926 cases in 2022 and peaking at 21,139 cases in 2023, before decreasing to 7,231 cases in 2024, as illustrated in Figure 2.

The observed cyclical pattern of dengue outbreaks aligns with previous studies indicating that dengue tends to recur in waves every 3–5 years, driven by factors such as declining herd immunity, shifts in viral serotypes, and weather variability (O'Driscoll et al., 2020). Churakov et al. (2019) further highlighted the influence of unusual weather conditions such as changes in rainfall and temperature, on vector proliferation and viral transmission, which help explain the peak outbreaks in 2015 and 2023.

Beyond these biological and climatic drivers, other critical factors have likely influenced the incidence trends. For instance, prevention and disease control measures implemented by local health authorities including vector surveillance, community engagement, and insecticide spraying can significantly impact transmission rates. Variations in the intensity, coverage, and timing of these interventions may partly explain some of the fluctuations observed, especially the dramatic decline in 2021, which coincided with pandemic-related disruptions to routine vector control activities.

Additionally, land use changes in the eastern region, such as rapid urbanization, agricultural expansion, and deforestation, have altered mosquito breeding habitats and human exposure patterns. Urban sprawl can increase artificial water containers and breeding sites, while agricultural practices may influence vector ecology differently, contributing to localized disease dynamics.

Socioeconomic factors, including population density, housing quality, and access to healthcare, also play roles in shaping dengue risk by affecting exposure and case detection rates. Changes in human behavior, public awareness, and mobility particularly during the COVID-19 pandemic further interact with these factors, influencing transmission patterns.

Taken together, these multifaceted influences underscore the complexity of dengue epidemiology in the eastern region and highlight the need for integrated surveillance and control strategies that address climatic, ecological, social, and healthcare determinants.

3.2 Climatic characteristics and their variations (2013–2024)

From the analysis of climate data in the eastern region of Thailand, key meteorological factors including temperature, rainfall, and relative humidity showed notable variation over the study period (Figure 3). In 2019, the average maximum temperature peaked at 33.58 degrees Celsius, while the highest average minimum temperature was recorded in 2021 at 24.08 degrees Celsius. Relative humidity reached its highest levels in 2020 (78.94%) and again in 2023 (76.37%). Rainfall varied, with the maximum average monthly rainfall recorded in 2017 at 168.55 millimeters, and the lowest in 2019 at 116.35 millimeters. The average number of rainy days per month ranged from 10 to 11, with 2020, 2021, and 2023 consistently experiencing 11 rainy days.

Regarding dengue fever incidence, the highest number of cases was reported in 2023, with 21,139 patients, while 2021 saw a sharp decline to only 757 cases. These variations in meteorological factors, specifically temperature, rainfall, and humidity, appeared closely linked to dengue outbreak trends, highlighting their critical role in disease dynamics. For example, warmer minimum temperatures observed from 2019 to 2023 may enhance the survival of *Aedes* mosquitoes and increase the efficiency of viral replication, thereby accelerating transmission. Wang et al. (2022) reported that elevated nighttime temperatures shorten the extrinsic incubation period of the dengue virus within the mosquito host, making transmission more efficient even when vector densities are low. Similarly, Sugeno et al. (2023) identified shifts in temperature, particularly minimum temperature, as one of the strongest predictors of dengue incidence in Southeast Asia.

Fluctuations in rainfall also contribute significantly to mosquito breeding. Increased precipitation in 2017 and the consistent number of rainy days during 2020, 2021, and 2023 likely created favorable habitats for mosquito larvae. Huber et al. (2018) emphasized that rainfall variability, especially in tropical environments, strongly influences larval habitat availability, thus affecting mosquito population dynamics and disease risk.

The combined effects of temperature, rainfall, and humidity likely contributed to the unusually high dengue

incidence in 2023 and the sharp decrease in 2021. The reduction in 2021 may also be partially attributed to behavioral changes during the COVID-19 pandemic, such as reduced human mobility due to lockdowns and travel restrictions, decreased healthcare-seeking behavior, and disruptions to routine mosquito control programs. These factors collectively may have altered both human-mosquito contact rates and vector management effectiveness, thereby influencing dengue transmission during that period.

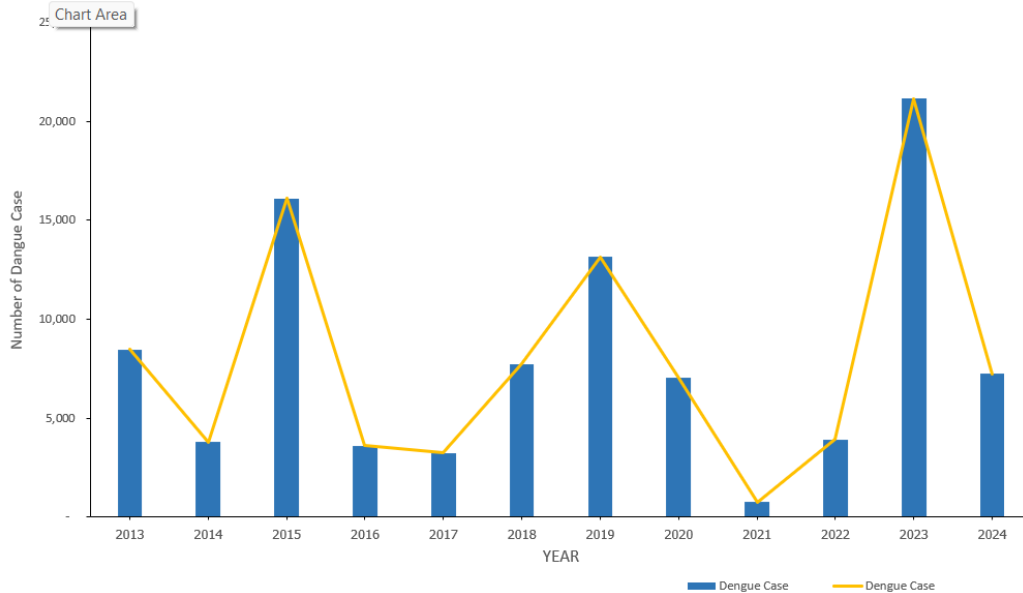


Figure 2. Trends of dengue fever (DF) cases and incidence in the eastern region of Thailand during 2013–2024

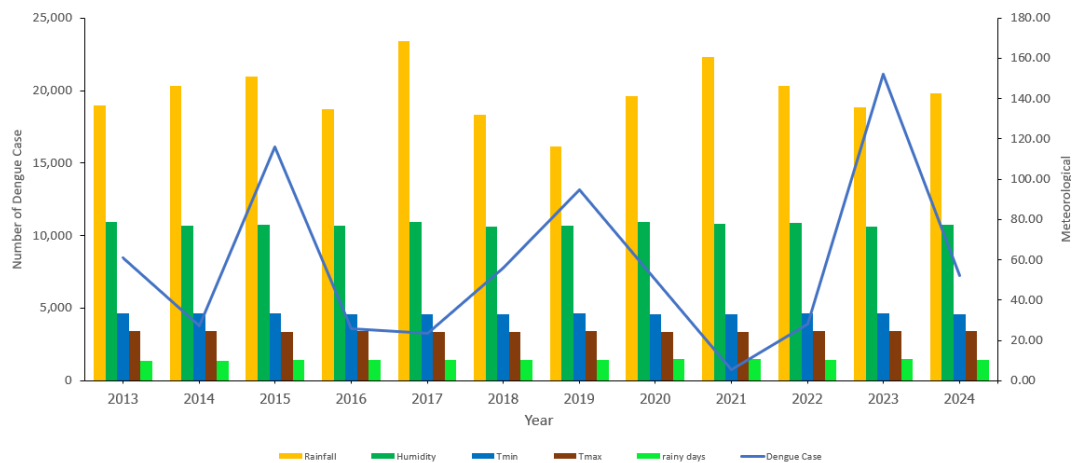


Figure 3. Precipitation, humidity, minimum temperature, maximum temperature, rainy days, and incidence of dengue fever in the eastern region of Thailand during 2013–2024

The average precipitation in the eastern region during 2013–2024 was 143.00 ± 13.68 mm (Table 1). The lowest recorded precipitation was 116.35 mm in 2019, and the highest was 168.55 mm in 2017. The average relative humidity was $78.00 \pm 0.90\%$. The minimum humidity was $76.37 \pm 0.21\%$ in 2023, and the maximum was 78.94% in 2020. The average minimum and maximum temperatures were 24.00°C and $33.00 \pm 0.25^\circ\text{C}$, respectively. The lowest minimum temperature was 24.08°C in 2021, while the

highest maximum temperature was 33.58°C in 2019. The average number of rainy days was 10 ± 0.27 days per month. The maximum number of rainy days recorded was 11 days (in 2020, 2021, and 2023). The average incidence of dengue fever was $8,013 \pm 5,995.56$ cases. The lowest number of dengue cases was 757 in 2021, and the highest was 21,139 in 2023, as shown in Table 1. These climatic patterns are consistent with various studies suggesting that temperature, rainfall, and humidity can affect the

outbreak of mosquito-borne diseases. These climatic parameters have been shown to have significant impacts on mosquito populations and disease transmission (Abdullah et al., 2022). In addition, temperature, rainfall, and relative humidity are also important factors linked to the spread of dengue fever (Chien & Yu, 2014). Climate

change also alters the mosquito distribution range and seasons, which affects the incidence of dengue fever (Lowe et al., 2018), potentially leading to an increase in the prevalence of diseases such as dengue fever (Ryan et al., 2019).

Table 1. Temperature, humidity, precipitation, rainy days, and dengue fever incidence in the eastern region of Thailand (2013–2024)

Variable	Mean	SD	Min	Max
Rainfall (mm)	143.00	13.68	116.35	168.55
Humidity (%)	78.00	0.90	76.37	78.94
Minimum temperature (°C)	24.00	0.21	24.08	24.81
Maximum temperature (°C)	33.00	0.25	32.79	33.58
Rainy days (day)	10.00	0.27	10.00	11.00
Incidence of DHF (Cases)	8,013.00	5,995.56	757.00	21,139.00

3.3 Regression analysis: Relationship between climatic factors and dengue fever incidence

The incidence of dengue fever in the eastern region of Thailand was found to be significantly related to three climate variables with a probability level of 0.05. These included average minimum temperature ($b = 34.408$, $t = 12.081$, $p < 0.001$), average maximum temperature ($b = -24.720$, $t = -7.838$, $p < 0.001$), and average relative humidity ($b = -3.913$, $t = -4.778$, $p < 0.001$). All three variables significantly predicted the incidence of dengue fever. The regression coefficients indicated that when the average minimum temperature increased, it was positively associated with the incidence rate, but when the average maximum temperature and relative humidity increased, they were negatively associated with the incidence rate. The corresponding regression model based on these variables is summarized in Table 2. Although the model explained only 14.2% of the variation in dengue fever incidence ($R^2 = 0.142$), the statistically significant predictors indicated that climatic factors play a measurable role in

shaping disease dynamics in this region. Research conducted in Northeastern Thailand revealed that maximum temperature and rainfall are associated with dengue incidence, particularly during the rainy season, which supports mosquito breeding (Phanitchat et al., 2019). In contrast, in southern Thailand, cloud cover was found to have a greater influence than humidity and temperature, serving as a significant predictor of outbreak patterns (Abdulsalam et al., 2021). Furthermore, empirical evidence shows that social and environmental contexts such as urban infrastructure, household water storage, and community behavior are closely linked to local patterns of dengue transmission (Alqassim, 2024). The limited explanatory power of the current model may result from the absence of in-depth data on vector control measures and demographic changes over time (Procopio et al., 2024). Future studies should therefore integrate environmental, economic, social, and public health policy data to enhance analytical depth and contribute to more sustainable strategies for disease prevention and control.

Table 2. Coefficients of determination for the dengue fever model in the 7 eastern provinces of Thailand

R	R ²	Adjusted R ²	Standard	Durbin-Watson
0.377	0.142	0.140	134.12301	0.239

Dependent variable: Dengue fever incidence rate

Dengue fever incidence rate = $377.760 + (34.408)$ average minimum temperature – (24.720) average maximum temperature – (3.913) average relative humidity.

For each additional degree Celsius of average minimum temperature, the incidence rate of dengue fever in the eastern population tends to increase by approximately 34.41 cases.

For each additional degree Celsius of average maximum temperature, the incidence rate of dengue fever in the eastern population tends to decrease by approximately 24.72 cases.

For each additional percent of average relative humidity, the incidence rate of dengue fever in the eastern population tends to decrease by approximately 3.91 cases.

When other variables in the equation are held constant and the standardized coefficients in Table 3 are considered, it was found that the independent variable average minimum temperature ($Beta = 0.435$) had the greatest

influence on the incidence rate of dengue fever, followed by average maximum temperature ($Beta = -0.256$) and average relative humidity ($Beta = -0.172$). Warmer nighttime temperatures increase the survival rate of the dengue mosquito, the vector of dengue fever, and allow the mosquito virus to replicate faster, which in turn allows the mosquito to spread the disease more effectively. Higher minimum temperatures are also associated with more frequent biting behavior and more foraging activity, which are important factors in facilitating virus transmission. Conversely, higher mean maximum temperatures and higher relative humidity have been found to be negatively related, which could mean that these conditions reduce mosquito survival or activity. Excessive daytime heat can shorten mosquito lifespans or cause them to adapt their behaviors, such as avoiding foraging during high temperatures (Carrington et al., 2013). Furthermore, temperatures above 34°C have been found to reduce virus

replication in mosquitoes (Liu-Helmersson et al., 2014). Prolonged high relative humidity may make breeding sites unsuitable for larval development (Ngugi et al., 2017) and may make it harder for mosquitoes to move and bite (da Cruz Ferreira et al., 2017). These results suggest that extreme weather conditions may be a factor limiting the ability of mosquito vectors to spread. The intersection between public health and climate change adaptation has become increasingly important in the context of sustainable development. Climatic variability, particularly shifts in temperature and precipitation, has been shown to influence the ecological conditions that favor mosquito proliferation and viral transmission, thereby elevating the risk of dengue outbreaks (George et al., 2024). Strengthening public health systems through community-based prevention, health education, and effective risk communication is therefore essential for building long-term resilience to vector-borne diseases such as dengue. The findings of this study align with and support the implementation of Sustainable Development Goal (SDG) 3, particularly Target 3.d, which calls for strengthening the capacity of all countries, especially developing nations, for early warning, risk reduction, and management of national and global health risks. Furthermore, the integration of

climate-responsive health strategies with SDG 13, specifically Target 13.2, which emphasizes incorporating climate change measures into national policies, strategies, and planning, can help enhance adaptive capacity at both local and national levels.

In the Thai context, these insights reinforce the relevance of the Twelfth National Economic and Social Development Plan (2017–2021) and the National Adaptation Plan (NAP), both of which highlight the need to integrate climate risk information into public health policy and to strengthen intersectoral collaboration. Specifically, the Thai Climate Change Master Plan (2015–2050) outlines goals for building climate-resilient communities and infrastructure, including health systems. To that end, coordinated action between the Ministry of Public Health, the Thai Meteorological Department, and local government units will be crucial for translating climate data into operational public health responses. The development of early warning systems, localized disease surveillance, and community-level adaptation strategies will ensure that dengue prevention measures remain adaptive, inclusive, and sustainable in the face of intensifying climatic threats and rapid urban development.

Table 3. Analysis of variance (ANOVA) for dengue fever incidence

Predictors	Sum of squares	df	Mean square	F	Sig.
Regression	2,998,717.429	3	999,572.476	55.566	.000
Residual	18,060,937.424	1004	17,988.981		
Total	21,059,654.853	1007			

4. CONCLUSION

This study underscores the partial yet significant influence of climatic factors, particularly nighttime temperature, on dengue transmission dynamics in Thailand's eastern region. The findings support the integration of localized climate data into early warning systems and public health planning. To enhance the effectiveness of disease prevention and control, policy responses should be tailored to the spatial and temporal characteristics of each province, considering both environmental and socio-demographic vulnerabilities. Future research should adopt a more integrated approach by incorporating land use patterns, vector control practices, and community behavior to better capture the multifaceted nature of dengue risk under climate change.

This study has several limitations. First, while the findings highlight statistically significant associations between climatic variables and dengue incidence, the model's explanatory power was relatively low, partly due to the exclusion of key non-climatic variables such as vector control interventions, demographic shifts, and land use patterns. Second, the analysis relied on provincial-level secondary data, which may have masked finer-scale heterogeneity in disease dynamics, especially across urban, peri-urban, and rural settings. Third, the absence of entomological and virological data, such as mosquito density, vector infection rates, and circulating dengue serotypes, restricted the study's ability to explore vector-pathogen-environment interactions directly. These limitations underscore the need for future multidisciplinary studies that integrate climatic, environmental, behavioral, and

health system variables to enhance the precision and policy relevance of dengue early warning models.

AUTHOR CONTRIBUTIONS

Pu.B. conceptualized and drafted the manuscript, as well as interpreted the analyses; I.S. provided guidance on the data analysis, reviewed and approved it, and Pi.B. assisted in studying the quantitative results. All authors have reviewed and approved the manuscript.

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