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Climate Variability And Dengue Outbreaks In Imphal Valley, Northeast India

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Abstract

Dengue fever has emerged as a significant public health concern in Northeast India, particularly in the Imphal Valley, where rapid urbanization, changing land use patterns and conducive climate have created favorable conditions for mosquito proliferation. This study investigates the relationship between climate variability and dengue incidence during the period 2020-2022. Climatic variables, including monthly temperature, rainfall and relative humidity, were collected from meteorological records and analyzed in conjunction with reported dengue cases obtained from the State Health Directorate. The analysis revealed a distinct seasonal pattern, with case numbers increasing sharply from late summer through the post-monsoon months, coinciding with peaks in rainfall and ambient humidity. A strong positive correlation was observed between precipitation levels and dengue incidence, suggesting that heavy rainfall contributes to the creation of breeding habitats for *Aedes* mosquitoes, while warm, moist conditions accelerate vector development and viral transmission. Although temperature fluctuations showed a moderate association with case trends, precipitation and humidity emerged as the most influential climatic drivers. These findings underscore the critical role of climate variability in shaping the dynamics of dengue outbreaks in the Imphal Valley. They point to the necessity of integrating climate-sensitive approaches into vector control, surveillance, and public health preparedness. Timely interventions, such as pre-monsoon source reduction, community awareness and enhanced entomological monitoring, can help mitigate the risk of large-scale outbreaks. Incorporating climate-based early warning systems into dengue management strategies would further strengthen the region's capacity to respond effectively to future climate-driven health challenges.

Keywords: Dengue, Climate variability, Imphal Valley, Rainfall, Vector-borne disease, Public health

1. Introduction

Climate change has emerged as one of the most pressing environmental challenges of the 21st century, exerting profound impacts on ecosystems, human health, and socioeconomic systems (IPCC, 2021; Singh & Devi, 2020). Among its diverse consequences, the increasing prevalence of vector-borne diseases such as dengue, malaria and Japanese Encephalitis has become a major concern, particularly in tropical and subtropical regions (WHO, 2022; Alam & Rahman, 2025). Dengue fever, caused by the dengue virus and primarily transmitted by *Aedes aegypti* and *Aedes albopictus* mosquitoes, has experienced a marked global surge in both incidence and severity over recent decades (Bhatt *et al.,* 2013; Rezza & Nicoletti, 2024).

The transmission of dengue is intricately linked to climatic factors that influence mosquito biology, viral replication, and human exposure patterns. Elevated temperatures accelerate mosquito development and shorten the extrinsic incubation period of the virus, thereby increasing the potential for transmission (Morin *et al.,* 2013; Sharma & Sharma, 2025). Rainfall and humidity further modulate breeding habitats, as stagnant water in containers, drains and paddy fields provides ideal larval habitats (Hii *et al.,* 2016; Banu, *et al.,* 2014). Consequently, shifts in temperature, precipitation and seasonal patterns can directly alter the timing and intensity of dengue outbreaks (Dhiman & Pahwa, 2019; Wibawa & Suryani, 2024).

In Northeast India, the Imphal Valley, comprising Imphal East, Imphal West Thoubal and Bishnupur districts, historically enjoys a humid tropical climate with relatively moderate seasonal variation (IMD, 2022; Mondal, 2023). However, recent years have witnessed increasing climate variability, including hotter summers, milder winters and extended, erratic monsoons (Singh & Devi, 2020; Lourembam & Singh, 2025). These changes enhance the proliferation of *Aedes* mosquitoes and prolong the transmission season for dengue, transforming what was once an occasional health problem into a recurrent public health challenge (Khan *et al,* 2020; Sureshkumar & Suresh, 2025).

Urbanization, changing land use, and population growth further compound these risks. Dense settlements, poor drainage infrastructure, inadequate waste management, and water storage practices create ideal breeding sites for mosquitoes, particularly in urban and peri-urban areas (Banu *et al.,* 2014; Lourembam & Singh, 2025). Such socio-environmental pressures interact with climatic variability, amplifying the intensity and frequency of dengue outbreaks (*Morin et al.,* 2013; Rezza & Nicoletti, 2024).

This study aims to analyze the relationship between climate variability and dengue incidence in the Imphal Valley during 2020-2022. By examining temperature, rainfall, and humidity patterns alongside epidemiological data, the research seeks to elucidate how climatic shifts influence dengue transmission dynamics. Furthermore, the study underscores the importance of climate-informed public health strategies, including predictive surveillance, vector control, community engagement and urban planning interventions (Morin *et al.,* 2013; Hii *et al.,* 2016; Alam & Rahman, 2025). Ultimately, this investigation contributes to a deeper understanding of the climate-health nexus in Northeast India and provides actionable insights for reducing the burden of climate-sensitive vector-borne diseases (IPCC, 2021; Sharma & Sharma, 2025; Wibawa & Suryani, 2024). This study aims to examine the relationship between climate variability and dengue incidence in the Imphal Valley from 2020 to 2022, focusing on temperature, rainfall, humidity and socio-environmental factors. It also seeks to identify district-level hotspots and provide insights for climate-informed public health interventions to mitigate dengue outbreaks.

2. Methodology

2.1 Study Area

The Imphal Valley, located in the central plains of Manipur, Northeast India, extends between 24°18′N-25°00′N latitude and 93°45′E-94°15′E longitude. Surrounded by the surrounding hill ranges, it comprises four major districts namely Imphal East, Imphal West, Thoubal and Bishnupur (IMD, 2022; Singh & Devi, 2020). The valley experiences a humid tropical climate with three distinct seasons such as summer (March-May), monsoon (June-September) and winter (November–February). Densely populated urban and semi-urban settlements, rapid infrastructure development and limited drainage capacity render the region highly susceptible to vector-borne diseases such as dengue (Khan, Ahmed, & Kumar, 2020; Hii *et al.,* 2016). The combination of environmental conditions and socio-demographic pressures provides abundant breeding habitats for *Aedes* mosquitoes and increases human-vector contact, thereby creating an ideal setting for dengue transmission (Banu *et al.,* 2014; Lourembam & Singh, 2025).

2.2 Data Collection

Climatic data covering the period 2020–2022 were sourced from the India Meteorological Department (IMD, 2022) and supplemented with records from local weather stations in Imphal (Mondal, 2023). Key variables included monthly average temperature, total rainfall and relative humidity, which are widely recognized as major determinants of mosquito ecology and dengue virus replication (Dhiman & Pahwa, 2019; Wibawa & Suryani, 2024; Morin *et al.,* 2013).

Dengue incidence data, including laboratory confirmed cases and fatalities, were obtained from the Manipur State Health Directorate and district-level health offices for the corresponding period (Banu *et al.,* 2014; Sureshkumar & Suresh, 2025). This enabled temporal and spatial analysis of outbreak patterns across the four districts.

In addition to secondary datasets, field surveys were conducted in dengue-prone localities to observe mosquito breeding habitats and assess community awareness, preventive practices and risk perceptions (Hii *et al.,* 2016; Sharma & Sharma, 2025). This on-ground data helped contextualize the quantitative findings, allowing the study to account for socio-environmental determinants that influence dengue transmission dynamics (Morin *et al.,* 2013; Lourembam & Singh, 2025).

2.3 Data Analysis

The study employed both descriptive and analytical approaches to examine the relationship between climatic variability and dengue incidence. Temporal trends in temperature, rainfall and humidity were analyzed alongside reported dengue cases to identify seasonal patterns, anomalies and potential climate-disease linkages (Dhiman & Pahwa, 2019; Liu-Helmersson *et al.,* 2014).

A district-wise spatial assessment was also undertaken to map hotspots and assess vulnerability based on urban density, drainage conditions and socio-environmental factors (Morin *et al.,* 2013; Rezza & Nicoletti, 2024). The integration of climatic, epidemiological and field survey data provided a comprehensive framework for understanding how climate variability drives dengue transmission in the Imphal Valley (IPCC, 2021; Hii *et al.,* 2016; Sharma & Sharma, 2025).

This methodology not only captures temporal trends and climatic influences but also emphasizes human-environment interactions**,** which are crucial for designing targeted vector control strategies, predictive surveillance and climate-informed public health interventions (Wibawa & Suryani, 2024; Lourembam & Singh, 2025).

3. Results and discussion

The analysis of dengue incidence in the Imphal Valley between 2020 and 2022 reveals a striking upward trend in both the number of reported cases and severity of outbreaks (Table1 & Fig.1).

Table 1: Dengue Cases and Deaths (2020–2022)

Year	Reported Cases	Deaths	Remarks
2020	27	0	First reported outbreak (low scale)
2021	168	1	Sudden increase (extended monsoon)
2022	452	3	Peak cases in Imphal West &Thoubal

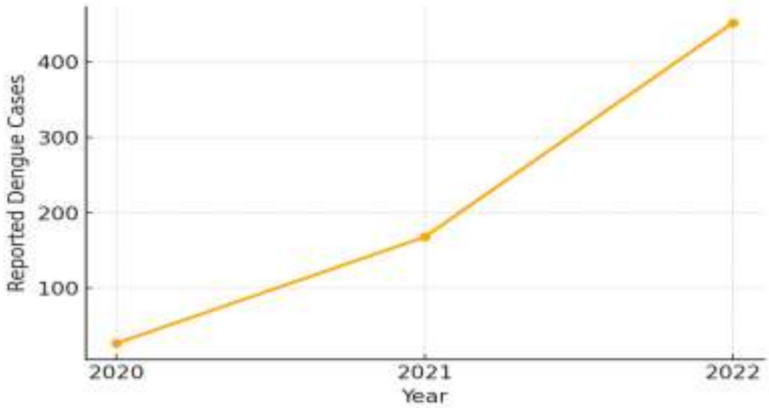

Fig 1: Dengue cases in Imphal Valley, Manipur

Table 1 summarizes the annual cases and deaths across the four districts. In 2020, dengue emerged as a low-scale outbreak with only 27 confirmed cases and no fatalities, mainly affecting rural and semi-urban areas. By 2021, cases rose sharply to 168, accompanied by one death, coinciding with an unusually prolonged monsoon season that likely extended breeding opportunities for *Aedes* mosquitoes. The year 2022 witnessed a further escalation, with 452 reported cases and three deaths, predominantly concentrated in the urbanized districts of Imphal West and Thoubal, where dense human settlements and poor drainage created persistent breeding sites (Banu *et al.,* 2014; Khan, Ahmed, & Kumar, 2020).

In 2020, the valley reported a relatively mild outbreak with 27 laboratory-confirmed cases and no deaths, primarily in rural and semi-urban areas (Banu *et al.,* 2014). By 2021, the number of cases increased sharply to 168, with one recorded death, coinciding with an unusually prolonged monsoon that likely expanded mosquito breeding habitats. The trend intensified in 2022, reaching 452 reported cases and three deaths, with urban districts like Imphal West and Thoubal accounting for the majority of cases (Khan *et al.,* 2020; Morin *et al.,* 2013).

Figure 1 illustrates the progressive increase in reported dengue cases over the three-year period, highlighting a clear upward trajectory that signals a transition from sporadic infections to a major public health concern**.** The escalation aligns with trends observed in other Southeast Asian regions, where post-monsoon periods, high humidity and urbanization have been linked to sharp increases in dengue incidence (Hii *et al.,* 2016; Morin *et al.,* 2013).

The district-wise pattern also reflects socio-environmental heterogeneity. Imphal West and Thoubal, characterized by dense population clusters, intermittent water storage and recurrent waterlogging, emerged as consistent hotspots. These findings indicate that dengue outbreaks in the Imphal Valley are not only driven by climatic factors but are amplified by humansettlement patterns and urban infrastructure (Lourembam & Singh, 2025; Rezza & Nicoletti, 2024).

The rise in dengue cases highlights the influence of urbanization, population density and waterlogging in creating persistent breeding hotspots. Densely populated areas with insufficient drainage provide ideal environments for *Aedes aegypti* and *Aedes albopictus*, facilitating sustained virus transmission (Hii *et al.,* 2016; Sharma & Sharma, 2025). These findings align with studies in Southeast Asia, which report post-monsoon surges in dengue incidence linked to prolonged rainfall and high humidity (Wibawa & Suryani, 2024; Rezza & Nicoletti, 2024).

3.2 Climatic Trends in the Imphal Valley (2020–2022)

Meteorological analysis shows a gradual increase in temperature and rainfall between 2020 and 2022 (IMD, 2022). Average summer temperatures rose from 32.1°C in 2020 to 33.2°C in 2022, while winter minima increased from 1.5°C to 2.3°C. Annual rainfall increased from 1,640 mm to 1,810 mm over the same period (Table 2).

Table 2. Climatic Trends (2020–2022)

Year	Avg. Summer Temp (°C)	Avg. Winter Temp (°C)	Annual Rainfall (mm)	Remarks
2020	32.1	1.5	1640	Near-normal rainfall
2021	32.8	2.0	1725	Extended monsoon season
2022	33.2	2.3	1810	Heavy rainfall; severe waterlogging

Between 2020 and 2022, average summer temperatures rose from 32.1°C to 33.2°C, and winter temperatures increased from 1.5°C to 2.3°C. Annual rainfall climbed from 1,640 mm in 2020 to 1,810 mm in 2022, with 2021 experiencing an extended monsoon and 2022 marked by heavy rains leading to waterlogging (IMD, 2022; Mondal, 2023). These shifts, though seemingly small, significantly influence mosquito life cycles and viral replication rates, as warmer temperatures shorten the extrinsic incubation period and accelerate reproduction (Liu-Helmersson *et al.,* 2014; Morin *et al.,* 2013).

Rainfall patterns further influence transmission. Moderate rainfall creates stable water pools suitable for larval growth, whereas heavy rainfall followed by stagnation promotes rapid mosquito proliferation(Banu *et al.,* 2014; Khan *et al.,* 2020). These findings align with studies in India and Southeast Asia, where seasonal rainfall peaks and humidity strongly correlate with dengue surges (Dhiman & Pahwa, 2019; Wibawa & Suryani, 2024).

3.3 Climate-Disease Linkages

The observed outbreak trends demonstrate a direct connection between climatic variability and dengue transmission**.** Warm, humid conditions accelerate mosquito development and viral maturation, while prolonged monsoon periods allow multiple mosquito breeding cycles within a single transmission season (Morin *et al.,* 2013; Liu-Helmersson *et al.,* 2014).

Urbanization acts as a compounding factor. Dense settlements, inadequate drainage, and poor waste management create ideal larval habitats. Conversely, districts with better sanitation, public awareness and preventive practices reported lower dengue incidence, highlighting the critical interplay between climate, ecology, and human behavior **(**Banu *et al.,* 2014; Lourembam & Singh, 2025).

Milder winters in recent years may permit low-level viral persistence beyond traditional dengue periods**,** potentially extending the transmission window and increasing the likelihood of outbreaks in subsequent seasons (Khan *et al.,* 2020; Sharma & Sharma, 2025).

3.4 Public Health Implications and Strategic Recommendations

The study underscores the necessity of climate-sensitive dengue management strategies. Early warning systems integrating rainfall, temperature forecasts and historical outbreak data can enable authorities to anticipate high-risk periods and allocate resources efficiently (Morin *et al.,* 2013; Wibawa & Suryani, 2024).

District-specific interventions are crucial. Imphal West and Thoubal, as identified hotspots, require targeted mosquito habitat reduction, active community engagement and strengthened epidemiological surveillance (Hii *et al.,* 2016; Rezza & Nicoletti, 2024).

Urban planning reforms, including improved drainage, systematic waste management, and safe water storage**,** can mitigate breeding opportunities. Pre-monsoon vector control campaigns, public awareness programs, and preparedness for post-monsoon case surges should be prioritized to reduce dengue vulnerability (Banu *et al.,* 2014; Khan *et al.,* 2020).

Overall, dengue outbreaks in the Imphal Valley reflect the complex interaction of climate, ecology and human activity**,** emphasizing the need for integrated, multi-sectoral approaches that combine meteorological monitoring, public health surveillance and community-based prevention (Lourembam & Singh, 2025; Sharma & Sharma, 2025).

Conclusion

Dengue fever in the Imphal Valley has transitioned from a sporadic health concern to a pressing public health challenge, strongly influenced by climate variability. Between 2020 and 2022, reported cases surged dramatically from 27 with no fatalities to 452 cases accompanied by three deaths, reflecting how even small shifts in temperature, rainfall and humidity can significantly impact disease dynamics. Hotter summers, milder winters and prolonged, heavy monsoon rains have created optimal conditions for *Aedes* mosquitoes to breed, survive and transmit the virus over extended periods.

The study underscores that dengue transmission is not merely a consequence of seasonal patterns but a complex interplay of climatic, ecological and socio-environmental factors. Rapid urbanization, inadequate drainage, waterlogging and insufficient waste management amplify the effects of weather variability, particularly in densely populated districts such as Imphal West and Thoubal. This demonstrates that climate-driven health risks cannot be managed by isolated interventions but require integrated strategies combining environmental management, urban planning and community engagement.

From a public health perspective, proactive measures are essential. These include early warning systems that incorporate meteorological data, targeted vector control campaigns, community mobilization to eliminate mosquito breeding sites and urban planning initiatives that improve drainage and sanitation. Ensuring safe water storage and raising household-level awareness are equally critical to reducing vulnerability.

Ultimately, the findings highlight the need for a coordinated, multi-sectoral approach. Collaboration among meteorologists, health authorities, urban planners and local communities is the key to mitigating the growing threat of dengue. Without such integrated and forward-looking action, the Imphal Valley risks facing dengue as a persistent, year-round challenge rather than a seasonal nuisance. By aligning climate-sensitive planning with sustained public health interventions, it is possible to protect communities, strengthen resilience and safeguard the valley against the evolving risks of vector-borne diseases in a changing climate.

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