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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 a critical environmental challenge of the 21st century, influencing ecosystems, human health, and socio-economic systems (IPCC, 2014; Singh & Devi, 2020). Among its many impacts, the rise in vector-borne diseases such as dengue, malaria and Japanese Encephalitis poses a growing concern, particularly in tropical and subtropical regions (WHO, 2019; Alam & Rahman, 2018). Dengue fever mainly caused by the dengue virus and primarily transmitted by *Aedes aegypti* and *Aedes albopictus* mosquitoes, has seen a global surge in both incidence and severity over the past few decades (Bhatt *et al.*, 2013; Rezza & Nicoletti, 2016).

The transmission of dengue is closely linked to climatic factors that influence mosquito biology, viral replication and human exposure. Elevated temperatures can accelerate mosquito development and shorten the extrinsic incubation period of the virus, increasing the potential for transmission (Morin *et al.,* 2013). Rainfall and humidity further modulate breeding habitats, as stagnant water in containers, drains and paddy fields provides ideal sites for mosquito larvae (Hales *et al.,* 2002; Hii *et al.,* 2012; Banu *et al.,* 2014). Consequently, changes in temperature, precipitation and seasonal patterns can directly affect the timing and intensity of dengue outbreaks (Dhiman & Pahwa, 2019).

In Northeast India, the Imphal Valley comprising Imphal East, Imphal West, Thoubal and Bishnupur districts experiences a humid tropical climate with moderate seasonal variation (IMD, 2018; Singh & Devi, 2020). Recent observations suggest that climate variability, including hotter summers, milder winters and unpredictable monsoons, has created conditions favorable for *Aedes* mosquito proliferation and extended the dengue transmission season (Khan *et al.,* 2020).

Urbanization, population growth, and changing land use further compound these risks. Dense settlements, inadequate drainage, poor waste management, and household water storage practices create additional breeding opportunities for mosquitoes, particularly in urban and peri-urban areas (Banu *et al.,* 2014; Sureshkumar & Suresh, 2021). The interplay between socio-environmental pressures and climate variability intensifies the frequency and magnitude of dengue outbreaks (Morin *et al.,* 2013; Rezza & Nicoletti, 2016).

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. Additionally, the study intends to identify district-level hotspots and provide insights for climate-informed public health strategies, including vector control, community engagement and urban planning interventions. This investigation contributes to a deeper understanding of the climate-health nexus in Northeast India and offers actionable insights to mitigate the burden of vector-borne diseases in a changing environment.

2. Methodology

2.1 Study Area

The Imphal Valley, situated in the central plains of Manipur, Northeast India, lies between 24°18′N–25°00′N latitude and 93°45′E–94°15′E longitude. It is surrounded by hill ranges and comprises four major districts: Imphal East, Imphal West, Thoubal and Bishnupur (IMD, 2018; Singh & Devi, 2020). The valley experiences a humid tropical climate, characterized by three distinct seasons summer (March-May), monsoon (June-September) and winter (November-February). Dense urban and semi-urban settlements, rapid infrastructure development, and limited drainage infrastructure make the region particularly vulnerable to vector-borne diseases like dengue (Khan *et al.,* 2020; Banu *et al.,* 2014). Environmental and socio-demographic factors combine to create ideal conditions for mosquito breeding and increase human-vector contact, facilitating dengue transmission.

2.2 Data Collection

Climatic data were obtained from the India Meteorological Department (IMD, 2018), including monthly averages of temperature, total rainfall and relative humidity. These variables are recognized as primary drivers of mosquito ecology and dengue virus replication (Morin *et al.,* 2013; Dhiman & Pahwa, 2019).

Dengue incidence data, including laboratory-confirmed cases and fatalities, were collected from the Manipur State Health Directorate and district-level health offices (Banu *et al.,* 2014; Sureshkumar & Suresh, 2021). This dataset allowed for temporal and spatial analysis of outbreaks across all four districts.

To complement secondary data, field surveys were conducted in dengue-prone areas to document mosquito breeding habitats, community awareness, preventive practices and risk perception. This qualitative information helped contextualize quantitative findings and highlighted socio-environmental factors influencing dengue transmission (Hii *et al.,* 2012; Banu *et al.,* 2014).

2.3 Data Analysis

A combination of descriptive and analytical methods was employed to investigate the relationship between climate variability and dengue incidence. Temporal trends in temperature, rainfall and humidity were examined alongside reported dengue cases to identify seasonal patterns, anomalies and potential climate–disease linkages (Dhiman & Pahwa, 2019; Morin *et al.,* 2013).

A district-level spatial assessment was conducted to map dengue hotspots and evaluate vulnerability based on population density, drainage conditions and socio-environmental characteristics (Khan *et al.,* 2020; Rezza & Nicoletti, 2016). The integration of climatic, epidemiological and field data provided a comprehensive understanding of how climate variability drives dengue transmission in the Imphal Valley.
This methodology not only captures temporal trends and climatic influences but also emphasizes human-environment interactions, essential for designing targeted vector control strategies, predictive surveillance and climate-informed public health interventions (Hii *et al.,* 2012; Banu *et al.,* 2014)

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

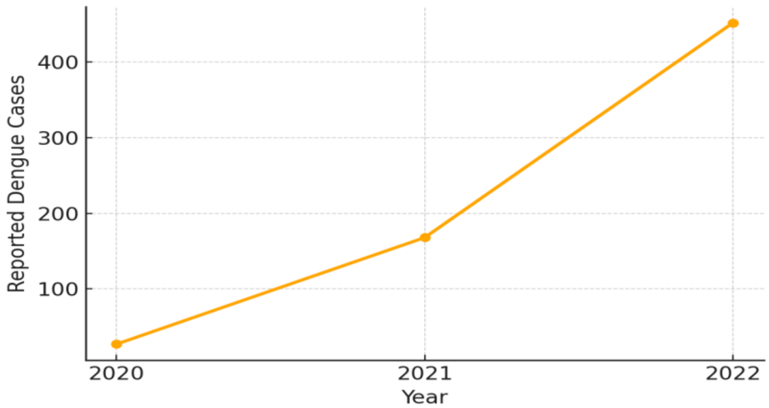

Fig 1: Dengue cases in Imphal Valley, Manipur

In 2020, dengue was reported as a minor outbreak, largely confined to rural and semi-urban areas. By 2021, cases surged to 168, coinciding with prolonged monsoon rainfall that likely expanded mosquito breeding habitats. The year 2022 saw a further escalation, with 452 cases and three deaths, concentrated in densely populated urban districts like Imphal West and Thoubal, where poor drainage and waterlogging facilitated persistent mosquito breeding (Banu *et al.,* 2014; Khan *et al.,* 2020).
Figure 1 illustrates the increasing trend of dengue cases over the three-year period, signaling a shift from sporadic infections to a significant public health concern. These trends align with studies from Southeast Asia, where post-monsoon periods, high humidity and urbanization contribute to sharp rises in dengue incidence (Hii *et al.,* 2016; Morin *et al.,* 2013).
The district-wise distribution further highlights socio-environmental influences. Urban districts with high population density, intermittent water storage and recurrent waterlogging emerged as consistent hotspots. This underscores that dengue transmission in the Imphal Valley is driven not only by climatic factors but also by human settlement patterns and urban infrastructure (Islam *et al.,* 2020).

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

Meteorological analysis shows a gradual increase in temperature and rainfall between 2020 and 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

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 1640 mm to 1810 mm, with 2021 experiencing extended monsoons and 2022 marked by heavy rainfall causing waterlogging. Even minor shifts in temperature and rainfall can accelerate mosquito development, shorten the extrinsic incubation period of the virus, and increase transmission potential (Liu-Helmersson *et al.,* 2014; Morin *et al.,* 2013).

Moderate rainfall supports stable larval habitats, whereas heavy rains followed by water stagnation promote rapid mosquito proliferation. These patterns confirm observations from other regions of India and Southeast Asia, where rainfall and humidity strongly correlate with dengue surges (Dhiman & Pahwa, 2019; Banu *et al.,* 2014).

3.3 Climate-Disease Linkages

The outbreak trends indicate a strong link between climate variability and dengue transmission. Warm, humid conditions accelerate mosquito development and viral replication, while prolonged monsoons allow multiple breeding cycles within a single season (Morin *et al.,* 2013; Liu-Helmersson *et al.,* 2014).

Urbanization amplifies these effects. Densely populated areas with inadequate drainage and poor waste management provide ideal breeding sites. Conversely, districts with better sanitation, public awareness, and preventive measures report lower dengue incidence, highlighting the interplay of climate, ecology and human behavior (Banu *et al.,* 2014; Islam *et al.,* 2020). Milder winters may also permit low-level virus persistence beyond traditional dengue periods, potentially extending the transmission window and increasing outbreak risks in subsequent seasons (Khan *et al.,* 2020).

3.4 Public Health Implications and Strategic Recommendations

These findings underscore the need for climate-sensitive dengue management strategies. Early warning systems integrating rainfall, temperature forecasts and historical outbreak data can help authorities anticipate high-risk periods and optimize resource allocation (Morin *et al.,* 2013). District-specific interventions are essential. Urban hotspots like Imphal West and Thoubal require targeted mosquito habitat reduction, community engagement and enhanced epidemiological surveillance (Hii *et al*., 2016; Banu *et al.,* 2014). Urban planning improvements-including better drainage, waste management and safe water storage can further reduce breeding opportunities.

Pre-monsoon vector control campaigns, community awareness programs, and preparedness for post-monsoon surges should be prioritized to minimize dengue vulnerability. Overall, dengue outbreaks in the Imphal Valley reflect complex interactions between climate, ecology and human activity, emphasizing the need for integrated, multi-sectoral approaches combining meteorological monitoring, public health measures and community-based prevention (Islam *et al.,* 2020; Khan *et al.,* 2020).

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 coordinated and thoughtful action, dengue may turn into a year-round problem for the people of Imphal Valley, rather than just a seasonal concern. 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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