IMPACT OF CLIMATE CHANGE ON VECTOR-BORNE DISEASES IN INDIA

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***Abstract*—Climate change alters temperature, precipitation, humidity and extreme-event patterns and thereby modifies the ecology and seasonality of vectors and vector-borne pathogens. India, home to large climatic gradients and multiple endemic vector-borne diseases (VBDs) malaria, dengue, chikungunya, Japanese encephalitis (JE), visceral leishmaniasis (VL), and lymphatic filariasis faces complex, spatially heterogeneous risks from climate change. This review synthesizes recent evidence on climate-driven changes in VBD distribution and transmission in India, discusses modelling approaches and projections, identifies surveillance and health-system gaps, and recommends climate-informed adaptation, surveillance and intersectoral policy priorities. [1], [4]**

***Index Terms*—Climate Change, Vector-Borne Diseases, Dengue, Malaria, Japanese Encephalitis, Visceral Leishmaniasis, India, Temperature Variability, Rainfall Patterns, Public Health, Disease Modeling, Climate Adaptation**

I. INTRODUCTION

Vector-borne diseases (VBDs) account for a substantial fraction of global infectious disease burden and are highly climate sensitive because temperature, rainfall and humidity influence vector survival, development rates, biting frequency and pathogen replication. Global warming and altered precipitation regimes affect vector abundance, seasonal windows of transmission, and geographic range, including expansion into higher altitudes and latitudes. India's diverse climates and large vulnerable populations make understanding climate-VBD linkages an urgent public health priority. [1], [2], [4]

II. SCOPE AND METHODS OF THIS REVIEW

This narrative review synthesizes literature (systematic reviews, national reports, modelling studies, and observational time-series) on climate drivers, empirical associations and projections for major VBDs in India. Studies published from 2010 onwards were prioritized, along with WHO and IPCC assessments. Search terms included: "climate change", "dengue", "malaria", "Japanese encephalitis", "leishmaniasis", "India", "temperature", "rainfall" and "models". [1], [4]

Study 1:- The study "Unravelling the interplay of space, time, and weather in dengue outbreaks: An insight from Bihar, India" was carried out by Shankar (2025). Over a five-year period from 2019 to 2023, the study looked at the relationship between climatic factors and dengue outbreaks in Bihar. Dengue cases significantly increased during the study period, according to the report. Dengue cases rose from 8,136 in 2019 to 19,093 in 2023, a growing trend that raises concerns for public health.

This rise indicates that dengue is spreading throughout Bihar and needs immediate public health intervention. The minimum, maximum, mean, and rainfall temperatures were among the climatic variables that the researchers examined. The results indicated that the strongest correlations with dengue incidence were rainfall and minimum temperature. The study also found that there was a lag of roughly 4–6 weeks between the rise in dengue cases and changes in the climate. This suggests that weather variations can forecast dengue outbreaks several weeks ahead of time. Geographical variation in dengue distribution was also discovered by the study. Compared to other regions, Central Bihar reported a higher incidence of dengue, indicating the existence of high-risk areas. These discrepancies could result from variations in the environment, population density, and breeding grounds for vectors.The study's conclusions emphasize how crucial climate variables are in affecting dengue transmission. The findings imply that early warning systems and prompt vector control measures can be developed using climate data to stop dengue outbreaks. The study did have some limitations, though. Detailed demographic information about the impacted populations was absent, and socioeconomic circumstances and vector control strategies were not examined.[23]

Table 2.1: Trend of Dengue Cases in Bihar

YEAR	DENGUE CASES
2019	8136
2022	11285
2023	19093

III. MAJOR CLIMATE DRIVERS AND MECHANISMS AFFECTING VBDS

Temperature:- Temperature shapes vector life-history (development rate, survival, biting frequency) and extrinsic incubation period (EIP) of pathogens. Small increases in mean temperature can accelerate pathogen development in mosquitoes, potentially increasing transmission in regions currently below thermal thresholds. However, excessively high temperatures can reduce vector survival — producing nonlinear relationships between temperature and transmission. [8], [2]

Rainfall and Humidity:- Rainfall affects availability of larval habitats; moderate rainfall often increases breeding sites, while extremely heavy rainfall can flush breeding habitats. Humidity influences adult mosquito survival and activity. The timing and intensity of monsoon rains are therefore critical drivers of disease seasonality in India. [6], [21], [2]

Extreme Events and Land Use Interactions:- Floods, cyclones and droughts alter vector habitats and human exposure, often exacerbating VBD risk. Urbanization and irrigation interact with climate to create new breeding habitats, especially in peri-urban zones. [3], [15]

IV. DISEASE-SPECIFIC EVIDENCE IN INDIA

Dengue and Aedes-borne Viruses:- Dengue incidence in India has risen markedly with large epidemics and widening geographic spread. Empirical time-series show significant associations of dengue incidence with temperature, rainfall and humidity at lagged intervals, and nonlinear temperature effects with optimal transmission in ~25–32 °C range. Climate change is expected to expand suitable transmission windows and potentially increase burden in many regions. [3], [6], [8], [16]

Malaria and Anopheles-borne Transmission:- India has achieved large reductions in malaria incidence, but transmission remains focal in forested, tribal and northeastern regions. Climate influences (temperature and rainfall) modify transmission windows and may permit northward and altitudinal shifts. Preparedness in previously low-risk highland areas is recommended. [5], [13], [22]

Japanese Encephalitis (JE):- JE transmission is influenced by temperature and precipitation patterns that affect Culex mosquito ecology and amplifying host populations (pigs, water birds). Recent evidence shows changing rainfall patterns and warm spells implicated in certain outbreaks, suggesting climate-sensitive dynamics. [11], [12], [20]

Visceral Leishmaniasis (VL / Kala-azar):- Sandfly vector abundance and VL incidence are influenced by temperature and rainfall. Machine-learning and climate models in Indian states like Bihar indicate significant associations between climate variables and VL risk, suggesting future spatial shifts under warming conditions. [9], [10], [17]

Chikungunya, Filariasis and Other VBDs:- Chikungunya (Aedes transmitted) has re-emerged in India since 2005, with climate impacts similar to dengue. Lymphatic filariasis transmission dynamics show associations with rainfall and water-storage practices, though evidence remains regionally variable. [1], [5]

V. MODELING AND PROJECTION APPROACHES

Studies use statistical time-series, mechanistic models (e.g., VECTRI), and hybrid machine-learning approaches. Process models incorporate entomological and climatic processes to project transmission windows; machine-learning models provide high-resolution predictive mapping. Projections generally indicate widening of transmission seasons and expansion of suitable areas for several VBDs under warming scenarios, but outcomes are sensitive to the choice of climate scenarios and control interventions. [14], [10]

VI. SURVEILLANCE, EARLY WARNING AND PUBLIC-HEALTH PREPAREDNESS

Climate-informed surveillance systems integrating meteorological data, entomological monitoring, and health surveillance can act as early-warning systems for outbreaks, e.g., predictive dengue models with 1-2month leads. Strengthening subnational surveillance and data sharing across sectors is critical. [6], [2]

VII. ADAPTATION AND CONTROL STRATEGIES

Key strategies include:
1. Climate-resilient vector control (timed larval source reduction).
2. Vaccination where available (like JE).
3. Water and sanitation improvements to reduce breeding.
4. Community engagement for behavioral change during transmission seasons. Multisectoral collaboration among health, meteorology, urban planning and agriculture sectors is essential. [1], [4]

VIII. KNOWLEDGE GAPS AND RESEARCH NEEDS

- Need for long-term entomological datasets.
- Integration of socio-economic and land-use drivers in models.
- Studies on compound climate events and VBD dynamics.
- Evaluation of early-warning systems in operational settings.
- Equity impact studies. [2], [3]

IX. POLICY RECOMMENDATIONS

- Integrate climate considerations into national VBD programs.
- Invest in interoperable climate-health surveillance.
- Prioritize adaptive urban planning and water management.
- Expand research funding for subnational modelling tailored to India. [1], [15]

X. CONCLUSION

Climate change is reshaping VBD risks in India in complex and regionally heterogeneous ways. Strong public health programs and climate-informed strategies can mitigate many impacts, but urgent multisectoral action is required. [1], [4]

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