Environmental Change and Disease Dynamics
https://www.sciltp.com/journals/ecdd

Review

Flood-Driven Dengue Risk under Climate Change: A Narrative Review

Qiao Liu [1,2] and Jue Liu [1,2,3,4,*]

[1] Department of Epidemiology and Biostatistics, School of Public Health, Peking University, Beijing 100191, China
[2] Institute of Environmental Medicine, Peking University, Beijing 100871, China
[3] Key Laboratory of Epidemiology of Major Diseases, Peking University, Ministry of Education, Beijing 100871, China
[4] Institute for Global Health and Development, Peking University, Beijing 100871, China
* Correspondence: jueliu@bjmu.edu.cn

How To Cite: Liu, Q.; Liu, J. Flood-Driven Dengue Risk under Climate Change: A Narrative Review. *Environmental Change and Disease Dynamics* **2026**, *1*(1), 2.

Received: 6 March 2026
Revised: 15 April 2026
Accepted: 9 May 2026
Published: 20 May 2026

Abstract: Climate change has been associated with increasing extreme precipitation and flood events, potentially creating conditions conducive to the transmission of mosquito-borne diseases such as dengue fever. This narrative review synthesizes current evidence on the mechanisms linking climate-driven flooding to dengue outbreaks, the spatiotemporal epidemiological patterns observed across regions, and emerging methodological approaches for prediction and prevention. Flood disasters influence dengue transmission through interconnected ecological, climatic, and socio-environmental pathways. Flooding can disrupt existing mosquito habitats while subsequently creating conditions that may generate abundant stagnant water in artificial containers and debris, facilitating the proliferation of Aedes mosquitoes, depending on local ecological and structural contexts. At the same time, extreme rainfall often coincides with elevated temperatures, accelerating mosquito development and viral replication. Flood-related disruptions to water supply, sanitation infrastructure, and housing conditions may further increase human exposure, particularly in densely populated urban settings and vulnerable communities. Epidemiological studies indicate that the flood–dengue relationship frequently exhibits nonlinear and delayed effects, with outbreaks emerging weeks to months after flooding events. Advances in statistical modeling, spatial analysis, and machine learning have improved the capacity to characterize these dynamics and support climate-informed early warning systems. Strengthening integrated surveillance, environmental management, and climate-resilient public health interventions will be critical to mitigating dengue risks under intensifying climate change.

Keywords: dengue; flooding; climate change; public health adaptation

1. Introduction

The twenty-first century is increasingly defined by growing impacts of anthropogenic climate change, which poses a significant threat to global human health and survival [1]. Despite international mitigation efforts such as the Paris Agreement, the global annual mean surface temperature reached a record high of 1.45 °C above the pre-industrial baseline in 2023 [1]. This persistent warming trajectory is not merely a gradual increase in temperature; it represents a significant shift in the Earth’s climate system. One of the most consequential outcomes of this disruption is the intensification of the global hydrological cycle, which manifests in amplified variability in precipitation regimes and a marked rise in the frequency, duration, and severity of extreme weather events [2–4].

Among these climate-driven anomalies, extreme precipitation events and the subsequent occurrence of flood disasters have emerged as some of the most destructive environmental hazards worldwide [5]. Comparative climatological analyses indicate that between the periods 1961–1990 and 2014–2023, approximately 61% of global land areas experienced an increase in the number of days characterized by extreme precipitation, thereby substantially elevating flood risk [1]. Such hydrometeorological extremes have produced cascading ecological, infrastructural, and socio-economic consequences. In 2022, for instance, severe monsoon-driven floods in Pakistan submerged nearly one-third of the country, displacing millions, crippling agricultural production, destabilizing the national economy, and precipitating extensive outbreaks of water-borne and vector-borne diseases [6,7]. Likewise, extreme precipitation episodes associated with cyclical climate oscillations and long-term warming trends have devastated coastal regions in Latin America, severely damaging local infrastructure and straining fragile public health systems [8,9]. Beyond immediate mortality and infrastructure destruction, extreme hydrological events exert long-term destabilizing effects on the environmental and social determinants of health. Flooding alters land cover, disrupts sanitation networks, contaminates freshwater supplies, and forces population displacement, thereby reshaping patterns of human–vector interaction and pathogen transmission [9,10]. Such disturbances create ecological niches conducive to the emergence, amplification, and spatial spread of infectious pathogens. In this context, climate change should be conceptualized not solely as a physical phenomenon but as an important contributing factor to shifts in global epidemiology.

Within the spectrum of climate-sensitive diseases, vector-borne diseases (VBDs) represent a particularly substantial public health challenge [11]. Arthropod vectors, especially mosquitoes, exhibit high sensitivity to ambient temperature, humidity, and precipitation patterns, all of which directly influence their survival, reproduction, biting behavior, and pathogen incubation periods [4,12]. Dengue fever, caused by four antigenically distinct serotypes of the dengue virus (DENV 1–4), has become the most rapidly expanding mosquito-borne viral disease globally. The virus is transmitted primarily by the highly anthropophilic Aedes aegypti mosquito and secondarily by Aedes albopictus, both of which have demonstrated remarkable ecological adaptability [13,14]. Clinically, dengue infection ranges from asymptomatic or mild febrile illness to severe manifestations such as dengue hemorrhagic fever and dengue shock syndrome, which can result in significant morbidity and mortality [15,16]. It is currently estimated that approximately half of the global population resides in areas at risk of dengue transmission, with hundreds of millions of infections occurring annually [17–19].

Historically confined to tropical and subtropical endemic zones, dengue's geographical footprint has expanded dramatically over recent decades [13]. This expansion is driven by a confluence of interacting forces, including rising global temperatures, rapid and often unplanned urbanization, intensified international travel, and increasing global connectivity [13,20]. Warmer climates enable vectors to colonize previously unsuitable temperate and high-altitude regions, while densely populated urban settings provide abundant artificial breeding containers and concentrated human hosts [21,22]. According to the Lancet Countdown assessments, the transmission potential for dengue mediated by Aedes aegypti has increased substantially across multiple world regions; in Latin America, for example, this potential rose by 54% from 1951–1960 to 2013–2022, while the global likelihood of transmission increased by 12% over comparable intervals [2,23].

Compounding the threat, there remains no universally effective antiviral therapy for dengue, and vaccine deployment strategies are constrained by serotype complexity, prior exposure status, and implementation challenges [14]. Consequently, vector control, environmental management, and community-level prevention remain the primary pillars of dengue mitigation. However, these strategies are often undermined in resource-limited settings, particularly when dengue outbreaks coincide with other systemic shocks. The overlapping occurrence of dengue epidemics with crises such as the COVID-19 pandemic or large-scale natural disasters frequently overwhelms already fragile healthcare infrastructures in low- and middle-income countries (LMICs), exacerbating morbidity and mortality [2,14,24].

While the broader effects of gradual warming on dengue expansion are well-documented [25,26], extreme flood events warrant dedicated analytical attention. Flooding introduces acute, highly disruptive perturbations to both vector ecology and public health infrastructure that differ fundamentally from the effects of uniform temperature shifts. Understanding these compound, post-disaster dynamics is critical, as they frequently trigger significant outbreaks that overwhelm local capacities [27,28]. Therefore, this narrative review aims to comprehensively synthesize the current evidence on the biological, ecological, and spatiotemporal mechanisms linking climate-driven flood disasters to dengue transmission dynamics. By critically evaluating recent epidemiological findings, examining advances in climate-sensitive predictive modeling and early warning systems, and analyzing the socio-environmental vulnerabilities that shape heterogeneous risk patterns, this review seeks to construct an integrated conceptual framework. Clarifying these interconnected pathways is essential not only for improving causal inference and outbreak forecasting accuracy but also for informing proactive, climate-resilient public health strategies and intersectoral adaptation policies in the face of accelerating global climate change. To synthesize these complex and interacting pathways, this review proposes an integrated conceptual framework linking climate-driven flooding to dengue transmission dynamics (Figure 1), which guides the subsequent discussion of ecological mechanisms, spatiotemporal epidemiology, methodological approaches, and public health interventions.

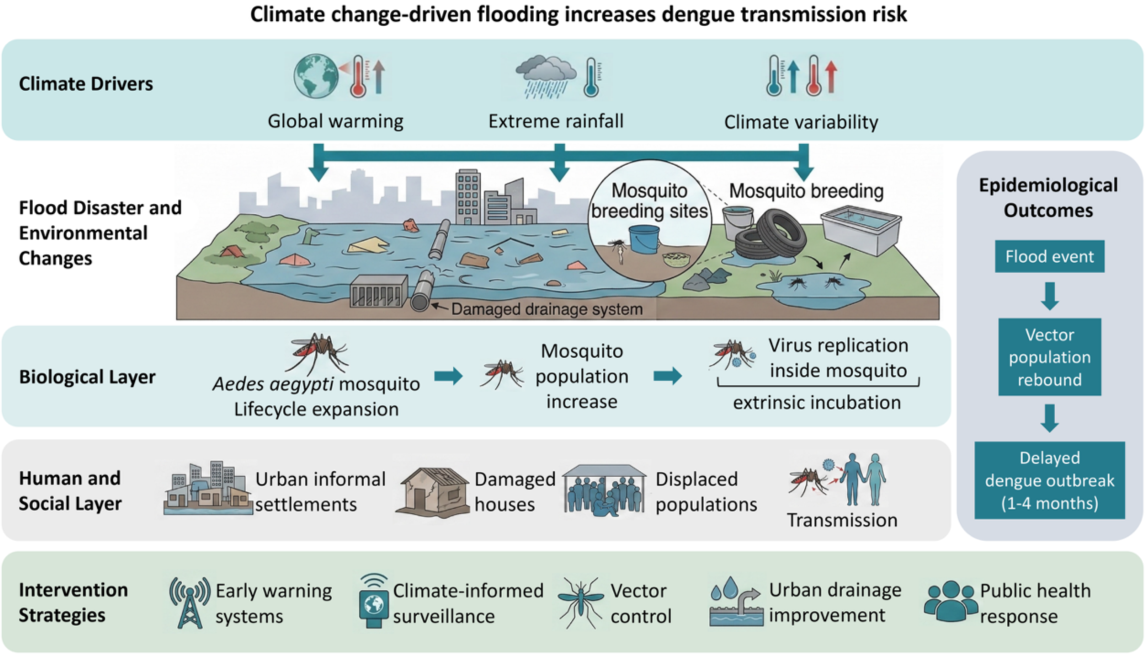

Figure 1. Integrated conceptual framework illustrating ecological, climatic, and socio-environmental pathways linking flood disasters to dengue transmission dynamics.

2. Climate-Induced Flooding and Dengue: Integrated Mechanisms, Inequities, and Research Imperatives

2.1. Ecological Disruption and Nonlinear Transmission Dynamics

The epidemiological relationship between climate-induced flooding and dengue transmission is neither linear nor uniform; rather, it is governed by a dynamic interplay of ecological disturbance, vector biology, climatic synergy, and socio-economic vulnerability [28]. While the influence of baseline temperature and seasonal rainfall on mosquito abundance and viral replication is well established [29,30], extreme flood disasters introduce acute perturbations that reshape transmission systems in more complex and temporally heterogeneous ways [28,31]. During the immediate, acute phase of intense rainfall and flooding, the mechanical force of torrential water may exert a flushing effect on immature mosquito stages. Larvae and pupae inhabiting shallow containers or surface water bodies can be washed away, and existing breeding habitats may be temporarily destroyed [28]. This short-term ecological disruption can produce a transient decline in entomological indices and, in some cases, a brief reduction in dengue incidence lasting less than one month [32].

However, this apparent suppression effect is typically misleading and short-lived. As floodwaters recede, they fundamentally transform the local landscape. Extensive stagnant water pools, waterlogged debris, damaged drainage systems, and disrupted sanitation infrastructure collectively create an expanded mosaic of aquatic habitats suitable for oviposition [9,33]. These environments are frequently predator-free and rich in organic material, conditions that facilitate rapid larval development and enhanced adult mosquito emergence [9,34]. Importantly, Aedes mosquitoes possess desiccation-resistant eggs that can remain viable for prolonged periods under dry conditions and hatch rapidly upon re-submersion [4]. Thus, post-flood inundation not only generates new breeding sites but also reactivates pre-existing egg banks embedded in the environment.

Consequently, the initial flushing effect is often followed by a pronounced and delayed epidemic surge. Epidemiological studies consistently report lag periods ranging from several weeks to up to four months between major flood events and peak dengue incidence, reflecting the time required for vector population rebound, viral amplification within mosquito populations, and subsequent human transmission [28,31]. Spatial lag analyses in Guangzhou, China, for example, demonstrated a significant increase in dengue cases approximately three months after extreme precipitation events [31]. Similarly, in the wake of Cyclone Yaku in 2023, Peru reported a record-breaking dengue outbreak [8]. While preliminary attribution models estimated that a high proportion of cases were linked to flooding, it is important to note that such estimates are model-dependent and specific to the unique ecological and infrastructural context of the region.

2.2. Climatic Synergy and Viral Amplification

The ecological consequences of post-flood stagnant water rarely operate in isolation. Instead, they interact synergistically with ambient temperature and humidity to amplify transmission intensity. Freshwater availability generated by extreme precipitation coincides in many regions with elevated seasonal temperatures, creating a highly conducive microclimate for both vector proliferation and viral replication [29]. Localized evidence indicates that the most substantial increases in dengue incidence after severe cyclones occur in districts where heavy flooding overlaps with temperatures exceeding 24 °C [8,25,35]. Warmer conditions accelerate mosquito development rates, increase biting frequency, and—critically—shorten the extrinsic incubation period (EIP) of the dengue virus within the vector [36,37]. A reduced EIP means that mosquitoes become infectious more rapidly after acquiring the virus, thereby intensifying the force of transmission during the hot and humid post-flood window. This biological acceleration creates a compounding effect: larger vector populations coincide with faster viral maturation, producing conditions for significant outbreaks. Thus, flood-induced dengue transmission should be conceptualized as the product of interacting climatic thresholds rather than as a simple rainfall–incidence correlation. Extreme precipitation expands aquatic habitats, while concurrent warmth enhances vector competence and viral kinetics. The resulting amplification effect helps explain why certain flood events trigger major epidemics whereas others produce more limited impacts, depending on background climatic conditions and local ecological contexts [28,38].

2.3. Socio-Economic Disruption and Structural Vulnerability

Beyond ecological and climatic mechanisms, extreme flood disasters profoundly disrupt the human socio-economic environment, creating structural conditions that facilitate viral spread. Floods frequently damage housing infrastructure, particularly in low-income areas characterized by poorly constructed roofs, walls, and window screens [8]. Such structural degradation increases indoor exposure to highly anthropophilic Aedes mosquitoes. Simultaneously, flood-induced destruction of municipal water supply and sanitation systems severely restricts access to safe and reliable water sources [9]. In response to acute water insecurity, affected households often resort to storing water in open containers. This coping strategy inadvertently generates artificial breeding sites within domestic environments, reinforcing the intimate human–vector contact that characterizes dengue transmission [39]. The behavioral dimension of water storage thus becomes a critical mediator linking hydrological disaster to epidemiological risk.

Massive flooding also frequently triggers population displacement. Individuals and families may be forced into overcrowded temporary shelters where sanitation is compromised and environmental management is minimal [9,40]. High population density in such settings increases the probability of human–vector contact and facilitates rapid, localized transmission once infected mosquitoes are present. Moreover, local healthcare facilities in vulnerable regions are themselves susceptible to flood damage and may lack adequate diagnostic capacity, vector surveillance systems, and surge preparedness to respond effectively to sudden increases in arboviral infections [41].

The burden of post-flood dengue outbreaks is therefore distributed inequitably. Marginalized populations residing in informal settlements, low-income neighborhoods, and areas with inadequate waste management and deficient drainage infrastructure face disproportionately elevated risks [11,34,42]. These communities often combine high exposure to environmental hazards with limited adaptive capacity, rendering them especially vulnerable to compound climate–health shocks.

2.4. Fragmented Responses and Research Imperatives

Despite the mounting frequency of compound hydrometeorological and epidemiological disasters, public health responses and scholarly analyses remain fragmented. Policy discourse often emphasizes short-term, reactive interventions such as emergency chemical fogging campaigns, while neglecting upstream environmental determinants and the structural necessity for climate-resilient urban planning and infrastructure investment [42]. Such reactive strategies may temporarily suppress adult mosquito populations but fail to address the ecological and socio-economic drivers of recurring outbreaks. Furthermore, important scientific gaps persist. There remains incomplete characterization of the spatial–temporal dynamics, lag structures, and potential nonlinear threshold effects linking extreme precipitation to dengue transmission across diverse geographic and socio-economic settings [28,38]. Variability in exposure definitions, modeling approaches, and data resolution complicates cross-regional comparisons and limits generalizability.

Addressing these challenges requires integrative, interdisciplinary research frameworks that combine hydrology, climatology, spatial epidemiology, entomology, and social science perspectives. Advances in predictive modeling and climate-sensitive early warning systems offer promising avenues for anticipatory governance [43,44]. By synthesizing biological, ecological, and socio-environmental mechanisms within a unified analytical framework, future research can more accurately forecast outbreak risk and guide targeted interventions. Ultimately, clarifying the complex and interacting pathways through which flood disasters influence dengue transmission is essential for developing proactive surveillance systems and integrated adaptation strategies. Strengthening climate-resilient infrastructure, enhancing community-level water and sanitation management, and embedding climate data into infectious disease monitoring networks are indispensable steps toward mitigating the intensifying public health risks posed by a warming and increasingly hydrologically volatile world [45,46].

3. Spatiotemporal Epidemiological Characteristics of Flood-Induced Dengue Risks

The temporal dynamics between extreme flooding events and subsequent dengue fever outbreaks are fundamentally characterized by pronounced lag effects, reflecting the time required for ecological and biological processes to unfold. Empirical evidence consistently demonstrates that the impact of extreme precipitation on dengue incidence is rarely immediate; instead, studies have observed a distinct biphasic temporal pattern. In the immediate aftermath of a flood, there is often a short-term decrease in dengue incidence, typically lasting less than a month, likely attributable to the physical flushing of mosquito breeding sites [28]. However, this initial suppression is subsequently followed by a substantial increase in disease incidence with a delayed lag period commonly ranging from one to four months [28]. For instance, spatiotemporal analyses in urban settings such as Guangzhou, China, have revealed that extreme precipitation exhibits its strongest amplifying effect on dengue cases at a three-month lag [31]. Similarly, entomological surveillance in Kenya has shown that mosquito egg and adult abundances peak significantly one month following an abnormally wet period [29]. Furthermore, predictive modeling across different regions corroborates these delayed effects, indicating that both heavy and prolonged precipitation anomalies shape the future trajectory of outbreaks over multi-month horizons [30,43]. The existence of such complex lag structures necessitates analytical frameworks capable of capturing multi-month temporal dependencies.

Beyond simple temporal delays, the epidemiological relationship between flooding and dengue risk is highly complex and characterized by non-linear associations and specific meteorological thresholds [28,29,43]. The influence of precipitation intensity and volume on mosquito abundance and subsequent viral transmission does not follow a straightforward positive correlation. Rather, the relationship often exhibits threshold effects, where moderate to heavy rainfall provides optimal breeding habitats, whereas exceptionally heavy rainfall might surpass a destructive threshold that temporarily suppresses mosquito populations [47,48]. Advanced spatiotemporal modeling frameworks have successfully captured these non-linearities, demonstrating that disease risk fluctuates dynamically based on compounding extreme weather indicators, including sustained drought conditions preceding heavy rains and specific phase shifts of the El Niño Southern Oscillation [43]. Additionally, the intensity of extreme precipitation events interacts non-linearly with concurrent temperature thresholds; for example, the amplifying effect of flooding is significantly magnified when ambient temperatures exceed optimal biological thresholds, such as 24 °C, further complicating the predictive modeling of epidemic trajectories [8].

The distribution of flood-induced dengue risk is profoundly shaped by spatial heterogeneity and underlying socio-economic vulnerabilities, creating distinct geographical hotspots of disease burden. Outbreaks are rarely uniform across an affected region; instead, they cluster heavily in areas where environmental hazards intersect with fragile human infrastructure [31]. Research highlights that vulnerable populations residing in informal urban settlements and low-income communities bear a disproportionate share of the disease burden following flood disasters [11,34]. In these highly susceptible areas, the lack of adequate drainage systems, coupled with inconsistent solid waste management and poor household trash collection, creates ubiquitous artificial breeding sites for vectors once floodwaters recede [34]. Furthermore, spatial analyses have demonstrated that the largest surges in dengue incidence post-flooding occur in districts characterized by a high prevalence of structurally deficient housing, such as residences with low-quality roofs and walls, which fail to protect inhabitants from human-vector contact [8]. The risk is also spatially amplified in densely populated central urban areas compared to rural peripheries, where the abundance of human hosts and concentrated built environments facilitate rapid viral transmission [11,31]. Consequently, understanding these spatial vulnerabilities is critical, as marginalized geographical zones with compounded socio-economic deprivation and high ecological exposure consistently emerge as the epicenters of post-flood dengue epidemics [49].

4. Methodological Approaches in Flood–Dengue Research

4.1. Data Sources and Integration

The rigorous evaluation of the epidemiological relationship between flood disasters and dengue fever outbreaks fundamentally relies on the integration of massive, multidimensional data sources. Contemporary research increasingly synthesizes localized public health surveillance records with high-resolution meteorological and earth observation data to capture the intricate dynamics of climate-sensitive diseases. For instance, satellite-based remote sensing tools, such as NASA's Moderate Resolution Imaging Spectroradiometer (MODIS), are highly utilized to extract land surface temperature and vegetation indices, providing a standardized method for quantifying extreme weather anomalies and their spatial extent over time [50]. However, the integration of these environmental metrics with human epidemiological data presents significant methodological challenges. Researchers frequently rely on national or regional government data repositories to track disease incidence; yet, these databases often suffer from critical limitations, including the inadequate collection of comprehensive socio-demographic information and the absence of unique patient identifiers, which severely hampers the accurate tracking and longitudinal analysis of health data [51]. Furthermore, existing literature emphasizes that overcoming these limitations requires leveraging regions with well-established mosquito-borne disease and weather surveillance systems to conduct standardized, multisite research, thereby allowing for the proper quantification of relevant flooding events across diverse socio-ecological settings [28].

4.2. Statistical Models

To decipher the intricate, delayed, and synergistic impacts of extreme precipitation on dengue transmission, epidemiological research has transitioned from traditional linear regressions to highly sophisticated statistical modeling frameworks. Standard linear approaches are inherently insufficient for capturing the complex threshold effects and delayed biological responses characteristic of vector-borne diseases. Consequently, distributed lag non-linear models (DLNM) have become a methodological cornerstone, explicitly utilized to account for the non-linear lagged effects of weather conditions on mosquito abundance and disease incidence over extended periods [30]. By mapping these distributed lags, DLNMs directly address the critical analytical challenge of determining precisely when and under what temperature thresholds post-flood stagnant water translates into epidemic peaks. Similarly, generalized additive models (GAM) are frequently employed to seamlessly delineate the non-linear relationships between extreme weather indicators, such as the standardized precipitation index, and infectious disease incidence rates [52]. When investigating the immediate causal impact of specific, catastrophic extreme weather events like cyclones, researchers have successfully applied generalized synthetic control methods to rigorously account for baseline climate variations and unobserved confounders [8]. Moreover, to model the exact count of disease cases following specific disasters such as floods and landslides, integer-valued autoregressive (INAR) models incorporating overdispersion distributional assumptions have proven highly effective in handling the excessive variability inherent in disaster-driven epidemiological data [44], thereby resolving the challenge of modeling extreme case fluctuations that typically violate standard statistical assumptions during acute emergencies.

In addition to temporal modeling, addressing spatial heterogeneity and transitioning toward proactive outbreak forecasting represent the forefront of methodological advancement in this field. Because dengue fever cases are rarely distributed randomly and often exhibit strong geographic clustering, advanced spatial econometric techniques are essential. Researchers have successfully implemented models such as the zero-inflated negative binomial spatial lag (ZINB-SAR) regression to simultaneously account for excessive zero-case observations in surveillance data and the spatial influence of disease transmission from neighboring areas [31]. This approach is essential for overcoming the challenge of spatial heterogeneity, ensuring that localized vulnerability hotspots are not masked by broader regional averages. Building upon these robust spatiotemporal analytical frameworks, recent studies prioritize climate-model-based forecasting to predict future outbreak trajectories. These advanced frameworks not only accurately describe in-sample historical incidence trends but also perform out-of-sample forecasting, demonstrating high accuracy in classifying future outbreaks while minimizing the probability of false alarms [43]. Ultimately, these predictive methodologies are being integrated with global climate projections to estimate long-term excess risks under various Shared Socioeconomic Pathways (SSP), providing policymakers with the critical, evidence-based foresight needed to design localized, climate-adaptive disease control interventions [52].

4.3. Machine Learning and AI Models

Machine learning (ML) and artificial intelligence (AI) algorithms are playing an increasingly important role in dengue and mosquito-borne disease prediction. Unlike traditional regression-based or time-series models, ML approaches such as Random Forest (RF), Support Vector Machines (SVM), Gradient Boosting, and Artificial Neural Networks (ANN) can flexibly capture nonlinear relationships and complex interactions among climatic, environmental, and sociodemographic predictors. Crucially, ML models address the analytical challenge of high-dimensional data integration, seamlessly processing disparate inputs—such as satellite imagery, daily weather extremes, and structural vulnerabilities—to capture synergistic outbreak drivers that traditional models often miss. Several studies have demonstrated that RF models outperform conventional generalized linear models in forecasting dengue incidence at both national and subnational scales [53–56]. Neural network-based approaches, including deep learning architectures, have shown strong performance in early outbreak detection and short-term prediction, particularly when integrating meteorological and remote sensing data [57,58]. Comparative analyses further indicate that ensemble and hybrid ML models often yield higher predictive accuracy and robustness than single-model frameworks [59,60]. As climate variability intensifies and surveillance datasets expand, AI-driven predictive systems are increasingly viewed as essential tools for real-time dengue risk assessment and public health decision-making [61–64].

5. Public Health Interventions and Adaptation Strategies

The escalating frequency and intensity of flood-induced dengue fever outbreaks necessitate a fundamental paradigm shift in global public health strategies, transitioning from reactive emergency responses to proactive, climate-resilient adaptation. As anthropogenic climate change fundamentally alters the ecological boundaries of vector-borne diseases, traditional disease control mechanisms are proving increasingly inadequate. To mitigate the compounding risks associated with extreme hydrological events, structural and sustained changes must be enacted across multiple human systems. This requires a comprehensive portfolio of adaptive interventions that integrate advanced predictive technologies, precision environmental management, resilient healthcare infrastructure, and robust socio-economic support mechanisms to protect highly vulnerable populations.

At the forefront of proactive adaptation is the development and deployment of Climate-sensitive Early Warning Systems (EWS). By integrating high-resolution meteorological forecasts with epidemiological and entomological surveillance data, public health authorities can anticipate periods of elevated transmission risk before an outbreak fully materializes. For instance, spatiotemporal forecasting models utilizing advanced climate indicators have successfully provided reliable, multi-month lead times for impending dengue emergencies in highly vulnerable coastal regions [43]. Empirical evidence further demonstrates that issuing early warnings and implementing targeted interventions during periods of abnormal rainfall and flooding can substantially reduce the subsequent risk of viral transmission [29]. However, a significant global deficit remains in the implementation of these proactive systems. Recent assessments indicate that only a fraction of countries worldwide report having functional health early warning systems specifically tailored to climate-driven infectious diseases [1], highlighting a critical gap between scientific forecasting capabilities and practical administrative execution. In response to this implementation gap, WHO and WMO have developed structured operational frameworks to institutionalize climate-based health early warning systems in LMICs, notably through the WHO Operational Framework for Building Climate Resilient (and Low Carbon) Health Systems and the WMO-led Global Framework for Climate Services (GFCS) [65,66]. These frameworks promote phased implementation—beginning with vulnerability and adaptation assessments, followed by co-production of climate–health services, establishment of threshold-based alert triggers, and formal integration of response protocols into national health and disaster risk governance structures [67,68].

Once an extreme flooding event occurs, the immediate post-disaster window is critical for interrupting the vector breeding cycle. However, the diagnostic and prognostic framing of epidemics by the media and policymakers often over-emphasizes short-term, top-down technical fixes, such as extensive chemical fogging. While adulticiding may provide transient relief, it fails to address the root environmental determinants of disease transmission and the decay of public health infrastructure [42].

Therefore, post-disaster precision vector control must be inextricably linked to comprehensive environmental management and the rapid restoration of Water, Sanitation, and Hygiene (WASH) infrastructure. Empirical studies conducted in informal urban settlements reveal that household trash collection and community-level flood management are highly significant interventions; effectively removing waterlogged debris and ensuring routine waste disposal substantially reduces Aedes mosquito breeding habitats and significantly lowers dengue seroprevalence among children [34]. However, the pragmatic scaling of WASH infrastructure in LMICs is often constrained by systemic barriers such as rapid, unplanned urbanization and the informal status of many high-risk settlements, which preclude the installation of permanent municipal networks [69]. In these resource-limited contexts, adaptation must prioritize decentralized, low-cost solutions—such as community-managed water storage treatment and localized waste collection initiatives—that can be maintained independently of fragile centralized systems during flood events [70]. Furthermore, broader environmental adaptation strategies, such as the creation or expansion of wetlands to mitigate coastal and inland flooding, must be meticulously designed and ecologically managed to prevent these new bodies of water from inadvertently serving as prolific mosquito breeding sites [33]. Occupational environments also require structural adaptations, as seen in labor-intensive manufacturing sectors where flooding, inadequate drainage, and expanding vector habitats directly compromise worker safety and productivity [46].

The effectiveness of any environmental or vector control intervention is ultimately contingent upon the resilience and preparedness of the frontline healthcare infrastructure. Unfortunately, public health facilities are often physically vulnerable to extreme weather events and operationally unprepared to manage sudden, massive surges of infectious diseases. During post-flood crises, local clinics frequently face critical shortages of medical supplies, personnel, and essential diagnostic capacities. For example, observational studies in flood-prone regions have documented that while most facilities may manage endemic malaria, a vast majority lack the specific ability to diagnose and treat dengue virus infections, leading to prolonged hospitalizations and severe health outcomes for vulnerable demographics such as children under five [41]. To systematically address these institutional vulnerabilities, national governments must prioritize the execution of comprehensive Vulnerability and Adaptation (V&A) assessments and the subsequent implementation of Health National Adaptation Plans (HNAPs). However, current progress remains insufficient; across vast regions such as Latin America, only a handful of nations have officially completed V&A assessments or formulated dedicated HNAPs, leaving their populations highly vulnerable to future climate shocks [23]. For example, the Pan American Health Organization's (PAHO) Safe Hospitals Initiative provides hazard-specific standards to ensure that facilities in flood-prone areas remain structurally and operationally functional during disasters, emphasizing elevated critical systems, flood-resistant design, and continuity-of-service planning through the Hospital Safety Index framework [71–73].

Transitioning toward a truly climate-resilient public health framework requires breaking down rigid disciplinary silos through the widespread adoption of a "One Health" approach [74,75]. This holistic paradigm explicitly recognizes the intricate interconnectedness of human health, animal ecosystems, and the broader changing environment. A One Health strategy advocates for sustained, intersectoral collaboration involving meteorological agencies, urban planners, environmental scientists, and public health officials to collaboratively design resilient urban infrastructures. Furthermore, the institutionalization of "One Health" approaches faces significant political and bureaucratic hurdles in LMICs, where sectoral silos between health, environment, and meteorological agencies are often reinforced by competing budget priorities and lack of integrated data-sharing mandates [76]. To move beyond high-level policy design, intersectoral collaboration must be embedded into national disaster risk reduction frameworks, supported by dedicated climate-health financing that bypasses fragmented administrative layers to reach frontline operational units [77]. However, bridging the persistent implementation gap between identifying climate-health risks and enacting tangible interventions requires a massive and sustained mobilization of climate finance. Currently, efforts are significantly hindered by a notable lack of predictable funding; adaptation projects with direct health benefits represent a disproportionately small fraction of the allocations from major financial mechanisms like the Green Climate Fund [1,23]. Addressing this financial disparity is paramount, as the economic benefits of investing in climate-resilient health infrastructure and sustainable urban development far exceed the substantial economic costs of inaction and recurrent post-disaster recovery.

Finally, structural and financial interventions must be deeply rooted in community capacity building and continuous education. Building localized community resilience is essential, as the most underserved and low-income disproportionately bear the burden of physical and economic losses following floods. Public health campaigns must rapidly deploy health education to flood-afflicted individuals, emphasizing the critical importance of avoiding contaminated environments, properly managing domestic water storage, and utilizing personal protective devices against insect bites [5,39]. Simultaneously, educational transformation is required within the medical community itself. Healthcare professionals and medical students must receive rigorous training on the epidemiological shifts driven by climate change, enabling them to recognize atypical presentations of vector-borne diseases and to act as informed advocates for climate mitigation and planetary health [78,79]. Only through a meticulously integrated approach that combines technological forecasting, ecological management, resilient healthcare systems, and empowered communities can global public health successfully adapt to the profound threats posed by climate-driven flood disasters.

6. Limitations and Future Directions

Despite substantial progress in elucidating the interactions among extreme precipitation, flooding, and dengue incidence risk, this field continues to face significant methodological and data-related constraints. First, limitations in data quality and spatiotemporal resolution substantially restrict the accuracy and generalizability of predictive models. Many low- and middle-income countries and regions that are disproportionately threatened by climate change lack long-term, continuous, and high-quality infectious disease surveillance systems, resulting in considerable data gaps and reporting bias [51]. In addition, although satellite remote sensing technologies provide broad meteorological and environmental coverage, their spatial resolution is often insufficient to precisely capture small household water storage containers or localized cryptic breeding sites that are critical for Aedes aegypti proliferation [50]. Beyond these external data constraints, we acknowledge the inherent limitations of this narrative review. The literature selection was primarily restricted to peer-reviewed articles indexed in major English-language databases, which may have overlooked relevant findings from grey literature, local institutional reports, or non-English publications. Additionally, there is an unavoidable geographical selection bias, as the synthesized evidence is largely drawn from regions with robust research infrastructure and established surveillance systems. Finally, as a narrative synthesis rather than a systematic review, our interpretation is subject to thematic prioritization and lacks the quantitative rigor of a meta-analysis, which may limit the generalizability of certain synthesized findings.

Existing macro-level epidemiological studies also face persistent challenges in adequately controlling for complex confounding factors. Dengue transmission dynamics are not solely driven by meteorological variables but are profoundly shaped by socio-ecological determinants, including baseline population immunity, local public health interventions, urbanization processes, and human mobility patterns [31]. Accurately disentangling these non-climatic influences within statistical models—particularly quantifying the long-term effects of adaptive strategies—remains a major research challenge. Future investigations should advance toward higher-resolution, interdisciplinary integration by combining hydrology, meteorology, and spatial epidemiology to more precisely characterize the effects of microclimatic variation on vector ecology and viral incubation dynamics, as empirical studies have shown that fine-scale temperature fluctuations significantly alter mosquito development rates, survival, and pathogen incubation periods [80,81]. Empirical evidence examining micro-environmental conditions—such as temperature and humidity fluctuations at the neighborhood or building scale—and their influence on vector biology would substantially strengthen mechanistic inference. Moreover, forthcoming empirical research should further leverage large-scale, authoritative public health databases, such as the Global Burden of Disease (GBD), in conjunction with standardized multicenter surveys to comprehensively assess the health inequalities and global disparities attributable to extreme hydrological events across countries at different levels of socioeconomic development. Such efforts would provide more robust evidence to inform highly targeted and region-specific public health policies.

7. Conclusions

In summary, against the escalating backdrop of climate change, flood disasters exert a significant and multifaceted influence on dengue incidence. Extreme precipitation and flooding events do not affect disease transmission through a single linear pathway; rather, they reshape vector breeding habitats, accelerate viral incubation cycles, and interact synergistically with the disruption of human infrastructure and post-disaster water storage behaviors, generating cascading epidemiological effects [9,28,29]. This association exhibits pronounced spatial heterogeneity and marked temporal lag structures, with marginalized urban informal settlements and vulnerable communities characterized by fragile sanitation infrastructure bearing a disproportionate disease burden [11,34]. In the face of increasingly frequent and intense extreme hydrological events, conventional reactive disease control strategies have revealed substantial limitations and are insufficient to meet contemporary global public health demands. The international community, national governments, and regional health authorities must urgently implement cross-sectoral climate adaptation strategies. These strategies should integrate high-resolution meteorological forecasting data with infectious disease surveillance networks to develop and refine climate-sensitive early warning systems [43,52]. Only through sustained and adequate investment in climate adaptation financing, the comprehensive implementation of interdisciplinary "One Health" collaboration frameworks, and the strengthening of bottom-up community-level healthcare and environmental intervention resilience can societies effectively curb the expansion of mosquito-borne diseases such as dengue under intensifying climate crises, thereby safeguarding the health and public health security of vulnerable populations worldwide.

Author Contributions

J.L.: conceptualization, supervision, funding acquisition, writing—review & editing; Q.L.: methodology, visualization, writing—original draft, writing—review & editing. All authors have read and agreed to the published version of the manuscript.

Funding

This work was funded by Prevention and Control of Emerging and Major Infectious Diseases-National Science and Technology Major Project Major Project (Awarded author: JL, Grant number: 2025ZD01900800). The funder had no role in the study design, data collection and analysis, decision to publish, or preparation of the paper.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

No new data were generated or analyzed in this narrative review. Data sharing is not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

References

1. Romanello, M.; Walawender, M.; Hsu, S.C.; et al. The 2024 Report of the Lancet Countdown on Health and Climate Change: Facing Record-Breaking Threats from Delayed Action. *Lancet* **2024**, *404*, 1847–1896.
2. Romanello, M.; Di Napoli, C.; Drummond, P.; et al. The 2022 Report of the Lancet Countdown on Health and Climate Change: Health at the Mercy of Fossil Fuels. *Lancet* **2022**, *400*, 1619–1654.
3. Martin, V.; Chevalier, V.; Ceccato, P.; et al. The Impact of Climate Change on the Epidemiology and Control of Rift Valley Fever. *Rev. Sci. Tech.* **2008**, *27*, 413–426.
4. Epstein, P.R. Is Global Warming Harmful to Health? *Sci. Am.* **2000**, *283*, 50–57.
5. Dayrit, J.F.; Bintanjoyo, L.; Andersen, L.K.; et al. Impact of Climate Change on Dermatological Conditions Related to Flooding: Update from the International Society of Dermatology Climate Change Committee. *Int. J. Dermatol.* **2018**, *57*, 901–910.
6. Iqbal, M.; Rabbani, A.; Haq, F.; et al. The Floods of 2022: Economic and Health Crisis Hits Pakistan. *Ann. Med. Surg.* **2022**, *84*, 104800.
7. Alied, M.; Salam, A.; Sediqi, S.M.; et al. Disaster after Disaster: The Outbreak of Infectious Diseases in Pakistan in the Wake of 2022 Floods. *Ann. Med. Surg.* **2024**, *86*, 891–898.
8. Harris, M.J.; Trok, J.T.; Martel, K.S.; et al. Extreme Precipitation, Exacerbated by Anthropogenic Climate Change, Drove Peru's Record-Breaking 2023 Dengue Outbreak. *medRxiv* **2024**, *9*, 101619.
9. Acosta-España, J.D.; Romero-Alvarez, D.; Luna, C.; et al. Infectious Disease Outbreaks in the Wake of Natural Flood Disasters: Global Patterns and Local Implications. *Infez. Med.* **2024**, *32*, 451–462.
10. Nava, A.; Shimabukuro, J.S.; Chmura, A.A.; et al. The Impact of Global Environmental Changes on Infectious Disease Emergence with a Focus on Risks for Brazil. *ILAR J.* **2017**, *58*, 393–400.
11. Nuñez Murillo, T.; Cadavid Restrepo, A.; Mayfield, H.J.; et al. Spatial Risk Factors of Vector-Borne Diseases in Pacific Island Countries and Territories: A Scoping Review. *Trop. Med. Infect. Dis.* **2026**, *11*, 6.
12. Githeko, A.K.; Lindsay, S.W.; Confalonieri, U.E.; et al. Climate Change and Vector-Borne Diseases: A Regional Analysis. *Bull. World Health Organ.* **2000**, *78*, 1136–1147.
13. Weaver, S.C.; Reisen, W.K. Present and Future Arboviral Threats. *Antiviral Res.* **2010**, *85*, 328–345.
14. Tabassum, S.; Naeem, A.; Nazir, A.; et al. Year-Round Dengue Fever in Pakistan, Highlighting the Surge amidst Ongoing Flood Havoc and the COVID-19 Pandemic: A Comprehensive Review. *Ann. Med. Surg.* **2023**, *85*, 908–912.

15. Guzman, M.G.; Harris, E. Dengue. *Lancet* **2015**, *385*, 453–465.
16. Guzman, M.G.; Gubler, D.J.; Izquierdo, A.; et al. Dengue Infection. *Nat. Rev. Dis. Primers* **2016**, *2*, 16055.
17. Messina, J.P.; Brady, O.J.; Scott, T.W.; et al. Global Spread of Dengue Virus Types: Mapping the 70 Year History. *Trends Microbiol.* **2014**, *22*, 138–146.
18. Murray, N.E.A.; Quam, M.B.; Wilder-Smith, A. Epidemiology of Dengue: Past, Present and Future Prospects. *Clin. Epidemiol.* **2013**, *5*, 299–309.
19. Bhatt, S.; Gething, P.W.; Brady, O.J.; et al. The Global Distribution and Burden of Dengue. *Nature* **2013**, *496*, 504–507.
20. Semenza, J.C.; Paz, S. Climate Change and Infectious Disease in Europe: Impact, Projection and Adaptation. *Lancet Reg. Health Eur.* **2021**, *9*, 100230.
21. Eder, M.; Cortes, F.; Teixeira de Siqueira Filha, N.; et al. Scoping Review on Vector-Borne Diseases in Urban Areas: Transmission Dynamics, Vectorial Capacity and Co-Infection. *Infect. Dis. Poverty* **2018**, *7*, 90.
22. Colón-González, F.J.; Sewe, M.O.; Tompkins, A.M.; et al. Projecting the Risk of Mosquito-Borne Diseases in a Warmer and More Populated World: A Multi-Model, Multi-Scenario Intercomparison Modelling Study. *Lancet Planet. Health* **2021**, *5*, e404–e414.
23. Hartinger, S.M.; Palmeiro-Silva, Y.K.; Llerena-Cayo, C.; et al. The 2023 Latin America Report of the Lancet Countdown on Health and Climate Change: The Imperative for Health-Centred Climate-Resilient Development. *Lancet Reg. Health Am.* **2024**, *33*, 100746.
24. Rahman, M.M.; Bodrud-Doza, M.; Shammi, M.; et al. COVID-19 Pandemic, Dengue Epidemic, and Climate Change Vulnerability in Bangladesh: Scenario Assessment for Strategic Management and Policy Implications. *Environ. Res.* **2021**, *192*, 110303.
25. Lowe, R.; Gasparrini, A.; Van Meerbeeck, C.J.; et al. Nonlinear and Delayed Impacts of Climate on Dengue Risk in Barbados: A Modelling Study. *PLoS Med.* **2018**, *15*, e1002613.
26. Lowe, R.; Lee, S.A.; O'Reilly, K.M.; et al. Combined Effects of Hydrometeorological Hazards and Urbanisation on Dengue Risk in Brazil: A Spatiotemporal Modelling Study. *Lancet Planet. Health* **2021**, *5*, e209–e219.
27. Alcayna, T.; Fletcher, I.; Gibb, R.; et al. Climate-Sensitive Disease Outbreaks in the Aftermath of Extreme Climatic Events: A Scoping Review. *One Earth* **2022**, *5*, 336–350.
28. Coalson, J.E.; Anderson, E.J.; Santos, E.M.; et al. The Complex Epidemiological Relationship between Flooding Events and Human Outbreaks of Mosquito-Borne Diseases: A Scoping Review. *Environ. Health Perspect.* **2021**, *129*, 96002.
29. Nosrat, C.; Altamirano, J.; Anyamba, A.; et al. Impact of Recent Climate Extremes on Mosquito-Borne Disease Transmission in Kenya. *PLoS Negl. Trop. Dis.* **2021**, *15*, e0009182.
30. Zheng, Y.; Yue, K.; Wong, E.W.M.; et al. Impact of Human Mobility and Weather Conditions on Dengue Mosquito Abundance during the COVID-19 Pandemic in Hong Kong. *Infect. Dis. Model.* **2025**, *10*, 840–849.
31. Ouyang, X.; Shi, F.; Qiu, Y.; et al. The Impact of Extreme Weather on Dengue Fever in Guangzhou, China: A Zero-Inflated Negative Binomial Spatial Lag Analysis. *Geohealth* **2025**, 9, e2025GH001330.
32. Sun, H.; Koo, J.; Dickens, B.L.; et al. Short-Term and Long-Term Epidemiological Impacts of Sustained Vector Control in Various Dengue Endemic Settings: A Modelling Study. *PLoS Comput. Biol.* **2022**, *18*, e1009979.
33. Medlock, J.M.; Vaux, A.G. Impacts of the Creation, Expansion and Management of English Wetlands on Mosquito Presence and Abundance—Developing Strategies for Future Disease Mitigation. *Parasit. Vectors* **2015**, *8*, 142.
34. Rosser, J.I.; Openshaw, J.J.; Lin, A.; et al. Seroprevalence, Incidence Estimates, and Environmental Risk Factors for Dengue, Chikungunya, and Zika Infection amongst Children Living in Informal Urban Settlements in Indonesia and Fiji. *BMC Infect. Dis.* **2025**, *25*, 51.
35. Stewart Ibarra, A.M.; Ryan, S.J.; Beltrán, E.; et al. Dengue Vector Dynamics (*Aedes aegypti*) Influenced by Climate and Social Factors in Ecuador: Implications for Targeted Control. *PLoS ONE* **2013**, *8*, e78263.
36. Tesla, B.; Demakovsky, L.R.; Mordecai, E.A.; et al. Temperature Drives Zika Virus Transmission: Evidence from Empirical and Mathematical Models. *Proc. R. Soc. B* **2018**, *285*, 20180795.
37. Carrington, L.B.; Armijos, M.V.; Lambrechts, L.; et al. Effects of Fluctuating Daily Temperatures at Critical Thermal Extremes on *Aedes aegypti* Life-History Traits. *PLoS ONE* **2013**, *8*, e58824.
38. Karakullukcu, S.; Dilaver, I.; Gurcan, F.; et al. Climate Change and Water-Related Diseases: A Bibliometric, Knowledge Map, Topic Modeling, and Content Analysis. *J. Water Health* **2026**, *24*, 278–300.
39. Singh, P.K.; Dhiman, R.C. Climate Change and Human Health: Indian Context. *J. Vector Borne Dis.* **2012**, *49*, 55–60.
40. Muzzamil, M.; Naz, S.; Mumtaz, H.; et al. Pakistan's Healthcare Preparedness after the NIH Warned of a New Diphtheria Strain and COVID-19 Variation. *J. Taibah Univ. Med. Sci.* **2023**, *18*, 1055–1057.
41. Ogony, J.; Menya, D.; Mangeni, J.; et al. Public Health Facility Vulnerabilities, Preparedness, and Health Outcomes for *Plasmodium falciparum* and Dengue Virus-Infected Children under 5 Years with Acute Febrile Illnesses in Western Kenya. *Front. Public Health* **2025**, *13*, 1526558.

42. Espinoza, M.I. Conflicting Diagnostic and Prognostic Framing of Epidemics? Newspaper Representations of Dengue as a Public Health Problem in Peru. *Soc. Sci. Med.* **2021**, *289*, 114398.
43. Mills, C.; Donnelly, C.A. Climate-Based Modelling and Forecasting of Dengue in Three Endemic Departments of Peru. *PLoS Negl. Trop. Dis.* **2024**, *18*, e0012596.
44. Wanda, D.; Jacinta, H.A.; Hakim, A.R.; et al. Infectious Diseases in Children: Diagnosing the Impact of Climate Change-Related Disasters Using Integer-Valued Autoregressive Models with Overdispersion. *Diseases* **2025**, *13*, 303.
45. Castonguay, A.C.; Chowdhury, S.; Shanta, I.S.; et al. Prioritizing Climate-Sensitive Zoonotic Diseases in Bangladesh: Integrating Climate Hazards, Pathogen Transmissibility and Potential Health Outcomes. *J. Clim. Chang. Health* **2025**, *26*, 100526.
46. Senadeera, D.; Sayem, A.S.M.; Filho, W.L.; et al. Workplace Health and Safety under Climate Stress in Sri Lankan Apparel SMEs. *BMC Public Health* **2026**, *26*, 587.
47. Lowe, R.; Barcellos, C.; Coelho, C.A.; et al. Dengue Outlook for the World Cup in Brazil: An Early Warning Model Framework Driven by Real-Time Seasonal Climate Forecasts. *Lancet Infect. Dis.* **2014**, *14*, 619–626.
48. Johansson, M.; Cummings, D.; Glass, G. Multi-year Climate Variability and Dengue-El Niño Southern Oscillation. Weather, and Dengue Transmission in Puerto Rico: A Longitudinal Data Analysis. *Am. J. Trop. Med. Hyg.* **2009**, *81*, 667–674.
49. Malik, S.M.; Awan, H.; Khan, N. Mapping Vulnerability to Climate Change and Its Repercussions on Human Health in Pakistan. *Global Health* **2012**, *8*, 31.
50. Anyamba, A.; Small, J.L.; Britch, S.C.; et al. Recent Weather Extremes and Impacts on Agricultural Production and Vector-Borne Disease Outbreak Patterns. *PLoS ONE* **2014**, *9*, e92538.
51. Kabir, M.I.; Hossain, D.M.; Shawon, M.T.H.; et al. Understanding Climate-Sensitive Diseases in Bangladesh Using Systematic Review and Government Data Repository. *PLoS ONE* **2025**, *20*, e0313031.
52. Choo, E.L.W.; Ma, P.; Chow, J.Y.; et al. Projecting Long-Term Excess Risks of Major Infectious Diseases Associated with Future Extreme Weather Events in Thailand. *PLoS Negl. Trop. Dis.* **2026**, *20*, e0013896.
53. Andrade Girón, D.C.; Marín Rodriguez, W.J.; Lioo-Jordan, F.d.M.; et al. Machine Learning and Deep Learning Models for Dengue Diagnosis Prediction: A Systematic Review. *Informatics* **2025**, *12*, 15.
54. Cheng, Y.; Cheng, R.; Xu, T.; et al. Integrating Meteorological Data and Hybrid Intelligent Models for Dengue Fever Prediction. *BMC Public Health* **2025**, *25*, 1516.
55. Tian, N.; Zheng, J.-X.; Li, L.-H.; et al. Precision Prediction for Dengue Fever in Singapore: A Machine Learning Approach Incorporating Meteorological Data. *Trop. Med. Infect. Dis.* **2024**, *9*, 72.
56. Kuo, C.-Y.; Yang, W.-W.; Su, E.C.-Y. Improving Dengue Fever Predictions in Taiwan Based on Feature Selection and Random Forests. *BMC Infect. Dis.* **2024**, *24*, 334.
57. Xu, J.; Xu, K.; Li, Z.; et al. Forecast of Dengue Cases in 20 Chinese Cities Based on the Deep Learning Method. *Int. J. Environ. Res. Public Health* **2020**, *17*, 453.
58. Guo, P.; Liu, T.; Zhang, Q.; et al. Developing a Dengue Forecast Model Using Machine Learning: A Case Study in China. *PLoS Negl. Trop. Dis.* **2017**, *11*, e0005973.
59. Muthuselvi, P.; Dhanasekaran, S.; Vasudevan, V. Intelligent Dengue Prediction and Management: A Companied-Optimized Ensemble Approach with Advanced Feature Selection and Dynamic Recommendations. In Proceedings of the 2025 International Conference on Machine Learning and Autonomous Systems (ICMLAS), Prawet, Thailand, 10–12 March 2025; pp. 745–753.
60. Ong, S.; Isawasan, P.; Ngesom, A.M.M.; et al. Predicting Dengue Transmission Rates by Comparing Different Machine Learning Models with Vector Indices and Meteorological Data. *Sci. Rep.* **2023**, *13*, 19129.
61. Li, Z.; Dong, J. Big Geospatial Data and Data-Driven Methods for Urban Dengue Risk Forecasting: A Review. *Remote Sens.* **2022**, *14*, 5052.
62. Shaikh, S.; Sureshkumar, B.; Narang, D. Development of Optimized Ensemble Classifier for Dengue Fever Prediction and Recommendation System. *Biomed. Signal Process. Control* **2023**, *85*, 104809.
63. Sebastianelli, A.; Spiller, D.; Carmo, R.; et al. A Reproducible Ensemble Machine Learning Approach to Forecast Dengue Outbreaks. *Sci. Rep.* **2024**, *14*, 3807.
64. Leung, X.Y.; Islam, R.; Adhami, M.; et al. A Systematic Review of Dengue Outbreak Prediction Models: Current Scenario and Future Directions. *PLoS Negl. Trop. Dis.* **2022**, *16*, e0010631.
65. World Health Organization. *Human Health and Climate Change in Pacific Island Countries*; WHO: Geneva, Switzerland, 2015.
66. World Health Organization. *Operational Framework for Building Climate Resilient and Low Carbon Health Systems*; WHO: Geneva, Switzerland, 2023.
67. Hussain-Alkhateeb, L.; Rivera Ramirez, T.; Kroeger, A.; et al. Early Warning Systems (EWSs) for Chikungunya, Dengue, Malaria, Yellow Fever, and Zika Outbreaks: What Is the Evidence? A Scoping Review. *PLoS Negl. Trop. Dis.* **2021**, *15*, e0009686.

68. Thomson, M.C.; Muñoz, Á.G.; Cousin, R.; et al. Climate Drivers of Vector-Borne Diseases in Africa and Their Relevance to Control Programmes. *Infect. Dis. Poverty* **2018**, *7*, 15–36.
69. Hyun, C.; Burt, Z.; Crider, Y.; et al. Sanitation for Low-Income Regions: A Cross-Disciplinary Review. *Annu. Rev. Environ. Resour.* **2019**, *44*, 287–318.
70. Narayan, A.S.; Marks, S.J.; Meierhofer, R.; et al. Advancements in and Integration of Water, Sanitation, and Solid Waste for Low- and Middle-Income Countries. *Annu. Rev. Environ. Resour.* **2021**, *46*, 193–219.
71. World Health Organization. *WHO Guidance for Climate-Resilient and Environmentally Sustainable Health Care Facilities*; WHO: Geneva, Switzerland, 2020.
72. Lestari, F.; Paramitasari, D.; Kadir, A.; et al. The Application of Hospital Safety Index for Analyzing Primary Healthcare Center (PHC) Disaster and Emergency Preparedness. *Sustainability* **2022**, *14*, 1488.
73. World Health Organization. *Hospital Safety Index: Guide for Evaluators*; WHO: Geneva, Switzerland, 2015.
74. Agyarko, R.K.D.; Kithinji, D.; Nsarhaza, K.B. Climate Change and the Rise of Emerging and Re-Emerging Infectious Diseases in Africa: A Literature Review. *Int. J. Environ. Res. Public Health* **2025**, *22*, 903.
75. Leal Filho, W.; Nagy, G.J.; Gbaguidi, G.J.; et al. The Role of Climatic Changes in the Emergence and Re-Emergence of Infectious Diseases: Bibliometric Analysis and Literature-Supported Studies on Zoonoses. *One Health Outlook* **2025**, *7*, 12.
76. Kayembe-Mulumba, B.; N'gattia, A.K.; Belizaire, M.R.D. One Health, Many Gaps: Rethinking Epidemic Intelligence in Resource-Limited Settings to Prepare for the Global Threat of Disease X. *Microorganisms* **2025**, *13*, 2615.
77. Borghi, J.; Cuevas, S.; Anton, B.; et al. Climate and Health: A Path to Strategic Co-Financing? *Health Policy Plan.* **2024**, *39*, i4–i18.
78. Munro, N. Climate Change and Emerging Infectious Diseases: A Precarious Relationship. *AACN Adv. Crit. Care* **2024**, *35*, 325–333.
79. Luschkova, D.; Ludwig, A.; Traidl-Hoffmann, C. Climate Crisis and Its Impact on Human Health. *Dtsch. Med. Wochenschr.* **2021**, *146*, 1636–1641.
80. Lambrechts, L.; Paaijmans, K.P.; Fansiri, T.; et al. Impact of Daily Temperature Fluctuations on Dengue Virus Transmission by *Aedes aegypti*. *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 7460–7465.
81. Paaijmans, K.P.; Blanford, S.; Chan, B.H.; et al. Warmer Temperatures Reduce the Vectorial Capacity of Malaria Mosquitoes. *Biol. Lett.* **2012**, *8*, 465–468.