



Climate Change Shapes the Dengue Landscape: A Narrative Review

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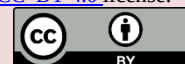
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ABSTRACT

Introduction: Climate change is a critical driver of vector-borne diseases, notably dengue. Rising global temperatures, altered precipitation patterns, and increased extreme weather events enhance Aedes mosquitoes' habitats, the primary vectors of dengue. The pathogenesis of dengue, driven by any of the four serotypes of the dengue virus (DENV-1 to DENV-4), is exacerbated by climate-induced changes that support mosquito breeding and survival. Methods: This review analyzes selective studies from the last decade, integrating epidemiological data and climate models to explore the impacts of climatic variables on dengue dynamics. Adaptation strategies, including vaccination, vector control, and community-based interventions, were evaluated for their effectiveness in mitigating dengue transmission. Results: Epidemiological data indicate approximately 390 million annual infections globally, with rapid urbanization and inadequate vector control compounding the issue. Climate models highlight significant increases in dengue incidence and shifts in its geographic distribution, particularly in regions such as the Americas, Asia, and potentially Europe. Promising adaptation strategies, such as the Communication for Behavioral Impact (COMBI) plan and constrained optimization models, have demonstrated efficacy in enhancing dengue prevention and control. Discussion: As climate change continues to alter ecosystems, integrating climatic data into public health strategies is essential for adaptive responses. Comprehensive and region-specific approaches, robust public health infrastructures, and international cooperation are paramount to address the rising threat of dengue. A need for international cooperation and robust public health infrastructure is necessary to address the multifaceted challenges posed by climate change on dengue transmission.

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INTRODUCTION

Climate change has emerged as a critical factor influencing the spread of vector-borne diseases, including dengue. As global temperatures rise, shifts in precipitation patterns and increases in extreme weather events create favorable conditions for the proliferation of Aedes mosquitoes, the primary vectors of dengue. The interplay of temperature, humidity, and rainfall significantly affects mosquito life cycles and virus transmission

dynamics. For instance, a study analyzing dengue incidence in Singapore found that higher rainfall correlates with increased dengue cases, while higher humidity can reduce them slightly.(Islam *et al.*, 2024) Another study highlighted that climate warming has expanded the dengue burden in the Americas and Asia, projecting substantial increases in incidence under future climate scenarios.(Childs *et al.*, 2024) Additional contributing factors include urbanization, population growth, and economic development, which create suitable conditions for the *Aedes aegypti* mosquito, the primary vector of dengue, to thrive.(Colón-González *et al.*, 2013) Human factors, including lifestyle choices and increased travel, have also been shown to exacerbate the spread of the virus. For instance, exceptional urban growth has intensified the association between dense human populations and the risk of dengue transmission, particularly in tropical areas.(Naish *et al.*, 2014)

Comprehensive reviews stress the necessity of integrating climate data into public health strategies to mitigate the rising threat of vector-borne diseases due to climate change.(Chikezie, Opara and Ubulom, 2024; Kumar *et al.*, 2024) As climate change continues to alter ecosystems, there is an urgent need for adaptive strategies to control the spread of dengue and protect public health. This paper will first explore the pathogenesis and epidemiology of dengue, followed by the impacts of climate change, and finally discuss adaptation strategies.

Pathogenesis and Epidemiology of Dengue

Dengue fever, caused by any of the four serotypes of the dengue virus (DENV-1 to DENV-4), is a mosquito-borne viral illness primarily transmitted by *Aedes aegypti* and *Aedes albopictus* mosquitoes. The disease has seen a dramatic increase in incidence globally, particularly in tropical and subtropical regions where environmental conditions are ideal for mosquito proliferation. The pathogenesis of dengue involves a complex interplay between the virus and the host immune response, leading to a range of clinical manifestations from mild febrile illness to severe dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS). Infection with one serotype provides lifelong immunity against that serotype but not against the others, making sequential infections with different serotypes a significant risk factor for severe disease due to antibody-dependent enhancement (ADE). Epidemiological studies have shown that dengue is responsible for approximately 390 million infections annually, with around 100 million of these presenting clinically and thousands resulting in fatalities each year.(Zerfu, Kassa and Legesse, 2023) Rapid urbanization, inadequate vector control, and climate change exacerbate the disease's burden by expanding the habitat of *Aedes* mosquitoes and thus the geographic distribution of dengue.(Wong *et al.*, 2022) Effective dengue management includes clinical diagnosis, supportive care, and vector control measures. The introduction of the Dengvaxia vaccine represents a significant advancement in prevention strategies.(Khanam *et al.*, 2022)

Climate Change: An Emerging Global Health Threat

Climate change is increasingly recognized as one of the most significant threats to global health. The rising global temperatures, altered precipitation patterns, and increased frequency of extreme weather events pose direct and indirect risks to human health. Direct health impacts include heat-related illnesses and deaths, while indirect effects stem from the disruption of natural and human systems. These changes exacerbate the spread of



infectious diseases, undermine food security, and strain water resources, significantly affecting vulnerable populations, particularly in low- and middle-income countries. Prolonged heatwaves, storms, floods, and droughts are already causing tens of thousands of deaths annually and threatening the existence of millions of people due to food and water scarcity.(Jayaraj and Ibrahim, 2023) Moreover, climate change intensifies diarrheal outbreaks, particularly in South Africa, where it contributes substantially to morbidity and mortality. Diarrheal diseases account for over 2.5 million annual deaths globally, with climatic variables such as temperature and precipitation playing a significant role in their incidence.(Abdullahi, Nitschke and Sweijd, 2022) The indirect impacts of climate change on food crops and drinking water availability further threaten global health security. The convergence of climate change with conflict and contagion (disease outbreaks), termed the "Toxic Triumvirate," is placing unprecedented pressure on global public health systems, highlighting the need for a robust international response.(Briggs, 2023) Ethical considerations and global health inequalities must be addressed to effectively tackle these challenges, with the concept of planetary health providing a framework for integrating environmental and public health efforts.(Gardiner and Tubig, 2023)

In addition to the immediate health impacts, climate change is also expected to have long-term effects on global health and security. The degradation of ecosystems and loss of biodiversity due to climate change will likely lead to the emergence and re-emergence of infectious diseases as wildlife habitats are disrupted, increasing human-animal interactions and the potential for zoonotic disease spillover. Changes in agricultural productivity due to shifting climate patterns could result in widespread food insecurity, malnutrition, and associated health problems, disproportionately affecting the most vulnerable populations. Furthermore, climate-induced migration and displacement are expected to increase, leading to crowded living conditions and heightened risks of disease transmission and mental health issues. The socio-economic impacts of climate change, including job losses and increased poverty, will exacerbate health inequalities and strain healthcare systems globally. It is imperative for policymakers to adopt a multi-faceted approach that includes climate mitigation, adaptation strategies, and robust healthcare infrastructure to address these complex and interrelated challenges. As climate change continues to reshape the global health landscape, coordinated international efforts and substantial investments in sustainable development and public health are crucial to mitigate its far-reaching effects.(L. Ostergard and Seltzer, 2023)

Vector Biology and Ecology: Influence of Climate Variables

In the context of how climate change shapes the dengue landscape, it is crucial to understand the biology and ecology of vectors, specifically how climate variables influence them.

Vector Biology: Sensitivity to Climate Variables:

Arthropod vectors like *Aedes* mosquitoes, which transmit dengue, are particularly sensitive to climatic conditions. Climate change affects vector populations by altering

their reproduction, development, and survival rates. Temperature, precipitation, and humidity are key factors that determine vector distribution and the prevalence of vector-borne diseases (VBDs). For instance, warmer temperatures can increase the biting rate and viral replication within mosquitoes, thereby enhancing transmission potential. Similarly, increased precipitation creates more breeding sites for mosquitoes, while humidity levels affect their survival and activity patterns (Chikezie, Opara and Ubulom, 2024). Temperature is a primary climatic factor affecting vector survival and pathogen transmission. Studies show that higher temperatures can decrease the survival rates of vectors like *Anopheles stephensi* and *Aedes aegypti*, with median survival days being notably higher for *Aedes aegypti* at elevated temperatures. (Dhiman, 2022)

Climate change induces shifts in seasonal patterns and geographical ranges of vectors, facilitating the spread of dengue to new areas. For example, in North America, rising temperatures and altered precipitation patterns have shifted vector activity periods and introduced dengue to previously unaffected regions (Kiryluk, Beard and Holcomb, 2024). Additionally, changes in climate variables influence vector behavior and life cycles in complex ways, complicating predictions of dengue transmission dynamics. Long-term research integrating environmental and climatic data is essential for effective vector control strategies and public health interventions (Ivanescu *et al.*, 2023).

Ecology and Pathogen-Vector Interaction:

Comparative data reveal that increased temperature accelerates mosquito development, reducing lifecycle duration by nearly 25% at 30°C compared to 22°C (Mordecai *et al.*, 2019). Rising temperatures also enable the geographic expansion of mosquito populations into new territories (Kraemer *et al.*, 2015). Moreover, climate change influences pathogen-vector interactions, such as accelerating the extrinsic incubation period of the dengue virus within mosquitoes, leading to earlier and more frequent transmission events (Khan *et al.*, 2023). Indirect effects, such as changes in vegetation and water availability, also impact mosquito breeding habitats and vector dynamics. For example, climate-induced changes in host-plant interactions and predator-prey relationships further complicate the prediction of vector behavior and disease transmission (Chandrakumara *et al.*, 2023).

Integrating environmental and climatic data into VBD models is crucial for adaptive strategies to mitigate climate change's impact on dengue. Continuous surveillance and advanced predictive tools can enhance outbreak response, ensuring preparedness and resilience against evolving threats (Ivanescu *et al.*, 2023).

Precipitation, Humidity, and Their Impact on Vector Proliferation

Precipitation and humidity are critical climatic variables that significantly impact the proliferation of vector species such as *Aedes* mosquitoes, which are primary vectors of dengue. These climatic factors influence various aspects of vector biology, including their breeding, survival, and overall population dynamics. Precipitation, for example, directly affects the availability of breeding sites for mosquitoes. Increased rainfall leads to the creation of more standing water habitats, which are essential for mosquito larval development. However, excessive rain can also flush out breeding sites, reducing larval populations temporarily. A study in Maricopa County, Arizona, highlighted that



significant rainfall events resulted in lower mosquito abundance shortly after the events due to habitat disruption, but overall, precipitation was necessary for maintaining mosquito populations.(Oliveira and Musis, 2014)

Humidity also plays a vital role in mosquito ecology. High humidity levels are conducive to mosquito survival and activity, as they reduce the risk of desiccation, enabling mosquitoes to live longer and thereby increasing their chances of transmitting diseases. Conversely, low humidity can lead to higher mortality rates among mosquitoes, limiting their lifespan and reproductive success. Research has shown that mosquitoes such as *Aedes aegypti* thrive in high humidity conditions, which supports their activity and enhances the potential for disease transmission.(Brown *et al.*, 2023) Additionally, the interaction between temperature and humidity is crucial, as high temperatures combined with low humidity can negatively impact mosquito physiology, while optimal conditions of both parameters can significantly boost mosquito proliferation and vectorial capacity.

Furthermore, the influence of precipitation and humidity on vector proliferation is not uniform across different species and geographic regions. In the Canadian Prairies, for instance, studies have shown that different mosquito species have varying preferences and tolerances for weather conditions. *Aedes vexans*, for example, favors high humidity and moderate temperatures, while other species like *Culex tarsalis* have distinct preferences that can change annually based on weather patterns.(Baril *et al.*, 2023) This variability underscores the importance of localized and species-specific studies to accurately predict and manage vector populations in different environmental contexts.

Understanding the complex interactions between precipitation, humidity, and vector proliferation is essential for developing effective vector control strategies. These insights help predict potential outbreaks and implement timely interventions to reduce the burden of vector-borne diseases such as dengue. Continuous monitoring and advanced modeling that incorporate climatic variables can enhance public health preparedness and response efforts, ultimately mitigating the impacts of climate change on vector dynamics and disease transmission.(Chikezie, Opara and Ubulom, 2024)

Climate Change Models and Predicted Shifts in Dengue Incidence

Climate change models consistently predict significant shifts in the incidence and geographic distribution of dengue fever. The rise in global temperatures, changes in precipitation patterns, and increased frequency of extreme weather events contribute to the expansion of dengue into new regions and the intensification of outbreaks in areas already affected. These models incorporate various climatic variables such as temperature, humidity, and precipitation to predict future dengue trends. A study examining the impact of climate change on dengue incidence in Singapore utilized a time-series seasonal analysis to identify meteorological factors contributing to dengue epidemics. The results indicated that rainfall positively correlated with dengue cases, while increased humidity had a substantial negative impact, reducing the incidence of the

disease significantly.(Islam *et al.*, 2024) This suggests that other factors, such as temperature or seasonal variations, might be influencing dengue transmission more than humidity alone. It underscores the importance of integrating weather data into dengue prevention programs to enhance public awareness and safety measures.

Similarly, another study quantified the impact of temperature on dengue spread in the Americas and Asia. The analysis revealed that historical climate change has already increased dengue incidence by 18% in these regions. Projections suggest a potential increase of 40% to 57% by mid-century under various climate scenarios, with some areas experiencing up to a 200% rise in incidence.(Childs *et al.*, 2024) This highlights the urgent need for mitigation strategies and low-emission scenarios to reduce the future dengue burden. In an urban endemic area, the influence of climatic variables on dengue fever incidence was studied over a 20-year period. The findings indicated that a 1°C increase in temperature could lead to a 90% increase in dengue incidence, emphasizing the critical role of temperature monitoring in disease prevention and control efforts.(Cruz *et al.*, 2023)

Research has also explored the potential effects of climate change on the distribution of dengue vectors. Models predict the expansion of *Aedes* mosquitoes in West and Central Africa, Southeast Asia, and potentially into Europe and the Mediterranean basin. These shifts necessitate enhanced surveillance and control measures, particularly in areas where dengue is not currently endemic but may become so due to changing climatic conditions.(Aliaga-Samanez *et al.*, 2023)

Adaptation Strategies for Dengue

Effective public health interventions and adaptation strategies are essential in mitigating the impact of dengue, particularly in the face of climate change. A comprehensive approach to dengue prevention involves community engagement, vaccination, vector control, and sustainable environmental management (Fig. 1).

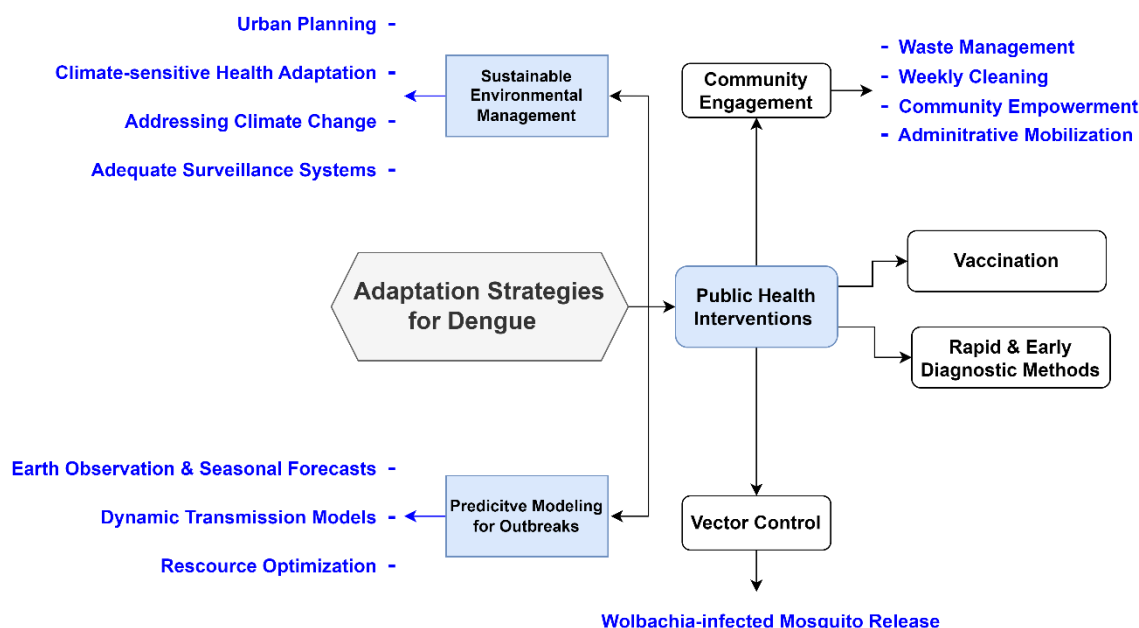


Figure 1. Schematic Diagram of different Adaptation Strategies for Dengue

One effective strategy is the Communication for Behavioural Impact (COMBI) plan, which focuses on changing community behaviors to prevent dengue. A study in Kurunegala District, Sri Lanka, developed a COMBI plan aimed at reducing dengue morbidity and mortality by improving household waste management and promoting weekly cleaning practices. The plan included community empowerment, administrative mobilization, public advocacy, and personal selling, demonstrating significant potential in enhancing dengue prevention behaviors.(Rajapaksha *et al.*, 2022)

Another multifactorial strategy involves addressing various factors driving dengue transmission, including climate change, urbanization, and inadequate surveillance systems. Mosquito vector control remains a key strategy, along with integrating multiple interventions such as rapid diagnostic methods, vaccination, and environmental management to curtail dengue transmission effectively.(Kua, 2022) Sustainable dengue prevention and management also require integrating vaccination strategies with population perspectives. The GEMKAP study identified key themes such as prioritizing dengue on national health agendas, fostering stakeholder collaboration, and incorporating population perspectives to drive behavioral change. This comprehensive approach enhances the effectiveness of dengue vaccination and overall prevention efforts.(Shafie *et al.*, 2024)

Additionally, the use of constrained optimization models helps in allocating limited resources effectively. A study in Thailand applied a dynamic transmission model to

predict dengue cases and identify the optimal combination of interventions within budget constraints. The model suggested that a balanced approach combining Wolbachia-infected mosquito release and pediatric vaccination could significantly reduce dengue incidence and disability-adjusted life years (DALYs) lost. (Knerer, Currie and Brailsford, 2021) In India, the coping strategies for dengue in Delhi emphasize urban adaptation to climate-sensitive health impacts. These strategies encompass urban planning, vector control, and community engagement to mitigate the spread of dengue. (Sahay, 2018)

Another model devised in Vietnam, combines Earth observations, seasonal climate forecasts, and historical dengue patterns to predict outbreaks up to 6 months in advance, enhancing public health planning. Its predictive accuracy, particularly in regions with regular transmission, provides an opportunity for timely interventions to curb the spread of dengue. By integrating these forecasts with disease control measures, this model offers a proactive approach to mitigating outbreaks in climate-sensitive regions. (Colón-González *et al.*, 2021)

Along with the local efforts, international collaborations to share data and strategies are vital, particularly in enhancing the capacity of countries in the Global South to respond to climate change scenarios. (Piovezan-Borges *et al.*, 2022) Sustainable practices, such as land restoration and combating deforestation, also contribute to reducing the incidence of dengue by minimizing the invasion of mosquito species. (Teillet *et al.*, 2024) By integrating public health planning with climate adaptation measures, the overall effectiveness of dengue prevention and control can be significantly improved.

Future Research Direction

Future research should prioritize understanding the long-term adaptation of *Aedes* mosquitoes to changing climatic conditions, particularly how temperature and humidity shifts influence breeding and survival. Region-specific studies are essential to capture localized impacts of climate variables, incorporating fine-grained modeling with data on weather, land use, and human mobility. Additionally, exploring the role of extreme weather events, such as floods and droughts, is crucial for understanding their effects on vector habitats and transmission dynamics. The development and evaluation of innovative, climate-resilient vector control strategies, alongside the integration of climate models with epidemiological data for real-time predictions, will enhance preparedness and response.

Conclusion

Climate change significantly influences the epidemiology of dengue fever by altering the habitats and dynamics of its primary vector, *Aedes* mosquitoes. Rising temperatures, changing precipitation patterns, and increasing extreme weather events enhance mosquito proliferation, extend transmission seasons, and expand the geographic range of dengue. The integration of climatic data into public health frameworks is crucial for developing effective adaptive strategies. Key measures include community-based vector control, vaccination programs, sustainable environmental management, and predictive modeling to anticipate outbreaks. Strengthening these efforts requires a reiteration of the urgency of addressing climate change as a pressing public health issue.



Immediate action through policy development, international collaboration, and community engagement is essential to mitigate the escalating global dengue burden. Robust public health infrastructures and a coordinated global response are indispensable in addressing this growing challenge.

Conflict of Interest:

The author declares no conflict of interest.

REFERENCE

- Abdullahi, T., Nitschke, G. and Sweijid, N. (2022) 'Predicting diarrhoea outbreaks with climate change', *PLoS One*, 17(4), p. e0262008.
- Aliaga-Samanez, A. et al. (2023) *Potential climate change effects on the distribution of urban and sylvatic dengue and yellow fever vectors*, *bioRxiv*.
- Baril, C. et al. (2023) 'The influence of weather on the population dynamics of common mosquito vector species in the Canadian Prairies', *Parasit. Vectors*, 16(1), p. 153.
- Briggs, A. (2023) 'Climate change, conflict, and contagion: Emerging threats to global public health', in *Healthcare Access - New Threats, New Approaches*. IntechOpen.
- Brown, J.J. et al. (2023) 'Humidity - The overlooked variable in the thermal biology of mosquito-borne disease', *Ecol. Lett.*, 26(7), pp. 1029–1049.
- Chandrakumara, K. et al. (2023) 'Variations in the biological and ecological attributes of insects due to climate change: A review', *Indian J. Entomol.*, pp. 1–10.
- Chikezie, F.M., Opara, K.N. and Ubulom, P.M.E. (2024) 'Impacts of changing climate on arthropod vectors and diseases transmission', *Nigerian Journal of Entomology*, 40(1), pp. 179–192.
- Childs, M.L. et al. (2024) 'Climate warming is expanding dengue burden in the Americas and Asia', *medRxiv* [Preprint].
- Colón-González, F.J. et al. (2013) 'The Effects of Weather and Climate Change on Dengue', *PLOS Neglected Tropical Diseases*, 7(11), pp. 1–9. Available at: <https://doi.org/10.1371/journal.pntd.0002503>.
- Colón-González, F.J. et al. (2021) 'Probabilistic seasonal dengue forecasting in Vietnam: A modelling study using superensembles', *PLOS Medicine*, 18(3), p. e1003542.
- Cruz, T.C. et al. (2023) *Impact of climate on the expansion of dengue fever in an endemic urban area*, *Preprints*.
- Dhiman, R.C. (2022) 'Revisiting the Impact of Temperature on Survival of *Anopheles stephensi* and *Aedes aegypti* and Implications on Extrinsic Incubation Period', *J. Commun. Dis.*, 54(1), pp. 60–66.
- Gardiner, S.M. and Tubig, P. (2023) 'Climate change, global health, and planetary health', in *Handbook of the Philosophy of Climate Change*. Cham: Springer International Publishing, pp. 799–819.
- Islam, M.T. et al. (2024) 'Impact of climate change on dengue incidence in Singapore: time-series seasonal analysis', *Int. J. Environ. Health Res.*, pp. 1–11.
- Ivanescu, L. et al. (2023) 'THE INFLUENCE OF CLIMATIC FACTORS IN THE TRANSMISSION OF VECTOR BORNE DISEASES', *Scientific Papers Journal VETERINARY SERIES*, 66, pp. 86–93. Available at: <https://doi.org/10.61900/SPJVS.2023.03.18>.
- Jayaraj, A.M.V. and Ibrahim, A.F.A. (2023) 'Climate Change and Health', *Haya Saudi J. Life Sci.*, 8(05), pp. 58–60.
- Khan, A. et al. (2023) 'Vector-borne disease and climate change', in *Arthropods - New Advances and Perspectives*. IntechOpen.
- Khanam, A. et al. (2022) 'Immune-mediated pathogenesis in dengue virus infection', *Viruses*, 14(11), p. 2575.
- Kiryluk, H.D., Beard, C.B. and Holcomb, K.M. (2024) 'The use of environmental data in descriptive and predictive models of vector-borne disease in North America', *J. Med. Entomol.*, 61(3), pp. 595–602.



- Knerer, G., Currie, C.S.M. and Brailsford, S.C. (2021) 'Reducing dengue fever cases at the lowest budget: a constrained optimization approach applied to Thailand', *BMC Public Health*, 21(1), p. 807.
- Kraemer, M.U.G. *et al.* (2015) 'The global distribution of the arbovirus vectors *Aedes aegypti* and *Ae. albopictus*.', *eLife*, 4, p. e08347. Available at: <https://doi.org/10.7554/eLife.08347>.
- Kua, K.P. (2022) 'A multifactorial strategy for dengue prevention and control: A public health situation analysis', *Trop. Doct.*, 52(2), pp. 367–371.
- Kumar, D.V.N. *et al.* (2024) 'Impact of climate change on vector borne diseases and public health: A review', *UTTAR PRADESH JOURNAL OF ZOOLOGY*, 45(1), pp. 18–26.
- L. Ostergard, R. and Seltzer, N. (2023) 'Climate change, global health, and international security', in *Handbook on Climate Change and International Security*. Edward Elgar Publishing, pp. 257–275.
- Mordecai, E.A. *et al.* (2019) 'Thermal biology of mosquito-borne disease', *Ecology Letters*, 22(10), pp. 1690–1708. Available at: <https://doi.org/https://doi.org/10.1111/ele.13335>.
- Naish, S. *et al.* (2014) 'Climate change and dengue: a critical and systematic review of quantitative modelling approaches', *BMC Infectious Diseases*, 14(1), p. 167. Available at: <https://doi.org/10.1186/1471-2334-14-167>.
- Oliveira, T.E.S. de and Muis, C.R. De (2014) 'Análise da flutuação das populações de *Aedes aegypti* e *Aedes albopictus* em uma escola de Cuiabá-MT', *Rev. Eletrônica em Gest. Educ. Tecnol. Ambient.*, 18(1).
- Piovezan-Borges, A.C. *et al.* (2022) 'Global trends in research on the effects of climate change on *Aedes aegypti*: international collaboration has increased, but some critical countries lag behind', *Parasites & Vectors*, 15(1), p. 346. Available at: <https://doi.org/10.1186/s13071-022-05473-7>.
- Rajapaksha, R.M.N.U. *et al.* (2022) *Development of a complex intervention package for dengue prevention*, *bioRxiv*.
- Sahay, S. (2018) 'Urban adaptation to climate sensitive health effect: Evaluation of coping strategies for dengue in Delhi, India', *Sustain. Cities Soc.*, 37, pp. 178–188.
- Shafie, A.A. *et al.* (2024) 'Sustainable dengue prevention and management: Integrating dengue vaccination strategies with population perspectives', *Vaccines (Basel)*, 12(2), p. 184.
- Teillet, C. *et al.* (2024) 'Exploring fine-scale urban landscapes using satellite data to predict the distribution of *Aedes* mosquito breeding sites', *International Journal of Health Geographics*, 23(1), p. 18. Available at: <https://doi.org/10.1186/s12942-024-00378-3>.
- Wong, J.M. *et al.* (2022) 'Dengue: A growing problem with new interventions', *Pediatrics*, 149(6).
- Zerfu, B., Kassa, T. and Legesse, M. (2023) 'Epidemiology, biology, pathogenesis, clinical manifestations, and diagnosis of dengue virus infection, and its trend in Ethiopia: a comprehensive literature review', *Trop. Med. Health*, 51(1), p. 11.