Climate Change and Vector-Borne Diseases: Understanding the Ecology and Modeling the Spread of Dengue Fever

Kashif Ali[1,*], Maham Saleem[1], Muhammad Farhan Nasir[1], Sadaqat Ali[2], Hibba Rasheed[1], Ayesha Abeer[1], Arifa Riaz[1], Amna Batool[1], Mariam Maqsood[1] and Muhammad Asif[1]

[1]Division of Science and Technology, Department of Zoology, University of Education, Lahore, Pakistan
[2]Institute of Applied Sciences, Zoology Division, Bahaduddin Zakariya University, Multan, Pakistan
*Corresponding author: kashif.ali@ue.edu.pk

Abstract

Dengue is caused by Retrovirus and known to be one of the most dangerous diseases, transmitted via mosquito bite. Annually more than a hundred nations are affected due to dengue virus. Within past few years, dengue has become a global issue. Dengue fever a vector borne diseases is highly impacted by climate change. This chapter highlight the *Adese* ecology changes due to increased temperature, severe weather changes and rainfall patterns. With more suitable breeding grounds there is a risk of spreading of dengue in areas non endemic. Advance techniques are being used to prevent dengue outbreaks. Determining areas with high risk of these outbreaks and developing a response to public health is crucial. This chapter shows importance of protecting dengue outbreak, involving communities and making public health better due to the linkage between dengue and climate. Climate awareness through one health system help preventing from dengue outbreak.

Keywords: Dengue fever, Vector borne diseases, Climate change, Aedes mosquito

Cite this Article as: Ali K, Saleem M, Nasir MF, Ali S, Rasheed H, Abeer A, Riaz A, Batool A, Maqsood M and Asif M, 2025. Climate change and vector-borne diseases: understanding the ecology and modeling the spread of dengue fever. In: Abbas RZ, Akhtar T and Arshad J (eds), One Health in a Changing World: Climate, Disease, Policy, and Innovation. Unique Scientific Publishers, Faisalabad, Pakistan, pp: 398-402. https://doi.org/10.47278/book.HH/2025.474

A Publication of Unique Scientific Publishers

Chapter No: 25-056

Received: 12-Jan-2025
Revised: 21-Apr-2025
Accepted: 15-May-2025

Introduction

Long-term change in the average weather patterns of the earth's local, regional, and global climates is called climate change. Climate change has a wide range of effects that have been observed in recent years and are expected to continue in the future as shown in figure 1. These changes are mainly due to human activities, and they are happening across all continents. Some of the main causes of climate change include the greenhouse effect, global warming, urbanization, and deforestation. As a result of these factors, we have seen a rise in temperatures, an increase in carbon dioxide (CO_2) levels, higher sea levels, and greater ocean acidity in the past. The Earth's ecosystems are changing quickly because of climate change. In this chapter, we will explain the reasons behind natural greenhouse gas emissions and discuss the roles of different groups of people in the climate change process (Naz et al., 2022).

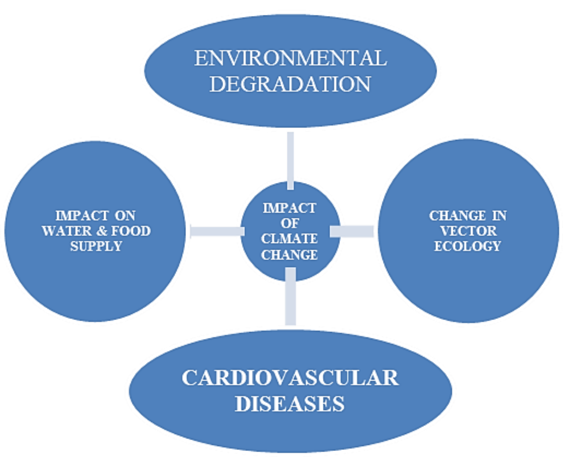

Figure 1: Impacts of Climate Change.

Vector-Borne Diseases

One of the most important global effects of climate change is likely to be on infectious diseases, especially those transmitted by insect vectors (e.g., mosquitos, ticks) that strongly depend on a specific climate for survival, population dynamics, and pathogen transmission. Vector-borne diseases significantly impact global health, and understanding how climate change affects their transmission is crucial. However, predicting the long-term risk of these diseases remains uncertain, especially with factors like urbanization, land use changes, and human movement influencing disease spread. Future models should account for these non-climatic factors. The risk of vector-borne diseases also depends on a population's vulnerability, or its ability to adapt to changes in environmental conditions suitable for disease transmission. This chapter reviews the current understanding of mosquito-borne diseases, focusing on the interplay of climatic and non-climatic factors, and highlights areas needing further research (Tozan et al., 2021).

Climate change and Dengue Transmission:

Addressing global change through sustainable development is a major challenge for society, particularly in terms of human health and infectious diseases. Pathogen, host and environment are the important component for transmission (Souza et al., 2021). Intermediate host are used to complete the life cycle and to survive weather play a vital role. Infectious diseases can be impacted by climate change, environment, host and vector. Diseases geographic range can be affected by long term warming of weather seen in previous literature which lead to outbreak at unusual time in unusual places. Moreover, Diseases pattern can be changed by climate (Wu et al., 2016).

A warming climate and increasing instability are becoming more important factors in the global rise, reappearance, and spread of infectious diseases. Many of the most common infectious diseases, especially those spread by insects, are very affected by changes in climate. We are seeing more cases of new and returning diseases that are spread by vectors (such as mosquitoes and rodents), including dengue, malaria, hantavirus, and cholera, in many parts of the world (Yu et al., 2015).

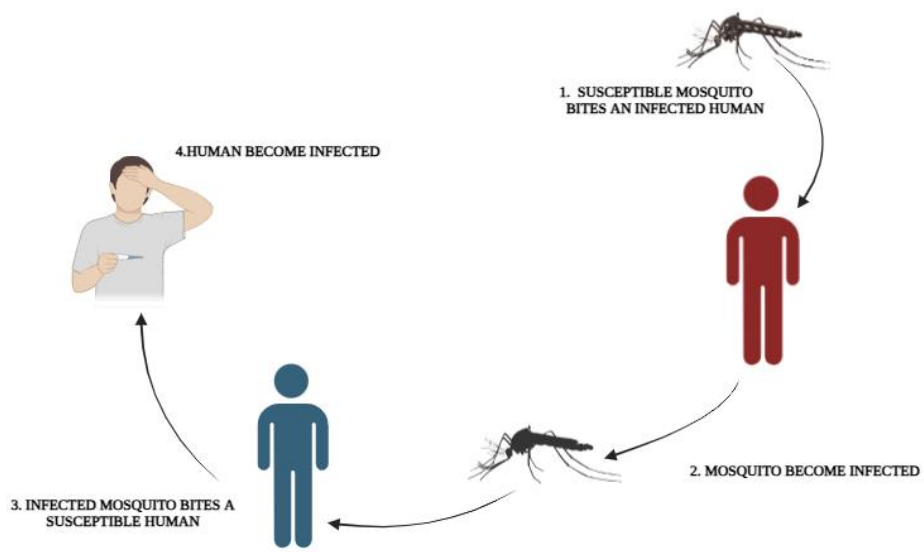

Figure 2: Dengue transmission cycle

Dengue is a sudden illness with a high fever, caused by arboviruses (viruses transmitted by insects) from the *Flaviviridae* family. The disease is spread by female *Aedes aegypti* mosquitoes. Tropical countries are most affected because of their specific environmental, climatic, and social conditions. Symptoms of dengue include a sudden high fever, severe headache, pain behind the eyes, joint and muscle pain, rash, and nausea as shown in figure 2. In some cases, it can cause severe complications like bleeding and organ damage. Climate plays a key role in determining when and where diseases like dengue fever spread. By studying climate factors, we can better understand and predict when epidemics are likely to happen, as the relationship between climate and mosquitoes is just as important as how mosquitoes interact with humans (Souza et al., 2021).

Ecological Factors Influencing Mosquito Population

Many studies have shown that climate factors and weather conditions can influence how diseases spread, even though there is still some uncertainty about the exact ways this happens. This impact can be direct, meaning that changes in the weather can directly affect how diseases are transmitted and influence the survival of pathogens. It can also be indirect, where changes in how diseases are spread occur because of how people and vectors (like mosquitoes) react to climate change. For example, Diseases transmission is determined by rainfall and temperature changes (Ogden et al., 2021).

Human activities and behaviors are influenced by climate variations. For example, it impacts on factors as migration, seasonal jobs, physical activity and winter or summer lifestyles. It also affects diseases outbreak. Immunity get weak by climate change, as diseases transmission affected people are more likely to get diseases. Moreover, ecosystem degradation cause issues like famine, malnutrition and crop failure all because of climate change. Human susceptibility to infectious diseases may be heightened by these pressures (Yadav & Upadhyay, 2023). Due to the highest minimum temperatures and total rainfall, which occur from November to March, the period with the highest number of hospital admissions for dengue fever usually occurs between January and April. Climate has an impact on dengue transmission, though its precise function is still unclear. It is essential to comprehend the role of climate since it aids in assessing the likelihood of epidemics and supports disease prevention initiatives (Rubel et al., 2021).

Precipitation and its Effect on Dengue Vector Populations

The availability of favorable climate conditions, such as temperature ranges, rainfall, and extreme weather events, has a significant impact on the rate at which viruses bite humans, their capacity to multiply, and the development and survival of vectors (disease carriers) (Mordecai et al, 2019). Last hundred years, the temperature of earth increased to 6.4 degree from 1.1. Dengue outbreaks increased due to change in ecology of virus and vector occur due to change in climate by temperature and precipitation increase (Zhu et al., 2020).

Population without protection get infection easily as these changes cause potential dengue spread. Instead of suitable temperature range for the activity of vector various previous studies discuss vector distribution with average temperature range (Messina et al.,2019). The

Suitability Climate Index (SCI) was calculated by multiplying the number of suitable months by the average monthly rainfall in each location, which included 8,980 administrative areas. Rainfall was included because previous studies have shown that it is necessary for vector proliferation (Fouque & Reeder, 2019). Although information on temperature and precipitation was unavailable for this study, these factors have a significant impact on dengue's spread and vector proliferation (Fouque & Reeder, 2019). Additional factors like sun, wind speed, and humidity radiation might be a serious problem. Future research may incorporate these variables to enhance prediction models. Non-climatic factors like urbanization, human behavior, micro-climates, water storage, and public health campaigns also have a significant influence on dengue transmission (Fouque & Reeder, 2019).

Modelling the Spread of Dengue Fever in a Changing Climate

Dengue, recognized as the most dangerous virus disease that humans can get from mosquitoes, is caused by retroviruses of four distinct stereotypes (Fundacao, 2024). Particularly in regions where dengue is prevalent, like many tropical and subtropical countries worldwide, its symptoms may at times mimic those of other illnesses, like COVID-19, making diagnosis more challenging (Camila et al. 2020). Over time, dengue has become much more common throughout the world, and its geographic range of transmission has expanded as well (Suha et al., 2023). Epidemics of the disease occur every three to five years throughout the Americas, following a cyclical pattern (Tiago et al, 2018). Efforts to limit or decrease the ongoing spread of dengue have been hampered by the lack of a significant reduction in vector density, despite large investments in monitoring and prevention measures, which involves more than half a billion dollars on an annual basis for mosquito control (Mauricio et al., 2011).

The intricate relationship between climate variability and the emergence of diseases like dengue fever, malaria, chikungunya, and Zika has been examined in recent research. The primary vectors of dengue fever, a virus caused by a flavivirus, are Aedes mosquitoes, particularly *Aedes aegypti*. This disease, which is now common in more than 100 countries, is growing in public health concern, especially in tropical and subtropical areas where *Aedes aegypti* is common. Dengue cases have increased dramatically in recent decades, and its geographic range has expanded due to factors such as urbanization, globalization, increased travel, inadequate vector management, and climate change (Manisha et al., 2022).

Dengue fever is transmitted in many ways by extreme weather conditions. Water which is stored after drought provide mosquito with habitats that are good for breeding (Rachel et al., 2021). Adittionally, water from rain store in containers and pots help mosquito in growth (Azael et al., 2021).

Global Distribution of Patterns of Dengue Fever

Dengue is a viral infection cause by mosquito. Few year ago dengue was not common but recently its spread across globe. In five years from 2010 to 2015 cases of dengue increased from 2.2 million to 3.2 million which is a dramatic increase. In late 90's only nine countries had the risk of dengue, bow a day almost 128 countries are facing this issue. Including US and UK the diseases in prevalent in 100 plus nations. WHO recorded around lack dengue cases each year with almost 22000 deaths. The areas most impacted include the Western Pacific, Southeast Asia, and the Americas. There have also been significant outbreaks in nations including China, Pakistan, Saudi Arabia, Japan, Yemen, Taiwan, Malaysia, Brazil, and Mexico (Heydari et al., 2018). Dengue fever, a virus spread by mosquitoes, is becoming a bigger worldwide health issue, especially in tropical and subtropical areas (Halstead, 2019).

All of the World Health Organization's (WHO) regions have seen an increase in cases in recent years, with Africa seeing the biggest increase. Africa only contributed 0.5% of the world's dengue cases in 2010 (Bhatt et al., 2013), however this percentage has been rising over time. In many African countries, the illness is now prevalent or epidemic, particularly in coastal and metropolitan areas. Senegal and Nigeria in West Africa, as well as East African nations including Tanzania, Kenya, and Mozambique, have recorded outbreaks. In temperate locations, isolated instances have also been found (Gainor et al., 2022). In addition to spreading Zika, chikungunya, and yellow fever, female Aedes mosquitoes—specifically, *Aedes aegypti* and *Aedes albopictus*—are the primary vectors of dengue. Its prevalence in tropical areas is greatly influenced by variables including temperature, rainfall, and urbanization. It is thought that around 800 years ago, the virus spread from monkeys to humans, and that humans are now crucial to sustaining its cycle of transmission by infecting mosquitoes that have not yet been exposed (Halstead, 2019).

Skin rashes, joint and muscle discomfort, headaches, and a high fever are all signs of dengue fever, which is comparable to a severe case of the flu. Dengue hemorrhagic fever (DHF) or severe dengue can cause hospitalization and even death, although though the condition is seldom lethal (Gainor et al., 2022). Dengue has no known cure, however the risk of mortality can be considerably decreased with early detection and appropriate medical treatment. Although exposure to one serotype of dengue confers immunity to that particular kind, it raises the risk of developing severe disease when infected with other serotypes later on. According to Kamgang et al. (2019), mosquito population management is still the most effective method of preventing dengue. Despite Africa's long-standing low dengue risk, recent outbreaks and environmental changes underscore the pressing need for preventative and control measures (Kamgang et al., 2019).

Predictive Models for Dengue Epidemics and Climate Variability

A serious public health issue that impacts millions of people globally is dengue fever. According to the World Health Organization (WHO), dengue affects more than 100 nations and is thought to cause 390 million infections a year. If treatment is not done on time the symptoms of diseases cause severe hemorrhagic fever which may be fatal. *Aedes* mosquito with infection cause spread of diseases with bite (WHO, 2023). The efficient and quicker treatment and prevention from outbreak is done by one health system by integrate climate awareness. Social variable influences the outbreak of diseases (Cataldo et al., 2023). Dengue is proved as an economic burden with ten thousand casualties every year and a hundred million cases with symptoms (Semenza et al., 2022). In America and Asia dengue is commonly found and majorly effect children under age 15. With increased occurrence of dengue, the difficulty in managing and controlling it leads to use of one health as a tactic to reduce diseases breakout (Yang et al., 2021). Human activities leads to climate change such as extreme weather and increased temperature (Muruganandam et al., 2023). Diseases which spread across animal known as zoonotic diseases are highly impacted by these changes (Nicoletti et al., 2020). Deforestation, fossil fuel burning and industrial activities leads to climate changes which cause global weather change (Turner et al., 2020).

These changes include change in pattern of rain fall, extreme weather condition and increased temperature (Hosseinzadehtalaei et al., 2020). Human beings and nature suffer with extreme issues which have effect on biodiversity, health of human and stability of ecosystem (Shroff et al., 2020).

Public Health Measures to Combat Dengue Transmission Due to Climate Change

One health technique is implemented by government of Punjab to reduce the outbreak of dengue fever (Akram et al., 2022). IVM include destruction of breeding ground, use of pesticide and public awarness campaign is important technique used in Punjab against dengue (Azhar et al., 2020). In Punjab reaction and survillance system is used to check the outbreak and seriousness of dengue (Khatri et al., 2022).

The HBM also known as health believe model often helps to clarify decision-making processes between healthcare workers' regarding different health behaviors, such as screening and immunization. Research based on the HBM framework has make it clear that healthcare workers are interested to accept vaccines (Chen et al., 2019; De Waure et al., 2022). Healthcare professionals play a important role in increasing healthcare delivery by enhancing knowledge, motivation, and the ability to maintain well-being (Aini, 2021; Md. Halimuzzaman et al., 2024; Faris et al., 2024; Zulfa et al., 2024).

In the 1950s, to acknowledge the widespread lack of participation in illness prevention and detection programs, social psychologists at the U.S. Public Health Service developed the Health Belief Model (HBM). The HBM has particularly participated to behavioral research, significantly in the fields of disease prevention, sick role behaviors, health education interventions, and health-related activities. Its key objective is to explain and predict individuals' health beliefs and the link between these beliefs and their behaviors. Theoretical frameworks that examine health beliefs and risk perception are essential for understanding the components that motivate or degrade people from engaging in health-related activities, ultimately influencing their decision-making (Chen et al., 2019; Shmueli, 2021).

Future Research and Predictions on Dengue

The dengue virus remains an immense public health issue that has created extensive research globally. This study provides a comprehensive overview of international research efforts on dengue by employing bibliometric and scientometric methods. 18,607 papers published between 1872 and 2019 were thoroughly evaluated using data from the Web of Science (WoS) and Scopus databases, by using advanced tools such as Mendeley, Biblioshiny, and VoS-viewer. The Auto Regressive Integrated Moving Average (ARIMA) model was applied to forecast future trends and tracking the holistic growth of publications. The study also highlights key parts of activity by giving all attention on the geographic distribution of research. Moreover, the research examine the networks involved in this area of study. Researchers' collaborations were thoroughly evaluated, highlighting significant contributions from institutions such as the Mahidol University, the University of Malaya, and National University of Singapore, with443, 505 and 1,070 publications, respectively. Additionally, the research made it clear that the top 15 papers have an average of 1,213 citations, underscoring the substantial effect of these works. Multi-authorship is prevalent, with closely one-fifth of the publications involving nine or more authors, which is a worthy finding. The study also elaborates the strong connections between authors and institutions, as demonstrated in co-authorship patterns. This comprehensive summary offers valuable views into the growth and current state of global dengue virus research, providing a base for future investigations (Arshed et al., 2023).

Conclusion

For protection of public health its crucial to have knowledge of environment changes and how it effect behaviors of mosquito and its transmission. Instability and major increase in temperature are important factor in spreading infectious diseases. The complex interplay between climate change and dengue fever underscores the urgent need for integrated, interdisciplinary approaches to public health. These environmental changes, compounded by socioeconomic vulnerabilities and limited healthcare resources, present significant challenges for disease prevention and control. Rising global temperatures, erratic rainfall patterns, and increasing urbanization create ideal conditions for *Aedes* mosquitoes to thrive, expanding the geographic and temporal reach of dengue transmission. Dengue outbreaks can be predicted and responded by understanding data modeling, ecology and climate change. One health system, community's involvement and public awareness is crucial for prevention of dengue fever.

References

Aini, M., & Aini, Q. (2024). Bibliometric analysis of the Health Belief Model in healthcare workers: Trends, insights, and future directions. *Journal of Angiotherapy, 8*(5), 1–12.

Aini, Q. (2021). Detecting nurse's personality models with DISC. *Bali Medical Journal, 10*(3 Special Issue), 1038–1041. https://doi.org/10.15562/bmj.v10i3.2819

Akram, M. I., Akram, W., Qayyoum, M. A., Rana, A. A., Yasin, M., & Saddiq, B. (2023). Vector indices and metrological factors associated with dengue fever outbreak in Punjab, Pakistan. *Environment, Development and Sustainability*, *25*(9), 9839-9850.

Arshad, M., Qamar, A. M., Missen, M. M. S., Lodhi, A. A., & Prasath, V. B. S. (2023). Global trends and collaborations in dengue virus research: A scientometric and bibliometric overview (1872–2019). *International Journal of Design & Nature and Ecodynamics*, *18*(6), 1539-1548.

Azhar, H., & Khan, A. (2020). Resistance to insecticides and synergism by enzyme inhibitors in *Aedes albopictus* from Punjab, Pakistan. *Scientific Reports*, 10, 1–8.

Barcellos, C., & Lowe, R. (2014). Expansion of the dengue transmission area in Brazil: The role of climate and cities. *Tropical Medicine & International Health, 19*(2), 159–168. https://doi.org/10.1111/tmi.12227

Bhatia, S., Bansal, D., Patil, S., Pandya, S., Ilyas, Q. M., & Imran, S. (2022). A retrospective study of climate change affecting dengue: Evidences, challenges and future directions. *Frontiers in Public Health, 10*, 884645. https://doi.org/10.3389/fpubh.2022.884645

Bhatt, S., Gething, P. W., Brady, O. J., Messina, J. P., Farlow, A. W., Moyes, C. L., ... & Hay, S. I. (2013). The global distribution and burden of dengue. *Nature*, *496*(7446), 504-507.

Cataldo, C., Bellenghi, M., Masella, R., & Busani, L. (2023). One Health challenges and actions: Integration of gender considerations to reduce risks at the human-animal-environmental interface. *One Health*, *16*, 100530.

Chen, I. H., Hsu, S. M., Wu, J. S. J., Wang, Y. T., Lin, Y. K., Chung, M. H., ... & Miao, N. F. (2019). Determinants of nurses' willingness to receive vaccines: Application of the health belief model. *Journal of Clinical Nursing*, *28*(19-20), 3430-3440.

De Waure, C., Shakeel, S., Martin, P., Agyekum, W., & Sertsu, A. (2022). Acceptance of COVID-19 vaccine and associated factors among health care workers at public hospitals in Eastern Ethiopia using the health belief model.

Fouque, F., & Reeder, J. C. (2019). Impact of past and on-going changes on climate and weather on vector-borne diseases transmission: A look at the evidence. *Infectious Diseases of Poverty, 8*(1), 51. https://doi.org/10.1186/s40249-019-0565-1

Gainor, E. M., Harris, E., & LaBeaud, A. D. (2022). Uncovering the burden of dengue in Africa: Considerations on magnitude, misdiagnosis, and ancestry. *Viruses, 14*(2), 233. https://doi.org/10.3390/v14020233

Halstead, S. (2019). Recent advances in understanding dengue. *F1000Research, 8*. https://doi.org/10.12688/f1000research.19197.1

Heydari, M., Metanat, M., Rouzbeh-Far, M. A., Tabatabaei, S. M., Rakhshani, M., Sepehri-Rad, N., & Keshtkar-Jahromi, M. (2018). Dengue fever as an emerging infection in southeast Iran. *The American Journal of Tropical Medicine and Hygiene*, *98*(5), 1469.

Hosseinzadehtalaei, P., Tabari, H., & Willems, P. (2020). Climate change impact on short-duration extreme precipitation and intensity–duration–frequency curves over Europe. *Journal of Hydrology, 590*, 125249. https://doi.org/10.1016/j.jhydrol.2020.125249

Intergovernmental Panel on Climate Change (IPCC). (2013). *Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://www.ipcc.ch/report/ar5/wg1/

Kamgang, B., Vazeille, M., Tedjou, A. N., Wilson-Bahun, T. A., Yougang, A. P., Mousson, L., ... & Failloux, A. B. (2019). Risk of dengue in Central Africa: Vector competence studies with Aedes aegypti and Aedes albopictus (Diptera: Culicidae) populations and dengue 2 virus. *PLoS neglected tropical diseases*, *13*(12), e0007985.

Khatri, G., Hasan, M. M., Shaikh, S., Mir, S. L., Sahito, A. M., Priya, ... & Elmahi, O. K. O. (2022). The simultaneous crises of dengue and COVID-19 in Pakistan: a double hazard for the country's debilitated healthcare system. *Tropical Medicine and Health*, *50*(1), 18.

Kulkarni, M. A., Duguay, C., & Ost, K. (2022). Charting the evidence for climate change impacts on the global spread of malaria and dengue and adaptive responses: A scoping review of reviews. *Globalization and Health, 18*(1), 1. https://doi.org/10.1186/s12992-021-00793-2

Lowe, R., Lee, S. A., O'Reilly, K. M., Brady, O. J., Bastos, L., Carrasco-Escobar, G., ... & Gasparrini, A. (2021). Combined effects of hydrometeorological hazards and urbanisation on dengue risk in Brazil: a spatiotemporal modelling study. *The Lancet Planetary Health*, *5*(4), e209-e219.

Messina, J. P., Brady, O. J., Golding, N., Kraemer, M. U., Wint, G. W., Ray, S. E., ... & Hay, S. I. (2019). The current and future global distribution and population at risk of dengue. *Nature microbiology*, *4*(9), 1508-1515.

Mordecai, E. A., Caldwell, J. M., Grossman, M. K., Lippi, C. A., Johnson, L. R., Neira, M., ... & Villena, O. (2019). Thermal biology of mosquito-borne disease. *Ecology letters*, *22*(10), 1690-1708.

Muruganandam, M., Rajamanickam, S., Sivarethinamohan, S., Gaddam, M. K. R., Velusamy, P., Gomathi, R., ... & Muniasamy, S. K. (2023). Impact of climate change and anthropogenic activities on aquatic ecosystem–A review. *Environmental Research*, *238*, 117233.

Naz, S., Fatima, Z., Iqbal, P., Khan, A., Zakir, I., Ullah, H., ... & Ahmad, S. (2022). An introduction to climate change phenomenon. *Building climate resilience in agriculture: theory, practice and future perspective*, 3-16.

Nicoletti, P. L. (2020). Relationship between animal and human disease. In *Brucellosis* (pp. 41–51). CRC Press.

Ogden, N. H., Beard, C. B., Ginsberg, H. S., & Tsao, J. I. (2021). Possible effects of climate change on ixodid ticks and the pathogens they transmit: Predictions and observations. *Journal of Medical Entomology, 58*(4), 1536–1545.

Rubel, M., Anwar, C., Irfanuddin, I., Irsan, C., Amin, R., & Ghiffari, A. (2021). Impact of climate variability and incidence on dengue hemorrhagic fever in Palembang City, South Sumatra, Indonesia. *Open Access Macedonian Journal of Medical Sciences*, *9*(E), 952-958.

Semenza, J. C., Rocklöv, J., & Ebi, K. L. (2022). Climate change and cascading risks from infectious disease. *Infectious diseases and therapy*, *11*(4), 1371-1390.

Shmueli, L. (2021). Predicting intention to receive COVID-19 vaccine among the general population using the Health Belief Model and the Theory of Planned Behavior model. *BMC Public Health, 21*, 804. https://doi.org/10.1186/s12889-021-10816-7

Souza, A. D., Abreu, M. C., & Oliveira-Júnior, J. F. (2021). Impact of climate change on human infectious diseases: Dengue. *Brazilian Archives of Biology and Technology, 64*, e21190502.

Tozan, Y., Branch, O. L. H., & Rocklöv, J. (2021). Vector-borne diseases in a changing climate and world. In *Climate Change and Global Public Health* (pp. 253–271). Springer.

Turner, M. G., Calder, W. J., Cumming, G. S., Hughes, T. P., Jentsch, A., LaDeau, S. L., ... & Carpenter, S. R. (2020). Climate change, ecosystems and abrupt change: science priorities. *Philosophical Transactions of the Royal Society B*, *375*(1794), 20190105.

World Health Organization. (2023). *Dengue and severe dengue*. https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue

Wu, X., Tian, H., Zhou, S., Chen, L., & Xu, B. (2016). Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. *Environment International, 86*, 14–23.

Yang, X., Quam, M. B., Zhang, T., & Sang, S. (2021). Global burden for dengue and the evolving pattern in the past 30 years. *Journal of Travel Medicine*, *28*(8), taab146.

Yu, C. Y., Liang, J. J., Li, J. K., Lee, Y. L., Chang, B. L., Su, C. I., ... & Lin, Y. L. (2015). Dengue virus impairs mitochondrial fusion by cleaving mitofusins. *PLoS Pathogens*, *11*(12), e1005350.