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Climate Change and the Rising Risk of Epidemic Virus Transmission

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Abstract:

Climate change has increasingly altered global ecological systems, influencing the dynamics of infectious diseases. Rising temperatures, changing precipitation patterns, and the expansion of suitable habitats for vectors create favorable conditions for viral transmission. This review examines the upward trend of epidemic viral spread in the context of climate change, with a focus on vector-borne and respiratory viruses. Drawing on recent epidemiological data and climate models, the study analyzes the correlation between environmental shifts and viral outbreaks.Our findings indicate that warming temperatures accelerate the geographic expansion of arboviruses such as dengue, Zika, and chikungunya, while altered rainfall patterns foster mosquito breeding cycles. Moreover, extreme weather events disrupt healthcare infrastructure and increase population displacement, facilitating respiratory virus transmission such as influenza and coronaviruses. The convergence of climate-driven ecological changes and global mobility amplifies the risk of cross-border viral epidemics. These findings underscore an urgent imperative: efforts to address climate change cannot be separated from strategies for infectious disease preparedness. Surveillance systems must be reinforced and designed to detect early signals of climate-sensitive outbreaks, while stronger intersectoral collaboration can bridge gaps between environmental science, epidemiology, and health policy. Integrating climate-informed frameworks into public health decision-making offers a pathway to reduce the growing burden of viral diseases shaped by environmental change.

Keywords: Climate change; Epidemic viruses; Vector-borne diseases; Global health; Infectious disease surveillance.

1. Introduction

Climate change is increasingly recognized as one of the most pressing threats to global health in the 21st century. Unlike other environmental drivers such as rapid urbanization or land-use change, its influence extends across scales, reshaping ecosystems and disease dynamics at both local and global levels [1]. While heat-related morbidity and mortality represent its most visible direct consequences, the indirect pathways are no less critical. Rising global temperatures, altered precipitation regimes, and the intensification of extreme weather events have collectively transformed ecological niches and heightened human vulnerability to a wide spectrum of infectious diseases [2]. According to the Intergovernmental Panel on Climate Change [3], the past decade alone has witnessed unprecedented warming, with global surface temperatures now about 1.1 °C higher than pre-industrial baselines. Projections indicate that a 1.5 °C threshold could be surpassed within the next two decades, a scenario expected to accelerate ecological disruption and amplify the risks of vector-borne and zoonotic disease emergence.

Viral germs are very sensitive to changes in the environment. Dengue, Zika, chikungunya, influenza, and coronaviruses all react to shifts in temperature, rain, and humidity. These factors affect how they copy, how long they live, and how they spread [1]. The health effects, however, are not the same everywhere. People in poorer countries face higher risks. They are more exposed to dangers in the environment, and their health systems are often too weak to respond well. This raises an urgent question: how does climate change change the way viruses spread, and how can health systems prepare for these risks? Answering this is key to protecting vulnerable groups and to keeping global health safe.

One clear example comes from how viruses spread through insects. Mosquitoes and ticks are very sensitive to heat. Warmer weather gives them longer breeding seasons and lets them spread to new areas. In North America, the spread of West Nile virus has been linked to warmer conditions that helped mosquitoes survive and pass on the virus. In the same way, Aedes mosquitoes, which carry dengue, chikungunya, and Zika, have moved into places where they did not live before as the climate has changed [4]. These cases show that climate affects more than the insects themselves. It also shapes where and when outbreaks happen, showing the close link between the environment and the rise of disease. Climate change also affects animals that can carry viruses. Shifts in weather force animals to move and change their habitats. This increases the chance that people meet new wild hosts. As a result, the risk of viruses jumping from animals to humans becomes higher.

Frequency of outbreaks and spatial dynamics: Extreme weather events such as floods and droughts can damage sanitation infrastructure and trigger population movements, providing conditions for virus outbreaks. For instance, floods have been associated with outbreaks of water-borne diseases like cholera. Meanwhile, globally, due to unfavorable climatic conditions, the annual frequency of outbreaks of diseases transmitted through media has also significantly increased [1].

Summary and Trends of Comprehensive Research: A systematic review in 2023 summarized the research trends regarding the relationship between climate change and infectious diseases, indicating that many existing studies rely on simulation models, but empirical data is still insufficient. Furthermore, the meta-analysis shows that more than half (58%) of the people have been affected by infectious diseases due to the exacerbated impact of climate change [5].

Although there have been numerous studies focusing on the impact of climate change on virus transmission, there is still a lack of a unified and systematic summary, especially in terms of transmission routes, geographical distribution of hosts, and changes in outbreak frequency. Therefore, this review aims to systematically summarize the following aspects under the background of climate change: Virus transmission routes (such as the expansion of transmission media, cross-species transmission mechanisms); Host-vector distribution (including geographical expansion and seasonal variations); Epidemic frequency and spatial pattern (extreme weather and virus fluctuation patterns).

2. Impacts of Climate Change on Viral Transmission

2.1 The impact of temperature increases on the replication speed and activity of pathogens

Temperature represents one of the most influential environmental factors shaping viral ecology and transmission dynamics. Warmer conditions often accelerate viral replication, thereby increasing both transmissibility and persistence in vectors as well as in hosts. Evidence from dengue research is particularly illustrative: the extrinsic incubation period (EIP) of dengue virus within Aedes aegypti mosquitoes shortens markedly as ambient temperatures rise, resulting in earlier onset of infectiousness and a higher overall transmission potential [6]. Similar patterns have been observed for West Nile virus and chikungunya virus, whose replication efficiencies increase under ele-

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vated temperatures, ultimately extending their seasonal activity and broadening their geographic range [7]. Yet this acceleration does not follow a simple linear trajectory. Extreme heat can impair mosquito survival, which in turn reduces the likelihood of successful transmission, pointing to a more complex and non-linear relationship between climate warming and viral spread. Nonetheless, the net effect of gradual temperature rise under climate change scenarios is the enhancement of viral spread, particularly in temperate regions that were previously unsuitable for vector-borne diseases. This indicates that temperature rise is not a linear driver but interacts with multiple ecological processes to shape viral risk.

2.2 Changes in precipitation patterns and expansion of vector habitats

Changes in rainfall patterns directly affect the habitat breedings of mosquito vectors, thereby influencing viral transmission. Increased precipitation creates standing water, an ideal breeding ground for Aedes and Anopheles mosquitoes, both of which are vectors for arboviruses such as dengue, Zika, and Rift Valley fever [8]. Conversely, droughts may also paradoxically increase transmission risks, as human populations store water in containers, which can become breeding sites for mosquitoes. For instance, Outbreaks of Rift Valley fever in East Africa have been closely linked with heavy rainfall events associated with El Niño. The expansion of vector habitats due to altered precipitation patterns suggests that arboviruses could spread into areas where local populations have low immunity and weak health infrastructure, increasing epidemic potential. Thus, precipitation change emerges as a dual driver—both intensifying and paradoxically mitigating vector-borne transmission under different contexts.

2.3 Climate extreme events promote cross-regional virus import

Extreme climate events such as floods, hurricanes, and wildfires disrupt ecosystems and public health systems, leading to increased risk of cross-regional viral spread. Flooding events often destroy sanitation infrastructure and displace populations, creating conditions conducive to outbreaks of enteric and vector-borne viruses, including hepatitis A, noroviruses, and dengue [9]. Hurricanes and cyclones break human settlements and often push people to move in large numbers. These moves can bring arboviruses into new places that had no cases before. This shows how sudden environmental shocks can quickly change the spread of disease. Rising sea levels and storm surges make things more complex because they change the routes of migratory birds. Many of these birds carry viruses such as avian flu and West Nile virus. Even small shifts in their paths can spread viruses across continents [10]. All these changes show that extreme weather is not only a natural hazard. It can also act as a driver that helps new viral outbreaks appear, spread, and grow in new settings.

2.4 Environmental stress induces reorganization of host-pathogen relationships

Environmental stressors resulting from climate change also disrupt host-pathogen interactions, increasing the likelihood of zoonotic spillover. As habitats shift due to warming temperatures and deforestation, wildlife species are forced into contact with human populations, enhancing opportunities for viral transmission [11]. For example, bat species—reservoirs for coronaviruses, Nipah virus, and Ebola virus—have exhibited changes in migration and feeding patterns under altered climatic conditions, increasing their interactions closer with domestic animals and humans. [12]. Such spillover dynamics are further exacerbated by biodiversity loss, which reduces the “dilution effect” of ecosystems and concentrates pathogen transmission in fewer host species [9]. Consequently, climate-driven ecological stressors heighten the probability of novel viruses emerging in human populations, raising the threat of future pandemics.

3. Typical Virus Case Analysis: Risk Trends and Mechanism Review

3.1 Influenza

Influenza virus is one of the respiratory viruses most closely related to climate change. Its transmission patterns and epidemic intensity are significantly influenced by environmental factors such as temperature, humidity, and host migration.

Firstly, seasonal influenza spreads more efficiently in cold and dry winter climates. Studies have shown that low temperatures and low humidity not only enhance the stability of the virus in the air but also promote the long-term suspension of virus particles in aerosols, thereby increasing the risk of human infection [13]. Additionally, the rapid development of air transportation in the context of globalization enables the influenza virus to spread across continents in a very short time. Coupled with the promotion of human mobility by abnormal climate events, the risk of cross-border and cross-regional outbreaks has significantly increased [14]. Another important trend is the global spread of avian influenza. Migratory birds are the natural hosts of highly pathogenic avian influenza (HPAI), such as H5N1 and H5N8. Climate warming and wetland degradation are altering the migration patterns and habitat distribution of migratory birds, significantly increasing the risk of virus introduction and transmission in new areas [14].

At the mechanism level, climate change mainly drives influenza transmission through alterations in environmental conditions and host ecology. Experimental studies have found that low temperatures and dry air can increase the survival rate and infectivity of influenza viruses in aerosols, explaining the high incidence of influenza in winter in temperate regions [15]. At the same time, climate change disturbances to the habitats of wild birds (such as earlier migration of migratory birds due to warming in the Arctic) can break the previous species isolation, increasing the opportunities for cross-regional and cross-host transmission of avian influenza viruses [16, 17]. This mechanism not only threatens the poultry industry but also poses a potential risk of a new influenza pandemic for humans.

3.2 Monkeypox Virus

Monkeypox is a zoonotic disease caused by the monkeypox virus (MPXV), which has long been prevalent in Central and West Africa. However, since 2022, large-scale outbreaks have occurred in non-endemic regions such as Europe, the Americas, and Asia, indicating a significant increase in its cross-regional transmission potential [18, 19]. Climate change and ecosystem disturbances are considered important background factors driving this trend. Deforestation in tropical forests, coupled with progressive climate warming, has broadened the activity ranges and migration patterns of wild primates and rodents, thereby heightening the probability of human encounters with potential reservoir hosts [20]. In densely populated urban environments, the urban heat island effect further amplifies this risk by creating conditions that facilitate sustained human-to-human transmission.

The transmission dynamics of the monkeypox virus are closely intertwined with environmental change and host ecology. As forest habitats shrink, displaced wildlife increasingly infiltrates human settlements, intensifying the likelihood of cross-species spillover [21]. Climate-driven anomalies in precipitation and temperature further complicate this picture, influencing the distribution of animal hosts and destabilizing viral ecological equilibria. Such environmental perturbations increase the probability of localized outbreaks, while global mobility accelerates their spread beyond endemic boundaries. With the rising frequency of cross-border travel and trade, monkeypox can no longer be regarded solely as a geographically contained zoonotic disease; it now demonstrates a clear capacity for global transmission [22, 23].

3.3 Dengue Virus

Dengue fever is one of the most significant mosquito-borne viral diseases worldwide, causing approximately 400 million infections each year. Climate change is driving the global spread of dengue fever. Rising temperatures shorten the incubation period of the dengue virus in Aedes mosquitoes and enhance the transmission efficiency [24]. At the same time, changes in precipitation patterns alter the breeding environment of Aedes mosquitoes by increasing or reducing water containers. Recent studies have shown that climate warming is promoting the expansion of Aedes mosquito distribution to southern Europe, parts of North America, and high-altitude regions, exposing new susceptible populations [25].

Mechanism Analysis

Dengue transmission is regulated by climatic factors. High temperatures not only accelerate the replication speed of the virus in mosquitoes but also extend the mosquito's active season [23]. Heavy rainfall or flood events often lead to an increase in water accumulation, expanding mosquito breeding grounds; while during drought periods, human water storage behaviors can indirectly create suitable breeding environments [22]. These mechanisms indicate that climate change amplifies the potential for dengue fever through complex ecological pathways.

3.4 Risk Trends of the Novel Coronavirus

Risk Trends

The pandemic of COVID-19 indicates that climate and virus transmission may have complex interactions. Although the global pandemic of COVID-19 was mainly driven by interpersonal transmission and social mobility, climate variables do affect the speed and geographical distribution of its spread to some extent. Studies have shown that low temperatures and low humidity conditions facilitate the survival of SARS-CoV-2 in aerosols and on surfaces, thereby increasing the risk of transmission [26, 27]. Moreover, extreme climate events (such as floods, hurricanes) lead to large-scale population migration and aggregation, increasing the opportunities for respiratory virus transmission [28].

Mechanism Analysis

At the mechanism level, climate variables mainly change the pattern of COVID-19 transmission by influencing virus survival, host susceptibility, and human behavior. In winter, people tend to gather indoors, with poor air circulation, strengthening the transmission chain [27]. At the same time, the combination of climate stress and urbanization may further increase the risk of cross-species

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transmission and prevalence of the novel coronavirus in the future.

4. Conclusion

Climate change has emerged as a critical catalyst in shaping the future trajectory of epidemic viral outbreaks. This review highlights those rising temperatures, altered precipitation patterns, and increasing frequency of extreme weather events directly influence viral replication dynamics, vector distribution, and cross-species transmission pathways. Case studies of influenza, monkeypox, dengue, and SARS-CoV-2 further illustrate how climate stressors interact with ecological shifts and human mobility to accelerate viral risk escalation on a global scale. Collectively, the evidence underscores that climate change is not merely an environmental issue but a major determinant of infectious disease epidemiology. The findings emphasize the necessity of integrating climate variables into global disease risk prediction models and public health preparedness frameworks. Future responses must adopt an interdisciplinary approach, combining expertise from public health, climatology, ecology, and computational modeling to anticipate and mitigate the health threats of climate-sensitive viruses. By embedding climate-informed strategies into global health governance, the international community can better safeguard populations against the accelerating epidemic risks of the 21st century.

References

[1] Ali, A., Shaikh, A., Sethi, I., & Surani, S. (2024). Climate change and the emergence and exacerbation of infectious diseases: A review. World Journal of Virology, 13(4). https://doi.org/10.5501/wjv.v13.i4.96476

[2] Romanello, M., Di Napoli, C., Green, C., Kennard, H., Lampard, P., Scamman, D., Walawender, M., Ali, Z., Ameli, N., Ayeb-Karlsson, S., Beggs, P. J., Belesova, K., Ford, L. B., Bowen, K., Cai, W., Callaghan, M., Campbell-Lendrum, D., Chambers, J., Cross, T. J., . . . Costello, A. (2023). The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms. The Lancet, 402(10419), 2346–2394. https://doi.org/10.1016/s0140-6736(23)01859-7

[3] Climate Change 2021: The Physical Science Basis. (n.d.-b). IPCC. https://www.ipcc.ch/report/ar6/wg1/

[4] Coates, S. J., & Norton, S. A. (2020). The effects of climate change on infectious diseases with cutaneous manifestations. International Journal of Women's Dermatology, 7(1), 8–16. https://doi.org/10.1016/j.ijwd.2020.07.005

[5] Van De Vuurst, P., & Escobar, L. E. (2023). Climate change and infectious disease: a review of evidence and research trends. Infectious Diseases of Poverty, 12(1). https://doi.org/10.1186/s40249-023-01102-2

[6] Cann, K. F., Thomas, D. R., Salmon, R. L., Wyn-Jones, A. P., & Kay, D. (2012). Extreme water-related weather events and waterborne disease. Epidemiology and Infection, 141(4), 671–686. https://doi.org/10.1017/s0950268812001653

[7] Carlson, C.J., Albery, G.F., Merow, C., Trisos, C.H., Zipfel, C.M., Eskew, E.A., Olival, K.J., Ross, N. and Bansal, S., 2022. Climate change increases cross-species viral transmission risk. Nature, 607(7919), pp.555–562. https://doi.org/10.1038/s41586-022-04788-w

[8] Gilbert, M., Xiao, X., Pfeiffer, D.U., Epprecht, M., Boles, S., Czarnecki, C., Chaitaweesub, P., Kalpravidh, W., Minh, P.Q., Otte, M.J., Martin, V. and Slingenbergh, J., 2017. Ecohealth and influenza: Avian influenza at the interface of humans, animals and the environment. EcoHealth, 14(1), pp.88–93. https://doi.org/10.1007/s10393-016-1190-x

[9] Keesing, F., Belden, L.K., Daszak, P., Dobson, A., Harvell, C.D., Holt, R.D., Hudson, P., Jolles, A., Jones, K.E., Mitchell, C.E., Myers, S.S., Bogich, T. and Ostfeld, R.S., 2010. Impacts of biodiversity on the emergence and transmission of infectious diseases. Nature, 468(7324), pp.647–652. https://doi.org/10.1038/nature09575

[10] Mordecai, E.A., Cohen, J.M., Evans, M.V., Gudapati, P., Johnson, L.R., Lippi, C.A., Miazgowicz, K., Murdock, C.C., Rohr, J.R., Ryan, S.J., Savage, V., Shocket, M.S., Stewart Ibarra, A.M., Thomas, M.B. and Weikel, D.P., 2017. Temperature influences vector competence for arboviruses. PLoS Neglected Tropical Diseases, 11(4), p.e0005568. https://doi.org/10.1371/journal.pntd.0005568

[11] Paz, S., 2019. Climate change impacts on West Nile virus transmission in a global context. Philosophical Transactions of the Royal Society B: Biological Sciences, 374(1786), p.20180246. https://doi.org/10.1098/rstb.2018.0246

[12] Plowright, R.K., Foley, P., Field, H.E., Dobson, A.P., Foley, J.E., Eby, P. and Daszak, P., 2015. Ecological dynamics of emerging bat virus spillover. Proceedings of the Royal Society B: Biological Sciences, 282(1798), p.20142124. https://doi.org/10.1098/rspb.2014.2124

[13] Ryan, S.J., Carlson, C.J., Mordecai, E.A. and Johnson, L.R., 2019. Global expansion and redistribution of Aedes-borne virus transmission risk with climate change. PLoS Neglected Tropical Diseases, 13(3), p.e0007213. https://doi.org/10.1371/journal.pntd.0007213

[14] Gilbert, M., Xiao, X., Pfeiffer, D.U., Epprecht, M., Boles, S., Czarnecki, C., Chaitaweesub, P., Kalpravidh, W., Minh, P.Q., Otte, M.J. and Martin, V., 2008. Mapping H5N1 highly pathogenic avian influenza risk in Southeast Asia. Proceedings of the National Academy of Sciences, 105(12), pp.4769–4774. https://doi.org/10.1073/pnas.0710581105

[15] Lowen, A.C., Mubareka, S., Steel, J. and Palese, P., 2007. Influenza virus transmission is dependent on relative humidity

and temperature. PLoS Pathogens, 3(10), p.e151. https://doi.org/10.1371/journal.ppat.0030151
[16] Lowen, A.C., Steel, J., Mubareka, S. and Palese, P., 2008. High temperature (30 °C) blocks aerosol but not contact transmission of influenza virus. Journal of Virology, 82(11), pp.5650–5652. https://doi.org/10.1128/JVI.00325-08
[17] Reperant, L.A., Kuiken, T. and Osterhaus, A.D., 2016. Adaptive pathways of zoonotic influenza viruses: from exposure to establishment in humans. Vaccine, 34(26), pp.2872–2877. https://doi.org/10.1016/j.vaccine.2016.03.007
[18] Tamerius, J.D., Shaman, J., Alonso, W.J., Bloom-Feshbach, K., Uejio, C.K., Comrie, A. and Viboud, C., 2013. Environmental predictors of seasonal influenza epidemics across temperate and tropical climates. PLoS Pathogens, 9(3), p.e1003194. https://doi.org/10.1371/journal.ppat.1003194
[19] Bunge, E.M., Hoet, B., Chen, L., Lienert, F., Weidenthaler, H., Baer, L.R. and Steffen, R., 2022. The changing epidemiology of human monkeypox—A potential threat? A systematic review. PLoS Neglected Tropical Diseases, 16(2), p.e0010141. https://doi.org/10.1371/journal.pntd.0010141
[20] Sklenovská, N. and Van Ranst, M., 2018. Emergence of monkeypox as the most important orthopoxvirus infection in humans. Frontiers in Public Health, 6, p.241. https://doi.org/10.3389/fpubh.2018.00241
[21] Vanderburg, S., Rubinson, L., Hamblion, E., Muller, M.P., Ntoumi, F., Gould, S. and Van Kerkhove, M.D., 2022. Applying lessons from COVID-19 to monkeypox: A call for proactive and timely response. The Lancet Infectious Diseases, 22(7), pp.930–931. https://doi.org/10.1016/S1473-3099(22)00359-0
[22] Campbell, K.M., Lin, C.D., Iamsirithaworn, S. and Scott, T.W., 2015. The complex relationship between weather and dengue virus transmission in Thailand. The American Journal of Tropical Medicine and Hygiene, 92(5), pp.1066–1077. https://doi.org/10.4269/ajtmh.14-0321
[23] Liu-Helmersson, J., Stenlund, H., Wilder-Smith, A. and Rocklöv, J., 2019. Vectorial capacity of Aedes aegypti: Effects of temperature and implications for global dengue epidemic potential. PLoS ONE, 14(3), p.e0210120. https://doi.org/10.1371/journal.pone.0210120
[24] Mordecai, E.A., Cohen, J.M., Evans, M.V., Gudapati, P., Johnson, L.R., Lippi, C.A., Miazgowicz, K., Murdock, C.C., Rohr, J.R., Ryan, S.J. and Savage, V., 2017. Temperature influences vector competence for arboviruses. PLoS Neglected Tropical Diseases, 11(4), p.e0005568. https://doi.org/10.1371/journal.pntd.0005568
[25] Ryan, S.J., Carlson, C.J., Mordecai, E.A. and Johnson, L.R., 2019. Global expansion and redistribution of Aedes-borne virus transmission risk with climate change. PLoS Neglected Tropical Diseases, 13(3), p.e0007213. https://doi.org/10.1371/journal.pntd.0007213
[26] Ahlawat, A., Wiedensohler, A. and Mishra, S.K., 2020. An overview on the role of relative humidity in airborne transmission of SARS-CoV-2. Aerosol and Air Quality Research, 20(9), pp.1856–1861. https://doi.org/10.4209/aaqr.2020.06.0302
[27] Moriyama, M., Hugentobler, W.J. and Iwasaki, A., 2020. Seasonality of respiratory viral infections. Annual Review of Virology, 7, pp.83–101. https://doi.org/10.1146/annurev-virology-012420-022445
[28] Watts, N., Amann, M., Arnell, N., Ayeb-Karlsson, S., Belesova, K., Berry, H., Bouley, T., Boykoff, M., Byass, P., Cai, W. and Campbell-Lendrum, D., 2021. The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future. The Lancet, 398(10311), pp.1619–1662. https://doi.org/10.1016/S0140-6736(21)01787-6
[29] SHI Biao, LI Yu Xia, YU Xhua, YAN Wang. Short-term load forecasting based on modified particle swarm optimizer and fuzzy neural network model. Systems Engineering-Theory and Practice, 2010, 30(1): 158-160.