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CLIMATE CHANGE AND VECTOR-BORNE DISEASES

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Abstract

Climate change is reshaping the environmental conditions in which mosquitoes, ticks, sandflies and other disease vectors survive and transmit pathogens. Changes in temperature, rainfall, humidity and the frequency of extreme events can alter vector development, breeding sites, seasonal activity and geographic distribution. These changes influence risks for diseases such as malaria, dengue, chikungunya, Zika, West Nile fever, tick-borne encephalitis and Lyme disease, but the direction and magnitude of impact differ by pathogen, vector and location. Climate is only one part of the picture: urbanization, land use, water and sanitation systems, housing, human mobility, immunity and public-health capacity can amplify or reduce risk. This narrative review summarizes the principal biological pathways linking climate change with vector-borne disease, highlights selected disease examples, and discusses surveillance, prevention and adaptation strategies. Current evidence supports climate-informed public-health planning, but it also cautions against assuming that warming will increase every vector-borne disease everywhere. Effective responses require local monitoring, reliable healthcare, community engagement and integrated vector management alongside climate mitigation. Research priorities include improved early-warning systems, comparable surveillance data and stronger evaluation of interventions in vulnerable communities.

Keywords: climate change; vector-borne diseases; malaria; dengue; mosquitoes; ticks; public health; climate adaptation; surveillance; vector control

1. Introduction

Vector-borne diseases are infections transmitted to humans or animals by living organisms such as mosquitoes, ticks, sandflies and fleas. They include parasitic diseases, including malaria; viral diseases, such as dengue, chikungunya and West Nile fever; and bacterial infections, such as Lyme disease. The World Health Organization reports that vector-borne diseases account for more than 17% of infectious diseases

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and cause over 700,000 deaths annually [1]. Their burden is unevenly distributed, with many affected communities facing poverty, limited healthcare access and environmental conditions that make prevention difficult.

Climate change matters because vectors and pathogens respond to their surroundings. Temperature can affect how quickly a mosquito develops, how often it bites, how long it survives and how rapidly a pathogen develops inside it. Rainfall can create breeding habitats, while drought may encourage households to store water in containers that become mosquito breeding sites. Humidity influences the survival of adult insects, and warmer conditions may allow some vectors to persist in areas where winters previously limited them.

Yet the relationship is not a simple rule that warmer weather always means more disease. Excessive heat can reduce vector survival, heavy rain can flush larvae from breeding sites, and drought can eliminate some habitats. Disease transmission also requires the pathogen, vector, human host and suitable social conditions to coincide. A careful review therefore needs to consider both climate-related mechanisms and the non-climatic factors that determine whether ecological change becomes a human health problem.

2. Review approach

This narrative review synthesizes selected evidence from World Health Organization resources, the Intergovernmental Panel on Climate Change (IPCC), and peer-reviewed reviews on climate and vector-borne disease. It is not a systematic review or meta-analysis, and no new data were collected. Examples are included to illustrate mechanisms rather than rank countries or predict individual outbreaks. Since effects vary by region and study design, the review avoids treating projections as direct observations or assuming that associations alone prove climate attribution.

3. How climate affects vectors and transmission

Temperature influences several stages of vector and pathogen biology. Within a suitable range, warmer conditions can accelerate insect development and pathogen replication, shorten the time before an infected vector becomes infectious, and extend seasonal activity. However, vectors have thermal limits. Beyond an optimal range, survival and reproduction may fall. These nonlinear responses help explain why warming can increase risk in some cooler areas while reducing suitability in locations that become too hot or dry [2,3].

Rainfall has similarly mixed effects. Moderate rainfall may create pools and containers in which mosquitoes breed. Flooding can disrupt sanitation and create standing water

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after waters recede, but intense rainfall may also wash away larvae. During drought, water storage can unintentionally provide breeding habitats for Aedes mosquitoes. Humidity, vegetation, soil moisture and the availability of animal hosts can further shape vector survival and contact with people.

Climate-related hazards can also affect health systems and behaviour. Floods and storms may damage clinics, interrupt vector-control programmes, displace families and delay diagnosis. Heat can alter outdoor activity and water-use patterns. Human travel and trade may introduce pathogens or vectors into newly suitable areas, while unplanned urban growth can create habitats around homes. The IPCC concludes that higher temperatures combined with land-use change are making more areas suitable for some vector-borne diseases, while emphasizing that outcomes depend on context [3].

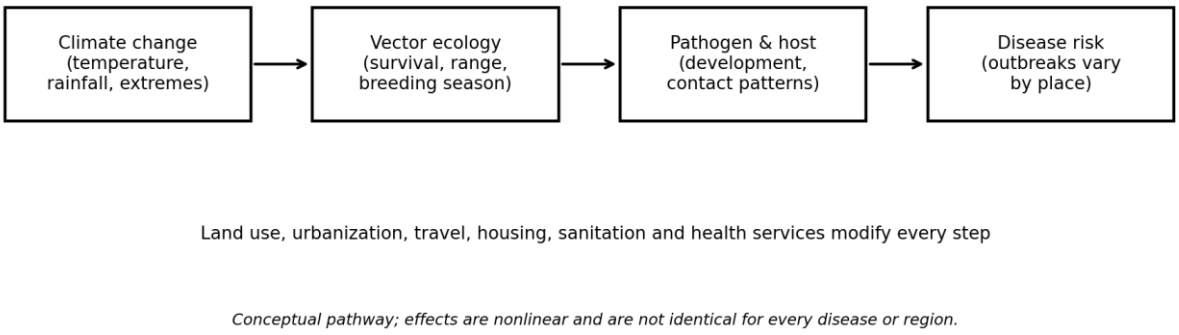


Figure 1. Conceptual pathways linking climate change with vector-borne disease risk. Non-climatic determinants modify each stage; the figure is explanatory rather than quantitative.

4. Selected diseases and climate-related patterns

4.1 Malaria

Malaria is transmitted by Anopheles mosquitoes. Temperature and rainfall affect mosquito survival, breeding habitats and the development of Plasmodium parasites inside the vector. In some highland or fringe regions, warmer conditions may increase seasonal suitability and expose populations with limited acquired immunity to outbreaks. In already hot areas, extreme temperatures or changes in rainfall may reduce suitability or produce less predictable effects. Malaria trends are also strongly shaped by insecticide-treated nets, indoor residual spraying, antimalarial treatment, housing,

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population movement and health-service access; climate alone cannot explain year-to-year changes.

4.2 Dengue and chikungunya

Dengue and chikungunya are primarily transmitted by Aedes mosquitoes, which often breed in small water-holding containers close to people. Warmer conditions can accelerate mosquito development and viral replication within a suitable temperature range. Rainfall, intermittent water supply and household water storage can influence breeding sites. The IPCC reports that climate change and variability have contributed to the spread of chikungunya and dengue suitability in several regions, while stressing interactions with human activities and urban conditions [3]. Dense housing, waste management, reliable water services and community participation remain central to prevention.

4.3 Tick-borne diseases

Ticks are affected by temperature, humidity, vegetation and the distribution of wildlife or other host animals. Milder winters and longer warm seasons can change tick activity and expand suitable habitat in some areas. Lyme disease vectors in North America and Europe, and tick-borne encephalitis in parts of Europe, are among the examples discussed in IPCC assessments [3]. Nonetheless, land management, outdoor behaviour, host populations, diagnostic practices and public awareness also affect observed case numbers. A change in the geographic range of a tick does not automatically mean that every location will experience sustained human transmission.

4.4 Other vector-borne infections

West Nile fever, Zika, yellow fever, leishmaniasis and Rift Valley fever illustrate the diversity of transmission systems. Some depend on mosquitoes and bird or mammal hosts; others involve sandflies, livestock or complex ecological cycles. Climate can alter the distribution and timing of vectors or reservoir hosts, but disease emergence usually requires additional conditions, including pathogen introduction and contact between vectors and susceptible people. These differences make disease-specific and locally grounded surveillance essential [2,4].

ISSN: 3060-4737 Volume 3, Issue 10 IF(Impact Factor) 10.98 / 2026

Table 1. Climate-sensitive pathways and examples

Disease / vector	Climate-sensitive mechanism	Possible pattern	Important modifiers
Malaria / Anopheles mosquitoes	Temperature affects mosquito survival and parasite development; rainfall affects breeding sites	Seasonal suitability may rise in some cooler or highland areas; extreme heat can limit transmission	Vector control, treatment access, housing, immunity and land use
Dengue / Aedes mosquitoes	Temperature affects vector and virus development; water availability shapes container habitats	Longer seasons or expansion into suitable areas; drought may increase household storage habitats	Urban density, waste collection, water supply and community action
Chikungunya / Aedes mosquitoes	Similar mosquito ecology to dengue; weather influences seasonal activity	Outbreak risk may shift where vectors and virus overlap	Travel, population susceptibility, surveillance and mosquito control
Lyme disease / Ixodes ticks	Temperature and humidity affect tick activity; vegetation and hosts shape habitat	Activity seasons or suitable ranges may change in some regions	Wildlife hosts, outdoor exposure, land management and awareness
West Nile fever / mosquitoes and birds	Weather affects mosquitoes and bird-vector contact	Local transmission may change with seasonal conditions	Bird ecology, urban design, surveillance and clinical detection

5. What the evidence does—and does not—show

Evidence is strongest for the biological sensitivity of vectors and pathogens to temperature and moisture, and for observed changes in suitability or distribution in particular settings. The IPCC reports that climate change and variability have facilitated the spread or changed the suitability of several vector-borne diseases, with

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confidence levels varying by disease and region [3]. A major review also emphasizes that climate change interacts with land use, human mobility and behaviour rather than acting in isolation [2].

Attribution remains challenging. Surveillance may improve over time, making previously undetected cases visible. Population growth, urbanization, conflict, changes in diagnostic access, insecticide resistance and public-health interventions can all alter disease incidence. Some studies project future suitability rather than actual cases, and a suitable climate is only one condition for transmission. The WHO has noted that the evidence base for some neglected tropical diseases and malaria remains uneven and that further research is needed to clarify impacts and adaptation options [4].

Table 2. Interpreting climate and disease evidence

Evidence type	What it can tell us	Main caution
Laboratory studies	How temperature or humidity affects vector or pathogen biology	Controlled conditions may not reflect field ecology
Field surveillance	Whether cases, vectors or seasons are changing locally	Case detection, reporting and interventions may also change
Climate-suitability models	Where conditions may become more or less suitable	Suitability is not the same as predicted case counts
Outbreak investigations	How weather, ecology and human exposure aligned during an event	Multiple causes often coincide; attribution needs careful analysis

6. Public-health prevention and adaptation

Climate-informed surveillance is a practical starting point. Health agencies can combine local temperature and rainfall information with vector monitoring, case reports, laboratory results and information about population movement. Early-warning systems are most useful when alerts trigger clear actions—for example, targeted vector control, community messaging, diagnostic readiness and supplies for clinics. Forecasts should be evaluated regularly so that warnings do not create unnecessary alarm or divert resources from other health priorities.

ISSN: 3060-4737 Volume 3, Issue 10 IF(Impact Factor) 10.98 / 2026

Integrated vector management combines environmental measures, personal protection, community engagement and appropriate insecticide use. Removing standing water, covering storage containers, improving drainage and waste collection, installing screens, using bed nets where appropriate and applying recommended repellents can reduce exposure. Interventions should be tailored to the vector: bed nets are particularly important for many malaria settings, while eliminating small water-holding containers is central to Aedes control. Insecticide resistance monitoring is essential to preserve effectiveness.

Health systems also need resilience. Clinics should maintain access to diagnostic tests, trained staff and effective treatments during floods, heatwaves and other disruptions. Risk communication should be clear, multilingual and locally trusted. Urban planning, reliable water and sanitation, safe housing and environmental management can reduce breeding sites while improving health more broadly. Climate mitigation is also a health intervention: limiting future warming reduces the scale of risks that communities will otherwise have to manage.

7. Equity and vulnerable populations

Climate-related disease risks are not distributed equally. People living in poorly constructed housing, informal settlements, remote communities or areas with unreliable water supply may face greater exposure and have fewer options for protection. Outdoor workers, displaced people and communities affected by conflict can have difficulty avoiding vectors or accessing timely diagnosis. Children, pregnant people, older adults and people with limited access to healthcare may face additional risks from infection or its complications.

Equitable adaptation means involving affected communities in programme design, supporting local health workers and ensuring that prevention tools and treatment are affordable. A technically sophisticated early-warning model will have limited value if the clinic cannot access tests or residents cannot act on the warning. Public-health planning should therefore pair climate information with investment in basic services and community trust.

8. Research priorities

Future research should link long-term climate records with standardized vector surveillance, laboratory-confirmed disease data and information on interventions, land use and human mobility. Studies should distinguish observed changes from projections and report uncertainty transparently. More evidence is needed from underrepresented regions and for diseases with limited research funding. Evaluations should also test

ISSN: 3060-4737 Volume 3, Issue 10 IF(Impact Factor) 10.98 / 2026

whether early-warning systems and climate-informed vector-control programmes reduce illness, deaths or response costs—not merely whether they predict environmental suitability.

Researchers and health agencies can strengthen collaboration between meteorology, ecology, entomology, infectious-disease medicine and public health. Shared data standards and accessible local dashboards may help convert climate information into timely decisions. Research should also examine unintended effects, such as the ecological consequences of control measures, and identify adaptation strategies that remain effective under different future climate scenarios.

9. Conclusion

Climate change is altering the environmental conditions that shape vector survival, pathogen development and human exposure. These changes can extend transmission seasons or create new areas of suitability for diseases such as malaria, dengue, chikungunya and some tick-borne infections. However, effects are complex and differ by location; heat can become excessive for vectors, rainfall can either create or remove breeding sites, and social conditions often determine whether ecological suitability leads to disease. Public-health responses should combine climate-informed surveillance, integrated vector management, resilient healthcare, community engagement and improvements in housing, water and sanitation. Reducing greenhouse-gas emissions is essential to limit future risk, while targeted adaptation can protect communities from risks already emerging. The goal is not to predict every outbreak perfectly, but to build systems capable of detecting changing threats and responding quickly and fairly.

Limitations

This is a narrative review of selected sources rather than a systematic review with formal screening and risk-of-bias assessment. Findings vary across diseases, regions and methods; the review should be updated as new evidence becomes available.

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