Test file: Climate Change and Vector-Borne Disease Transmission: A Systematic Review of Epidemiological Evidence

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Abstract

This systematic review synthesizes current epidemiological evidence on the impacts of climate change on vector-borne disease transmission patterns. Following PRISMA guidelines, we analyzed 127 studies examining relationships between climatic variables and disease incidence of malaria, dengue, Lyme disease, and other vector-borne illnesses. Results demonstrate significant associations between temperature increases, precipitation changes, and altered transmission dynamics across diverse geographic regions. The evidence supports the development of climate-informed surveillance and early warning systems for vector-borne disease control.

Keywords: Climate Change; Vector-Borne Diseases; Environmental Epidemiology; Infectious Diseases; Systematic Review; Public Health Preparedness

1. Introduction

Climate change represents one of the most significant global health threats of the 21st century, with particular implications for infectious disease epidemiology [1]. Vector-borne diseases, responsible for approximately 17% of all infectious diseases globally, demonstrate particular sensitivity to climatic conditions due to the ectothermic nature of their arthropod vectors and the temperature dependence of pathogen development within these vectors [2]. Understanding how changing climate patterns influence disease transmission dynamics is crucial for developing effective public health responses and adaptation strategies.

The complex relationships between climate variables and vector-borne disease transmission involve multiple pathways and feedback mechanisms. Temperature influences vector development rates, survival, biting frequency, and the extrinsic incubation period of pathogens [3]. Precipitation affects vector breeding sites and habitat suitability, while extreme weather events can disrupt both vector ecology and human vulnerability [4]. Previous reviews have examined specific aspects of climate-disease relationships, but a comprehensive synthesis of epidemiological evidence across multiple diseases and geographic regions is needed to inform public health practice [5].

This systematic review aims to: (1) synthesize epidemiological evidence on climate change impacts on major vector-borne diseases; (2) identify consistent patterns and knowledge gaps across different ecological contexts; and (3) discuss implications for surveillance, prevention, and control programs in a changing climate.

2. Methods

2.1 Search Strategy and Selection Criteria

We conducted this systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [6]. A comprehensive search of PubMed, Web of Science, Scopus, and EMBASE databases was performed for literature published between January 2000 and December 2023. Search terms included combinations of climate-related keywords ("climate change," "global warming," "temperature," "precipitation," "extreme weather") and vector-borne disease terms ("malaria," "dengue," "Lyme disease," "vector-borne," "arbovirus").

Inclusion criteria comprised: (1) original observational or modeling studies; (2) quantitative analysis of relationships between climate variables and vector-borne disease outcomes; (3) clear methodological description of climate exposure assessment and health outcome measurement; (4) peer-reviewed publication in English. Exclusion criteria included: (1) studies without empirical climate-disease analysis; (2) laboratory studies without field epidemiological data; (3) reviews, commentaries, and editorials.

2.2 Data Extraction and Quality Assessment

Two reviewers independently screened titles/abstracts and full-text articles using Covidence software. Data extraction utilized a standardized form capturing: study characteristics (author, year, location, design), population details, climate exposure measurements, disease outcomes, statistical methods, effect estimates, and key findings. Study quality was assessed using the Navigation Guide methodology for environmental health studies, evaluating risk of bias, directness, precision, and consistency [7].

2.3 Data Synthesis and Analysis

Given the methodological heterogeneity across studies, we employed a narrative synthesis approach organized by disease category and climate exposure type. We developed evidence tables summarizing key findings and assessed the strength of evidence using predefined criteria considering study quality, consistency, and effect magnitude. Where feasible, we conducted random-effects meta-analysis for specific climate-disease relationships with sufficient comparable data.

3. Results

3.1 Study Selection and Characteristics

The literature search identified 4,287 potentially relevant records, from which 127 studies met inclusion criteria after duplicate removal and screening. Included studies encompassed diverse geographical regions: 38% from Asia, 25% from North America, 18% from Africa, 12% from Europe, and 7% from South America. Study designs included time series analyses (42%), spatial analyses (28%), case-crossover studies (15%), and mathematical modeling studies (15%).

3.2 Malaria and Climate Relationships

Among 45 studies examining malaria-climate relationships, consistent positive associations emerged between temperature increases and malaria transmission intensity, particularly in highland areas previously unsuitable for transmission. A meta-analysis of 12 studies found each 1°C temperature increase was associated with a 15-30% increase in malaria incidence in endemic regions (pooled RR: 1.22, 95% CI: 1.15-1.30). Precipitation patterns showed more complex relationships, with both drought and extreme rainfall influencing transmission cycles through different mechanisms.

3.3 Dengue and Other Arboviral Diseases

The 38 studies on dengue/climate relationships demonstrated strong temperature dependencies, with optimal transmission occurring between 24-29°C. Non-linear relationships were common, with transmission declining above approximately 35°C. Precipitation effects varied by ecological context, with water storage behaviors modifying the relationship between rainfall patterns and vector breeding. Similar patterns emerged for other arboviruses including chikungunya and Zika, though with pathogen-specific variations in climate sensitivities.

3.4 Tick-Borne Diseases

Among 27 studies on Lyme disease and other tick-borne illnesses, climate relationships involved more complex pathways including indirect effects on host populations and vegetation. Warmer temperatures extended tick activity seasons and expanded geographic ranges northward, while humidity influences affected tick survival off-host. The rate of range expansion for Ixodes scapularis in North America has accelerated in recent decades, consistent with warming trends.

3.5 Heterogeneity and Modifying Factors

Significant heterogeneity in climate-disease relationships was observed across ecological contexts. Urbanization, land use changes, vector control programs, and socioeconomic factors modified climate effects, highlighting the importance of local contextual factors. Studies accounting for these effect modifiers demonstrated stronger and more consistent climate-disease relationships.

4. Discussion

4.1 Key Findings and Public Health Implications

This systematic review provides robust evidence that climate change is already affecting vector-borne disease transmission patterns globally. The consistency of findings across diverse methodological approaches and geographic regions strengthens causal inference regarding climate impacts on disease ecology. These changes have direct implications for public health planning, resource allocation, and intervention strategies.

The observed expansion of vector habitats into new regions, changes in transmission seasonality, and altered epidemic dynamics necessitate adaptations in surveillance systems, diagnostic capabilities, and control programs. Public health agencies should prioritize development of climate-informed early warning systems that integrate meteorological data, vector surveillance, and vulnerability assessments to guide timely interventions.

4.2 Methodological Considerations and Research Gaps

While the evidence base has substantially improved in recent years, important methodological challenges remain. Few studies adequately account for lag effects, non-linear relationships, and effect modification by non-climatic factors. Most research focuses on temperature and precipitation, with limited attention to climate variability, extreme events, and interacting environmental changes.

Significant geographic disparities exist in research coverage, with limited studies from highly vulnerable regions including small island developing states and conflict-affected areas. Future research should address these gaps while developing standardized methodologies for climate-health impact assessment and strengthening capacity in understudied regions.

4.3 Limitations

This review has several limitations. Publication bias may favor studies reporting significant climate-disease relationships. The exclusion of non-English literature and gray literature may omit relevant evidence. The narrative synthesis approach, while necessary given methodological heterogeneity, precludes quantitative summary of all relationships. Finally, the rapidly evolving nature of both climate change and vector-borne disease epidemiology means new evidence continues to emerge.

5. Conclusion

This systematic review demonstrates substantial and growing epidemiological evidence for climate change impacts on vector-borne disease transmission patterns. The consistency of findings across diseases, methodologies, and geographic regions provides compelling evidence for integrating climate considerations into public health practice for vector-borne disease control. Future efforts should focus on developing predictive models, early warning systems, and adaptation strategies that account for the complex, context-dependent relationships between climate and vector-borne disease dynamics. Enhancing surveillance, building resilient health systems, and addressing knowledge gaps in vulnerable regions will be essential for mitigating the public health impacts of climate change on vector-borne diseases.

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