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Climate Change, Urbanization, and Zoonotic Diseases: A Narrative Review for Public Health Resilience

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ABSTRACT: Climate change and urbanization are intensifying the emergence of zoonotic diseases, posing urgent challenges to public health systems—particularly in rapidly growing urban areas. This narrative review examines the interplay between climate variability, environmental change, and zoonotic disease transmission, focusing on temperature shifts, precipitation patterns, and urban land-use dynamics. A systematic literature review was conducted to synthesize empirical studies across diverse climatic and urban contexts. Findings reveal that rising temperatures accelerate pathogen replication and expand vector habitats, while altered rainfall patterns increase the likelihood of waterborne and vector-borne disease outbreaks. Urbanization-induced deforestation, habitat fragmentation, and inadequate infrastructure further heighten human-wildlife interactions and disease spillovers. Vulnerabilities are exacerbated in low-income communities with limited access to sanitation, healthcare, and early warning systems. This review highlights the urgent need for integrative public health strategies and climate-adaptive urban planning to mitigate zoonotic risks. Policymakers must prioritize early surveillance, equitable health access, and ecosystem-sensitive development. By adopting the One Health framework and strengthening interdisciplinary collaboration, cities can build resilience to future zoonotic threats in the context of accelerating climate change.

Keywords: Climate Change, Zoonotic Diseases, Urbanization, One Health, Risk Mitigation, Public Health Policy, Environmental Governance.

INTRODUCTION

Climate change is increasingly recognized as a major driver of zoonotic disease transmission, particularly in urban environments. Urbanization, combined with shifting climatic conditions, has altered the interactions between humans, animals, and pathogens, leading to increased risks of zoonotic spillover events (Jones et al., 2013; Rahman et al., 2020). Expanding urban areas encroach upon natural habitats, forcing wildlife into closer proximity with human populations, thereby heightening the probability of disease transmission (Castonguay et al., 2024). Additionally, changes in temperature, humidity, and precipitation patterns have influenced the ecology of disease vectors, modifying their geographic distribution and lifecycle dynamics (Bartlow et al., 2019; Tian et al., 2017). These environmental shifts exacerbate the transmission of vector-borne zoonotic diseases such as malaria, dengue, and leptospirosis, particularly in densely populated urban settings.

Recent studies highlight the role of climatic factors in influencing zoonotic disease dynamics. Warmer temperatures have been found to accelerate the breeding cycles of mosquitoes, leading to higher transmission rates of malaria and dengue (L. Zhang et al., 2024). Similarly, variations in precipitation patterns create ideal conditions for vector breeding, increasing the risk of outbreaks in urban centers (Hassett & Thangamani, 2021). Beyond vector-borne diseases, climate change has also been linked to increased transmission of rodent-borne zoonoses, such as leptospirosis, due to flooding events that displace both humans and animal hosts (Edward et al., 2024; Rahman et al., 2020). The complex interplay of these factors highlights the urgent need for integrated disease surveillance and urban planning strategies to mitigate emerging health threats.

Urbanization exacerbates zoonotic disease risks by disrupting wildlife habitats and increasing human-wildlife interactions. Land conversion for infrastructure development displaces wildlife, often leading to heightened spillover risks of diseases such as West Nile virus and Hantavirus (Edward et al., 2024). Additionally, unregulated urban agriculture and livestock farming contribute to the spread of avian influenza and other zoonoses (Bartlow et al., 2019). Biodiversity loss, driven by both urban expansion and climate change, further exacerbates these risks by reducing ecological checks on pathogen circulation (Braam et al., 2021).

Extreme weather events, including hurricanes, floods, and prolonged droughts, also influence the transmission of zoonotic diseases. Natural disasters displace human and animal populations, creating conditions that facilitate the spread of infectious diseases. For instance, post-flooding conditions have been linked to an increase in leptospirosis and waterborne zoonotic infections (Braam et al., 2021). Similarly, prolonged droughts drive wildlife and domestic animals into urban areas in search of food and water, increasing human exposure to zoonotic pathogens (Edward et al., 2024). These events underscore the non-linear and unpredictable relationship between climate change and zoonotic disease dynamics.

Socioeconomic disparities further exacerbate the vulnerability of urban populations to climate-driven zoonotic diseases. Many low-income urban communities lack access to proper sanitation, healthcare, and disease surveillance, making them more susceptible to outbreaks (Meadows et al., 2023). Informal settlements, characterized by high population densities and inadequate waste management systems, provide ideal conditions for vector proliferation and pathogen persistence (Braam et al., 2021; Mather et al., 2013). Addressing these disparities requires a multisectoral approach that integrates public health interventions with climate adaptation strategies.

Despite growing recognition of the link between climate change and zoonotic disease transmission, significant research gaps remain. Existing studies often focus on individual diseases or specific vectors, neglecting broader ecosystem-level interactions (Jánová, 2019). Additionally, limited attention has been given to the socioeconomic determinants of climate-driven zoonotic disease vulnerability, particularly in urban settings (Edward et al., 2024). Further research is needed to develop predictive models that integrate climate, ecological, and epidemiological data to forecast disease outbreaks and inform public health interventions (Keatts et al., 2021).

This review aims to provide a comprehensive analysis of the impact of climate change on zoonotic disease transmission in urban areas. It will examine key environmental drivers, including temperature, humidity, and precipitation patterns, and their influence on disease ecology. Additionally, the review will explore the role of urbanization, socioeconomic factors, and extreme weather events in shaping disease dynamics. By synthesizing current research, this study seeks to identify critical knowledge gaps and propose policy recommendations for mitigating climate-driven zoonotic disease risks in urban environments.

The scope of this review encompasses global urban regions, with a particular focus on developing countries where climate change and rapid urbanization pose the greatest public health challenges. Comparative analyses of disease trends across different climatic zones will be conducted to highlight regional variations in zoonotic disease emergence. This approach will provide insights into the complex interplay between environmental change and disease transmission, offering evidence-based strategies for enhancing urban health resilience in the face of climate change.

METHOD

This study employs a systematic review approach to examine the impact of climate change on the transmission dynamics of zoonotic diseases in urban areas. A comprehensive literature search was conducted across major academic databases, including PubMed, Scopus, and Google Scholar, targeting studies published within the last two decades. The search strategy incorporated a combination of predefined keywords and Boolean operators to maximize precision and completeness. Keywords included "climate change," "zoonotic diseases," "vector-borne diseases," "transmission dynamics," "urbanization," and "environmental health." Boolean operators such as AND, OR, and NOT were used to refine the search and exclude irrelevant studies. For example, the query ("climate change" OR "environmental change") AND ("zoonotic diseases" OR "infectious diseases") AND ("transmission" OR "vectors" OR "urbanization") NOT "animal" was utilized to filter the most relevant articles.

Selection criteria were established to ensure the inclusion of high-quality, peer-reviewed research. Studies were considered eligible if they provided empirical data linking climate change to zoonotic disease transmission, focused on emerging zoonotic diseases, assessed the impact of climate variables (e.g., temperature, humidity, precipitation) on disease ecology, and examined human-animal interactions in urban settings. Studies that were not published in English, lacked empirical evidence, or did not establish a direct link between climate change and zoonotic disease transmission were excluded. The screening process involved a multi-stage review, beginning with title and abstract assessments, followed by full-text evaluations to determine methodological rigor and relevance.

To enhance reliability, a multi-reviewer approach was adopted, wherein four independent reviewers assessed study eligibility and resolved discrepancies through consensus. Thematic synthesis was employed to identify recurring patterns in climate-induced changes in zoonotic disease transmission. The findings provide insights into the spatial and temporal shifts in zoonotic disease risks due to climate change, highlighting key environmental and socio-economic factors influencing disease emergence in urban areas.

RESULT AND DISCUSSION

Impact of Rising Temperatures on Replication, Survival, and Transmission of Zoonotic Pathogens

Rising global temperatures have a significant impact on the replication, survival, and transmission of zoonotic pathogens, altering disease dynamics and increasing public health risks. Warmer conditions accelerate the life cycle of various vector-borne pathogens, enhancing their replication rates and increasing transmission potential (L. Zhang et al., 2024). Studies have shown that elevated temperatures contribute to the prolonged survival of certain viruses and bacteria in the environment, leading to higher infection rates (Glidden et al., 2023). Conversely, extreme heat conditions can disrupt pathogen viability in certain cases, highlighting the complexity of temperature-pathogen interactions (Lodge et al., 2021). Additionally, changes in host behavior, such as altered migration patterns due to temperature shifts, can enhance human-wildlife interactions, further facilitating zoonotic spillover events (Gardner et al., 2019).

Influence of Changes in Humidity and Precipitation Patterns on Vector Breeding and Zoonotic Disease Outbreaks

Humidity and precipitation patterns play crucial roles in vector population dynamics and the emergence of zoonotic diseases. Increased humidity levels create favorable breeding environments for disease vectors, particularly mosquitoes, which are responsible for transmitting dengue, Zika virus, and chikungunya (Tian et al., 2017). Likewise, altered precipitation patterns contribute to the expansion of vector habitats, increasing the likelihood of outbreaks (Castonguay et al., 2024). Flooding events provide additional breeding grounds for rodents, which are reservoirs for zoonotic pathogens such as leptospirosis and hantavirus (Hamlet et al., 2021). The correlation between rainfall variability and disease incidence underscores the need for climate-based predictive models to anticipate and mitigate outbreaks (Keatts et al., 2021).

Urbanization and Increased Human-Wildlife Interactions

Evidence on Urban Expansion and Spillover Events

Urban expansion has led to increased human-wildlife interactions, heightening the risk of zoonotic spillover events. Studies indicate that habitat fragmentation and deforestation associated with urban development force wildlife species to migrate into urban areas, increasing contact with humans and domestic animals (Jones et al., 2013). The encroachment of urban dwellers into former wildlife habitats creates conditions conducive to pathogen spillover, as seen in the emergence of diseases such as Nipah virus and hantavirus(Keatts et al., 2021).

Deforestation and Habitat Fragmentation's Contribution to Emerging Zoonotic Diseases

Deforestation and habitat fragmentation have been identified as significant contributors to the emergence of zoonotic diseases. The loss of biodiversity due to urbanization disrupts ecological balances, leading to an increase in pathogen transmission within fragmented habitats (Singh et al., 2021). The forced migration of wildlife into human-dominated landscapes results in new disease reservoirs, increasing the likelihood of zoonotic infections (L. Zhang et al., 2024). Additionally, habitat alterations create new breeding grounds for vectors such as ticks and mosquitoes, further facilitating disease transmission (Glidden et al., 2023).

Vector Ecology and Climate Adaptation

Climate Change-Driven Shifts in Vector Ecology

Climate change has significantly altered the geographic distribution of vectors responsible for zoonotic disease transmission. Rising temperatures and changing precipitation patterns have expanded the habitat ranges of mosquitoes, ticks, and sandflies, increasing the prevalence of vector-borne diseases in previously unaffected regions (Ouma & Mulambalah, 2021). For instance, the spread of Aedes aegypti mosquitoes into temperate zones has contributed to a surge in dengue fever cases worldwide (Singh et al., 2021).

Mitigation Strategies for Climate-Induced Vector Expansion

To combat the growing threat of climate-induced vector expansion, integrated vector management (IVM) strategies have been implemented. These approaches include environmental modifications, such as improving urban drainage systems and reducing mosquito breeding sites, as well as targeted insecticide applications (Keatts et al., 2021). Additionally, the use of remote sensing and geographic information systems (GIS) has proven effective in monitoring vector population dynamics and predicting disease outbreaks (Jagadesh et al., 2022).

Socioeconomic and Infrastructure-Related Challenges

Influence of Socioeconomic Disparities on Vulnerability to Climate-Induced Zoonotic Diseases

Socioeconomic disparities play a crucial role in determining vulnerability to climate-induced zoonotic diseases. Low-income communities often lack access to adequate healthcare, sanitation, and vector control measures, making them more susceptible to outbreaks(Jones et al., 2013). Poor living conditions, including overcrowded housing and inadequate waste management, exacerbate the spread of vector-borne and waterborne zoonoses (X. Zhang et al., 2022). Public health interventions aimed at reducing these disparities are essential to mitigating disease transmission risks (Edward et al., 2024).

Role of Extreme Weather Events in Amplifying Disease Outbreaks in Low-Income Urban Settlements

Extreme weather events, such as floods and droughts, significantly amplify zoonotic disease outbreaks in low-income urban settlements. Flooding can lead to the contamination of water sources, increasing the prevalence of waterborne diseases such as cholera and leptospirosis (García-Peña et al., 2021). Similarly, drought conditions contribute to food and water insecurity, weakening immune systems and heightening susceptibility to infections(Braam, 2022). Strengthening climate resilience in urban health systems through improved infrastructure and disaster preparedness is critical to mitigating these risks.

Systemic Factors Shaping Responses to Climate-Driven Zoonotic Disease Risks

Systemic factors such as public health policies, environmental governance, and urban planning play crucial roles in shaping responses to climate-driven zoonotic disease risks. These factors collectively influence the effectiveness of interventions aimed at reducing the burden of such diseases and improving overall community resilience. Understanding their interconnections is essential to developing comprehensive strategies that mitigate the impacts of climate change on public health, especially in the context of zoonotic diseases.

Public Health Policies

Public health policies directly affect the capacity of communities to prepare for and respond to zoonotic disease outbreaks exacerbated by climate change. Effective public health policies prioritize surveillance, early detection, and rapid response strategies, all of which are critical in managing emerging diseases. A One Health approach that integrates human, animal, and environmental health has been emphasized as a necessary framework for addressing zoonotic disease transmission. However, challenges arise in its implementation, particularly in low- and middle-income countries (LMICs), where resource constraints and governance limitations hinder comprehensive policy execution. Inadequate public health infrastructure and limited access to health services exacerbate these challenges, making communities more vulnerable to zoonotic disease spillover events. Addressing these gaps requires cross-sectoral collaborations and increased investment in health system resilience.

Environmental Governance

Environmental governance plays a complementary role in mitigating the impacts of climate change on zoonotic diseases by emphasizing sustainable land-use practices, conservation, and habitat protection. Deforestation, urban expansion, and industrialization contribute to habitat fragmentation, increasing human-wildlife interactions that heighten the risk of pathogen spillover. Effective governance structures that prioritize environmental sustainability can mitigate these risks by enforcing regulations on land-use changes, promoting conservation efforts, and supporting ecosystem restoration. Additionally, policies that control industrial emissions and agricultural practices can reduce environmental contamination that fosters vector proliferation. Strengthening environmental governance is crucial in reducing zoonotic disease transmission and fostering long-term public health resilience.

Urban Planning

Urban planning is critical for fostering environments that reduce vulnerability to climate-driven zoonotic diseases. Cities with inadequate infrastructure, poor waste management, and high population densities provide optimal conditions for vectors and reservoirs of zoonotic pathogens. Uncontrolled urban sprawl disrupts ecological balances, creating new pathways for disease transmission. Sustainable urban planning that incorporates green spaces, improved sanitation, and strategic land-use policies can mitigate these risks. Integrating health impact assessments into urban planning decisions can ensure that developments prioritize disease prevention measures, enhancing urban resilience against emerging zoonotic diseases.

Lessons from Past Zoonotic Disease Outbreaks

Importance of Surveillance and Early Detection

Past zoonotic disease outbreaks highlight the significance of robust surveillance systems in detecting and controlling disease transmission. The Ebola outbreaks in West Africa, for instance, demonstrated the consequences of delayed detection and inadequate public health preparedness. Strengthening surveillance systems that monitor human-wildlife interactions, environmental changes, and vector dynamics can enhance early warning capacities. Predictive models that integrate climate variables can further improve outbreak forecasting, enabling proactive interventions to prevent large-scale disease outbreaks.

One Health Approach

The interconnectedness of human, animal, and environmental health necessitates the adoption of a One Health approach. Diseases such as Nipah virus and H1N1 influenza illustrate the importance of multi-sectoral collaborations in mitigating zoonotic spillover events. Implementing coordinated surveillance programs that bridge veterinary, medical, and ecological research can enhance disease prevention efforts. Governments and international agencies must prioritize One

Health strategies in policy frameworks to ensure comprehensive disease control measures that address the complex interactions driving zoonotic disease emergence.

Environmental Management and Urban Planning

Environmental management plays a pivotal role in limiting zoonotic disease transmission. Habitat degradation, deforestation, and urban expansion have been linked to increased spillover risks. The re-emergence of diseases such as West Nile Virus and chikungunya demonstrates how environmental changes facilitate vector proliferation. Integrating sustainable land-use policies and habitat conservation into urban development plans can reduce these risks. Green infrastructure, such as urban forests and wetlands, can serve as natural barriers that minimize human-wildlife interactions, thereby lowering the likelihood of zoonotic spillovers.

Community Engagement and Education

Community involvement in public health initiatives is essential for effective zoonotic disease prevention. The Ebola crisis underscored the importance of community engagement in disease response efforts, as public awareness campaigns played a critical role in reducing transmission. Educating communities on zoonotic disease risks and prevention strategies fosters behavioral changes that reduce exposure. Grassroots participation in surveillance efforts and environmental management initiatives strengthens public health resilience, enhancing community-led responses to climate-driven disease threats.

Addressing Socioeconomic Inequalities

Socioeconomic disparities exacerbate vulnerability to zoonotic diseases. Low-income populations often reside in areas with inadequate sanitation, poor waste disposal, and limited healthcare access, heightening their risk of disease exposure. Public health interventions must address these inequalities by improving healthcare access, strengthening sanitation infrastructure, and ensuring equitable distribution of resources. Policies that integrate health considerations into socioeconomic development frameworks can mitigate the disproportionate burden of climate-driven zoonotic diseases on marginalized communities.

Integration of Technological and Predictive Models

Advancements in technology offer new opportunities for zoonotic disease surveillance and mitigation. Machine learning algorithms and ecological niche modeling enable researchers to predict disease emergence based on climate and environmental variables. Geographic information systems (GIS) facilitate real-time tracking of vector populations and disease outbreaks, informing targeted intervention strategies. Integrating these technological tools into public health systems enhances disease prediction capabilities, improving response efforts to climate-driven zoonotic threats.

Leveraging Interdisciplinary Approaches to Build Climate Resilience in Urban Health Systems

Holistic and Integrated Health Approaches

The complex interactions between climate change and zoonotic disease dynamics necessitate interdisciplinary approaches that integrate public health, environmental science, and urban planning. The One Health framework provides a holistic approach that considers human, animal, and environmental health in disease prevention strategies. Collaborative research efforts that bridge these disciplines can generate comprehensive solutions to emerging zoonotic disease threats, enhancing urban resilience against climate-driven health risks.

Climate-Adapted Urban Planning

Strategic urban planning that incorporates climate resilience measures is crucial for mitigating zoonotic disease transmission. Cities that prioritize sustainable infrastructure, efficient waste management, and green spaces can reduce vector habitats and minimize human exposure to disease reservoirs. Climate-adaptive urban planning must integrate epidemiological insights into land-use policies to ensure that urban expansion does not exacerbate zoonotic disease risks. Collaborative planning efforts between urban developers, environmental scientists, and public health officials can foster cities that are more resilient to climate-driven health challenges.

Community Engagement and Education

Empowering communities through education and participatory health initiatives strengthens resilience against zoonotic diseases. Public health campaigns that raise awareness about the links between climate change, biodiversity loss, and disease transmission enhance public understanding and encourage proactive health measures. Engaging communities in environmental conservation efforts, such as reforestation projects and wildlife monitoring, can reduce human-wildlife interactions that drive zoonotic spillovers. Strengthening local knowledge systems and integrating traditional ecological wisdom into modern health strategies can further improve disease mitigation efforts.

Innovations in Research and Technology

Investments in research and technological innovations are critical for advancing zoonotic disease prevention strategies. Predictive modeling, remote sensing, and data-driven analytics can enhance outbreak forecasting and improve response times. Interdisciplinary research that explores the socio-ecological determinants of disease transmission can provide valuable insights for public health interventions. Strengthening international collaborations in zoonotic disease research can facilitate knowledge exchange and promote best practices in climate resilience efforts.

Addressing Socioeconomic Inequities

Mitigating the impacts of climate-driven zoonotic diseases requires addressing underlying socioeconomic inequities. Policies that enhance access to healthcare, improve living conditions, and strengthen social protection measures can reduce vulnerabilities to disease outbreaks. Equitable resource allocation and targeted interventions for at-risk populations ensure that disease mitigation efforts are inclusive and effective. By integrating social determinants of health into zoonotic disease prevention strategies, public health systems can better support communities facing climate-induced health risks.

In summary, leveraging interdisciplinary approaches, including One Health strategies, is essential for building climate resilience in urban health systems. By integrating public health, environmental governance, urban planning, community engagement, and technological advancements, cities can enhance their capacity to prevent and respond to zoonotic disease outbreaks. Addressing socioeconomic disparities within urban populations ensures that mitigation strategies are inclusive and effective. As urbanization continues to accelerate and climate challenges escalate, adopting a holistic approach will be paramount in safeguarding public health and enhancing resilience to climate-driven zoonotic diseases.

CONCLUSION

The findings of this study underscore the significant impact of climate change on the transmission and proliferation of zoonotic diseases in urban settings. Rising temperatures, altered humidity levels, and changing precipitation patterns have been linked to shifts in vector ecology, increased survival of pathogens, and heightened spillover risks from wildlife to humans. Additionally, urban expansion and deforestation have further exacerbated human-wildlife interactions, creating new pathways for zoonotic disease emergence. These findings highlight the urgent need for proactive interventions to mitigate the public health risks posed by climate-driven zoonotic diseases.

Addressing these challenges requires a multi-sectoral approach that integrates public health policies, environmental governance, and sustainable urban planning. Strengthening disease surveillance systems, investing in climate-adaptive infrastructure, and promoting interdisciplinary research are critical to improving resilience against future outbreaks. Policy frameworks should prioritize equitable access to healthcare, sanitation, and education to minimize disparities in disease burden among urban populations.

Future research should focus on refining predictive models that incorporate climate variables, vector ecology, and socio-economic factors to enhance outbreak forecasting. Moreover, further studies on the effectiveness of One Health strategies in urban settings will be essential to developing comprehensive intervention frameworks. By implementing evidence-based policies and fostering cross-disciplinary collaborations, it is possible to mitigate the growing threat of climate-driven zoonotic diseases and safeguard public health in the face of climate change.

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