Assessing the Impact of Climate Change on The Transmission Dynamics of Infectious Diseases Worldwide

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Abstract

Climate change has emerged as a major global health threat, profoundly altering the transmission, distribution, and seasonality of infectious diseases. However, the magnitude and pattern of these effects across disease categories and regions remain incompletely synthesised. A systematic review was conducted following PRISMA 2020 guidelines, where 75 eligible articles that utilized real world epidemiological and meteorological data were included and qualitatively synthesized.

The evidence consistently showed a strong link between climate change and infectious disease dynamics. Vector-borne disease, especially dengue and malaria, showed the highest climate sensitivity. Several studies reported that a 1 ^{0}C increase in temperature elevated incidences of dengue by about 13- 17%, while a rainfall increase of approximately 100mm was associated with up to thirty (30) percent higher cases of dengue within endemic areas. Waterborne illnesses like Cryptosporidiosis, Cholera, as well as Shiga toxin liberating E.coli infections rose by 48-52% following very extreme rainfall and flooding events. Food-borne diseases such as Salmonellosis were positively linked with higher ambient temperatures,

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whereas airborne infections like tuberculosis and influenza demonstrated a mixed but significant connection with humidity and temperature extremes. The elderly, children and communities in low- and middle-income countries (LMIC) were disproportionately impacted because of limited adaptive capacity and weaker systems of health.

This study finding concludes that climate change is fundamentally reshaping the patterns of infectious diseases globally through altering pathogen survival, vector ecology, environmental contamination, as well as human exposure pathways. The currently available surveillance systems remain inadequate to capture these complex interactions between climate and health. The study recommends; integration of meteorological and ecological data into routine disease surveillance and early warning system as well as integration of climate components in existing training frameworks for healthcare, especially in vulnerable areas. Coordinated international data sharing as well as sustained investment in climate-resilient health infrastructure are very necessary in order to reduce future disease burdens.

Keywords: *Climate change, Infectious diseases, Vector-borne diseases, Water-borne diseases, Global health, Disease dynamics.*

1. Introduction

Climate change refers to long-term changes in the Earth's climate systems that are driven mainly by an imbalance between the incoming solar radiation and the outgoing inferred radiations 7, a process that has been significantly intensified by accumulations of greenhouse gases (GHGs) like carbon dioxide, nitrous oxide and methane in the lower region of the atmosphere. Greenhouse gases occur naturally; however, human activities have significantly increased their atmospheric concentrations, thereby accelerating global warming and climate variability [1, 2]. The variation in concentrations of GHGs due to the natural process is the main cause of the temperature fluctuations within the atmosphere. Nevertheless, human activities like deforestation, which account for about 15-20% of total concentrations of GHGs, worsen the situation as it contributes to a higher concentration of GHGs. Since plants utilize carbon (IV) oxide in the process of photosynthesis, human activities contribute significantly to the accumulation of GHGs, which has a resultant effect on global climate change [3].

Carbon (IV) oxide gas makes up a bigger portion of the GHGs with 81%, and it results from the combustion of fossil fuels like petroleum products, natural gases, and coal. In addition, methane gases constitute about 10% of the total concentrations of the GHGs and are produced from coal mines, natural gas operatives, oil plants, agriculture and landfills, while nitrous oxide, which accounts approximate 5% of the total GHGs emissions, is produced in various processes of waste management, burning fossil fuels, as well as nitrogen fertilizer applications in the farms [4].

According to studies on trapped air bubbles in Antarctic Ice, which showed a rapid rise in the levels of greenhouse gases from mid 1800s/the industrialization ages, when compared to prior years before human civilizations. The mean carbon (IV) oxide concentrations before the industrial age were about 280 parts per million, and their concentrations have risen to about 380 parts per million since that age [5]. As a result, the GHG concentrations have been on the rise, attaining higher levels in the atmosphere, causing a rise in global temperatures. In addition, the ocean temperature is also on the increase as results while the sea levels are increasing by 9-88 cm because of the melting sea ice. Due to the retention of moisture by the warm air, there is a disruption in the hydrological cycle, thus, certain places will experience more rainfall above the normal, while in other places, because of the extremely bad weather conditions, like heat waves and storms, will start experiencing severe drought conditions.

Given these possibilities of changed patterns of rainfall as well as the extreme weather patterns of drought, climate change is expected to have a substantial influence on human health, with an emphasis on the dynamics of infectious diseases globally. As noted, there are alterations in pathogen development, pathogen distributions, as well as changes in human behaviour.

These rapid climatic changes pose a substantial risk to human health, especially through influencing the emergence, re-emergence, and patterns of transmission of infectious diseases. Fluctuations in temperature, altered rainfall patterns, changes in humidity and the disruptions in the ecological cycles have a great influence on the pathogen survival, distributions of vectors and the human behavioural patterns. Consequently, climate change has intensified the burden of vector-borne diseases like malaria, West Nile virus and dengue, waterborne illnesses like cryptosporidiosis and cholera and finally, foodborne diseases and airborne infections like tuberculosis and influenza [6]. The most vulnerable group, particularly the children, the elderly and populations within the low and middle-income nations, are the most affected as they face disproportionate risks because of the limited adaptive capacity and weaker health systems.

The World Health Organization (WHO) in 2019 identified climate change as one of the greatest health threats of the 21st century. According to the scientific evidences shows consistently a strong link between climate variability and the trends in infectious diseases [6]. The emphasis on the infectious diseases was due various reasons like the recent outbreaks of infectious diseases such as Ebola, dengue and Covid-19, assists in diseases identifications influenced by climate change, identify the regions preparedness in case of an outbreak of infectious diseases and finally

there an emphasis by the international organizations like WHO on the influence of climate change on the public health and infectious diseases, resulting to more studies on the current topic since the influence of climate change on the global disease dynamics remains complex and unevenly understood across regions [7]. Evaluating the existing body of research, it is therefore essential to identify the most current sensitive disease, guiding preparedness efforts as well as informing future public health policies.

Due to this urgency, the current study assesses global evidence on the influence of climate change on the dynamics of infectious diseases. The study focuses on climate-sensitive infectious diseases, synthesizing key epidemiological patterns, highlighting vulnerable populations and identifying the limitations and future research areas necessary for strengthening global health resilience in a warming world.

2. Materials and Methods

2.1. Database Search Strategy, Inclusion Criteria, and Exclusion Criteria

This present study employed a systematic review approach to assess the global evidence on the influence of climate change on the infectious disease dynamics. The review is based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) guideline 2020 [7]**,** to ensure transparency, reproducibility and methodological validity. The database search was conducted across the three main electronic sites, namely PubMed, Scopus and Google Scholar. The literature search covered the period from January 2000 to March 2025, which captured the contemporary studies that reflect the recent climatic and epidemiological trends. The keywords included “climate change”, “global warming”, “world warming” “infectious diseases”, “waterborne”, “foodborne”, and “vector borne”. The search keywords employed the Boolean combination logic. The database outputs were exported to Microsoft Excel for management. Screening of articles was carried out to remove duplicates, and then the title and abstract of the article were considered for checking eligibility. Articles that made it through the stage of screening were examined to see if they met the predefined criteria for full-text eligibility before being used for data extraction.

The eligibility criteria for the articles which were included in this research were as follows, peer–reviewed original articles and published with no disapproval, the manuscript utilized the main data, the disease, parasite, vector, or pathogen of interest affected humans, the study used non-simulated future climate data and was descriptive, retrospective, and grounded in real-world systems, the published article was in English language. This current study did not include the articles, study articles that examined seasonal impacts only, as well as studies categorized as clinical trials,

conference abstracts, non-human studies, case reports, reviews, posters, books, commentaries and editorials. Therefore, the articles that met the above selection criteria were collected and considered for full text.

2.2. Data synthesis

The most relevant information obtained from the articles that were selected was taken out and put together in an Excel spreadsheet. The information obtained entailed the disease, the kind of infectious disease, the most vulnerable groups, the impact of climate change, and the evidence source/ references.

3. Results

3.1. Study selection

The initial database search generated a total of 1785 articles, which consist of 986 articles from Google Scholar, 599 articles from PubMed and 200 articles from Scopus. Screening removed 171 duplicate articles, resulting in 1614 articles that underwent further screening. Screening based on titles and abstracts selected 554 articles, while 1060 articles were removed based on titles and abstracts. Moreover, 7 articles were removed since they were not retrievable. 547 articles were selected for full text review, which resulted to removal of 472 articles that did not meet the eligibility criteria. Therefore, data were extracted from the remaining 75 articles [Figure 1].

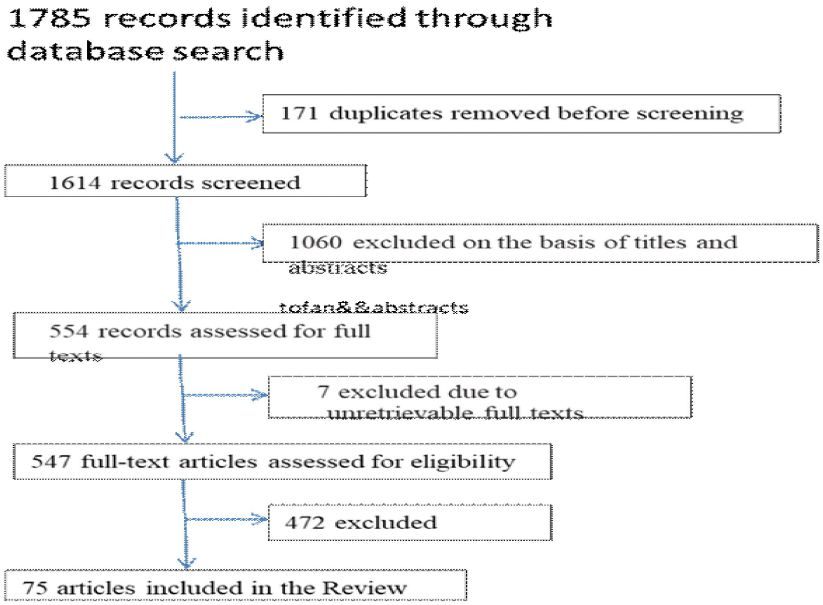

Figure 1. Flow diagram of article selection

3.2. Literature Analysis

Literature analysis is given in Table 1.

Table 1: Summary of evidence linking climate change variables to infectious disease transmission

Disease transmission pathway	Key climate drivers	Infectious diseases affected	Geographic evidence	Consistent findings	References
Vector-borne	Increased temperature, rainfall, humidity, and extreme heat events	Malaria, dengue, chikungunya, Ross River virus	Asia, Africa, Australia	Climate warming and increased precipitation enhance vector breeding, expand transmission zones, and increase disease incidence	[8-15]
Water-borne	Heavy rainfall, flooding, cyclones, temperature rise	Cholera, Escherichia coli, cryptosporidiosis, legionellosis	United States, Belgium, Nigeria, Eastern Africa	Extreme rainfall contaminates water sources, leading to increased outbreaks of water-borne diseases	[10, 15-17]
Airborne/ respiratory	Temperature extremes, rainfall variability, humidity	Tuberculosis, measles-like illness, influenza, pneumonia, RSV	China, Bangladesh, Belgium, Australia	Temperature extremes influence respiratory disease transmission, depending on pathogen and population vulnerability	[14, 18-20]
Food-borne	Minimum and maximum temperature increases, rainfall	Food poisoning, salmonellosis, leptospirosis	Malaysia, Belgium	Higher temperatures promote pathogen growth in food systems, increasing food-borne disease incidence	[14]
Multiple transmission routes	Climate variability, extreme weather events	Gastrointestinal, respiratory, vector-borne, enterovirus infections	China, Belgium	Climate extremes disproportionately affect vulnerable populations, increasing infection risks	[10, 21]

4. Discussion

The findings synthesized in Table 1 provide compelling evidence that climate change is a major determinant of infectious disease dynamics across varied ecological settings and transmission pathways. Collectively, the reviewed studies showed that changes in rainfall, temperature, humidity and elevated frequency and intensity of extreme weather events systematically influence the incidence, distribution and seasonality of waterborne, foodborne, vector-borne and airborne infectious diseases. These effects are not uniform but are shaped through interactions between climatic factors, vector biology, pathogen biology, population vulnerability, and health system capacity. This multifaceted influence underscores climate change as a risk multiplier that amplifies existing health challenges rather than acting as an isolated driver.

4.1. Vector-borne Disease Transmission

Vector-borne disease showed the most consistent and robust connection with climatic variable factors, especially precipitation and temperature. Evidence from Africa, Australia, Asia and the Middle East indicates that elevated temperatures enhance vector survival, biting frequency and reproductive rates, as well as shortening the extrinsic incubation period of pathogens within vectors [22, 23]. These biological responses resulted in higher transmission efficiency and expanded geographic ranges for diseases like dengue, chikungunya, Ross River virus and malaria. Increased rainfall further contributes by creating additional breeding habitats for mosquito vectors, especially in tropical and subtropical areas where accumulation of water happens rapidly during rainy seasons [24].

Various studies summarized in **Table 1** highlight that heavy rainfall and flooding events often coincide with peaks in malaria and dengue incidence. These findings suggest that climate change influences not only average disease burden, but also epidemic timing and intensity. In regions like South Asia and sub- Saharan Africa, where vector control and health system infrastructure are always limited, climate-driven changes in transmission dynamics can overwhelm existing control measures. Furthermore, warming trends may enable vectors to establish in previously unsuitable areas, raising attention about the re-emergence or emergence of vector-borne diseases in temperate regions. These observations reinforce the need to integrate climate projections into vector surveillance and control strategies.

4.2. Waterborne diseases transmission

Waterborne diseases emerge as particularly sensitive to extreme weather events, including heavy rainfall, flooding and cyclones. The summarized evidence shows a strong link between such events and outbreaks of cholera, cryptosporidiosis, *legionellosis* and *Escherichia coli* infections across both high-income and low/middle-income nations. Climate change exacerbates these risks through the elevated frequency and severity of hydrological extremes, which disrupt water and sanitation systems [25].

Events of flooding can overwhelm sewage systems, contaminate drinking water sources and facilitate pathogen spread through surface runoff, while prolonged droughts may force populations to depend on unsafe water supplies. These mechanisms are especially pronounced in urban informal settlements and refugee or displacement camps where access to safe water and sanitation is already constrained. The evidence indicates that climate-driven waterborne disease risks are not limited to developing areas; even nations with advanced systems experience increased disease incidence during extreme weather events [26], highlighting the universal vulnerability of water systems to climate stress.

4.3. Foodborne disease transmission

Foodborne disease represents an additional pathway through which climate change affects the burden of infectious diseases. The summarized studies indicate that increases in minimum and maximum temperatures are strongly linked with food poisoning, salmonellosis and leptospirosis. Increased temperatures enhance pathogen survival and replication along food production, storage, processing and distribution chains. Climate change also influences food safety indirectly through impacts on agricultural practices, water availability and livestock health, thereby increasing chances for contamination [27]. These findings highlight the need to consider food systems as critical interfaces between climate change and public health, especially in rapidly urbanizing regions where food demand and supply chains are expanding.

4.4. Airborne and respiratory infections transmission

The connection between climate change and airborne or respiratory infections is more complex and less linear than for vector or water-borne diseases. Studies from China, Bangladesh, Belgium and Australia demonstrate that extreme temperatures, both hot and cold, as well as rainfall and humidity variability, influence diseases like tuberculosis, influenza, pneumonia, measles-like illnesses and respiratory syncytial virus infections. Unlike vector-borne disease, where warming generally increases transmission potential, respiratory infections showed pathogen-specific responses to climatic conditions.

Extreme cold may increase respiratory infection risk by promoting indoor crowding and impairing host immune responses, while extreme heat can alter human behaviour, ventilation patterns and pathogen survival [28]. The heterogeneity observed across areas suggests that socio- environmental factors like housing quality, air pollution, population density and healthcare access strongly modulate climate-respiratory disease relationships. These findings emphasize the importance of localized assessments and caution against generalized assumptions regarding climate impacts on airborne infections.

4.5. Population vulnerability, displacement and social determinants

A recurring theme across the summarized evidence is the role of social vulnerability in mediating climate disease relationships. Climate-driven disasters like floods, droughts and cyclones often result in forced migration and displacements, leading to overcrowded living conditions, inadequate sanitation, limited access to clean water and disrupted healthcare services. These conditions create environments conducive to rapid infectious disease transmissions across multiple routes.

Children are particularly vulnerable due to developing immune systems, nutritional deficiencies and greater exposure to contaminated environments. Moreover, populations in informal settlements and refugee camps experience compounded risks due to high population density and limited resources [29]. These findings highlight that climate change does not act independently but interacts with socioeconomic and structural determinants of health to shape infectious disease outcomes.

4.6. Strengths and Limitations of the Evidence Base

The strength of summarized evidence lies in its geographic breadth and consistency across multiple disease categories and climatic contexts. However, limitations remain, including variability in study design, data quality and analytical approaches. Many studies depend on ecological or observational data that may limit causal inferences. In addition, underreporting of infectious diseases in low-resource conditions may underestimate true disease burden and climate impacts.

Future research should prioritize longitudinal studies, high-resolution climate and health data integration and modelling approaches that account for socioeconomic and demographic factors. Such efforts will enhance understanding of causal pathways and improve predictive capacity under future climate scenarios.

4.7. Surveillance, Data Gaps and Early Warning Systems

The healthcare globally and the disease surveillance system are currently overburdened, and there persist to face significant challenges because of climate change. Disease surveillance poses a special challenge for the conventional system of surveillance, which depends mostly on past data and fails to sufficiently account for demographic and climatic factors, thereby reducing its capability to monitor the effects of rising temperatures on the spread of diseases and forecast future burden of disease [30]. Several studies emphasized gaps in worldwide disease surveillance and the limited capacity of many countries to detect early signs of climate-related outbreaks. Conventional systems of surveillance don't integrate adequately meteorological, ecological and health data, hence limiting their predictive power [31, 32]. Multiple data sources, namely vector surveillance, weather data and conventional surveillance of diseases, incorporated by this system enable a more precise infectious disease diagnosis, investigation and response. They depend on prompt and open information exchange and collaboration across various agencies, both internationally and nationally, namely departments of agriculture and health, meteorological organizations, as well as the surveillance program for both animals and vectors [33]. The development of an effective system of disease surveillance, prevention, mitigation, and control actions as well as interventions relies on adoption of a strategy of "one health" that include human, animal and environmental health

is necessary for managing the climate sensitive diseases particularly the zoonotic and vector borne infections through emphasizing promotion of cooperation, collaboration, and sharing information across regions and sectors.

Utilization of early warning systems that aid in predicting risks depending on regularly gathered climatic, epidemiological, environmental, demographic, and entomological data. Integrated systems of surveillance can improve readiness and capacity for adaptation by accounting for the impact of climate variables on disease risk. Geographic information system technologies and satellite remote sensing make it possible to discover both temporal and spatial climate trends that might affect the risks of infectious diseases, thus epidemics can be predicted [34]. It is essential to comprehend the cases' distribution geographically to enable both preventive and resource initiatives to target proactively risky populations and locations [35]. Additionally, it is essential to promote notifications of disease online and digital surveillance of disease, especially in low/middle-income.

This review study underscores the need to strengthen the climate-informed surveillance as well as expand the utilization of various tools like remote sensing, geographic information systems (GIS), artificial intelligence and machine learning for real-time predictions and preparedness for outbreaks. The findings of this study review reinforce the need for strong policy action at both global and national levels. The integrations of the one health approach that include human, animal and environmental health are necessary for managing the climate-sensitive diseases, particularly the zoonotic and vectorborne infections. International collaborations, data sharing and investments in climate adaptation strategies are necessary in order to reduce health vulnerabilities.

4.8. Healthcare system preparedness and capacity of the workforce

Infectious diseases driven by climate change place a significant strain on the health care system, especially during extreme weather events. The capacity and knowledge of the healthcare workforce are taken into account in addressing the challenge of infectious diseases brought on by climate change. For instance, climate change may result in an increase in temperatures, which leads to geographic dissemination and a rise in infectious disease cases. Health care providers may be less equipped to recognize and treat these conditions, especially in areas that were not previously frequently impacted. According to a Chinese survey of employees at the Centres for Disease Control and Prevention, only 27% of them thought they understood climate change well, and 85% believed they needed more knowledge about how it affects health [36]. Many health workforces lack training on health risks linked to climate change, resulting in delayed diagnosis and reduced effectiveness of response strategies.

Climate change, which is associated with rising temperatures alongside other extremes in climate, may result in a rise in general consultations to practitioners, visits to the department of emergency, and admissions to the hospital for infectious diseases. Moreover, these factors may also lead to an increase in healthcare providers' workloads, which may be unsustainable, thereby reducing their ability to address the health issues raised by climate change. According to a survey carried out on general practitioners found in Australia, specifically within rural New South Wales, 33-44 % were unsure or did not think their general practice could effectively address the health effects of extreme weather events, like excessive heat waves. However, with a rise in temperatures, first highlighting knowledge gaps in the health workforce and leading to unsustainable workloads, they also offer a significant chance to modify healthcare professional training to place a greater emphasis on the effects of extreme climate change on the risk of infectious diseases and the wider health effects of climate change.

Integrations of climate change as well as infectious diseases epidemiology into medical education and professional development are therefore necessary. This offers a significant chance to create an education that is specialized alongside programs for training to be part of medical curricula and professional development packages. These programs must incorporate materials that educate and increase health professionals' knowledge of data collection and disease surveillance, in order to positively contribute to capacity building and improve the capacity and timing of infectious disease surveillance data. In addition, climate resilient healthcare infrastructure that includes improved water systems, improved sanitation systems, and infection control system in vital in reducing health risks.

5. Conclusion

This systematic review provides robust and comprehensive evidence that climate change is significantly reshaping the global transmission dynamics of infectious diseases. Across varied geographic regions and transmission pathways, climatic factors including elevated temperatures, altered precipitation patterns, increased humidity and more frequent extreme weather events consistently influence incidence of diseases, intensity, seasonality, as well as spatial distribution. Vector-borne diseases, especially malaria and dengue, demonstrate the strongest and most consistent sensitivity to climate change, while food, water and airborne infections are increasingly affected by environmental contamination, ecosystem distribution and climate-based changes in human behaviour.

The findings highlight that the health impacts of climate-sensitive infectious diseases are not evenly distributed. Children, older adults and populations in low/ middle income nations bear a disproportionate burden because of constrained

adaptive capacity, fragile health systems and heightened exposure to climate-related risks. Despite the growing scientific acceptance of these risks, substantial gaps exist and persist in disease surveillance, predictive modeling and integration of metrological and ecological data into public health decision making. The traditional system of surveillance remains largely reactive and insufficiently equipped to capture the complex, non- linear interactions between climate change and infectious disease transmission.

Addressing these challenges needs a paradigm shift toward climate-informed, anticipatory public health approaches. Strengthening integrated early warning systems, adoption of the one health framework, promoting workforce capacity and investing in climate-resilient health infrastructure are critical steps to improve preparedness and response. Moreover, sustained international collaboration, equitable data sharing and targeted studies investment, especially in underrepresented areas and disease categories, are necessary to improve predictive capacity and inform appropriate interventions.

Therefore, climate change represents one of the most marked threats to global infectious disease control. Proactive, coordinated, and interdisciplinary techniques that bridge climate science, epidemiology and public health practices are needed urgently to mitigate future disease risks and safeguard population health in an increasingly warming world.

6. Data Availability

All data supporting the findings of this study are available within the article.

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