EHDI

Epidemiology & Health Data Insights
(eISSN 3080-8111)

Australasia Publishing Group

Review Article

Climate Change and Emerging Infectious Diseases: A Global Review of Shifting Patterns, Pathogens, and Public Health Risk

Alliah Kris-Ann Wright[1], Cyril Ifeanyichukwu Ezugwu[2], John Kelenna Iregbu[3], Ezeamii Patra Chisom[4], Adaobi Amelia Ozigbo[5], Morayo Anne Ajobiewe[6], Ebenezer Oluwadamilare Oyekanmi[7], Aliyu Olanrewaju Olaniyi[8]

[1]*Faculty of Graduate Nursing, Alverno College Milwaukee, Wisconsin, USA*

[2]*Emergency Resident, Emergency Department, Ahad Al-Masaraha General Hospital, Ahad Al-Masaraha, Jizan Region, Kingdom of Saudi Arabia*

[3]*Department of Family Medicine, Nnamdi Azikiwe University Teaching Hospital, Nnewi, Anambra State, Nigeria*

[4]*Department of Biostatistics, Epidemiology and Environmental Health Sciences, Jiann-Ping Hsu College of Public Health, Georgia Southern University, USA*

[5]*Department of Medicine, Chukwuemeka Odumegwu Ojukwu University, College of Medicine, Awka, Anambra State, Nigeria*

[6]*Nursing Program, Faculty of Health Science, University of Lethbridge, Lethbridge, Alberta, Canada*

[7]*Department of Medical Laboratory Science, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria*

[8]*Stockport NHS foundation trust, Stepping Hill Hospital, Stockport, Manchester, United Kingdom*

Received: July 16, 2025

Accepted: Aug 09, 2025

Corresponding author's email: Olanrewaju42005@gmail.com

Abstract:

Climate change is changing how emerging infectious diseases (EIDs) spread over the world. The ecological conditions in which diseases, vectors, and hosts interact are changing because of rising temperatures, shifting patterns of rainfall, and increasingly frequent extreme weather events. This narrative review compiles existing research on climate-sensitive infectious illnesses and elucidates the principal mechanisms influencing observed changes. Food- and water-borne illnesses (e.g., cholera, leptospirosis) are increasingly linked to droughts, floods, and disruptions in infrastructure. Vector-borne diseases like dengue, chikungunya, malaria, and Lyme disease are spreading to highland and temperate areas. At the same time, zoonotic spillovers like Ebola, Nipah, and SARS-CoV-2 are happening more commonly in areas where the ecosystem has been altered. New worries are thermotolerant fungal infections and microorganisms that live in permafrost. This review does not offer new epidemiological modelling; instead, it puts recent Global Burden of Disease (GBD) estimates into context. These estimates reveal that the burden of infectious diseases is rising in regions that are sensitive to climate change, including sub-Saharan Africa, South Asia, and Latin America. Weak surveillance systems, health disparities caused by climate change, and broken data streams are some of the biggest gaps in response. Improvements in AI-based forecasting, satellite surveillance, pathogen genomes, and One Health methods provide useful tools for taking action before something happens. It is important to build public health systems that are climate-responsive, transdisciplinary, and fair in order to reduce the growing dangers posed by infectious illnesses connected to climate change.

Keywords: Climate Change; Emerging Infectious Diseases; Vector-Borne Transmission; Zoonotic Spillover One Health Framework

Introduction

Climate change is now universally recognized as both an environmental problem and a serious threat to world health [1]. Anthropogenic increases in greenhouse gas emissions have caused a cascade of ecological changes, including rising global temperatures, changing precipitation patterns, sea-level rise, and an increase in the frequency of extreme weather events. These environmental changes are hastening transitions in the habitats and life cycles of many disease vectors, upsetting ecological balances, and intensifying interactions between humans, animals, and pathogens [2]. As a result, the landscape of infectious illnesses is experiencing rapid and complicated alterations, with previously geographically restricted pathogens spreading into new territory and previously controlled infections resurfacing under novel climatic conditions [3].

Emerging infectious diseases (EIDs) are infections that have recently arrived in a community or are rapidly rising in prevalence or geographical spread. They could be caused by previously unknown pathogens or by existing agents developing new pathogenicity, host range, or resistance profiles. Importantly, the origin and re-emergence of infectious illnesses are becoming more closely related to climate-sensitive dynamics [4]. Vector-borne diseases like malaria and dengue fever, for example, are now showing up in highland and temperate zones that were previously thought to be non-endemic. Waterborne outbreaks of cholera, leptospirosis, and other enteric illnesses are common after floods and natural disasters, while deforestation and changing land use have encouraged the zoonotic spread of viruses such as Ebola, Nipah, and SARS-CoV-2. These patterns highlight the complexities and changing nature of climate-driven infectious hazards [5].

Although understanding of these connections has improved, significant gaps remain in the research. Much of the existing work is still divided by region, disease kind, or disciplinary viewpoint. Few reviews have combined the global scale of climate-related EID dynamics, highlighting novel patterns of emergence, pathogen adaptation, and regional vulnerability. Furthermore, while international organizations have built frameworks for climate-resilient health systems, the translation of climate science into infectious disease preparedness is still unequal and inadequate in many locations, particularly in low- and middle-income nations [6].

While this review does not conduct original interdisciplinary modelling like the formal GBD studies, its findings are consistent with GBD trends showing an increasing proportion of infectious disease burden in regions highly exposed to climate variability (e.g., sub-Saharan Africa, South Asia, and Latin America). Recent GBD estimates confirm a rise in climate-sensitive infectious disease DALYs — particularly vector-borne diseases such as dengue, malaria, and Lyme disease — in geographic areas where temperature and rainfall anomalies have intensified over the past two decades. Our discussion aligns with these trends by synthesizing ecological and epidemiological mechanisms that help explain the burden patterns documented by GBD. Hence, rather than contradicting GBD, our findings contextualize and support GBD observations by providing mechanistic pathways linking climate change to the shifts in infectious disease burden captured in GBD estimates.

This study aims to fill these essential gaps by giving a thorough and up-to-date overview of how climate change is altering the worldwide distribution, dynamics, and risk profile of emerging infectious illnesses.This paper is structured as a *narrative review*, drawing on peer-reviewed literature and global data sources to synthesize current knowledge on climate-sensitive infectious disease trends. Targeted searches were conducted in PubMed, Web of Science, and Scopus using combinations of the keywords *"climate change," "emerging infectious diseases," "vector-borne," "zoonotic," "public health,"* and *"global burden."* Grey literature from global health organizations (e.g., WHO, IPCC, GBD) was also included. Sources were selected based on their relevance, credibility, and contribution to understanding climate-related disease dynamics and response gaps. No systematic inclusion/exclusion protocol or meta-analysis was employed, in keeping with the integrative nature of a narrative review. We specifically look at the ecological mechanisms by which climate factors promote disease onset, identify key disease categories that are changing, investigate regional trends and hotspots of concern, and assess the current status of public health preparedness. This review intends to guide future research, surveillance tactics, and policy frameworks for anticipating and managing climate-sensitive infectious disease risks by emphasizing current data and incorporating interdisciplinary viewpoints [7].

Methodology

Search Strategy and Selection Criteria: Literature searches were conducted in PubMed, Web of Science, and Scopus using combinations of the keywords "climate change," "emerging infectious diseases," "vector-borne," "zoonotic," "public health," and "global burden." Grey literature from reputable global health organizations (e.g., WHO, IPCC, GBD) was also included.

Inclusion criteria were: (i) peer-reviewed articles or authoritative reports published between 2000 and 2025; (ii) studies that explicitly examined links between climate variables and infectious disease emergence, distribution, or transmission; and (iii) works providing empirical data, modeling, or systematic reviews relevant to climate-sensitive infectious diseases.

Exclusion criteria were: (i) studies without a clear focus on climate–disease interactions; (ii) opinion pieces without supporting data; and (iii) duplicate records across databases.

Climate-Driven Mechanisms of Disease Emergence

Interdisciplinary research that combines climatology, ecology, and epidemiology is shedding new light on the relationship between climate dynamics and infectious disease onset. Climate change disrupts the biological and environmental processes that regulate pathogen transmission, acting as both a catalyst and an amplifier of infectious disease risks. Several climate-sensitive systems play an important role in shaping current and future patterns of disease onset [8].

One of the most obvious and well-documented effects is the impact of temperature and rainfall on vector life cycles. Mosquitoes, ticks, sandflies, and other arthropod vectors are ectothermic creatures whose development, reproduction, and feeding habits are heavily influenced by environmental temperature [9]. Rising global temperatures have increased disease vectors' geographic range and seasonal activity, allowing diseases including malaria, dengue fever, chikungunya, and Lyme disease to spread into previously non-endemic highland and temperate regions. Changes in rainfall patterns, such as increased frequency of heavy precipitation events and protracted droughts, can affect breeding habitats, increasing mosquito multiplication in stagnant water collections and bringing wildlife closer to human settlements during times of water scarcity [10]. Notably, new vector-pathogen connections are emerging, such as Aedes albopictus' adaptation to milder climes, which could indicate an evolutionary shift in vector competence under climatic stress.

Extreme weather phenomena, particularly floods, storms, and droughts, act as acute triggers for infectious disease outbreaks. Flooding not only contaminates water supplies, raising the risk of waterborne diseases like cholera, hepatitis A, and leptospirosis, but it also disrupts health infrastructure and forces people to live in overcrowded, unhygienic shelters. Heatwaves can exacerbate respiratory infections by raising particulate matter and allergen levels, whereas wildfires have been associated with an increase in hospitalizations for viral respiratory disorders [11]. The clustering of epidemics following these events suggests increased pathogen exposure as well as decreased disease control capabilities. Importantly, the temporal association between climate anomalies and disease outbreaks is becoming more predictable, opening pathways for anticipatory public health interventions [12].

Climate change also fosters disease onset through habitat destruction and zoonotic spillovers. As ecosystems deteriorate due to deforestation, desertification, and agricultural encroachment, which is typically caused by climate-related land degradation, wildlife is forced to interact more closely with human populations [13]. This ecological convergence enhances disease transmission from wildlife reservoirs to human hosts. The advent of SARS-CoV-2, as well as earlier zoonoses like Ebola and Nipah virus, demonstrates the increasingly porous barrier between wildlife and human disease ecologies. Recent research has highlighted the expansion of bat habitats as a result of rising temperatures and changing food availability, raising the potential of bat-borne virus spillovers in new geographic areas [14].

Thawing permafrost and releasing ancient germs is an unexplored but potentially significant frontier. As Arctic and sub-Arctic permafrost melts at a faster rate, long-dormant microorganisms such as viruses, bacteria, and fungal spores may revive. A commonly recognized incident occurred in 2016, when a decades-old anthrax-infected reindeer carcass thawed, resulting in a human outbreak in Siberia [15]. While the full scope of this hazard is unknown, new metagenomic analysis of permafrost cores has revealed viable microbial DNA extending back tens of thousands of years, raising valid concerns about the resurgence of illnesses against which present populations may be immune [16].

Emerging information also points to previously underappreciated illness amplification pathways. These include climate-induced variations in host immunity caused by heat stress and nutritional shortages, microbial evolution in response to environmental stressors, and changes in soil ecology that affect fungal pathogen dynamics [17]. For example, Candida auris, a multidrug-resistant fungus, is thought to have developed as a result of temperature adaptation in reaction to global warming. Toxigenic fungi, such as Aspergillus and Fusarium, also show increased sporulation in response to drought and high temperatures, which has implications for respiratory and foodborne infections [18].

Together, these climate-driven mechanisms highlight the profound and complex ways in which a warming world is changing the global infectious disease landscape. As these processes intensify and overlap, they necessitate proactive, integrated responses based on ecological awareness and predictive surveillance [7]. The intricate interplay of climatic variables, ecological disruption, and infectious disease dynamics can be viewed as a systems-based cascade of interconnected factors. Figure 1 depicts a graphic framework that connects these components and demonstrates how climate change influences public health outcomes via numerous interrelated routes [19].

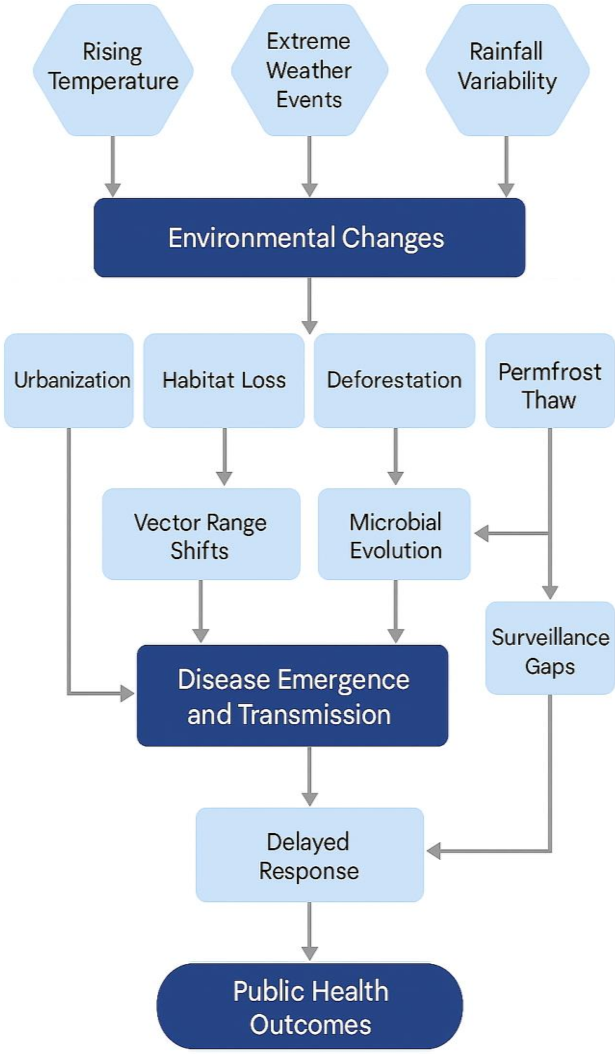

Figure 1. Conceptual Framework: Climate Change as a Driver of Infectious Disease Emergence. This diagram depicts the causal pathways that connect climate drivers—such as temperature rise, rainfall variability, and extreme weather events—to environmental and

ecological changes, pathogen dynamics, and, ultimately, public health consequences. Altering vector habitats, displacing wildlife, increasing urban congestion, health disparities, and inadequate surveillance systems are all important intermediate processes.

These combined pressures result in increased epidemic frequency, geographical distribution, and mortality from developing infectious diseases. The framework promotes integrated, system-level thinking in public health preparation and climate adaptation planning.

Changing Patterns of Key Infectious Diseases

Climate change is reshaping vector ecology, water systems, and human-animal interfaces, causing significant changes in the distribution and epidemiology of infectious diseases. This section investigates climate-induced changes in three key categories of infectious diseases: vector-borne, water- and food-borne, and zoonotic spillover events, with a focus on novel geographies, changed seasonality, and developing transmission mechanisms.

Vector-borne Diseases

Vector-borne diseases are among the most vulnerable to climate change, as arthropod vectors such as mosquitoes, ticks, and sandflies rely heavily on environmental temperature, humidity, and rainfall for survival, reproduction, and biting activity. Climate change has significantly altered the geographic and seasonal distribution of numerous major vector-borne diseases, resulting in epidemics in formerly climatically inappropriate places [20].

Malaria, which was formerly confined to tropical and subtropical zones, is now being reported in high-altitude parts of East Africa and South America, where rising temperatures have allowed Anopheles mosquitoes to establish seasonal transmission [21]. The highland regions of Ethiopia and Kenya, for example, have seen episodic spikes in malaria prevalence coincide with unusually warm seasons, a pattern now corroborated by predictive climate-epidemiological models. These developments pose significant risks for immunologically vulnerable individuals and poor health systems in highland areas [22].

Dengue fever, principally transmitted by Aedes aegypti and Aedes albopictus, has rapidly spread throughout Asia, the Americas, and, increasingly, Europe. Dengue fever, long thought to be a tropical disease, is now being recorded on a seasonal basis in southern France, Croatia, and areas of the southern United States [23]. The adaptive migration of Aedes albopictus into temperate areas, enabled by diapause (cold-hardy eggs), demonstrates the vectors' evolutionary adaptability under climate constraints. Furthermore, the expansion of the dengue transmission season, typically by several weeks or months, puts further strain on already overburdened vector-control operations [24].

Chikungunya and Zika virus, which are both spread by Aedes mosquitoes, have followed similar regional expansion trends. Chikungunya outbreaks in Italy and France, as well as the rapid spread of Zika across the Americas in 2015-2016, demonstrate how quickly vector-borne viruses may establish themselves in new climatic zones when ecological and immunological conditions meet. Climate variability has a crucial role in facilitating epidemics, particularly during El Niño periods or warm seasons [25].

Lyme disease, caused by Borrelia burgdorferi and transmitted by Ixodes ticks, has progressively spread in North America and Europe. Warmer winters and longer growing seasons have increased tick survival and host-vector contact, especially in peri-urban and suburban settings. In Canada, the northern border of Ixodes scapularis has changed several hundred kilometers in the last two decades, and portions of Scandinavia now record endemic transmission zones that were not there in earlier decades [26].

Collectively, these examples illustrate that vector-borne diseases are not only moving geographically but also becoming less predictable in their seasonality and intensity, challenging traditional surveillance frameworks.

Water- and Food-borne Infections

Water- and food-borne diseases are inextricably linked to climatic conditions, including precipitation patterns, flooding, temperature, and water infrastructure reliability. These illnesses are especially frequent in low-resource areas where climate extremes exacerbate existing infrastructure deficiencies.

Cholera, caused by Vibrio cholerae, has a significant link to rising sea surface temperatures, increased rainfall, and coastal flooding—conditions that promote the expansion of planktonic hosts and the contamination of drinking water. El Niño occurrences have been linked to cholera epidemics in the Bay of Bengal and East Africa. Models may predict regional outbreaks weeks ahead using sea surface temperature anomalies. In Haiti, the disastrous 2010 outbreak following an earthquake and flooding demonstrated how climatic and sociopolitical fragilities converge to create epidemic conditions [27].

Typhoid fever, caused by Salmonella enterica serovar Typhi, is still endemic in many parts of South Asia and Sub-Saharan Africa. Flooding occurrences have been associated with an increase in typhoid cases due to overburdened sewage systems and contamination of water sources. At the same time, drought circumstances may result in the concentration of pathogens in stagnant water or the usage of contaminated water sources, as seen in northern Nigeria and southern India [28,29].

Leptospirosis, a zoonotic bacterial infection spread through water polluted with diseased animals' urine, is becoming more well recognized as a climate-sensitive disease. Outbreaks are frequently followed by heavy rainfall and flooding, especially in tropical and subtropical areas with inadequate sanitation and urban drainage systems. Recent research from Brazil, Sri Lanka, and the Philippines has shown that seasonal leptospirosis outbreaks coincide with monsoon rains, and accumulating data suggest that climate change may potentially be altering rodent reservoir dynamics [30].
These diseases exemplify how climate change exacerbates existing water insecurity and sanitation gaps, disproportionately affecting vulnerable populations with limited access to safe water and health care services [31]. Furthermore, they highlight the urgent need for climate-resilient water and sanitation infrastructure as a core component of infectious disease prevention.

Zoonotic and Viral Spillover Events

Climate change is also accelerating the emergence of zoonotic diseases—those transmitted from animals to humans—by increasing human encroachment into wildlife habitats and altering the behavior, distribution, and immune dynamics of both wildlife and domestic animals.

Nipah virus, a bat-borne paramyxovirus discovered in Malaysia in 1998, has resurfaced irregularly in Bangladesh and India, frequently with high case fatality rates [32]. Deforestation and changes in fruiting tree phenology have brought fruit bats closer to human settlements, where viral transmission can occur through contaminated food sources (for example, raw date palm sap) or direct contact. Climate change, which affects food availability and bat roosting habits, is increasingly being linked to the seasonal risk of spillover [33].

Ecological disturbances brought on by hunting, deforestation, and climate irregularities have also been connected to epidemics of the Ebola virus disease in Central and West Africa. Deforestation and landscape have increased human exposure to bat reservoirs [34]. Although little is known about Ebola's zoonotic potential, there is growing evidence that ecosystem stress brought on by climate change may increase the likelihood of future outbreaks [35].

The virus that causes COVID-19, SARS-CoV-2, is a powerful illustration of how anthropogenic factors linked to climate change, such as habitat encroachment, animal trade, and urbanization, can foster the formation of new pathogens [36]. The pandemic has brought attention to the delicate ecological balance that prevents the introduction of high-consequence zoonotic viruses, even though the exact causes are still being investigated [37].

Beyond isolated outbreaks, the global risk environment is currently characterized by a higher frequency of spillovers, partly due to changes in host biodiversity, migration patterns, and pathogen shedding dynamics that are connected to climate change. According to studies, by fragmentation in Guinea led to an atypical climate during the 2013–2016 West African Ebola epidemic, which may

2070, climate change may cause hundreds of mammal species to move geographically, which could lead to new cross-species viral transmission events[38]. Many of these occurrences could take place in areas with dense populations of people and little surveillance capability.

The significant ecological and epidemiological effects of climate change are reflected in the shifting trends of infectious diseases in these three categories. These changes are qualitative, altering the parameters of risk and necessitating new frameworks for surveillance, readiness, and intervention, in addition to being quantitative in kind, measured in new cases or outbreaks [39]. The diseases that will influence our public health futures will change along with the climate. Figure 2 shows the spatiotemporal distribution of a few high-burden infections over the past few decades, emphasizing important transition zones and new risk areas across regions to illustrate the growing geographic footprint of climate-sensitive infectious illnesses.

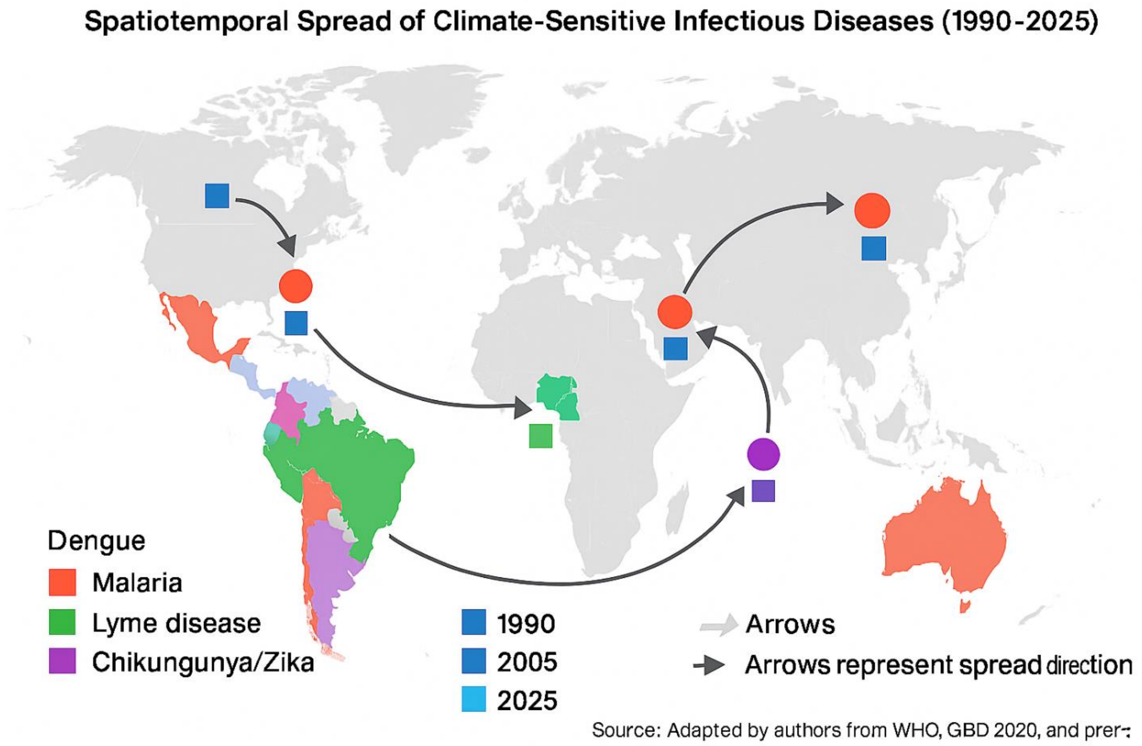

Figure 2 shows how climate-sensitive diseases have spread geographically between 1990 and 2025. From 1990 to anticipated trends in 2025, this choropleth global map shows the chronological and spatial spread of four main climate-sensitive diseases: dengue, malaria, Lyme disease, and chikungunya/Zika. Whereas directional arrows show migration patterns across continents and biological zones, color gradients show the times when diseases first appeared or became more severe. With obvious ramifications for public health readiness in recently impacted areas, the graphic illustrates the poleward and altitudinal changes in disease distribution brought on by warmer temperatures, changed precipitation, and ecological disturbance.

Regional and Global Hotspots

The prevalence of infectious diseases that are impacted by climate change is not distributed equally around the world. Instead, it depicts intricate relationships between regional ecological systems, public health infrastructure, sociopolitical settings, and climatic factors [40]. This section examines major geographic regions where the dangers of infectious diseases caused by climate change are growing, emphasizing emergence and reemergence patterns that indicate both immediate vulnerabilities and more general global trends. Table 1 lists the main EIDs by globe area, principal vector or reservoir, and related climatic determinants to put the spatial variability of climate-sensitive emerging infectious diseases (EIDs) into perspective [41].

Table 1: Climate-Sensitive Emerging Infectious Diseases by Region and Vector.

Climate-Sensitive Emerging Infectious Diseases and Their Main Vectors of Transmission by Region. The main EIDs impacted by climate change are listed in this table, arranged by global region, linked vectors or reservoirs, and climate-related causes (such as rising temperatures, flooding, and changes in land use).

Table 1. Climate-Sensitive Emerging Infectious Diseases by Region and Vector

Region	Disease(s)	Primary Vector/Reservoir	Climate Driver(s)
Sub-Saharan Africa[22]	Malaria, Rift Valley Fever	Anopheles spp., livestock, mosquitoes	Rising temperature, heavy rainfall
Asia-Pacific[30]	Dengue, Leptospirosis, Japanese Encephalitis	Aedes spp., rodents, pigs, Culex spp.	Monsoon variability, urban flooding
The Americas[42]	West Nile Virus, Hantavirus	Birds, mosquitoes, rodents	Drought–flood cycles, warming trends
Europe[43]	Tick-borne Encephalitis, Dengue	Ixodes ticks, Aedes spp	Milder winters, urban heat islands
Arctic/Sub-Arctic[15]	Anthrax (permafrost), ancient microbes	Reindeer, thawed microbes	Permafrost melting

Africa: Malaria Resurgence and Rift Valley Fever

Due to its tremendous ecological diversity, limited ability to adapt, and significant reliance on livelihoods that are dependent on the climate, Africa continues to be one of the most climate-sensitive regions in the world [44]. Long endemic in sub-Saharan Africa, malaria is making a comeback in highland regions that were previously thought to be transmission-free. Warming temperatures have made it easier for Anopheles mosquitoes to migrate upward in Ethiopia, Uganda, and Kenya, increasing the risk of malaria among high-altitude populations with weak acquired immunity and little ability for surveillance [45]. Tens of millions more people might be exposed to endemic transmission by 2050 if temperatures rise by 1°C, according to climate modeling research [45].

Extreme weather events like El Niño-induced flooding are increasingly linked to Rift Valley Fever (RVF), a zoonotic arboviral illness spread by mosquitoes and exacerbated by livestock. East African outbreaks, such as those in Kenya, Tanzania, and Sudan, have coincided with unusual rainfall patterns that lead to an increase in livestock-human interaction and a jump in mosquito hatching. The connection of climate, health, and food security in the region is highlighted by the resurgence of RVF, which not only endangers human health but also destroys agricultural livelihoods [46].

Asia-Pacific: Leptospirosis, Dengue, and Japanese Encephalitis

Rapid urbanization, monsoonal instability, and dense human-animal-environment interfaces increase the complex web of new infectious disease concerns in the Asia-Pacific area. In flood-prone cities like Manila, Mumbai, and Jakarta, where inadequate drainage and rodent infestation provide the perfect environment for transmission after intense rains, leptospirosis—an often-overlooked bacterial zoonosis—has grown in prevalence. With an increasing yearly frequency in a number of nations, the disease increasingly exhibits seasonal peaks closely associated with climatic trends [47].

In Southeast Asia and the Western Pacific, dengue fever is still spreading rapidly. Aedes mosquito breeding habitats are sporadic due to unpredictable rainfall, and transmission windows have been extended by warming temperatures [48]. Over the past 20 years, annual cases have increased several times in countries like Bangladesh, the Philippines, and Vietnam; these increases are frequently attributed to climatic variability. Due to increased vector suitability and international travel, dengue has resurfaced in Queensland, Australia [49].

Previously unaffected regions, such as the highlands of Nepal and southern China, are now experiencing the spread of Japanese encephalitis (JE), a virus spread by mosquitoes that is prevalent in portions of South and East Asia. This geographic distribution is being aided by changes in the patterns of rice cultivation, the growth of pig farming, and climatic circumstances that favor Culex mosquitoes. Notably, under different warming scenarios, climate models anticipate that JE transmission zones will move northward [50].

The Americas: West Nile Virus and Hantavirus

In both tropical and temperate regions of the Americas, rodent-borne and vector-borne diseases associated with climate change are becoming more prevalent. Since its introduction to the US in 1999, the West Nile Virus (WNV) has spread over most of North America. Longer mosquito breeding seasons and more effective viral replication within vectors have been made possible by warmer temperatures, earlier springs, and fewer frost days [51]. Notably, new research shows that heat waves and drought conditions that draw birds and mosquitoes to areas with dwindling water supplies are associated with the severity and length of WNV epidemics [52].

Climate variations that impact rat population dynamics are increasingly linked to hantavirus pulmonary syndrome (HPS), which is brought on by rodent-borne hantaviruses. Increased rainfall after drought times causes vegetation booms and consequent spikes in rodent hosts like deer mice in the southwestern United States and parts of South America [53]. Usually, human exposure comes next, especially in peri-domestic and rural areas with substandard housing. These patterns highlight how the climate may affect zoonotic reservoir cycles in addition to vector biology.

Europe: Tick-borne Encephalitis and Emerging Arboviruses

Despite its historical temperance, Europe is seeing a continuous rise in infectious diseases that are susceptible to the climate, especially those spread by ticks and mosquitoes. In Central and Eastern Europe, tick-borne encephalitis (TBE), which is spread by Ixodes ricinus and caused by a flavivirus, is moving northward and higher in elevation. Increased case incidence is a result of warmer winters and milder springs, which improve tick survival and prolong activity periods in nations like Germany, Poland, and the Baltic states [54].

At the same time, new arboviruses, such as dengue, chikungunya, and Zika, are spreading locally over southern Europe, especially in France, Italy, and Spain. Aedes albopictus has established itself in these regions thanks to international trade and climate change adaptability, which has made the environment favorable for occasional outbreaks. The possibility of prolonged arboviral transmission in some regions of Europe is becoming more apparent and less speculative, as climate projections show further warming and increased extreme weather variability [55].

Together, these regional hotspots show that climate change is a geographically distinct phenomenon that alters local disease ecologies in context-specific ways rather than being a uniform or distant hazard. Designing specialized, climate-informed surveillance, control, and public health adaptation methods requires an understanding of these regional dynamics. Therefore, a worldwide response to newly developing infectious diseases needs to be based on local facts, supported by regional realities, and sensitive to the particular vulnerabilities of each hotspot [56].

Public Health Implications and Response Gaps

For public health systems around the world, the expanding relationship between infectious disease development and climate change poses a serious and intricate problem. The institutional ability to identify, decipher, and respond to these signals is still severely limited, despite a growing understanding of the molecular and ecological mechanisms that connect disease and climate. Public health infrastructures, especially those in vulnerable areas, are finding it difficult to keep up with the speed and complexity of new threats as climate-driven disease risks increase in both frequency and extent.

Surveillance Systems Under Pressure

The rapidly changing spatiotemporal dynamics of diseases that are sensitive to climate change are beyond the capabilities of disease monitoring systems, which are already burdened by ongoing underfunding and restricted geographic coverage. Conventional surveillance models, which are intended to identify known infections in known ecological environments, are reactive rather than predictive [7]. These models, however, fall short of capturing the whole picture of new threats as vectors spread to new areas and zoonotic spillovers increase in frequency. For example, the emergence of Anopheles mosquitoes in East African highlands or Aedes albopictus in temperate Europe has often occurred years before official public health acknowledgment, highlighting systemic delays in detection. The use of manual reporting, a lack of laboratory diagnostic capabilities, and a restricted ability to integrate with environmental monitoring data further impair surveillance systems in low- and middle-income countries (LMICs) [57].

Climate Vulnerability and Health Inequities

Marginalized populations—those with the most exposure to climate fluctuation and the least ability to adapt—are disproportionately affected by the public health burden of infectious illnesses that are climate-sensitive. Socioeconomic deprivation and geographic vulnerability frequently coexist, generating a risk feedback loop. Underfunded health systems, subpar housing, restricted access to clean water, and a reliance on climate-sensitive livelihoods (such as agriculture) increase the risk of contracting diseases and suffering serious consequences in sub-Saharan Africa, South Asia, and tiny island states. Additionally, within-country disparities continue to exist: national surveillance and health response systems frequently do not reach Indigenous groups, informal urban settlements, or climate migrants. There is a significant equity gap in the global health response to climate change, as seen by the rarity with which these inequities are addressed in national adaptation strategies [58].

Delays in Outbreak Detection Due to Fragmented Data Systems

The fragmentation of pertinent data streams is one of the most enduring problems in the management of climate-sensitive diseases. Data related to health, weather, ecology, and land use are usually kept apart in different institutional domains with different regulations, formats, and privacy policies [59]. The capacity to create predictive models and send out timely notifications is hampered by this fragmentation. Integration is still uneven, even in wealthy nations with sophisticated digital infrastructure. For instance, the effectiveness of early warning systems for vector-borne outbreaks is restricted by the incompatibility of environmental data platforms and public health reporting systems [60]. The majority of monitoring in LMICs is still done on paper and in retrospect, which slows down reaction times and compromises situational awareness in areas where digital infrastructure may be completely absent.

Challenges in Integrating Climate Models with Public Health Forecasting

Adaptive public health planning is made more difficult by the scientific and methodological differences between epidemiological forecasts and climate modeling. Although climate models are now much better at forecasting trends in temperature, precipitation, and extreme weather, their incorporation into public health decision-making is still in its infancy. While climate scientists frequently create models without direct involvement from health authorities, the majority of public health experts are not trained in interpreting climate data [61]. The co-development of useful technologies suited to the demands of the health industry is hampered by this separation.

Furthermore, nonlinear climate factors, delayed effects, and compounding vulnerabilities like population relocation and malnutrition are frequently overlooked by existing infectious disease forecasting models. For example, real-time data on rainfall variability, vector breeding cycles, and urban infrastructure are rarely included in dengue prediction models, which limits their use in dynamic environments. To close this gap, funding for transdisciplinary cooperation is crucial, especially between academic modelers, health ministries, and meteorological institutes [62].

All things considered, the public health response to infectious diseases brought on by climate change is still reactive, dispersed, and inadequately sensitive to the ecological complexity and social injustice of new threats. Rethinking surveillance as a multisectoral enterprise, integrating equality into preparedness frameworks, and encouraging ongoing, interdisciplinary cooperation across institutions, borders, and data systems are all necessary to meet these problems. The health sector will continue to lag in terms of climate-related disease hazards in the absence of such systemic changes [39].

Innovative Tools and Opportunities

Technological innovation and transdisciplinary frameworks present intriguing pathways for foresight, adaptation, and mitigation as the global health community faces the growing threat of infectious illnesses that are sensitive to climate change. A more proactive and environmentally based approach to disease prevention is being provided by recent developments in artificial intelligence, remote sensing, genomic monitoring, and integrative policy frameworks, which are starting to change the landscape of outbreak prediction, vector control, and pathogen tracking [63].

Real-time predictions of the onset and spread of infectious diseases are increasingly being made using artificial intelligence (AI), big data analytics, and climate modeling [39]. In order to find trends and create prediction risk maps, machine learning algorithms can combine large, diverse datasets, such as satellite observations, weather records, electronic health records, and social media signals. For example, dengue epidemics based on changes in precipitation, humidity, and vector breeding patterns have been significantly predicted by AI-driven models. Early warning systems have been improved in East Africa by combining seasonal climatic forecasts with models of malaria transmission. This has allowed for the more prompt distribution of resources for prevention [64]. However, continuous capacity building in low-resource environments and fair access to data infrastructure are essential for the successful deployment of such technologies.

Vector monitoring has been transformed by satellite imaging and remote sensing technologies, which allow for the real-time tracking of environmental factors that facilitate the spread of illness. Changes in vegetation, standing water, and urban heat islands—all important markers of mosquito breeding grounds—can be identified with high-resolution photography. By enabling the dynamic detection of new hotspots, these technologies lessen the need for static risk maps [22].

Rift Valley Fever and malaria epidemics are already being predicted in the Sahel and Amazon regions using satellite-derived vegetation indices and surface water models, respectively. When used with geographic information systems (GIS), these tools increase the efficiency of resource allocation and the spatial targeting of vector control efforts [46].

Another revolutionary field that makes it possible to track pathogen evolution, drug resistance, and transmission dynamics in real time is genomic epidemiology. Characterizing epidemics, differentiating between imported and endemic strains, and detecting zoonotic spillover events have all benefited from whole-genome sequencing. Genomic surveillance aided in the quick discovery of new variations during the COVID-19 pandemic and guided international response plans. In the future, combining pathogen genomics with climate-sensitive surveillance systems may offer early warning signs of evolutionary changes brought on by environmental stressors, such as vector-mediated viral recombination or fungal pathogens' adaptability to heat [65].

Lastly, as comprehensive models for comprehending and addressing the interdependencies between environmental, animal, and human health, the One Health and Planetary Health frameworks are becoming more and more popular worldwide. These methods support the breakdown of academic silos and the promotion of cross-sectoral cooperation amongst climatologists, ecologists, veterinarians, and public health professionals. A paradigm change toward more integrated, anticipatory health governance is indicated by the institutionalization of One Health initiatives in national disease control programs, such as those that address zoonotic outbreaks or antibiotic resistance. As the cornerstone of global health security, planetary health highlights the wider ecological boundaries of human growth and calls for structural changes to slow down climate change and biodiversity loss [66].

In sum, these innovative tools and frameworks represent critical opportunities for transforming reactive public health systems into anticipatory, climate-resilient structures. Their effective deployment will require not only technological capacity but also political will, intersectoral coordination, and ethical considerations regarding data equity and access.

Ethical Considerations and Biases

While these tools offer transformative potential, they also raise important ethical concerns. AI-based models may reinforce existing data biases if trained on geographically or demographically incomplete datasets, potentially excluding high-risk but underrepresented populations. Satellite and genomic surveillance raise issues of data privacy, consent, and potential misuse, particularly in low-resource or politically sensitive settings. In addition, the digital divide and unequal access to these technologies can exacerbate global health inequities unless safeguards for data governance, equity, and transparency are integrated into their deployment.

Literature Gaps and Review Limitations

Despite growing research on climate-sensitive infectious diseases, several critical gaps remain in the literature. Much of the current evidence is fragmented by geography, disease type, or disciplinary silo, limiting comprehensive, system-level understanding. There is a lack of longitudinal, high-resolution studies linking specific climate variables to pathogen emergence, particularly in low- and middle-income countries where surveillance data are sparse. Moreover, the interactions between climate change, social determinants of health, and microbial evolution remain underexplored. This narrative review also has several limitations. It does not follow a systematic review protocol, and the selection of literature may reflect some degree of selection bias despite efforts to include high-quality, relevant sources.

Quantitative meta-analysis was not feasible due to variability in study designs and metrics across included sources. Additionally, while this review integrates findings across climatology, public health, and epidemiology, it may not fully capture the breadth of region-specific knowledge published in non-English or local-language sources. These limitations highlight the need for more coordinated, interdisciplinary, and globally inclusive research to better understand and address the climate–infectious disease nexus.

Conclusion and Recommendation

With increasing evidence of changing pathogen ecologies, extending geographic ranges, and changing transmission patterns, climate change is unquestionably changing the worldwide landscape of infectious disease emergence. The upward and poleward migration of vector-borne diseases like Lyme disease, dengue, and malaria; the amplification of waterborne infections after climate extremes; and the increased risk of zoonotic spillovers in ecologically disrupted landscapes are some of the new and underappreciated developments highlighted in this review. Furthermore, a wider reconfiguration of microbial risk under planetary change is indicated by new risks, such as the emergence of fungal species that can adapt to heat stress and the possible release of ancient diseases due to the thawing of permafrost.

The urgent need to create integrated, flexible public health systems that are sensitive to climate cues and quick to react is at the core of these changes. In the face of nonlinear, climate-driven hazards, traditional disease surveillance and forecasting methods—which are limited by sectoral silos and historical baselines—are becoming less and less effective [67]. Though the One Health framework, satellite surveillance, AI-based modeling, and genetic epidemiology are now accessible, their operationalization is still unequal, especially in high-risk and low-resource areas.

We need to develop a radically multidisciplinary paradigm that connects ecology, public health, climate science, and data systems in order to solve the current challenges. Addressing context-specific risks requires regionalized preparedness strategies that are based on local epidemiology and climate data. National and international health initiatives must prioritize strengthening community-based early warning systems, increasing integrated climate-health surveillance, and establishing cross-sectoral collaboration.

High-resolution, longitudinal investigations that connect pathogen dynamics across scales with environmental variables should be given priority in future studies. Equally important are investments in staff training, data integration, and fair access to forecasting tools. Important steps toward sustainable planetary health governance at the policy level include making sure that global climate funding mechanisms specifically take health aspects into account and integrating climate-sensitive illness planning into national adaptation plans [68].

In conclusion, the combination of infectious disease development and climate change is not only a challenge but also an invitation to rethink health security from the perspectives of scientific innovation, environmental resilience, and international solidarity.

Acknowledgments

Author Contributions:

Alliah Kris-Ann Wright: Conceptualization, Literature Search, Writing – Original Draft.

Cyril Ifeanyichukwu Ezugwu: Literature Search, Data Curation, Writing – Review & Editing.

John Kelenna Iregbu: Methodology, Validation, Writing – Review & Editing.

Ezeamii Patra Chisom: Data Curation, Visualization, Writing – Review & Editing.

Adaobi Amelia Ozigbo: Formal Analysis, Writing – Review & Editing.
Morayo Anne Ajobiewe: Resources, Writing – Review & Editing.
Ebenezer Oluwadamilare Oyekanmio: Literature Search, Project Administration.
Aliyu Olanrewaju Olaniyi: Supervision, Final Manuscript Approval, Correspondence.
All authors have read and agreed to the published version of the manuscript.

Disclosures: The authors declare no conflicts of interest.

Acknowledgements: The authors acknowledge the support and the contributions of colleagues who provided feedback on earlier drafts of this manuscript.

Funding: This research received no external funding.

Ethics Approval: Not applicable. This study is a narrative review based on previously published data and did not involve human participants or animals.

References

1. World Health Organization. Climate change [Internet]. [cited 2025 Jul 16]. Available from: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health
2. Nunes LJR. The Rising Threat of Atmospheric CO2: A Review on the Causes, Impacts, and Mitigation Strategies. Environments. 2023 Apr;10(4):66. https://doi.org/10.3390/environments10040066
3. He Y, Liu WJ, Jia N, Richardson S, Huang C. Viral respiratory infections in a rapidly changing climate: the need to prepare for the next pandemic. eBioMedicine. 2023 May 9;93:104593. https://doi.org/10.1016/j.ebiom.2023.104593
4. Sabin NS, Calliope AS, Simpson SV, Arima H, Ito H, Nishimura T, et al. Implications of human activities for (re)emerging infectious diseases, including COVID-19. J Physiol Anthropol. 2020 Sep 25;39:29. https://doi.org/10.1186/s40101-020-00233-6
5. Alcayna T, Fletcher I, Gibb R, Tremblay L, Funk S, Rao B, et al. Climate-sensitive disease outbreaks in the aftermath of extreme climatic events: A scoping review. One Earth. 2022 Apr 15;5(4):336–50. https://doi.org/10.1016/j.oneear.2022.03.007
6. Issa R, Sarsour A, Cullip T, Toma S, Ruyssen I, Scheerens C. Gaps and opportunities in the climate change, migration and health nexus: Insights from a questionnaire based study. J Migr Health. 2023 Mar 23;7:100171. https://doi.org/10.1016/j.jmh.2023.100171
7. Liao H, Lyon CJ, Ying B, Hu T. Climate change, its impact on emerging infectious diseases and new technologies to combat the challenge. Emerg Microbes Infect. 2024;13(1):2356143. https://doi.org/10.1080/22221751.2023.2356143
8. Piscitelli P, Miani A. Climate Change and Infectious Diseases: Navigating the Intersection through Innovation and Interdisciplinary Approaches. Int J Environ Res Public Health. 2024 Mar;21(3):314. https://doi.org/10.3390/ijerph21030314
9. Adepoju OA, Afinowi OA, Tauheed AM, Danazumi AU, Dibba LBS, Balogun JB, et al. Multisectoral Perspectives on Global Warming and Vector-borne Diseases: a Focus on Southern Europe. Curr Trop Med Rep. 2023;10(2):47–70. https://doi.org/10.1007/s40475-023-00260-9

10. Caminade C, McIntyre KM, Jones AE. Impact of recent and future climate change on vector-borne diseases. Ann N Y Acad Sci. 2019 Jan;1436(1):157–73. https://doi.org/10.1111/nyas.13950
11. Acosta-España JD, Romero-Alvarez D, Luna C, Rodriguez-Morales AJ. Infectious disease outbreaks in the wake of natural flood disasters: global patterns and local implications. Infez Med. 2024;32(4):451–62.
12. Zhao AP, Li S, Cao Z, Hu PJH, Wang J, Xiang Y, et al. AI for science: Predicting infectious diseases. J Saf Sci Resilience. 2024 Jun 1;5(2):130–46. https://doi.org/10.1016/j.jssr.2024.05.004
13. Wegner GI, Murray KA, Springmann M, Muller A, Sokolow SH, Saylors K, et al. Averting wildlife-borne infectious disease epidemics requires a focus on socio-ecological drivers and a redesign of the global food system. eClinicalMedicine. 2022 Apr 18;47:101386. https://doi.org/10.1016/j.eclinm.2022.101386
14. Agusi ER, Allendorf V, Eze EA, Asala O, Shittu I, Dietze K, et al. SARS-CoV-2 at the Human–Animal Interface: Implication for Global Public Health from an African Perspective. Viruses. 2022 Nov 9;14(11):2473. https://doi.org/10.3390/v14112473
15. Yarzábal LA, Salazar LMB, Batista-García RA. Climate change, melting cryosphere and frozen pathogens: Should we worry…? Environ Sustain (Singap). 2021;4(3):489–501. https://doi.org/10.1007/s42398-021-00197-w
16. Imberti L, Tiecco G, Logiudice J, Castelli F, Quiros-Roldan E. Effects of Climate Change on the Immune System: A Narrative Review. Health Sci Rep. 2025 Apr 18;8(4):e70627. https://doi.org/10.1002/hsr2.7062
17. Pfenning-Butterworth A, Buckley LB, Drake JM, Farner JE, Farrell MJ, Gehman ALM, et al. Interconnecting global threats: climate change, biodiversity loss, and infectious diseases. Lancet Planet Health. 2024 Apr;8(4):e270. https://doi.org/10.1016/S2542-5196(24)00049-5
18. Mojahed N, Mohammadkhani MA, Mohamadkhani A. Climate Crises and Developing Vector-Borne Diseases: A Narrative Review. Iran J Public Health. 2022 Dec;51(12):2664–73.
19. Masse RS, Vythilingam I, Fornace K, Othman H, Liu X, Jaafar AJ, et al. Impact of environmental factors on the bionomics of Anopheles mosquito vectors of zoonotic malaria: A narrative review. One Health. 2025 Jul 14;101141. https://doi.org/10.1016/j.onehlt.2024.101141
20. Lühken R, Brattig N, Becker N. Introduction of invasive mosquito species into Europe and prospects for arbovirus transmission and vector control in an era of globalization. Infect Dis Poverty. 2023 Nov 30;12(1):109. https://doi.org/10.1186/s40249-023-01128-7
21. Delrieu M, Martinet JP, O'Connor O, Viennet E, Menkes C, Burtet-Sarramegna V, et al. Temperature and transmission of chikungunya, dengue, and Zika viruses: A systematic review. Curr Res Parasitol Vector Borne Dis. 2023 Aug 24;4:100139. https://doi.org/10.1016/j.crpvbd.2023.100139
22. Couper LI, MacDonald AJ, Mordecai EA. Impact of prior and projected climate change on US Lyme disease incidence. Glob Chang Biol. 2021 Feb;27(4):738–54. https://doi.org/10.1111/gcb.15432
23. Usmani M, Brumfield KD, Jamal Y, Huq A, Colwell RR, Jutla A. A Review of the Environmental Trigger and Transmission Components for Prediction of Cholera. Trop Med Infect Dis. 2021 Aug

5;6(3):147. https://doi.org/10.3390/tropicalmed6030147

24. Kaljee LM, Pach A, Garrett D, Bajracharya D, Karki K, Khan I. Social and Economic Burden Associated With Typhoid Fever in Kathmandu and Surrounding Areas: A Qualitative Study. J Infect Dis. 2018 Nov 10;218(suppl_4):S243–9. https://doi.org/10.1093/infdis/jiy479
25. Folorunsho S. The Role of Social Determinants of Health in Shaping Racial and Disability Disparities Among Older Adults in the United States. J Aging Soc Policy. 2025;1–17. https://doi.org/10.1080/08959420.2025.2329841
26. Bradley EA, Lockaby G. Leptospirosis and the Environment: A Review and Future Directions. Pathogens. 2023 Sep 16;12(9):1167. https://doi.org/10.3390/pathogens12091167
27. Folorunsho S, Ajayi V, Sanmori M, Suleiman M, Abdullateef R, Abdulganiyu A. Access to and Utilization of Dental Care Services by Older Adults in Nigeria: Barriers and Facilitators. Spec Care Dentist. 2025;45(3):e70040. https://doi.org/10.1111/scd.70040
28. Hauser N, Gushiken AC, Narayanan S, Kottilil S, Chua JV. Evolution of Nipah Virus Infection: Past, Present, and Future Considerations. Trop Med Infect Dis. 2021 Feb 14;6(1):24. https://doi.org/10.3390/tropicalmed6010024
29. Poirier O, Castañeda RR de, Bolon I, Ray N. Modelling forest degradation and risk of disease outbreaks in mainland Equatorial Guinea. J Public Health Emerg. 2021 Jun 25;5(0). Available from: https://jphe.amegroups.org/article/view/7288
30. Elechi KW, Igboaka CD, Tiamiyu BB, Ugbor MJE, Arthur C, Ezeh OM, et al. Phytochemical Screening of Ficus globosa Latex (Moraceae) as a Source of Novel Antimicrobial Compounds. Path Sci. 2025 Mar 31;11(3):9001–10. https://doi.org/10.22178/pos.1103-2
31. Hemmeda L, Shabani MM, Kolawole BO, Muhammad SA, Fatima K, Siddiqui A, et al. Third wave of COVID-19 pandemic in Africa: Challenges and recommendations. Ann Med Surg. 2022 Aug;80. Available from: https://journals.lww.com/annals-of-medicine-and-surgery/fulltext/2022/08000/third_wave_of_covid_19_pandemic_in_africa_.189.aspx
32. Carlson CJ, Albery GF, Merow C, Trisos CH, Zipfel CM, Eskew EA, et al. Climate change increases cross-species viral transmission risk. Nature. 2022 Jul;607(7919):555–62. https://doi.org/10.1038/s41586-022-04788-w
33. Lawal OP, Igwe EP, Olosunde A, Chisom EP, Okeh DU, Olowookere AK, et al. Integrating Real-Time Data and Machine Learning in Predicting Infectious Disease Outbreaks. Asian J Microbiol Biotechnol. 2025 May;10(1):147–63. https://doi.org/10.9734/ajmob/2025/v10i1203
34. Folorunsho S, Ajayi V, Abdulrazaq O. Juvenile delinquency as a contemporary issue in Nigeria. Afr J Soc Issues. 2024 Mar 23;7(1):116–32. https://doi.org/10.5281/zenodo.10920064
35. McMichael AJ, Woodruff RE. Climate change and infectious diseases. In: Mayer KH, Pizer HF, editors. The Social Ecology of Infectious Diseases. San Diego: Academic Press; 2008. p. 378–407. Available from: https://www.sciencedirect.com/science/article/pii/B9780123704665500194
36. D'Amore C, Grimaldi P, Ascione T, Conti V, Sellitto C, Franci G, et al. West Nile Virus diffusion in temperate regions and climate change. Infez Med. 2023 Mar 1;31(1):20–30.
37. Adepoju OA, Afinowi OA, Tauheed AM, Danazumi AU, Dibba LBS, Balogun JB, et al. Multisectoral Perspectives on Global Warming and Vector-borne Diseases. Curr Trop Med Rep. 2023;10(2):47–70. https://doi.org/10.1007/s40475-023-00260-9

38. Ezhova E, Orlov D, Suhonen E, Kaverin D, Mahura A, Gennadinik V, et al. Climatic Factors Influencing the Anthrax Outbreak of 2016 in Siberia, Russia. Ecohealth. 2021;18(2):217–28. https://doi.org/10.1007/s10393-021-01531-4
39. Aik J, Ong J, Ng LC. The effects of climate variability and seasonal influence on diarrhoeal disease in Singapore. Int J Hyg Environ Health. 2020 Jun 1;227:113517. https://doi.org/10.1016/j.ijheh.2020.113517
40. Ryan SJ, Lippi CA, Zermoglio F. Shifting transmission risk for malaria in Africa with climate change. Malar J. 2020 May 1;19:170. https://doi.org/10.1186/s12936-020-03259-1
41. Ndishimye P, Umuhoza T, Umutoni B, Zakham F, Ndayambaje M, Hewins B, et al. Rift Valley Fever outbreaks in the East African Community. Front Public Health. 2024 Dec 11;12:1298594. https://doi.org/10.3389/fpubh.2024.1298594
42. Hassell JM, Begon M, Ward MJ, Fèvre EM. Urbanization and Disease Emergence: Dynamics at the Wildlife–Livestock–Human Interface. Trends Ecol Evol. 2017 Jan;32(1):55–67. https://doi.org/10.1016/j.tree.2016.09.012
43. Jamal MK, Sanaei B, Naderi M, Past V, Abadi SHA, Khazaei R, et al. Investigating the recent outbreak of dengue fever in Iran. Egypt J Intern Med. 2025 Feb 18;37(1):37. https://doi.org/10.1186/s43162-025-00224-9
44. Sah R, Mohanty A, Rohilla R, Asija A, Sedhai YR, Chandran D, et al. Japanese encephalitis prevalence and outbreaks in Nepal. Int J Surg. 2023 Mar 3;110(10):6822. https://doi.org/10.1016/j.ijsu.2023.106822
45. Beermann S, Dobler G, Faber M, Frank C, Habedank B, Hagedorn P, et al. Impact of climate change on vector- and rodent-borne infectious diseases. J Health Monit. 2023 Jun 1;8(Suppl 3):33.
46. Wang HR, Liu T, Gao X, Wang HB, Xiao JH. Impact of climate change on West Nile virus and adaptation responses. Infect Dis Poverty. 2024 May 24;13(1):38. https://doi.org/10.1186/s40249-024-01174-5
47. Douglas KO, Payne K, Sabino-Santos G, Agard J. Influence of Climatic Factors on Human Hantavirus Infections in Latin America and the Caribbean. Pathogens. 2021 Dec 23;11(1):15. https://doi.org/10.3390/pathogens11010015
48. El-Sayed A, Kamel M. Climatic changes and their role in emergence and re-emergence of diseases. Environ Sci Pollut Res Int. 2020;27(18):22336–52. https://doi.org/10.1007/s11356-020-08764-6
49. Kraemer MUG, Reiner RC Jr, Brady OJ, Messina JP, Gilbert M, Pigott DM, et al. Past and future spread of Aedes aegypti and Aedes albopictus. Nat Microbiol. 2019 Mar 4;4(5):854. https://doi.org/10.1038/s41564-019-0376-y
50. Muluneh MG. Impact of climate change on biodiversity and food security: A review. Agric Food Secur. 2021 Sep 6;10(1):36. https://doi.org/10.1186/s40066-021-00325-y
51. Liao H, Lyon CJ, Ying B, Hu T. Climate change, its impact on emerging infectious diseases and new technologies to combat the challenge. Emerg Microbes Infect. 2024;13(1):2356143. https://doi.org/10.1080/22221751.2023.2356143
52. Martins FP, Paschoalotto MAC, Closs J, Bukowski M, Veras MM. The Double Burden: Climate Change Challenges for Health Systems. Environ Health Insights. 2024 Nov 20;18:11786302241298789. https://doi.org/10.1177/11786302241298789
53. Lawal O, Oyebamiji HO, Kelenna IJ, Chioma FJ, Oyefeso E, Adeyemi BI, et al. A Review on

Usage of Digital Health Literacy to Combat Antibiotic Misuse in Nigeria. J Pharma Insights Res. 2025 Apr 5;3(2):258–69.

54. Onwuemelem LA, Orobator ET, Onyedum NN, Chibueze ES, Kanu I, Christopher AA, et al. Molecular Mechanisms of Clonal Hematopoiesis in Age-Related Cardiovascular Disease. J Pharma Insights Res. 2025 Apr 5;3(2):358–72.
55. Hess JJ, McDowell JZ, Luber G. Integrating Climate Change Adaptation into Public Health Practice. Environ Health Perspect. 2011 Oct 13;120(2):171. https://doi.org/10.1289/ehp.1103515
56. Thiede BC, Strube J. Climate Variability and Child Nutrition: Findings from Sub-Saharan Africa. Glob Environ Change. 2020 Nov;65:102192. https://doi.org/10.1016/j.gloenvcha.2020.102192
57. Lawal OP, Egwuatu EC, Akanbi KO, Orobator ET, Eweje OZ, Omotayo EO, et al. Fighting Resistance With Data: Leveraging Digital Surveillance in Nigeria. Path Sci. 2025 Mar 31;11(3):1009–17. https://doi.org/10.22178/pos.1103-3
58. Ayomide IT, Promise LO, Christopher AA, Okikiola PP, Esther AD, Favour AC, et al. The Impact of Antimicrobial Resistance on Co-INFECTIONS. Int J Pathogen Res. 2024 Nov 29;13(6):117–28.
59. Pronyk PM, Alwis R de, Rockett R, Basile K, Boucher YF, Pang V, et al. Advancing pathogen genomics in resource-limited settings. Cell Genomics. 2023 Nov 17;3(12):100443. https://doi.org/10.1016/j.xgen.2023.100443
60. Hobusch U, Scheuch M, Heuckmann B, Hodžić A, Hobusch GM, Rammel C, et al. One Health Education Nexus. Front Public Health. 2024 Mar 22;11:1337748. https://doi.org/10.3389/fpubh.2023.1337748
61. Lawal O, Elechi K, Adekunle F, Farinde O, Kolapo T, Igbokwe C, et al. A Review on Artificial Intelligence and Point-of-Care Diagnostics in Nigeria. J Pharma Insights Res. 2025 Apr 5;3(2):166–75.
62. Oseghale ID, Lawal OP, Ubebe DO, Orjiewulu VC, Igunma AA, Odey OP, et al. Ethnomedicinal and Phytopharmacological Aspects of Vernonia amygdalina. Asian J Res Biochem. 2024 Oct 14;14(6):41–57. https://doi.org/10.9734/ajrb/2024/v14i62403