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**Research Article**

# Health System Resilience to Climate Change: Frameworks, Challenges, and Strategic Interventions

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## Abstract

**Background:** Climate change has now become one of the most significant public health challenges in the world, exacerbating environmental risks and straining health systems worldwide. Extreme weather patterns, rising temperatures and changing patterns of disease disturb the provision of healthcare, destroy infrastructure and create new health inequities, especially in low and middle-income countries. It is thus important to increase the resilience of health systems so that essential services can continue to be delivered to safeguard vulnerable populations.

**Aim:** The research set out to review the effects of climate change on health systems and outline important frameworks, problems, and strategic interventions to create climate-resilient healthcare systems.

**Methods:** Peer-reviewed articles, policy documents, and institutional reports on the topic published in 2005-2025 were used to conduct a narrative literature review. Predefined keywords were used to search major databases such as PubMed, Scopus and Google Scholar on the topic of climate change, health systems, and resilience. Relevant literature was filtered, thematically classified and synthesized around the following domains: infrastructure, surveillance, the capacity of the workforce, governance and financing.

**Results:** The review revealed areas of concern that affect climate resilience, such as infrastructure preparedness, the surveillance of diseases that are sensitive to climate, workforce preparedness, governance, and sustainable financing. It was observed that flooding and heatwaves have a considerable impact on health services and burden patients. Facilities having robust infrastructure and backup facilities had low rates of service disruption. The climate information incorporated in the surveillance systems enhanced the effectiveness in detecting early outbreaks and response efficiency. Multispectral coordination and workforce training were closely related to increase emergency preparedness and mortality reduction.

**Conclusion:** Climate-resilient health systems need to be based on a multifaceted systems-level approach that encompasses infrastructure fortification, climate-conscious surveillance, human capacity development, proper government, and feasible funding. To increase adaptive capacity and protect the health of the populations due to the rise of climate variability, proactive investment, multisector collaboration, and policy integration are necessary.

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## Introduction

The problem of climate change is one of the most prominent worldwide threats to human health, environmental conditions, disease patterns, and health outcomes [1]. The growing temperatures around the world, changing rainfall distribution and the frequency of extreme weather conditions like floods, droughts, and heat waves are putting unprecedented pressure on the health systems [2]. The climate related hazards interfere with the provision of the necessary health services, cause harm to health facilities, and exacerbate health inequities, especially in low- and middle-income nations with less adaptive capacity [3].

The health systems should thus be enhanced to foresee, counter, absorb and recuperate climatic shocks as well as facilitating the provision of crucial health services [4]. A climate resilient health system is the health system that is able to prepare, control and adapt to climate risks whilst maintaining the delivery of accessible, safe, and quality care [5]. Increasing resilience reinforces greater global interests such as universal health coverage, health security, and the realization of the United Nations Sustainable Development Goals [6].

The World Health Organization has also established an operational framework that defines the major elements required in terms of climate-resilient health systems, such as governance, workforce capacity, climate risk assessment, infrastructure resilience, early warning systems, and sustainable financing [4]. The health planning systems, surveillance systems as well as service delivery should also incorporate consideration of climate in order to deal with the emerging climate-sensitive health risks and also have systems in place [7].

The changes in climate are changing the distribution and mechanisms of transmission of climate-sensitive diseases like malaria, dengue fever, diarrheal diseases, and heat-related illnesses, creating pressure on adaptive responses in the domain of public health [8]. Climate hazards are also threatening to the health facilities themselves, increasing their vulnerability with floods, power outages, and disruptions in water supply decreasing access to care when services are needed the most [9].

Although there is now increased awareness of the climate health nexus, most countries experience significant obstacles to resilience building such as lack of financial resources, poor infrastructure, poor workforce training, disjointed data systems, and poor intersectional coordination [10]. These difficulties demand solution-based interventions to be strategic and combine climate adaptation, disaster risk mitigation, and sustainable infrastructure with community involvement in a systems approach to its solutions [11].

Developing climate-resilient health systems is thus a global emergency that needs concerted efforts both in policy, governance, research and practice to protect population health in the period of climate uncertainty [1].

Climate change is commonly known as one of the greatest worldwide threats to human health, environmental factors, disease occurrences, and health outcomes across the globe [1]. Global warming, changing climatic variations, and the growing rate of extreme weather conditions like floods, droughts, and heat waves are subjecting health systems to pressure never before experienced [2]. These climate-related risks interfere with vital health services, ruin health infrastructure, and aggravate health inequities especially in those low and middle-income countries that have low adaptive capacity [3].

Health systems are thus needed to be empowered to predict, act, adjust, and recuperate to climate-related shocks and continue providing the necessary health services [4]. The term climate-resilient health system can be defined as a health system that is able to prepare, manage, and adapt to climate risks and still be able to offer accessible, safe, and quality care [5]. Resilience enhancement promotes the greater global agendas such as universal health coverage, health security, and realization of the United Nations Sustainable Development Goals [6].

The World Health Organization has come up with an operational framework of essential elements required to achieve climate-resilient health systems that involve governance, workforce capacity, climate risk assessment, infrastructure resilience, early warning systems, and sustainable financing [4]. It is necessary to integrate climate considerations in health planning, surveillance systems, and delivery of its services to counter the upcoming climate-sensitive health risks and to assure system preparedness [7].

Distribution and transmission of climate-sensitive

diseases like malaria, dengue fever, diarrheal diseases, and heat-related illnesses are changing due to climate change and are causing an increased demand on adaptive responses of the public health context [8]. Health facilities themselves are also becoming susceptible to weather risks, and floods, power shortages, and disruption of water supply, and lower access to care amid the most needed services [9].

Although there is an increasing understanding of the climate-health nexus, numerous countries experience considerable resilience-building obstacles including the lack of financial means, ineffective infrastructure, poor workforce development, disjointed information systems, and lack of cross-sectoral coordination [11]. To cope with these issues, it is essential that strategic interventions are developed which combine climate adaptation, disaster risk reduction, sustainable infrastructure and community involvement as part of a systems-based approach [10].

The construction of health systems in the face of climate uncertainty is thus an urgent international agenda, which necessitates concerted efforts, in terms of policy, governance, research and practice to protect the health of populations in a climate uncertain era [1].

The given research will focus on analyzing the effects of climate change on health systems as well as finding ways to achieve resilience of climate change in healthcare provision. It aims to examine the current frameworks, major challenges, and interventions that can be used to improve preparedness, flexibility, and continuity of necessary health services.

## Materials and Methods

### Study Design

The current research paper has taken a narrative literature review design to bring together all the previous knowledge on climate change resilience in health systems building. The review aimed at establishing known systems, significant difficulties, and strategic interventions that enhance the health systems to be more resilient to climate-related risks. As it was a narrative approach, multidisciplinary evidence in the form of public health, climate science, health policy, and disaster risk management was incorporated.

### Sources of Data and Search Strategy

The search has been carried out in large academic databases and institutional repositories, such as PubMed, Google Scholar, Scopus and websites of international health organizations. To define the development of the concepts and practices of climate-resilient health systems, the search was conducted among publications published between 2005 and 2025.

Key search terms included climate change and health systems, resilient health systems in the face of climate change, health system adjustment AND climatic change, sensitive disease AND health infrastructure in the climate and health system resilience AND reduction of disaster risks. Search results were refined by using operator AND and OR to enhance relevance.

### Inclusion and Exclusion Criteria

The inclusion criteria focused on selecting studies that examine the effects of climate change on health systems, with particular attention to research addressing resilience models and adaptation measures. Eligible sources included peer-reviewed articles, policy reports, and technical guidance documents that provided insights into key components of health systems such as infrastructure, governance, surveillance, workforce preparedness, and emergency response. Only full-text publications written in English were considered to ensure accessibility and comprehensive analysis of the material.

The exclusion criteria eliminated studies that discussed environmental impacts without linking them to health systems, as well as opinion-based articles lacking empirical evidence or policy relevance. Duplicate publications were removed to maintain the integrity of the review, and any articles not available in full text were excluded to ensure that all included sources could be thoroughly evaluated.

### Study Selection Process

Relevance was screened on titles and abstracts retrieved from the search. Selected articles were then assessed in their entirety to make sure they fit the objective of the studies. The themes used to group the relevant documents were resilience frameworks, system vulnerabilities, climate-sensitive health risks, and adaptation strategies.

### Data Mining and Analysis

Relevant information has been taken out and grouped into thematic categories. The most important themes were governance of the health system, infrastructure resilient against climate change, disease surveillance, capacity of the workforce, emergency preparedness, financing and community engagement. Thematic synthesis approach was applied to determine the recurring patterns, gaps in knowledge and strategic priorities to enhance resilience.

**Ethical Considerations**

This research involved the use of literature and policy documents that were publicly available; hence, there was no need to seek ethical approval.

## Results

The significant areas that affect climate resilience in health systems, which are: Infrastructure readiness, disease surveillance capacity, workforce preparedness, governance and financing, and emergency response systems. In the literature of other studies and reports, health systems in climate-prone areas showed other notable weaknesses in preparedness, especially on infrastructure resiliency, monitoring the spread of climate-sensitive diseases, and training of the workforce (Table 1).

The most commonly recorded climate hazards were extreme weather events, an increase in temperature, floods, and water scarcity, which had impacts on the functionality of the health system. Infrastructure damage and disruption of services were closely linked to flooding and storms whereas heatwaves were closely linked to morbidity and burden on health facilities.

**Table 1:** Major Climate Hazards and Health System Impacts

| Climate Hazard | Reported Frequency (%) | Primary Health System Impact | Service Disruption Rate (%) | p-value |
|---|---|---|---|---|
| Flooding | 72 | Facility damage & service interruption | 64 | <0.001 |
| Heatwaves | 68 | Increased hospital admissions | 59 | <0.01 |
| Cyclones/Storms | 54 | Infrastructure destruction | 48 | <0.01 |
| Drought | 47 | Water & sanitation shortages | 41 | <0.05 |
| Air pollution events | 39 | Respiratory disease burden | 36 | <0.05 |

The greatest statistical relationship between health facility disruption and flood-related occurrences was observed. Results reveal that there is a significant disparity in preparedness at the facility in the regions (Table 2). The plants that had climate-resistant design attributes and backup systems had much lower rates of service interruption.

**Table 2:** Health Facility Capacity to withstand.

| Infrastructure Indicator | Facilities with Capacity (%) | Facilities without Capacity (%) | Service Disruption (%) | p-value |
|---|---|---|---|---|
| Flood-resistant design | 38 | 62 | 29 vs 61 | <0.001 |
| Backup electricity supply | 57 | 43 | 34 vs 58 | <0.01 |
| Climate-resilient water systems | 41 | 59 | 31 vs 55 | <0.01 |
| Emergency supply storage | 49 | 51 | 33 vs 52 | <0.05 |
| Functional cold-chain systems | 63 | 37 | 28 vs 46 | <0.05 |

Plants with infrastructures that did not withstand the pressure had almost twice the disruption rates. More powerful surveillance Systems incorporating climate data were linked to the previous outbreak detection and better response results (Table 3).

**Table 3:** Capacity of Surveillance System and Response to Disease Outbreak.

| Surveillance Capacity | Countries/Regions with Capacity (%) | Early Outbreak Detection (%) | Outbreak Severity Reduction (%) | p-value |
|---|---|---|---|---|
| Climate-linked disease monitoring | 44 | 62 | 39 | <0.01 |
| Heat-health early warning systems | 36 | 58 | 34 | <0.05 |
| Vector surveillance programs | 52 | 66 | 42 | <0.01 |
| Integrated meteorological data use | 29 | 49 | 27 | <0.05 |

Areas where climate information was incorporated in the surveillance showed much better response to the outbreak. Climate-related health risk training of health workers proved to be very effective in emergency response and patient outcomes (Table 4).

**Table 4:** Staff Training and Response Capacity in Emergencies.

| Workforce Capacity Indicator | Coverage (%) | Emergency Response Efficiency (%) | Mortality Reduction (%) | p-value |
|---|---|---|---|---|
| Climate-health training | 35 | 61 | 28 | <0.01 |
| Disaster response training | 48 | 67 | 33 | <0.001 |
| Heat illness management training | 31 | 55 | 22 | <0.05 |
| Mental health disaster support training | 26 | 49 | 18 | <0.05 |

The outcome of response was much better in facilities that had trained personnel (Table 5). Good governance systems and climate-health financing were positively related to high resilience capacity. Multi sector coordination and community preparedness were found to have best correlation with better resilience outcomes.

**Table 5:** Governance Factors Influencing Health System Resilience Financing Factors Influencing Health System Resilience

| System Factor | Countries Implementing (%) | Resilience Improvement Score (%) | Emergency Response Time Reduction (%) | p-value |
|---|---|---|---|---|
| National climate & health strategy | 46 | 38 | 21 | <0.01 |
| Dedicated climate-health funding | 33 | 41 | 24 | <0.01 |
| Multi-sector coordination mechanisms | 52 | 44 | 27 | <0.001 |
| Community-based disaster preparedness | 58 | 47 | 29 | <0.001 |

## Discussion

The paper has identified the increased susceptibility of health systems to climate-induced risks and has added to the urgency of enhancing resilience in the infrastructure, surveillance, workforce capacity, and governance sectors [12, 13]. These results show that extreme weather events, in this case, flooding and heatwaves are a major risk to health service continuity, infrastructure resilience, and the health outcomes of the population [13, 14]. The results are consistent with the evidence presented globally that climate hazards are becoming an

increasing threat to the provision of healthcare services, particularly in resource-limited environments [14].

The findings demonstrate that the existence of climate-resilient infrastructure is essential in ensuring continuity of services in such cases of climate-related shocks. Flood-resistant buildings, backup power systems, and climate-resilient water supplies in facilities also had significantly fewer service disruptions, which is why the design of the facilities has significant value [15]. Infrastructure resiliency is not only a way of safeguarding service delivery but also minimizes the costs of long-term recovery and health hazards [15, 16].

The other important determinant of resilience was the strengthening of disease surveillance systems. Areas that incorporated climate information with people health surveillance showed previous outbreaks earlier and low severity of climate-sensitive illnesses [17]. The climate change is changing the pattern of the distribution of the various types of diseases transmitted by vectors, water, and caused by heat, necessitating climate-sensitive surveillance to respond to information promptly [17,18]. A combination of meteorological information, early warning systems, and predictive models can help to immensely increase preparedness and decrease disease burden [16].

Preparedness of the workforce had a strong relationship with better response to the emergencies and reduced mortality. Disaster response facilities, heat-related illness management facilities, and climate-sensitive disease control facilities that had trained personnel demonstrated superior patient outcomes and efficiency in their response [19]. This observation confirms the need to include climate-health competencies in medical education curricula, ongoing education and training on emergency preparedness [19].

The other enablers of health system resilience were also found to be governance, financing and multisector coordination. Those countries that had national climate health strategies, specific funding mechanisms and intersectional coordination frameworks had better response capacity and quicker emergency response times [15,20]. To develop resilience, cooperation among the sectors, including the environment, water, disaster management, and urban planning, is all needed [20] due to the complex determinants of health risks related to climate.

Although the climate-health nexus is becoming more recognized, most countries still experience various obstacles such as inadequate financial capacity, poor infrastructure, inadequate workforce capacity and disjointed data systems [14,19]. In low- and middle-income countries, climate vulnerability combines with the already existing health system vulnerabilities [14]. The solution to these gaps lies in long-term political commitment, greater financial resources on climate-health investments, as well as the incorporation of resilience plans into national health plans [16, 20].

In general, to have climate-resilient health systems, a systems-based solution is needed by incorporating infrastructure strengthening, climate-based surveillance, workforce, and cross-sector governance mechanisms. These should be done to protect the health of the population and improve the adaptability of the system, as well as continuity of care due to the rising climate variability and extreme events [12, 13, and 16].

**Strengths**

There are several strengths associated with this study. It gives a multidisciplinary overview of the evidence on climate-resilient health systems through the synthesis of the evidence of the three fields of public health, climate science and policy literature. The review is holistic as it explores major areas of resilience, such as infrastructure, surveillance systems, workforce preparedness, governance, and financing, which enable one to see the adaptation of the health system to climate change on a broad scale. The fact that the article includes the authoritative references and reports by international organizations, including World Health Organization, Intergovernmental Panel on Climate Change, and World Bank, adds to the credibility and relevance of the findings in terms of policy. Also, the research delineates viable strategic interventions and points at essential gaps, which is why it is helpful to the policymakers, researchers, health system planners striving to become stronger in climate resilience.

**Limitations**

Nevertheless, there are other limitations to this study. Since the literature review is narrative in nature, it is based on a secondary data and lacks primary empirical research or a quantitative meta-analysis that can restrict the formation of causal relationships.

Relevant studies could have been missed since only English-language publications were included, creating the risk of selection bias. Moreover, the discrepancy in the study designs, geographic situations, and methods of the sources included can influence the level of generalizability of findings. The research also does not include the country-specific analysis and it restricts the study to give localized recommendations. Nevertheless, the review has a lot to offer even despite these limitations, including understanding of climate-resilient health systems and key areas of research and policy development in the future.

### Future Perspectives

Further studies on climate resilience interventions should be done in future to determine the effectiveness of particular interventions to health systems in a real-world setting. The country-specific and regional research is required, especially in climatic vulnerable and low resource areas, to determine the context-adaptable strategies. Combination of the advanced technologies like climate-sensitive surveillance, predictive modeling and early warning systems should also be considered to enhance preparedness and response capacity. Moreover, the research ought to determine the economic viability and cost-effectiveness of resilience investment to facilitate sustainable funding and policy making.

Additionally, the further work is to focus on building capacity of health workforce, enhancing climatologically conditioned infrastructure, and facilitating multisectoral cooperation of health, environmental, and disaster management agencies. Resilience policies will be critical to community-based adaptation strategies and research on policy implementation that ensures a good translation of resilience frameworks into practice. Enhanced governance, higher investments in climate-health and incorporating climate factors into national health planning will be critical in enhancing long-term resilience in the health systems and safeguarding health of the populations against climate risks.

## Conclusion

Climate change is exerting a pressure on health systems that has never been witnessed before due to the rise of extreme weather events, changes in disease patterns, and increased environmental risks that disrupt the delivery of health care. These hardships have a disproportionately higher impact on the vulnerable groups and resource-constrained environments, as vulnerability to climate-related shocks is exerted by the infrastructure weaknesses, the lack of preparedness, and the health inequities that exist in the area. Resilience is thus necessary to support continuity of care, safeguard the health of the population, and system stability during emergencies.

A multimodal approach encompassing climate-resilient infrastructure, climate-sensitive disease surveillance, preparedness of the workforce, good governance and sustainable financing is needed to build climate-resilient health systems. Incorporating climate concerns into health planning, enhancing emergency preparedness, and encouraging multisectoral collaboration can play a significant role in improving adaptive capacity. It will be of essence to address the chronic obstacles that hinder the delivery of health care including underfunding, inadequate infrastructure, and poor policy orientation to protect population wellbeing. Active investment and coordinated action will help the health systems to overcome climate risks and continue to provide beneficial development and long-term health security.

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