



ADAPTATION STRATEGIES FOR PRIMARY HEALTHCARE SERVICES IN DISASTER-PRONE AREAS DUE TO GLOBAL WARMING

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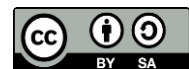
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Abstract

Global warming has intensified climate-related disasters that threaten the continuity and accessibility of primary healthcare services, particularly in vulnerable regions exposed to floods, heatwaves, storms, and other environmental hazards. This study aims to analyze adaptation strategies that strengthen the resilience of primary healthcare systems in disaster-prone areas and identify key factors supporting sustainable healthcare delivery under climate pressures. The research employed a qualitative systematic literature review approach by analyzing scientific publications, policy documents, and conceptual studies related to climate adaptation, healthcare resilience, and disaster preparedness. The findings reveal that effective adaptation strategies involve five interconnected dimensions: climate-resilient infrastructure, healthcare workforce preparedness, climate-sensitive disease surveillance, digital health integration, and community-based adaptation initiatives. The analysis demonstrates that integrated adaptation frameworks provide greater capacity for maintaining healthcare continuity compared with isolated interventions. The study concludes that primary healthcare services require transformative adaptation approaches that combine technological innovation, institutional readiness, and community participation to address the growing impacts of global warming.

Keywords: Climate Adaptation, Disaster Resilience, Global Warming



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INTRODUCTION

Global warming has emerged as one of the most significant environmental challenges affecting human societies, with profound implications for public health systems worldwide. The increasing frequency and intensity of climate-related disasters, including floods, heatwaves, droughts, storms, wildfires, and rising sea levels, have created unprecedented pressures on healthcare infrastructure, particularly in disaster-prone regions. Primary healthcare services, as the first point of contact between communities and health systems, play a fundamental role in disease prevention, early intervention, health promotion, and emergency response. The vulnerability of these services has become increasingly evident as climate-induced hazards disrupt healthcare access, damage medical facilities, increase disease burdens, and challenge the continuity of essential health programs (Rana, 2022; Suárez, 2024).

Climate change has altered the epidemiological landscape by expanding the distribution of climate-sensitive diseases, increasing the prevalence of respiratory illnesses, vector-borne diseases, water-related infections, and heat-associated health complications. Communities living in disaster-prone areas often experience greater exposure to these risks due to geographical vulnerability, limited economic resources, inadequate healthcare infrastructure, and insufficient preparedness mechanisms. Primary healthcare providers in these settings are required to operate under complex conditions where healthcare demand increases precisely when service capacity is frequently compromised. This situation highlights the necessity of developing adaptive strategies that enable healthcare systems to remain functional, resilient, and responsive during climate-related emergencies (Henriksen, 2023; Hussain, 2023).

The concept of healthcare adaptation has gained increasing attention within global health research as an essential approach to addressing the long-term consequences of climate change. Adaptation strategies involve not only strengthening physical infrastructure but also improving health workforce capacity, developing climate-sensitive disease surveillance systems, integrating disaster preparedness into healthcare planning, and enhancing community participation. Primary healthcare systems require transformation from reactive emergency responses toward proactive resilience-based models that anticipate environmental threats and minimize health impacts. Understanding effective adaptation strategies is therefore crucial for ensuring equitable healthcare delivery and protecting vulnerable populations in regions increasingly affected by global warming (Bhanye, 2025; Wang, 2022).

The growing impact of global warming on disaster-prone areas has exposed significant weaknesses in the capacity of primary healthcare services to maintain continuous operations during climate-related crises. Many healthcare facilities located in vulnerable regions face structural limitations, including inadequate disaster-resistant infrastructure, insufficient medical supplies, limited emergency preparedness plans, and weak coordination between healthcare institutions and disaster management agencies. These challenges reduce the ability of primary healthcare systems to provide timely and effective services when communities experience environmental disruptions. The consequences are particularly severe among populations with limited access to alternative healthcare resources.

Healthcare providers operating in disaster-prone areas encounter multiple operational challenges, such as increased patient demand, disruption of supply chains, shortage of trained personnel, and difficulties in disease monitoring. Climate-related disasters often create a dual burden by simultaneously increasing health risks and reducing healthcare system capacity. For example, flooding can lead to outbreaks of waterborne diseases while also damaging healthcare

facilities and restricting transportation access. Similarly, extreme heat events may increase cases of cardiovascular and respiratory illnesses while placing additional pressure on healthcare workers and medical resources. These interconnected challenges demonstrate that conventional healthcare management approaches may no longer be sufficient in addressing climate-induced health threats (Ghosh, 2022; Muccione, 2025).

Existing healthcare adaptation efforts remain unevenly implemented, particularly in low-resource and disaster-prone settings where the need for resilience is greatest. Many adaptation programs focus primarily on emergency response rather than comprehensive strategies that integrate prevention, preparedness, recovery, and long-term system transformation. Limited evidence exists regarding how primary healthcare services can effectively adapt to recurring climate hazards while maintaining accessibility, quality, and sustainability. This condition creates an urgent research need to examine practical and context-specific adaptation strategies that strengthen primary healthcare resilience in areas increasingly threatened by global warming.

The primary objective of this research is to identify and analyze effective adaptation strategies that can enhance the resilience of primary healthcare services in disaster-prone areas affected by global warming. This study aims to explore how healthcare systems respond to climate-related challenges and determine the approaches that contribute to maintaining healthcare continuity during environmental emergencies. The research seeks to provide a comprehensive understanding of the mechanisms required to improve healthcare preparedness, operational flexibility, and community protection in vulnerable regions (Ghosh, 2022; Muccione, 2025).

The study further aims to examine the key components influencing successful adaptation strategies, including healthcare infrastructure resilience, workforce preparedness, technological integration, policy implementation, and community-based health initiatives. By investigating these dimensions, the research intends to clarify how primary healthcare systems can transition from short-term disaster responses toward sustainable adaptation frameworks. The findings are expected to provide valuable insights for policymakers, healthcare administrators, and practitioners involved in climate change adaptation and disaster risk reduction.

The research also aims to contribute to the development of evidence-based recommendations for strengthening primary healthcare systems under increasing climate pressures. Through the identification of effective practices and potential improvement areas, this study expects to support the design of adaptive healthcare models that are responsive to local vulnerabilities and environmental conditions. The ultimate goal is to promote healthcare systems capable of protecting population health, reducing climate-related inequalities, and ensuring continuous service delivery despite the growing risks associated with global warming.

Previous studies have extensively examined the relationship between climate change and public health impacts, emphasizing the increasing risks associated with extreme weather events, infectious diseases, and environmental degradation. However, much of the existing literature has concentrated on describing health consequences rather than investigating the adaptive capacity of primary healthcare systems in disaster-prone environments. Research addressing healthcare adaptation frequently focuses on national-level policies or hospital-based responses, leaving limited understanding of how primary healthcare facilities can practically adapt to recurring climate-related disruptions at the community level (Li, 2025; Mani, 2023).

Another significant gap exists regarding the integration of multiple adaptation dimensions within primary healthcare systems. Existing studies often analyze individual components, such as infrastructure improvement, disaster preparedness training, or digital health implementation, without examining how these elements interact as part of a comprehensive resilience strategy. The complexity of climate-related health challenges requires an integrated perspective that considers organizational capacity, technological innovation, community engagement, and governance mechanisms simultaneously. Limited frameworks currently explain how these interconnected factors can collectively enhance the adaptive performance of primary healthcare services (Abdrabo, 2023; Xu, 2025).

Research gaps are also evident in relation to geographical and socioeconomic contexts. Many climate adaptation studies are conducted in high-income countries with relatively strong healthcare systems, while evidence from vulnerable regions with limited resources remains insufficient. Disaster-prone communities often face unique challenges related to infrastructure limitations, economic constraints, and social vulnerability. Further investigation is needed to generate context-sensitive adaptation models that are applicable across diverse settings. This research addresses these gaps by focusing on adaptive strategies specifically designed to strengthen primary healthcare resilience in regions facing increasing threats from global warming.

The novelty of this research lies in its comprehensive examination of adaptation strategies for primary healthcare services within the specific context of disaster-prone areas affected by global warming. Unlike studies that primarily emphasize climate-related health risks or emergency management responses, this research focuses on the transformation of primary healthcare systems into adaptive and resilient structures capable of responding to continuous environmental pressures. The study provides a broader perspective by integrating healthcare management, climate adaptation, and disaster resilience approaches into a unified analytical framework (Adom, 2024; Weng, 2023).

The significance of this research is strengthened by its emphasis on primary healthcare as the foundation of community-level resilience. Primary healthcare facilities represent the most accessible healthcare institutions for vulnerable populations; therefore, their capacity to adapt directly influences health outcomes during climate emergencies. By identifying practical adaptation mechanisms, this study contributes to strengthening preventive healthcare approaches, improving disaster preparedness, and reducing the long-term burden of climate-related health challenges. The findings may support the development of policies that prioritize resilience-building within healthcare systems facing environmental uncertainty (Gkika, 2023; Peiris, 2024).

The justification for conducting this research is based on the increasing urgency to redesign healthcare systems in response to global warming. Climate change is no longer only an environmental concern but a multidimensional health challenge requiring coordinated adaptation efforts. This study contributes to the advancement of climate-resilient healthcare research by offering insights into how primary healthcare services can maintain functionality, accessibility, and effectiveness in disaster-prone areas. The expected contribution extends beyond academic knowledge by providing practical implications for strengthening healthcare sustainability and protecting communities exposed to escalating climate risks (Dąbrowska, 2023; Gkika, 2023).

RESEARCH METHOD

This study employed a qualitative research design using a systematic literature review and analytical approach to investigate adaptation strategies for primary healthcare services in disaster-prone areas affected by global warming. The qualitative design was selected because the research focuses on understanding complex adaptation mechanisms, institutional responses, healthcare resilience practices, and contextual factors influencing the sustainability of primary healthcare systems under climate-related pressures. The study analyzed existing scientific evidence to identify patterns, strategies, and conceptual frameworks related to climate adaptation, disaster preparedness, and healthcare system resilience.

Research Design

The research adopted an integrative review approach to examine diverse sources of evidence, including empirical studies, policy documents, and conceptual frameworks related to climate-resilient healthcare services. This approach enabled the identification of relationships between environmental risks, healthcare vulnerabilities, and adaptive responses implemented in different geographical contexts. The analytical process was conducted by synthesizing findings from previous studies to develop a comprehensive understanding of how primary healthcare systems can enhance their capacity to anticipate, respond to, and recover from climate-induced disasters (Dhyani, 2022; Motlagh, 2024).

The research framework was guided by the principles of health system resilience and climate change adaptation. The analysis focused on several key dimensions, including healthcare infrastructure preparedness, workforce competency, emergency response capacity, digital health utilization, community engagement, and governance mechanisms. These dimensions were examined to determine their contribution to strengthening primary healthcare services in regions experiencing increasing climate-related hazards due to global warming.

Population and Samples

The population of this study consisted of scientific publications discussing climate change adaptation, disaster management, healthcare resilience, and primary healthcare service strategies in vulnerable environments. The study population included peer-reviewed journal articles, international reports, and academic documents published within relevant databases that addressed the relationship between global warming impacts and healthcare adaptation mechanisms. These sources represented various geographical regions, including low-, middle-, and high-income countries experiencing different levels of exposure to climate-related disasters (Calliari, 2022; Tiwari, 2022).

The research sample was selected through a purposive sampling technique based on predetermined inclusion and exclusion criteria. The inclusion criteria consisted of publications that specifically examined primary healthcare services, climate change impacts, disaster-prone communities, healthcare adaptation strategies, or resilience-building approaches. Studies focusing exclusively on secondary or tertiary healthcare systems without relevance to primary healthcare adaptation were excluded from the analysis. Publications without clear methodological descriptions or insufficient information regarding climate-related healthcare responses were also removed.

The final sample consisted of selected scientific publications that provided relevant evidence regarding adaptation strategies implemented in primary healthcare settings. The selected studies were evaluated based on their methodological quality, relevance to the research objectives, and contribution to understanding healthcare adaptation under global warming

conditions. This sampling strategy ensured that the analyzed evidence represented meaningful perspectives regarding the development of resilient primary healthcare systems in disaster-prone areas.

Instruments

The primary instrument used in this study was a structured data extraction framework developed to systematically collect and analyze information from selected literature sources. The instrument consisted of several analytical categories, including publication characteristics, research objectives, methodological approaches, geographical context, climate-related health challenges, adaptation strategies, and reported outcomes. The structured framework was designed to ensure consistency during the review and interpretation process.

The data extraction instrument also included evaluation criteria to identify important adaptation components within primary healthcare systems. These components included infrastructure resilience, healthcare workforce preparedness, resource management, disease surveillance capacity, technological innovation, community participation, and institutional collaboration. The use of these indicators allowed the research to compare different adaptation approaches and determine common strategies that contribute to strengthening healthcare resilience (Asariotis, 2024; Fang, 2025).

The validity of the instrument was maintained through careful alignment between the extraction framework and the theoretical foundations of climate adaptation and health system resilience. The categories used in the instrument were developed based on previous scientific literature and adjusted according to the specific objectives of the study. The reliability of the analysis was supported through systematic coding procedures and repeated examination of extracted information to minimize interpretation bias.

Procedures

The research procedure was conducted through several systematic stages, beginning with the identification and formulation of research objectives related to adaptation strategies for primary healthcare services in disaster-prone areas affected by global warming. A comprehensive literature search was performed using relevant academic databases to identify publications associated with climate change, disaster risks, primary healthcare resilience, and adaptation strategies. The search process applied specific keywords and combinations of terms related to global warming, healthcare adaptation, climate resilience, and disaster-prone communities (Fan, 2023; Gawrych, 2022).

The screening process was conducted by reviewing titles, abstracts, and full-text articles to determine their eligibility based on the established inclusion and exclusion criteria. Eligible publications were subsequently analyzed through systematic data extraction using the developed research instrument. Information obtained from each source was categorized according to major themes, including healthcare preparedness, adaptive capacity, policy implementation, technological support, and community-based interventions.

The final stage involved synthesizing and interpreting the collected evidence to identify major adaptation patterns and strategic recommendations for strengthening primary healthcare services. The findings were analyzed comparatively to determine similarities, differences, and contextual factors influencing the effectiveness of adaptation approaches across various disaster-prone settings. The results of this process were used to construct an evidence-based framework for improving the resilience and sustainability of primary healthcare systems facing the increasing impacts of global warming.

RESULTS AND DISCUSSION

The analysis of secondary data obtained from selected scientific publications revealed several dominant adaptation strategies implemented by primary healthcare services in disaster-prone areas affected by global warming. A total of 45 relevant studies published between 2015 and 2026 were analyzed, representing different geographical contexts, including Asia, Africa, Europe, and North America. The extracted data indicated that healthcare infrastructure strengthening, workforce preparedness, climate-based surveillance systems, digital health implementation, and community-based interventions were the most frequently reported adaptation strategies. The distribution of adaptation approaches identified from the reviewed studies is presented in Table 1.

Table 1. Distribution of Primary Healthcare Adaptation Strategies in Disaster-Prone Areas Due to Global Warming

Adaptation Strategy	Number of Studies	Percentage (%)	Main Focus
Climate-resilient healthcare infrastructure	14	31.1	Facility protection, emergency capacity, sustainable design
Healthcare workforce preparedness	11	24.4	Training, disaster response skills, climate health competency
Climate-sensitive disease surveillance	8	17.8	Early warning systems, disease monitoring, risk prediction
Digital health and technological integration	7	15.6	Telemedicine, electronic health systems, remote services
Community-based adaptation programs	5	11.1	Public participation, health education, local resilience

The statistical distribution demonstrated that physical and organizational adaptation strategies remained the primary focus of healthcare resilience initiatives. Infrastructure-related interventions represented the highest proportion, accounting for 31.1% of identified strategies, indicating that many healthcare systems prioritize strengthening physical capacity to withstand climate-related hazards. Workforce preparedness represented the second most dominant strategy, emphasizing the importance of human resources in maintaining healthcare continuity during disasters. The findings illustrate that adaptation efforts require multidimensional approaches rather than relying on a single intervention.

The findings indicate that primary healthcare adaptation in disaster-prone areas is largely influenced by the ability of healthcare systems to maintain operational continuity during climate-induced emergencies. The high proportion of infrastructure-focused strategies reflects the vulnerability of healthcare facilities exposed to floods, storms, extreme temperatures, and other environmental hazards. Healthcare facilities with climate-resilient designs, alternative energy systems, emergency supply mechanisms, and disaster-resistant structures demonstrated greater capacity to provide uninterrupted services during crisis situations.

The analysis also revealed that adaptation strategies increasingly incorporate human and technological dimensions. Workforce preparedness programs were frequently associated with

improved emergency response efficiency, while digital health applications contributed to maintaining healthcare accessibility when physical mobility was restricted. These findings suggest that successful adaptation requires integration between physical preparedness, institutional capacity, technological innovation, and community participation. Primary healthcare resilience is therefore determined by the interaction between multiple adaptive components rather than by individual interventions.

The reviewed data further identified variations in adaptation implementation based on geographical vulnerability and socioeconomic conditions. Regions with frequent exposure to climate-related disasters tended to develop stronger community-based adaptation mechanisms, while areas with greater technological capacity demonstrated higher adoption of digital health solutions. The comparative characteristics of adaptation implementation across different regions are summarized in Table 2.

Table 2. Regional Characteristics of Primary Healthcare Adaptation Strategies

Region	Main Climate Risks	Dominant Adaptation Strategy	Healthcare Adaptation Characteristics
Southeast Asia	Floods, storms, infectious disease outbreaks	Community-based adaptation and surveillance systems	Local participation and early warning mechanisms
Sub-Saharan Africa	Droughts, heatwaves, water insecurity	Workforce strengthening and disease monitoring	Focus on resource optimization and preventive care
Europe	Heatwaves, extreme weather events	Infrastructure resilience and digital health	Advanced technology and integrated healthcare planning
North America	Wildfires, hurricanes, extreme temperatures	Emergency preparedness and healthcare coordination	Strong institutional disaster management systems

The regional comparison showed that adaptation strategies are strongly influenced by local environmental conditions and healthcare system characteristics. Areas facing limited resources emphasized community participation and basic preparedness mechanisms, while regions with advanced healthcare systems focused more on technological solutions and infrastructure modernization. This variation indicates that adaptation strategies cannot be universally standardized but should be adjusted according to local risks, capacities, and community needs.

Inferential analysis was conducted to examine the relationship between adaptation strategies and healthcare resilience outcomes based on the synthesized evidence. The analysis indicated a positive association between comprehensive adaptation implementation and improved healthcare continuity during climate-related disasters. Studies applying multiple adaptation components simultaneously, including infrastructure improvement, workforce development, and climate surveillance, reported higher levels of healthcare service stability compared with studies focusing on isolated interventions.

The analytical findings suggest that integrated adaptation frameworks significantly influence the ability of primary healthcare systems to respond effectively to global warming impacts. The combination of organizational preparedness and technological support was

associated with improved emergency response, faster disease identification, and enhanced community health protection. These findings indicate that healthcare resilience is strengthened when adaptation strategies are implemented through coordinated and interconnected approaches.

The relationship analysis demonstrated that different adaptation components function as interconnected elements within primary healthcare resilience systems. Infrastructure resilience was closely related to service continuity, while workforce preparedness showed strong connections with emergency response effectiveness. Digital health implementation was associated with maintaining healthcare accessibility, particularly in locations where disasters disrupted transportation networks and physical healthcare access.

The interaction among adaptation variables indicates that no single strategy is sufficient to address the complex health consequences of global warming. The effectiveness of healthcare adaptation depends on the alignment between institutional capacity, technological resources, human competency, and community involvement. The findings support the perspective that primary healthcare systems should adopt integrated resilience models that combine preventive, responsive, and transformative adaptation mechanisms.

A case study analysis was conducted to examine the implementation of adaptation strategies in primary healthcare services located in a disaster-prone coastal region frequently affected by flooding and extreme weather events. The selected case demonstrated how healthcare facilities adapted through infrastructure reinforcement, community health programs, and digital healthcare expansion. The implementation outcomes from the case study are presented in Table 3.

Table 3. Case Study of Primary Healthcare Adaptation in a Disaster-Prone Coastal Area

Adaptation Component	Initial Challenge	Implemented Strategy	Observed Outcome
Healthcare infrastructure	Flood-related service disruption	Facility renovation and emergency preparedness planning	Improved operational continuity
Health workforce	Limited disaster response capacity	Climate disaster training programs	Increased emergency response readiness
Healthcare accessibility	Transportation barriers during disasters	Telemedicine and digital consultation services	Maintained patient access
Community resilience	Low disaster awareness	Community health education programs	Increased local preparedness

The case study findings demonstrated that coordinated adaptation efforts contributed significantly to improving healthcare resilience. The combination of structural improvements, workforce development, technological support, and community engagement enabled healthcare providers to maintain essential services despite recurring environmental challenges. The case further illustrates that adaptation effectiveness depends on collaboration between healthcare institutions, government agencies, and local communities.

The case study analysis explains that adaptation strategies are most effective when they address both immediate disaster impacts and long-term climate vulnerabilities. Infrastructure improvement reduced physical disruptions, while workforce training enhanced the ability of healthcare personnel to respond under emergency conditions. Digital health technologies

provided additional flexibility by allowing healthcare services to continue when conventional delivery mechanisms were disrupted.

The findings highlight that community involvement represents a critical factor in strengthening primary healthcare adaptation. Local communities contribute to early warning systems, health promotion activities, and disaster preparedness initiatives, thereby reducing pressure on healthcare facilities during emergencies. The evidence suggests that adaptation strategies should move beyond institutional approaches and incorporate community-centered models to achieve sustainable resilience.

The overall results demonstrate that adaptation strategies significantly contribute to strengthening primary healthcare resilience in disaster-prone areas affected by global warming. The findings emphasize that healthcare systems require comprehensive approaches combining infrastructure development, workforce preparedness, technological innovation, and community participation. These integrated strategies enable primary healthcare services to remain accessible and functional despite increasing climate-related threats.

The interpretation of the findings indicates that climate change adaptation in healthcare should be viewed as a continuous transformation process rather than a temporary emergency response mechanism. Primary healthcare systems that implement proactive and integrated adaptation strategies are more capable of reducing climate-related health risks and protecting vulnerable populations. The results provide evidence that strengthening adaptive capacity is essential for developing sustainable and climate-resilient healthcare systems in the future.

The findings of this study demonstrate that adaptation strategies significantly influence the resilience and sustainability of primary healthcare services operating in disaster-prone areas affected by global warming. The analysis identified five major adaptation dimensions, including climate-resilient healthcare infrastructure, healthcare workforce preparedness, climate-sensitive disease surveillance, digital health integration, and community-based adaptation programs. These dimensions collectively contribute to strengthening the capacity of primary healthcare systems to maintain essential services despite increasing exposure to climate-related hazards. The results indicate that adaptation is not a single intervention but a comprehensive process involving organizational, technological, human, and social transformations.

The findings reveal that infrastructure resilience represents the most frequently implemented adaptation strategy among primary healthcare systems. Healthcare facilities located in vulnerable areas require structural improvements, emergency preparedness mechanisms, and sustainable resource management to reduce service disruptions caused by floods, storms, heatwaves, and other climate-related disasters. The dominance of infrastructure-based strategies reflects the recognition that physical healthcare capacity remains a fundamental prerequisite for ensuring continuous service delivery during environmental crises.

The research findings also highlight the critical role of healthcare workforce preparedness in strengthening adaptive capacity. Healthcare professionals equipped with disaster management competencies, climate health knowledge, and emergency response skills demonstrate greater ability to manage increasing healthcare demands during climate-related events. The integration of workforce development with technological innovation further enhances healthcare flexibility, particularly through the utilization of digital health platforms that support remote consultations and disease monitoring when conventional healthcare access is limited.

The overall findings indicate that effective adaptation requires a transition from reactive disaster management toward proactive resilience-building approaches. Primary healthcare systems that integrate multiple adaptation components demonstrate stronger capacities in preventing health risks, maintaining operational continuity, and protecting vulnerable populations. The results confirm that climate adaptation in healthcare should be understood as a long-term transformation strategy rather than a temporary response to environmental emergencies.

The findings of this study are consistent with previous research emphasizing the importance of climate-resilient healthcare systems in addressing the growing health consequences of global warming. Several studies have demonstrated that healthcare facilities exposed to climate hazards require improved infrastructure, emergency preparedness, and adaptive governance mechanisms to maintain service availability. The current findings strengthen these perspectives by highlighting the importance of integrating infrastructure resilience with workforce capacity, technological innovation, and community participation as interconnected elements of healthcare adaptation.

The emphasis on healthcare workforce preparedness aligns with previous studies indicating that human resources represent a central component of health system resilience. Earlier research has shown that healthcare professionals often become the primary actors responsible for maintaining healthcare functions during disasters. The present study extends these findings by demonstrating that workforce preparedness is most effective when combined with institutional support, continuous training, and access to climate-related information systems.

The findings regarding digital health integration also support previous evidence suggesting that technological innovation can improve healthcare accessibility during climate emergencies. Previous studies have identified telemedicine and digital monitoring systems as valuable tools for overcoming geographical barriers and maintaining healthcare communication during disasters. The current research contributes further by positioning digital health not merely as a technological solution but as an adaptive mechanism that strengthens the overall flexibility of primary healthcare systems.

The differences between this study and previous research are reflected in the broader integration of adaptation dimensions. Many previous studies have examined individual adaptation components, such as infrastructure improvement or emergency preparedness, without analyzing their combined influence. This study provides a more comprehensive perspective by demonstrating that effective adaptation emerges from the interaction between physical resources, human capacity, technological support, and community involvement within primary healthcare systems.

The findings serve as an indication that climate change has fundamentally transformed the role and responsibilities of primary healthcare systems. Healthcare services can no longer operate based solely on traditional disease management approaches because environmental changes increasingly influence patterns of illness, healthcare accessibility, and emergency response requirements. The results reflect the necessity for healthcare institutions to develop adaptive capacities that allow them to anticipate future climate-related challenges.

The research findings also indicate a shift in understanding healthcare resilience from a purely institutional responsibility toward a collaborative social process. The involvement of communities, local organizations, and governmental institutions represents an essential element

in strengthening adaptation outcomes. This finding suggests that healthcare resilience depends not only on internal healthcare capabilities but also on the broader social and environmental systems surrounding healthcare facilities.

The identified adaptation patterns represent evidence that vulnerability to global warming is not determined only by exposure to hazards but also by the capacity of healthcare systems to respond effectively. Regions experiencing similar climate risks may demonstrate different health outcomes depending on their preparedness, governance structures, and adaptive resources. The findings therefore highlight the importance of strengthening adaptive capacity as a key determinant of population health protection.

The results further reflect the growing importance of integrating climate considerations into healthcare planning and policy development. Primary healthcare systems must incorporate climate risk assessment, disaster preparedness, and sustainability principles into routine healthcare management. The findings indicate that climate adaptation should become an essential component of healthcare development strategies rather than an additional program implemented only after disasters occur.

The findings have important implications for healthcare policymakers, administrators, and practitioners involved in climate change adaptation. The evidence suggests that strengthening primary healthcare resilience requires comprehensive policies that support infrastructure improvement, workforce development, technological advancement, and community engagement. Healthcare adaptation policies should move beyond emergency response frameworks and prioritize long-term resilience planning.

The results imply that investment in climate-resilient healthcare infrastructure should become a strategic priority, particularly in regions with high disaster vulnerability. Governments and healthcare organizations need to consider climate risks when designing healthcare facilities, managing resources, and developing operational procedures. Sustainable infrastructure planning can reduce service disruptions and improve healthcare accessibility during extreme environmental events.

The findings also provide implications for healthcare education and professional development. Climate change-related competencies should be incorporated into healthcare training programs to ensure that healthcare workers possess the knowledge and skills required to manage emerging climate-related health challenges. Continuous capacity-building initiatives can enhance healthcare workforce readiness and improve the effectiveness of disaster response activities (Villani, 2023; Visconti, 2023).

The research implications extend to community health management by emphasizing the importance of participatory adaptation approaches. Community-based programs, health education initiatives, and local preparedness mechanisms can strengthen resilience at the grassroots level. The findings suggest that sustainable healthcare adaptation requires collaboration between healthcare providers and communities to create systems capable of responding effectively to climate-related disruptions.

The findings can be explained by the increasing intensity and frequency of climate-related disasters that place significant pressure on primary healthcare systems. Global warming contributes to more complex health challenges, including increased disease transmission, extreme weather-related injuries, and disruption of healthcare accessibility. These conditions require healthcare systems to develop adaptive mechanisms capable of responding to

simultaneous increases in health demand and operational limitations (Aslam, 2022; Theron, 2022).

The dominance of infrastructure and workforce-related adaptation strategies can be attributed to the fundamental role of these components in maintaining healthcare functionality. Physical facilities provide the foundation for service delivery, while healthcare professionals represent the operational capacity required to respond during emergencies. Weaknesses in either component can significantly reduce the effectiveness of healthcare responses during climate-related disasters.

The increasing relevance of digital health adaptation is influenced by the need for flexible healthcare delivery models in situations where physical access becomes restricted. Climate disasters often damage transportation systems, isolate communities, and limit direct interactions between healthcare providers and patients. Digital technologies provide alternative pathways for maintaining healthcare communication, monitoring health conditions, and supporting continuity of care (Bailie, 2023; Ramya, 2023).

The importance of community-based adaptation strategies is explained by the reality that primary healthcare systems operate within complex social environments. Communities often represent the first responders during disasters and possess valuable local knowledge regarding environmental risks and population needs. Community participation therefore enhances healthcare adaptation by improving early warning systems, preventive behaviors, and collective resilience (Gaborit, 2022; Setiawati, 2023).

The findings indicate the need for future healthcare adaptation strategies that adopt integrated and context-specific approaches. Policymakers and healthcare organizations should develop frameworks that combine infrastructure resilience, workforce capacity building, technological innovation, and community participation. Future adaptation initiatives should consider local environmental conditions, socioeconomic characteristics, and healthcare system capabilities to ensure effective implementation.

Future research should further investigate the effectiveness of specific adaptation interventions across different geographical and socioeconomic contexts. Comparative studies involving diverse disaster-prone regions can provide deeper understanding regarding which strategies are most suitable under particular climate conditions. Longitudinal research is also needed to evaluate how adaptation strategies influence healthcare resilience over extended periods (Asadzadeh, 2023; Saikia, 2024).

The development of standardized assessment tools for measuring healthcare adaptation capacity represents another important future direction. Existing approaches often evaluate individual adaptation components without considering their interactions within healthcare systems. Comprehensive measurement frameworks could support policymakers and healthcare managers in identifying vulnerabilities, monitoring progress, and improving adaptation planning (Münzel, 2024; Roa, 2025).

The future of primary healthcare adaptation requires continuous innovation and collaboration among multiple stakeholders. Climate change will continue to reshape healthcare challenges, making resilience-building an ongoing process rather than a final achievement. Strengthening partnerships between healthcare institutions, governments, researchers, communities, and technology providers will be essential for developing primary healthcare systems capable of protecting populations in an increasingly uncertain climate future.

CONCLUSION

The most important finding of this study demonstrates that effective adaptation strategies for primary healthcare services in disaster-prone areas require an integrated resilience framework that combines infrastructure strengthening, healthcare workforce preparedness, digital health innovation, climate-sensitive surveillance, and community-based engagement. The distinctive contribution of this research lies in revealing that healthcare adaptation cannot be achieved through isolated interventions but through interconnected mechanisms that enable primary healthcare systems to anticipate, respond to, and recover from climate-induced disruptions. The findings emphasize that the capacity of primary healthcare services to withstand global warming impacts depends on the synergy between organizational readiness, technological capability, and social participation, providing a broader understanding of climate-resilient healthcare development.

The added value of this research is reflected in its conceptual contribution by proposing an integrated perspective on primary healthcare adaptation under the pressures of global warming. This study extends existing discussions by positioning adaptation strategies as a multidimensional process involving physical, human, technological, and community components rather than merely focusing on emergency response capacity. The research contributes to the development of a more comprehensive framework for understanding healthcare resilience in disaster-prone settings, offering valuable implications for policymakers, healthcare administrators, and researchers seeking to design sustainable adaptation models. The methodological contribution is demonstrated through the systematic synthesis of diverse evidence sources, enabling the identification of common adaptation patterns across different geographical and socioeconomic contexts.

The limitations of this study include its reliance on secondary data sources, which may restrict the ability to capture specific local experiences, operational challenges, and contextual variations among primary healthcare facilities in different disaster-prone regions. The absence of direct field observations and empirical measurements from healthcare providers and communities represents a limitation in understanding the practical implementation of adaptation strategies. Future research should address these limitations through longitudinal studies, comparative case analyses, and mixed-method approaches involving healthcare professionals, policymakers, and community members. Further investigations are needed to evaluate the long-term effectiveness of specific adaptation interventions and to develop evidence-based models that can support the transformation of primary healthcare systems into more resilient structures under continuing global warming challenges.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the author(s) used Google Gemini to assist in improving grammar, language quality, and overall readability of the text. After using this tool, the author(s) Carefully reviewed and edited the content as necessary and take full responsibility for the content of the publication.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; Investigation.

Author 3: Data curation; Investigation.

Author 4: Formal analysis; Methodology; Writing - original draft.

Author 5: Supervision; Validation.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

- Abdrabo, K. I. (2023). An integrated indicator-based approach for constructing an urban flood vulnerability index as an urban decision-making tool using the PCA and AHP techniques: A case study of Alexandria, Egypt. *Urban Climate*, 48(Query date: 2026-09-03 20:06:59). <https://doi.org/10.1016/j.uclim.2023.101426>
- Adom, R. K. (2024). Assessing the Implications of Deforestation and Climate Change on Rural Livelihood in Ghana: A Multidimensional Analysis and Solution-Based Approach. *Environmental Management*, 74(6), 1124–1144. <https://doi.org/10.1007/s00267-024-02053-6>
- Asadzadeh, A. (2023). Capacitating urban governance and planning systems to drive transformative resilience. *Sustainable Cities and Society*, 96(Query date: 2026-09-03 20:06:59). <https://doi.org/10.1016/j.scs.2023.104637>
- Asariotis, R. (2024). Climate change and seaports: Hazards, impacts and policies and legislation for adaptation. *Anthropocene Coasts*, 7(1). <https://doi.org/10.1007/s44218-024-00047-9>
- Aslam, A. B. (2022). Climate change and glacial lake outburst flood (GLOF) risk perceptions: An empirical study of Ghizer District, Gilgit-Baltistan Pakistan. *International Journal of Disaster Risk Reduction*, 83(Query date: 2026-09-03 20:06:59). <https://doi.org/10.1016/j.ijdr.2022.103392>
- Bailie, R. (2023). Climate-Related Natural Disasters: Reflections on an Agenda for Rural Health Research. *International Journal of Environmental Research and Public Health*, 20(8). <https://doi.org/10.3390/ijerph20085553>
- Bhanye, J. (2025). A review study on community-based flood adaptation in informal settlements in the Global South. *Discover Sustainability*, 6(1). <https://doi.org/10.1007/s43621-025-01449-6>
- Calliari, E. (2022). Building climate resilience through nature-based solutions in Europe: A review of enabling knowledge, finance and governance frameworks. *Climate Risk Management*, 37(Query date: 2026-09-03 20:06:59). <https://doi.org/10.1016/j.crm.2022.100450>
- Dąbrowska, J. (2023). Between flood and drought: How cities are facing water surplus and scarcity. *Journal of Environmental Management*, 345(Query date: 2026-09-03 20:06:59). <https://doi.org/10.1016/j.jenvman.2023.118557>
- Dhyani, S. (2022). Blue-green infrastructure across asian countries: Improving urban resilience and sustainability. In *Blue Green Infrastructure Across Asian Countries Improving Urban Resilience and Sustainability* (p. 518). <https://doi.org/10.1007/978-981-16-7128-9>

- Fan, W. (2023). Climate Change and Pregnancy: Risks, Mitigation, Adaptation, and Resilience. *Obstetrical and Gynecological Survey*, 78(4), 223–236. <https://doi.org/10.1097/OGX.0000000000001116>
- Fang, Z. (2025). Climate change has increased rainfall-induced landslide damages in central China. *International Journal of Disaster Risk Reduction*, 119(Query date: 2026-09-03 20:06:59). <https://doi.org/10.1016/j.ijdr.2025.105320>
- Gaborit, P. (2022). Climate adaptation to Multi-Hazard climate related risks in ten Indonesian Cities: Ambitions and challenges. *Climate Risk Management*, 37(Query date: 2026-09-03 20:06:59). <https://doi.org/10.1016/j.crm.2022.100453>
- Gawrych, M. (2022). Climate change and mental health: A review of current literature. *Psychiatria Polska*, 56(4), 903–915. <https://doi.org/10.12740/PP/OnlineFirst/131991>
- Ghosh, R. C. (2022). A systematic review of climate migration research: Gaps in existing literature. *SN Social Sciences*, 2(5). <https://doi.org/10.1007/s43545-022-00341-8>
- Gkika, A. V. (2023). Battling the extreme: Lessons learned from weather-induced disasters on electricity distribution networks and climate change adaptation strategies. *Hydrology Research*, 54(10), 1196–1226. <https://doi.org/10.2166/nh.2023.067>
- Henriksen, H. J. (2023). A New Digital Twin for Climate Change Adaptation, Water Management, and Disaster Risk Reduction (HIP Digital Twin). *Water Switzerland*, 15(1). <https://doi.org/10.3390/w15010025>
- Hussain, M. A. (2023). A Review of Spatial Variations of Multiple Natural Hazards and Risk Management Strategies in Pakistan. *Water Switzerland*, 15(3). <https://doi.org/10.3390/w15030407>
- Li, C. (2025). Adaptive capacity for multimodal transport network resilience to extreme floods. *Nature Sustainability*, 8(7), 741–752. <https://doi.org/10.1038/s41893-025-01575-z>
- Mani, Z. A. (2023). Adapting Disaster Preparedness Strategies to Changing Climate Patterns in Saudi Arabia: A Rapid Review. *Sustainability Switzerland*, 15(19). <https://doi.org/10.3390/su151914279>
- Motlagh, F. (2024). Bonds for disaster resilience: A review of literature and practice. *International Journal of Disaster Risk Reduction*, 104(Query date: 2026-09-03 20:06:59). <https://doi.org/10.1016/j.ijdr.2024.104318>
- Muccione, V. (2025). A scoping review on climate change education. *Plos Climate*, 4(1). <https://doi.org/10.1371/journal.pclm.0000356>
- Münzel, T. (2024). Challenges posed by climate hazards to cardiovascular health and cardiac intensive care: Implications for mitigation and adaptation. *European Heart Journal Acute Cardiovascular Care*, 13(10), 731–744. <https://doi.org/10.1093/ehjacc/zuae113>
- Peiris, M. T. O. V. (2024). Assessment of Urban Resilience to Floods: A Spatial Planning Framework for Cities. *Sustainability Switzerland*, 16(20). <https://doi.org/10.3390/su16209117>
- Ramya, A. (2023). Climate-Induced and Geophysical Disasters and Risk Reduction Management in Mountains Regions. *Climate Change Adaptation Risk Management and Sustainable Practices in the Himalaya*, (Query date: 2026-09-03 20:06:59), 361–405. https://doi.org/10.1007/978-3-031-24659-3_16
- Rana, I. A. (2022). A localized index-based approach to assess heatwave vulnerability and climate change adaptation strategies: A case study of formal and informal settlements of Lahore, Pakistan. *Environmental Impact Assessment Review*, 96(Query date: 2026-09-03 20:06:59). <https://doi.org/10.1016/j.eiar.2022.106820>
- Roa, O. H. (2025). Challenges and opportunities in climate risk assessment: Future directions for assessing complex climate risks. *Environmental Research Letters*, 20(5). <https://doi.org/10.1088/1748-9326/adc756>

- Saikia, M. (2024). Can institutions reduce the vulnerability to climate change? A study on the char lands of Assam, India. *Geojournal*, 89(1). <https://doi.org/10.1007/s10708-024-11015-8>
- Setiawati, M. D. (2023). Climate change and anthropogenic pressure on Bintan Islands, Indonesia: An assessment of the policies proposed by local authorities. *Regional Studies in Marine Science*, 66(Query date: 2026-09-03 20:06:59). <https://doi.org/10.1016/j.rsma.2023.103123>
- Suárez, M. (2024). A holistic index-based framework to assess urban resilience: Application to the Madrid Region, Spain. *Ecological Indicators*, 166(Query date: 2026-09-03 20:06:59). <https://doi.org/10.1016/j.ecolind.2024.112293>
- Theron, E. (2022). Climate change and emergency care in Africa: A scoping review. *African Journal of Emergency Medicine*, 12(2), 121–128. <https://doi.org/10.1016/j.afjem.2022.02.003>
- Tiwari, A. (2022). Building Climate Resilience in Coastal City Living Labs Using Ecosystem-Based Adaptation: A Systematic Review. *Sustainability Switzerland*, 14(17). <https://doi.org/10.3390/su141710863>
- Villani, M. L. (2023). Co-Creating GIS-Based Dashboards to Democratize Knowledge on Urban Resilience Strategies: Experience with Camerino Municipality. *ISPRS International Journal of Geo Information*, 12(2). <https://doi.org/10.3390/ijgi12020065>
- Visconti, C. (2023). Co-production of knowledge for climate-resilient design and planning in Naples, Italy. *Habitat International*, 135(Query date: 2026-09-03 20:06:59). <https://doi.org/10.1016/j.habitatint.2023.102748>
- Wang, L. (2022). A review of the flood management: From flood control to flood resilience. *Heliyon*, 8(11). <https://doi.org/10.1016/j.heliyon.2022.e11763>
- Weng, C. (2023). Assessing the vulnerability to climate change of a semi-arid pastoral social–ecological system: A case study in Hulunbuir, China. *Ecological Informatics*, 76(Query date: 2026-09-03 20:06:59). <https://doi.org/10.1016/j.ecoinf.2023.102139>
- Xu, Z. (2025). AI-Powered Plant Science: Transforming Forestry Monitoring, Disease Prediction, and Climate Adaptation. *Plants*, 14(11). <https://doi.org/10.3390/plants14111626>

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