

## Original Article

# Climate Change and Human Health: Impacts and Vulnerability

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## ABSTRACT

**Background:** Background: Climate change is a global health emergency, with its impacts being profoundly felt across various regions of Pakistan. Rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events pose significant threats to public health, agriculture, and water resources. Understanding these impacts is crucial for developing targeted interventions to mitigate health risks associated with climate change.

**Objective:** This study aims to assess the effects of climate change on health outcomes in Pakistan, focusing on temperature variations, precipitation changes, agricultural impacts, vector-borne diseases, and socio-economic vulnerabilities.

**Methods:** A cross-sectional study was conducted in four regions of Pakistan (Punjab, Sindh, KPK, and Balochistan) from January 2022 to January 2023. A sample size of 3000 participants was selected through systematic random sampling. Meteorological data was collected from local weather stations, and health data was gathered through structured surveys, interviews, and medical examinations. Descriptive and inferential statistics were used to analyze the data, employing SPSS version 25 for statistical analysis. GIS mapping visualized the spatial patterns of climate change impacts.

**Results:** The study found significant regional variations in climate change impacts. Temperature increases were most pronounced in Sindh (1.8°C), leading to heightened risks of heat-related ailments. Precipitation changes showed decreased rainfall in Punjab, causing water scarcity and an increase in waterborne diseases. Agricultural impacts revealed a 10% crop yield reduction in Punjab, resulting in increased malnutrition rates. Vector-borne diseases saw a noticeable rise in Sindh due to habitat expansion of disease vectors. Socio-economic vulnerability analysis indicated high vulnerability in urban areas of Sindh, with limited adaptive capacities.

**Conclusion:** Climate change significantly affects health outcomes in Pakistan, with regional disparities necessitating targeted interventions. The study underscores the importance of incorporating climate change considerations into public health planning and policy-making to enhance resilience and adaptive capacities across vulnerable regions.

**Keywords:** Climate change, Health outcomes, Pakistan, Temperature variations, Precipitation changes, Agricultural impacts, Vector-borne diseases, Socio-economic vulnerability.

## INTRODUCTION

Climate change emerges as a formidable challenge, reshaping our global environment in ways that extend far beyond mere elevations in temperature and modifications in weather patterns (1). As the Earth undergoes significant transformations, the complex link between climate change and human health becomes increasingly apparent, highlighting a dynamic interplay where environmental shifts intersect with human well-being, thus imposing profound implications on societies worldwide (2). This relationship is multifaceted, encompassing a broad spectrum of direct and indirect impacts. Changes in temperature, precipitation patterns, and the frequency of extreme weather events generate significant ripple effects through ecosystems, affecting vectors for infectious diseases, air and water quality, and the availability of essential resources (4). Moreover, these environmental shifts exacerbate existing health vulnerabilities, disproportionately impacting communities with limited resources or those residing in regions more susceptible to climate-induced risks (5).

The urgency of addressing the health ramifications of climate change is underscored by scientific consensus, as highlighted in reports from the Intergovernmental Panel on Climate Change (IPCC) and the World Health Organization (WHO) (6). These implications are far-reaching, affecting vector-borne diseases, heat-related illnesses, malnutrition due to altered agricultural patterns, and mental

health challenges amplified by climate-induced disruptions (7). Climate change, as a global challenge with extensive consequences, directly impacts the health and well-being of communities around the world, necessitating a focus on region-specific investigations to fully understand its effects (8).

This study ventures into the heart of Pakistan, a province marked by its diverse landscapes, to examine the intricate connections between climate change and the health of its inhabitants. With temperatures fluctuating, extreme weather events becoming more frequent, and shifts in precipitation patterns, Pakistan is at the forefront of experiencing the tangible effects of climate change. The nuanced implications for the population's health remain a central focus, requiring empirical exploration. Research by Smith et al., 2023, emphasizes the global implications of climate variability on health outcomes, noting how shifts in temperature and precipitation patterns alter the dynamics of infectious diseases, vector habitats, and waterborne illnesses. Another study highlights the importance of considering geographical disparities and socio-economic vulnerabilities in understanding the health impacts of climate change (9). The correlation between temperature changes and the spread of diseases carried by vectors is well-documented, providing a framework for exploring how similar patterns manifest in Pakistan and affect public health (10).

By examining the health outcomes influenced by climate shifts, this investigation aims to contribute to the expanding body of literature on global climate change and health. More importantly, it seeks to offer insights tailored to the unique context of Pakistan. Through this exploration, the findings generated will not only deepen our understanding of the climate-health nexus but also inform targeted interventions and policies crucial for safeguarding the well-being of Pakistan's residents in an era defined by environmental uncertainty.

## MATERIAL AND METHODS

The research was carried out at a Tertiary Care Hospital in Peshawar, spanning from January 2022 to January 2023. Adopting a cross-sectional design, this study aimed to investigate the link between climate change factors and health outcomes across various regions of Pakistan, accounting for the country's diverse topography and climatic conditions. To ensure a broad representation, specific urban and rural areas were selected. The sample comprised 3,000 participants, determined via systematic random sampling. This involved identifying clusters within each region and then randomly selecting households within these clusters for participation. Prior to inclusion, informed consent was obtained from all participants, in accordance with ethical standards.

Recruitment was facilitated through collaborations with local community leaders and healthcare providers, promoting a sample that was both diverse and representative of the population. Meteorological data, including information on temperature variations, precipitation patterns, and extreme weather events, were collected from local weather stations. Health data were extensively gathered through structured surveys, interviews, and medical examinations, focusing on indicators such as the prevalence of vector-borne diseases and respiratory symptoms among others.

The development of customized questionnaires, tailored to address both climate-related variables and health indicators, was a critical component of the data collection process. These instruments underwent preliminary testing to ensure clarity and cultural appropriateness. The analytical approach utilized descriptive statistics to summarize the demographic characteristics, climate data, and health outcomes. Further, inferential statistics, specifically regression analyses, were employed to investigate the associations between climate change factors and health indicators. Geographic Information System (GIS) mapping played a pivotal role in visualizing the spatial distribution of climate change impacts and health outcomes within Pakistan, highlighting regional disparities. The study was conducted in strict adherence to ethical guidelines, prioritizing participant confidentiality, privacy, and voluntary participation throughout the research process. Ethical approval was secured from the relevant institutional review boards, ensuring compliance with both local regulations and the ethical principles outlined in the Declaration of Helsinki. Data analysis was performed using SPSS version 25, allowing for rigorous statistical examination of the collected data. This included the use of advanced statistical techniques to explore potential correlations and patterns within the data, providing a comprehensive understanding of the complex interactions between climate change and health outcomes in Pakistan.

## RESULTS

The study reveals significant findings across various regions in Pakistan, highlighting the multifaceted impacts of climate change on health outcomes. In Table 1, the average temperature increase is observed to vary significantly across regions, with Sindh experiencing the highest increase at 1.8°C, leading to a higher risk of heat-related ailments. Punjab follows with a 1.5°C increase, resulting in an increase in heat-related illnesses. KPK sees a moderate increase of 1.2°C, correlating with moderate heat-related issues, whereas Balochistan experiences the least increase at 0.5°C, indicating only a minor impact on health due to temperature changes.

Table 2 focuses on the changes in precipitation patterns and their health impacts. Punjab reports decreased rainfall in some areas, leading to water scarcity and a subsequent increase in waterborne diseases. In contrast, Sindh experiences increased rainfall in coastal areas, resulting in a monsoon-related surge in waterborne illnesses. KPK shows varied changes in rainfall patterns, leading to localized impacts on water-related diseases, while Balochistan observes an overall decrease in rainfall, having minimal impact on waterborne diseases.

Table 1 Temperature Variation and Health Outcomes

Region	Avg. Temp Increase (°C)	Health Outcomes
Punjab	1.5	Heat-related illnesses increase
Sindh	1.8	Higher risk of heat-related ailments
KPK	1.2	Moderate increase in heat-related issues
Balochistan	0.5	Minor health impact from temperature

Table 2 Changes in Precipitation and Health Impact

Region	Rainfall Pattern Change	Health Impact
Punjab	Decreased in some areas	Increased waterborne diseases due to water scarcity
Sindh	Increased in coastal areas	Monsoon-related surge in waterborne illnesses
KPK	Varied changes	Localized impact on water-related diseases
Balochistan	Overall decrease	Minimal impact on waterborne diseases

Table 3 Agricultural Impacts and Nutritional Consequences

Region	Crop Yield Reduction (%)	Nutritional Consequences
Punjab	10	Malnutrition rates up due to reduced wheat/rice yield
Sindh	8	Moderate impact on food availability and nutrition
KPK	12	Significant food security challenges in rural areas
Balochistan	5	Minor impact on nutrition

Table 4 Vector-Borne Diseases

Region	Disease Vector Changes	Health Risks
Punjab	Distribution shift	Slight increase in vector-borne diseases
Sindh	Habitat expansion	Rise in dengue, malaria cases in urban areas
KPK	Prevalence pattern alter	Moderate increase in vector-borne diseases in regions
Balochistan	Stable conditions	Minimal impact on vector-borne diseases

Table 5 Vulnerability and Adaptive Capacities

Region	Socio-economic Vulnerability	Adaptive Capacities
Punjab	Moderate (urban-rural disparities)	Adequate healthcare infrastructure supports adaptation
Sindh	High (urban areas)	Limited in densely populated urban centers
KPK	Varied (regional socio-economic)	Moderate, with improvement potential
Balochistan	Low to moderate	Limited due to resource constraints

Agricultural impacts and their nutritional consequences are detailed in Table 3, where crop yield reduction percentages directly influence nutritional outcomes across the regions. Punjab faces a 10% reduction in crop yields, significantly increasing malnutrition rates due to reduced wheat and rice yields. Sindh encounters an 8% reduction, leading to moderate impacts on food availability and nutrition. KPK is affected by a 12% reduction, posing significant food security challenges, especially in rural areas. Balochistan, with a 5% reduction, experiences minor impacts on nutritional outcomes.

Vector-borne diseases, as shown in Table 4, vary across regions with changes in disease vectors. Punjab experiences a shift in distribution patterns, resulting in a slight increase in vector-borne diseases. Sindh sees an expansion of vector habitats, leading to a

noticeable rise in dengue and malaria cases, particularly in urban areas. KPK witnesses altered prevalence patterns, causing a moderate increase in vector-borne diseases in certain regions, while Balochistan maintains stable conditions, leading to minimal impact on vector-borne diseases.

Table 5 examines the socio-economic vulnerability and adaptive capacities of each region. Punjab, with moderate vulnerability due to urban-rural disparities, has adequate healthcare infrastructure supporting adaptation. Sindh, highly vulnerable in urban areas, possesses limited adaptive capacities, especially in densely populated centers. KPK's varied vulnerabilities based on regional socio-economic factors allow for moderate adaptive capacities with potential for improvement. Balochistan, having low to moderate vulnerability, is limited in adaptive measures due to resource constraints.

## DISCUSSION

In this study, the observed temperature increases in regions such as Punjab and Sindh not only align with global trends signaling a rise in temperatures due to climate change (11) but also highlight the consequential surge in heat-related illnesses. This accentuates the critical need for implementing adaptive measures tailored to urban areas, as recommended by the World Health Organization (WHO) for managing heat-health risks (12). The moderate temperature increase in Khyber Pakhtunkhwa (KPK) calls for region-specific strategies to mitigate evolving health risks, demonstrating the necessity of localized approaches in addressing the impacts of climate change on health. Meanwhile, Balochistan's minimal impact underscores the influence of diverse regional climates on health outcomes, suggesting a degree of resilience or differing vulnerability to climate-induced health effects (13).

The study's findings on shifts in precipitation patterns, particularly the increase in Sindh, resonate with projections anticipating intensified monsoon patterns in specific regions due to climate change. The corresponding rise in waterborne diseases in these areas corroborates existing research on the association between heavy rainfall and outbreaks of waterborne illnesses (14), highlighting the imperative for regionally adapted water management and health strategies. The varied precipitation patterns observed in KPK emphasize the importance of localized approaches to address water-related health risks effectively (15), further underscoring the study's contribution to understanding the multifaceted nature of climate change impacts.

The vulnerability of agriculture to climate change, evidenced by the reduction in crop yields across Punjab, Sindh, and KPK, aligns with global assessments of climate change's adverse effects on food security and malnutrition (16). This correlation underscores the broader implications of climate change on nutritional health and food availability, highlighting the need for sustainable agricultural practices and resilience-building among affected communities. Balochistan's minor impact on agricultural sectors suggests some resilience, yet it prompts considerations for enhancing sustainable practices to ensure future food security.

The observed shifts in disease vectors and the resultant health risks highlight the intricate relationship between climate change, ecology, and public health (17). Sindh's increase in vector-borne diseases, paralleling global trends, necessitates adaptive strategies for disease vector management, while KPK's regional variations in disease prevalence call for targeted vector control efforts in specific areas (18). Balochistan's stable conditions in this regard offer insights into the impact of climatic stability on disease patterns, potentially guiding future preventive measures.

The study navigates the complex interplay between socio-economic vulnerability, adaptive capacities, and climate change impacts across different regions of Pakistan. The high vulnerability observed in urban areas of Sindh demands urgent interventions to bolster adaptive capacities, aligning with IPCC recommendations for enhancing resilience (20). The potential for improvement in adaptive strategies in KPK presents an opportunity for targeted interventions and community-based resilience programs, while the challenges posed by resource constraints in Balochistan highlight the necessity for innovative approaches to adaptation within limited means. Incorporating the study's strengths, it provides a comprehensive analysis of the impacts of climate change on health across diverse Pakistani regions, offering valuable insights into region-specific vulnerabilities and adaptive capacities. However, the study is not without limitations. The reliance on cross-sectional data limits the ability to establish causality between climate change factors and health outcomes, suggesting a need for longitudinal studies to better understand these dynamics over time. Furthermore, the study's findings underscore the importance of integrating socio-economic determinants, community engagement, and the effectiveness of adaptive strategies into future research to enhance the resilience of vulnerable populations.

The recommendations stemming from this study highlight the need for informed policymaking, resilient infrastructure, and the development of region-specific adaptive strategies to safeguard public health against the evolving challenges of climate change. As Pakistan navigates these complexities, the insights provided by this research contribute to the global discourse on climate change and human health, advocating for a holistic approach that acknowledges regional disparities and leverages evidence-based decision-making to ensure the well-being of diverse populations in a changing climate.

## CONCLUSION

The findings of this study elucidate the profound implications of climate change on human health across various regions of Pakistan, revealing a spectrum of vulnerabilities and adaptive capacities. Rising temperatures, altered precipitation patterns, agricultural impacts, and shifts in disease vectors underscore the urgent need for tailored interventions and policies that address both immediate and long-term health risks. This research not only contributes to the global understanding of climate change's health impacts but also emphasizes the critical need for integrated healthcare strategies that incorporate climate resilience and adaptive measures. By highlighting regional disparities and potential areas for targeted action, the study advocates for a comprehensive approach to healthcare planning and policy-making, aimed at mitigating the adverse effects of climate change on vulnerable populations, ensuring a healthier future in the face of environmental uncertainties.

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