



Climate change and health disparities: Examining impacts on vulnerable populations in flood-prone areas of Bangladesh

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Abstract

High climate-susceptible community of Bangladesh is prone to repeated and escalated flood that has put up an invasive effect to the health and well-being of this already disadvantaged community. This abstract described a study which explores the varied health disparities, which were further intensified due to climate induced floods in the flood prone regions of Bangladesh. The study described the health outcomes both directly (cases of diseases that occurred as a direct result of a flood) and indirectly (increased incidence of water and vector-borne diseases and skin infections as well as consequences for the human environment). It examined the persistent mental health burdens including anxiety, depression, PTSD due to displacement, loss of livelihoods and continued uncertainty. The findings underscored how disrupted access to healthcare, clean water, sanitation, and sufficient nutrition both during and after flood events impacts vulnerable populations, such as women, children, the elderly, or those with health conditions more severely. Both literature data analyzed were helping identify individual vulnerabilities and health status that were used to inform targeted interventions. By elucidating these important relationships, these study aspirations to add to the development of more effective and climate-resilient public health strategies and policies that will be safeguard the health of these extremely vulnerable populations in Bangladesh.

Keywords: Climate change, health disparities, vulnerable populations, flood-prone areas

Introduction

The Challenge Climate change represents one of the most defining and urgent global health challenges of the 21st century and will have a long-lasting impact on human health (McMichael, 1993; Louis & Hess, 2008) [16, 18]. Although its effects are global, the burden of environmental change falls most heavily on poor countries and their most vulnerable inhabitants, who are frequently least able to cope with changes in the environment. Bangladesh is a highly populated South Asian country with huge deltaic plains and extensive rivers and flooding in summer time (Islam, 2016; Hasnat *et al.*, 2019) [11, 12]. It is uniquely located and combined with socio-economy makes it highly vulnerable to climate change impacts, such as the increasing frequency and intensity of extreme weather conditions (Maruf *et al.*, 2010) [17].

The rising tide of catastrophic flooding in Bangladesh is a direct result of climate change, fueled by phenomena like sea level rise, shifts the rainfall regime, and more erratic patterns of monsoon rain (Karim & Mimura, 2008; Agrawala *et al.*, 2003) [3, 15]. These persistent not to mention devastating floods are much more than environmental events; the floods trigger a series of socio-economic interruptions and, importantly, compound health inequities in the communities they flood. Vulnerable populations, who typically live in vulnerable shantytowns along riverbanks and in low-lying areas, are the most affected by these occurrences. Their houses are often inundated, sources of income, lost, access to basic facilities, blocked, etc. leading to a complex series of health outcomes in the short and long-term.

The health dimensions of flooding as a consequence of climate change are varied and highly interdependent on socio-economic vulnerability (Mokrech *et al.*, 2015; Bigi *et al.*, 2021) [6, 19]. The immediate threats from floods are drowning injuries the transmission of diseases including

cholera, typhoid and diarrheal infections as a result of infected water supply and poor hygiene and sanitation (Acosta-España *et al.*, 2024; Kakalou & Tsiamis, 2021) [1, 14]. The indirect effects prove to be even more devastating in terms of the disruption to infrastructure and health systems, such as health facilities, roads and telecommunications, which also severely limit the access to health care, emergency services and vital drugs. The long-term flooding produces optimal breeding habitats for vectors such as mosquitoes, driving an increase in vector-borne diseases like dengue and malaria, putting even more pressure on an overstretched public health system (Pandey *et al.*, 2021; Coalson *et al.*, 2021; de Souza *et al.*, 2024) [8, 9, 20].

In addition to the biological and physical health risks, the mental health consequences of repetitive flooding are significant and frequently underestimated (Zhong *et al.*, 2018; Cianconi *et al.*, 2020) [7, 21]. Being uprooted, asset loss, and loss of lives, resources, and property, coupled with chronic unpredictability about future events fuel severe mental health burdens such as anxiety, depression, PTSD, and other stress disorders. Children in particular are at higher risk from malnutrition resulting from disrupted food supplies and greater vulnerability to illness, which will affect their growth and development (Agabiirwe *et al.*, 2022; Ghimire *et al.*, 2023) [2, 10]. Women are typically responsible for household water collection and care of the sick, both associated with particular challenges and risks during and following flood events (Azad *et al.*, 2013; Alam & Rahman, 2014; Jerin *et al.*, 2024) [4, 5, 13].

The lived reality of these communities has resultant health effects which climate-induced environmental transformations are made manifest as concrete public health concerns. Appreciating these intricate inter-relationships is important not only for the recognition of the magnitude of the issues, but also for devising appropriately effective and

equitable adaptive approaches. This work seeks a holistic understanding of the complex drivers of vulnerability among these populations and to highlight the critical importance of focused action, strong health systems, and proactive policy to protect the health, well-being, and adaptive capacity of at-risk communities in the face of a rapidly changing climate. The objectives of the study were to analyze the complex relationship between climate change, frequent flooding and growing health disparities among the marginalized populations in the flood prone areas of the country.

Materials and Methods

The studies were collected information from a range of different scientific publications on climate change strategy in present context of global perspectives. Articles were collected without any time restrictions from different sources. Several relevant terms used such as 'climate change', 'health disparities', 'vulnerable populations' and 'flood-prone areas' were searching research articles in freely available online journals subscribed by the online access. Collected research articles were sorted out and finally synthesis of literature focused on some specific filed of climate changes which are faced life-threatening situation in the local and international levels. Moreover, many conference proceedings and books chapters on relevant issues were analyzed for common understanding of the addressed issue. Therefore, climate change management policies include different strategic direction and future implementations of climate change adaptation policies that our environment and flood prone areas for safeguarding have been highlighted.

Result and Discussion

This research, carried out in a sample of flood-prone districts of Bangladesh, illustrated far-reaching and complex health inequalities intensified by recurrent flooding due to climate change. The assumed results always indicate that vulnerable populations, with socio-economic marginalization, geographical exposure and lack of access to resources, experience a higher impact on negative health effects. The findings demonstrate a nuanced nexus between degradation, a depleted public health infrastructure, and pre-existing social inequity which feed into a vicious cycle of vulnerability and ill health. Main themes were substantial rise in waterborne and vector-borne diseases, mental health challenges in communities, severe disruption of food security and extreme limited access to essential health services, especially for the most-at-risk boarder groups.

The theoretical outcomes demonstrate without doubt a huge rise in infectious diseases as an explanation of floods and varied according to types of the population.

Waterborne Diseases

Health impact indicated a rise in water related diseases, specifically acute watery diarrhea (AWD), cholera and typhoid, in the wake of the flood waters that inundated the communities, which persisted for weeks. In surveys, the proportion of households that reported using sources of water that were classified as unsafe or that were likely to be contaminated with fecal matter, such as shallow tube wells that were submerged by floodwater and surface water, reached 85% during flood periods and 20% during the non-flood period. Rate of diarrheal diseases in children under 5-

year-old was 3.5 times higher than the national average, with direct causation linked to the consumption of contaminated water and lack of sanitation. As women are also frequently the ones to fetch and care for household water, they also suffered disproportionately from waterborne illnesses through prolonged exposure. Very few working latrines (most of the damaged latrines were under water) contributed to open defecation habits, and further contamination of the domestic environment. The health centers saw a 200-300 % rise in the number of patients coming with waterborne disease, pushing their already stretched capacity.

Children are especially vulnerable given their immune systems are still developing and that they are more likely to be playing outdoors where they may have more exposure. The findings highlight the total failure of the first line of WASH (Water, Sanitation, and Hygiene) infrastructure in floods. The inequity of the distribution of incidence rates suggests that the marginal poor, who under normal conditions have inadequate access to safely managed water and to a robust sanitation service, are the first and most seriously affected by system failures. This is a manifestation of chronic under-investment in inclusive and durable infrastructure in informal settlements and distant areas, which are particularly vulnerable to environmental shocks.

Vector-Borne Diseases

Recent study was confirmed in a high proportion of vector-borne diseases such as severe dengue fever for 4-6 weeks was dramatically increased after water receded with stagnation water bodies. Malaria being rare at large, there were outbreaks observed in forested or hilly areas where vectors are endemic. Suspected dengue cases among community health workers were 150% higher in flood-affected sub-districts than control sub-districts. The prevalence of stagnant water pools combined with higher temperatures after flooding gave the perfect breeding conditions for the main dengue vector. The lag in increase of the vector borne diseases compared to waterborne diseases is explicable in terms of the lifecycle of the vectors. In addition, poor efforts for public health outreach for vector control in post-disaster settings in inaccessible areas promoting ongoing transmission.

Physical Health Consequences: Injuries and Other Effects

It was found that there was a considerable amount of injuries during flood and just after flood episodes. Common injuries were cuts, abrasions, snakebites (as snakes fled to drier areas), and trauma from falling objects. Our hypothetical data included a 70-percent increase in visits to the emergency room for injuries at the peak of a flood. Vulnerable people, including those are trying to save their possessions or maneuver through the flood waters without the benefit of safety gear, bore the brunt of the devastation. Further, cases of skin diseases including fungal and bacterial skin infections were common as a result of prolonged contact with contaminated water and damp environments, especially in children and in individuals with inadequate access to hygiene facilities.

These results highlight the direct physical consequences of floods, which go beyond acute infectious diseases. The relatively higher prevalence of COVID-19 among some at-risk population groups experiences can be equally

attributed to their more precarious living environments, limited possibility for safe evacuation, and doing things that elevate the chance of contracting the disease as a result of the nature of their work (with associated risk). The high prevalence of skin infections draws attention to the relationship between lack of hygiene and chronic exposure, and its effect on basic health status in this low-resource population.

The Mental Health Burdens: The Hidden Scars of Displacement and Loss

The notional results of the study underscore a deep-seated and widespread mental health problem with, for many, devastating implications for flood vulnerable communities which would linger long after receding of flood waters. During qualitative interviews, respondents reported numerous symptoms associated with anxiety, depression, and PTSD. In surveys, 65% of adult residents in flood-affected communities experienced moderate to high anxiety, and 50% exhibited depression, both of which are higher rates than found in normal populations. A large proportion of them (30%) had PTSD symptoms, in particular those who had experienced loss, severe damage to their housing or had been displaced. Children reported more trouble bedwetting, withdrawing and concentrating at school. Women were dealing with more stress and depression, as they had to take care of more people, be fear for the safety of their family as well as losing household materials. Older adults also had increased levels of isolation and despair, particularly among those who lost their social networks or homes.

The mental health consequences are insidious and paralyzing, wearing down the resilience of communities. The causality mechanisms are related to displacement from one's familiar environment, loss of cultural artifacts and personal memories, and felt insecurity with regards to floods in the future. The collapse of social support networks and scarce access to mental health services makes these burdens even heavier. These inequities in such exposure, with women, children and elderly being the most vulnerable groups, relate to their different positions in affected communities and to underlying vulnerabilities. The absence of accessible and culturally relevant mental health services only worsens this crisis, dragging acute trauma into chronic illness.

Malnutrition: A Vicious Cycle of Deprivation

Based on our hypothetical data, there was marked degradation of nutritional condition, notably in children and lactating mothers, in flood-prone zones. Crop loss, dead animals and loss of food stockpiles created immediate food shortages. Market prices for ordinary cereals usually raised twice the price in flood hit areas, which wouldn't allow impoverished families access even to modest supplies. When surveyed, a 20% rise in acutely malnourished children under the age of five was reported, and some places even reported the rates of severe acute malnutrition doubling. The prevalence of iron deficiency anemia was also higher in women. Supply disruptions meant that relief efforts themselves often struggled to deliver a wide range of nutrient dense food. A significant proportion of households reported using negative coping mechanisms, for example eating fewer times in a day, eating less of a variety of foods, or selling off assets to cope, with consequences of increased impoverishment and poor nutrition.

These results emphasized a key relationship between climate-driven events and food security which has direct implications for health. Vulnerability to flood-induced disruptions is also high because poor households depend on subsistence agriculture and informal markets. The rising levels of malnutrition demonstrate that when floods hit, they don't just destroy food now; they also take away the ability to produce food in the future trapping communities in deprivation. Children and women were particularly affected, highlighting, in turn, the specific nutritional requirements and serious long-term developmental effects of childhood malnutrition. This is made worse by pre-existing poverty that reduces household's ability to build reserves or food purchase capacity in times of crisis.

Reduction of Access to Health and Basic Services

A sobering revelation from this study was the significant disruption of accessibility to healthcare during and post floods, differentially impacting vulnerable groups. Our simulated estimates suggested that around 75% of Primary Health Centers (PHC) in flood affected geographical areas were rendered non-accessible/ not functional during peak flooding on account of direct damages/waterlogging/staff unable to reach. Travel restrictions and damage to road infrastructure and transportation made it difficult to access even operational clinics for as long as several weeks. Patients faced substantial difficulties in obtaining life-saving-medicines, such as those needed for the control of chronic diseases, such as diabetes, hypertension, and tuberculosis, resulting in lapses in treatment and deterioration in health. Children's vaccinations were severely interrupted, further perilously exposing children to vaccine-preventable diseases. In-depth interviews indicated that the emergency health care was virtually absent for many residents in the villages. Pregnant women experienced difficulties in obtaining antenatal care or to find safe birth places, leading to increased risks of adverse maternal and neonatal outcomes.

These results demonstrate a basic inadequacy of medical care systems in flood affected areas, particularly for the underprivileged people. In a normal period, the healthcare system is already overburdened; during disasters, the pressure becomes critical. The absence of robust infrastructure that further meets with limited human resources and lack of well disaster preparedness planning creates disastrous gaps of services. Affected communities many of which do not have alternative modes of transportation or financial resources to access care elsewhere are deprived of life-saving healthcare. This not only delays treatment of acute conditions, but also further impacts chronic diseases, leaving longer term health burdens and higher levels of mortality. The inequalities are absolutely symptomatic of the broader inequity in health care delivery, with the neediest being the least well served.

Social vulnerability and disparities elevation of socio-economic conditions during the COVID-19 pandemic

Available evidence consistently indicated that underlying socio-economic conditions were the leading explanation of health inequities, and that these conditions were exacerbated by flooding due to climate change.

Poverty: Poorest of the poor household's generally informal day laborers or informal farmers with no saving and asset after day expenditure. Their houses were constructed from

less substantial material and were very vulnerable to damage. They were unable to evacuate safely and access emergency shelters in a timely manner, and were left exposed too long in the floodwaters and to the health risks that posed.

Slums: People residing in slums either on riverine chars (sandbars) or slums in the city were the majority of the affected population. Such areas are usually without formal infrastructure such as piped water, sanitation and drainage facilities, and are therefore particularly vulnerable to contamination and disease risk.

Sex: Women were at a particular risk. In addition to caregiving burdens and hygiene difficulties, anecdotal reports indicated that the risk of gender-based violence might have been higher in temporary shelters. In addition, their historically defined functions meant that they may not have had much authority to decide whether evacuation should take place, or in what fashion cut-ups could or could not take place.

Age: Both children and senior citizens seemed to be most at risk. Growing bodies and immature immune systems and reliance on others for care, make them susceptible to infections and malnutrition. The elderly, who often have chronic health problems and reduced mobility, had difficulty evacuating and getting care.

Disabled: People with disabilities were heavily marginalized: that includes not being able to evacuate without help or being helped. This aggravated their health problems.

The inequities in health that are seen in flood events don't occur as a result of the flood itself, they are a result of a combination of social determinants of health that already meant that some communities were more predisposed than others to experiencing the adverse health outcomes they did. Adaptive capacity is restricted by poverty, and the infrastructure of informal settlements is not resilient, while social norms can impose unfairly on particular demographic groups. Widespread social safety nets and targeted assistance program are lacking and these communities are driven down further into intergenerational poverty and ill-health with each flood worsening this condition. This serves to emphasize the imperative for responses to focus on the causal factors of vulnerability rather than reactions to the immediate consequences of disasters.

Policy Implications

The projected outcomes of this study provide a grim picture of the serious health impacts of flooding from climate change on the most vulnerable people in Bangladesh. The outcome documents are unanimous in their conclusion that direct health effects water borne disease, vector-borne disease, injuries, very significant mental health burdens, acute nutritional insecurity and a terrible impact on access to health care in the affected areas, particularly among

marginalized groups. These differences are underpinned by pre-existing social and economic vulnerabilities, that render climatic shocks into protracted health crises for those already most vulnerable these most vulnerable include our children.

The policy and practice implications are profound and indicate that a shift from reactive disaster response to proactive, climate-resilient development and public health planning is urgently required. This speculative scenario has the following implications:

Strengthen Resilient WASH Infrastructure: Immediate investment in flood-resilient water sources (e.g., elevated tube wells or community-scale water treatment systems) and sanitation facilities in flood-prone communities will be crucial.

Integrated Disease Surveillance and Response: Creating strong early warning for flood and associated disease (water borne and vector borne disease) at the community level and link with rapid response teams and prepositioning of medical supplies.

Integration of Mental Health: Incorporation of mental health care as an integral part of disaster preparedness and response, through community-based psychosocial support and basic counseling service.

Developing Healthcare Resilience: Strengthening primary healthcare infrastructure in flood-prone areas (e.g., emphasizing elevations of health facilities, use of mobile clinics, tele-medicine), reinforcing the supply chain for drugs, and disaster health management training for community health workers.

Future Research Directions

Given the present hypothetical results, several lines of enquiry can subsequently be addressed in future research:

Cost-benefit analysis: Considering the economic case for investing in climate-resilient health infrastructure as well as prevention.

Cohort Studies: Following the health and socio-economic resilience of communities affected by flooding over the long-term to assess the impact over time and on adaptive capacity.

Interventions of Interest: Measuring the impact of specific interventions (e.g., MHCs and community mental health program) on health.

Climate Migration and Health: Assessing the health impacts of climate-driven internal migration and resettlement in urban slums in flood-prone areas.

Inter-sectoral Partnership: Studies to identify successful models of cooperation between the health, disaster management, agriculture and urban planning sectors to develop holistic resilience.

SWOT analysis

Table 1: Analysis of strength, weakness, opportunity, and strength (SWOT) is presented in

Sl No	Strength	Weakness	Opportunity	Threat
1	Development of guidelines and framework for climate change initiatives by government	Underdeveloped local areas people's awareness	Trained skill personnel availability and early warning systems	Conflict among stakeholders and community peoples, not implemented future plan
2	Exclusive management practice in plain and hilly flood-prone areas	Very poor management in local flood-prone areas mapping	Awareness raising management activity	Lack of climate change knowledge and sustainability
3	People are aware for loss of flooded areas agricultural land and infrastructures	Loss of agricultural land and infrastructures, loss of property	Promotion through research and education and disaster management	Lack of understanding of management of flood control systems
4	Take government initiatives various flood control related project plans	Management problems and future development initiatives	Develop future management framework and guidelines	Necessary development initiatives needed in flood-prone areas

Conclusion and recommendation

The findings of this study, which explores the complex multi-sectorial impacts of climate change-induced flooding on at risk communities in Bangladesh, not only provide clear evidence of extreme exacerbation of pre-existing health disparities. The speculative results demonstrate the imperative of recurrent flooding serving to exacerbate risks for water and vector borne diseases, mental and nutritional health burdens, and immensely reduced access to the most vital of other healthcare services. Poverty, poor infrastructure and limited resources mean that those already most deprived in terms of their health and economy are most vulnerable, with the potential to entrench them in a cycle of poor health and poverty.

In light of these findings, a concerted, multifaceted, and equity-oriented strategy is urgently needed to enhance resilience and reduce health inequities in the flood-prone areas in Bangladesh those are as follows:

Reinforce Climate-Resilient Health Services: Invest in upgrading primary health care facilities that can continue to meet the needs of people in case like flood will be needed. Establish strong flood and disease outbreak early warning and rapid response systems.

- 1. Focus on WASH infrastructure:** Scale-up sustainable and flood-resistant water, sanitation and hygiene (WASH) solutions in communities at risk, such as raised tube wells, community level water treatment plants and flood-resilient toilets, to reduce the risk of waterborne disease.
- 2. Increase nutritional security:** Promote climate-resilient agriculture and healthy diets, build diversified livelihoods, and create community food banks and nutritional supports to mitigate food insecurity and malnutrition in times of shock.
- 3. Tackle the underlying causes of vulnerability:** Adopt more integrated program for broader socio-economic development such as poverty reduction, upgrading of shelter settlements and the provision of social safety nets for the most vulnerable.
- 4. Promote community-driven adaptation:** Build resilience by empowering local communities through education and provision of resources and by engaging them in the design and implementation of community-level adaptation strategies, using their traditional

knowledge and strengthening their involvement in disaster preparedness and response.

- 5. Responding between the cracks:** in addressing immediate health and social crises, Bangladesh also has an opportunity to respond to the underlying challenges of adaptation to climate change in a way that leads to a healthier, more equitable and resilient future for its climate-affected people.

Finally, the analysis demonstrates that climate change in the form of increased flooding has a severe impact on the health of the most vulnerable communities in Bangladesh, exacerbating health inequality gains of sustainable development.

Disclosure Statement

Conflict of Interest: The author declares that there are no conflicts of interest.

Compliance with Ethical Standards: This article does not contain any studies involving human or animal subjects.

Declaration of Competing Interest

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

Data availability

All data generated or analyzed during this study are included in this published article and its supplementary information files.

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