THE IMPACT OF CLIMATE CHANGE ON PUBLIC HEALTH IN HUMANITARIAN SETTINGS

UNIVERSITY OF WASHINGTON STRATEGIC ANALYSIS, RESEARCH & TRAINING (START) CENTER
REPORT TO THE BILL & MELINDA GATES FOUNDATION

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Executive Summary

Project Background

The University of Washington's Strategic Analysis, Research & Training (START) Center, in conjunction with the Emergency Response team within the Global Development division of Bill & Melinda Gates Foundation, has developed a comprehensive report that explores the escalating impact of climate change on public health in humanitarian settings. This executive summary describes the critical findings and recommendations drawn from research on the climate adaptation strategies to public health crises, focusing on Haiti, Ethiopia, and Pakistan.

Methods

The START Center team conducted a scoping review of peer-reviewed and grey literature to understand the public health repercussions of climate change in humanitarian contexts. An initial review explored all climate events and associated public health outcomes in nine low- and middle-income countries, the findings of which were then used to select narrowed focus on: 1) hurricanes and infectious diseases in Haiti; 2) drought and malnutrition in Ethiopia; and 3) flooding and infectious diseases in Pakistan.

Key Country-Level Takeaways

Haiti

- About 96% of Haiti's population is exposed to natural hazards including hurricanes, floods, and earthquakes. Haiti's climate and socioeconomic vulnerabilities result in high population risk of infectious disease outbreaks following cascades of disasters.

- Limited adaptive strategies were discussed in peer-reviewed literature. The most well-documented adaptations were storm early warning systems and cholera outbreak tracking methodologies, however implementation gaps for these strategies remain.

- Prioritizing construction of climate-resilient health infrastructure and roads is necessary to mitigate population risk of infectious diseases following extreme weather events such as hurricanes.

- There are clear implementation gaps for strategies addressing population vulnerabilities and exposures to hurricanes and infectious disease outbreaks, in particular scaling evidence-based interventions.

Ethiopia

- Ethiopia faces a severe threat from drought, which leads to food and water insecurity and has a dire impact on public health, specifically malnutrition among children and vulnerable populations.

- The research findings indicate that by integrating early warning systems for drought and malnutrition, along with climate-resilient agricultural practices, Ethiopia can significantly mitigate the adverse effects of these climate events.

- Social safety nets such as cash transfers, food fortification with essential micronutrients, and therapeutic feeding programs are identified as effective measures for addressing acute malnutrition in drought-stricken areas.

- Despite these strategies, there are gaps in implementation, especially in expanding the reach of these programs and ensuring their integration with other drought resilience strategies.

<u>Pakistan</u>

- Pakistan is highly susceptible to flooding, which is exacerbated by monsoon rains and glacial melts, leading to a heightened prevalence of infectious diseases.

- Strengthening flood early warning systems, enhancing the healthcare system's capacity, and investing in water, sanitation, and hygiene infrastructure are pivotal strategies to prevent the spread of diseases following floods, particularly in agrarian communities.

- The need for community-specific interventions, such as targeted vaccination campaigns and education on disease prevention, is highlighted to effectively manage health risks during and after flood events.

- The research findings reveal implementation gaps, particularly in local specificity of flood warnings and the provision of adequate sanitation systems, which are crucial for reducing infectious/waterborne diseases post-flood.

Cross-Country Strategic Recommendations

Across the three case studies discussed in this report, several overarching themes and gaps arose despite focus on varying geographies, climate events, and public health outcomes:

1. Given the overarching climate-related and socio-economic vulnerabilities in each country, the best way to improve climate resilience and emergency preparedness across all three contexts is to invest in economic development and health system strengthening with ongoing attention to building resilience to climate change.

2. Post-disaster response may be an opportune moment to implement adaptations to increase a community's climate resilience given the interruption to existing systems but should not preclude disaster risk reduction efforts in advance of disaster conditions.

3. Early warning systems for both weather events themselves and their consequences only work when people receive and trust the notices, have options for protective responses, and believe that acceptable evacuation and other options are available to them, their families, and their assets.

4. Interdisciplinary collaboration in prevention and response activities are key to ensuring appropriate intervention implementation and uptake.

5. As exemplified by comprehensive National Adaptation Plans (NAP) in each of the three countries, governments are already aware of their vulnerabilities and have established priority areas for future development to improve climate resilience alongside estimates of the resources required to realize those priorities.

Conclusion

Haiti, Ethiopia, and Pakistan are vulnerable countries due to extreme weather events caused by climate change and recurring political, economic, and social insecurities. In all these contexts, economic development and health system strengthening are key to improving climate resilience and reducing population risk to negative health outcomes. Each country has a climate adaptation strategy in place, with various development priorities outlined in their respective National Adaptation Plans. However, they do not necessarily have the resources and capacity to fulfill these plans on their own. Collaborations across sectors with an emphasis on community involvement and trust-building are necessary to implement appropriate and effective adaptation strategies.

Contents

Introduction

Project Overview

This report is the product of analyses by the University of Washington, Department of Global Health's Strategic Analysis, Research, & Training (START) Center [1] in response to a request from the Emergency Response team within the Global Development division at the Bill & Melinda Gates Foundation (BMGF). This report presents lessons learned and best practices for climate adaptation in a set of three focus countries: Haiti, Ethiopia, and Pakistan. These were identified through literature reviews and analysis and are meant to serve as input for teams at the Foundation who are working to help avoid and address public health crises and humanitarian emergencies that arise when extreme weather events and natural disasters cause acute suffering for vulnerable populations and considering how to integrate climate change resilience into their work and programming.

Methods

The START Center was commissioned by the BMGF to research Climate Adaptation strategies to inform the foundation's Emergency Response Program (ERP). This project aimed to collect, assess, and analyze evidence from peer-reviewed literature related to the impacts of climate change on public health in humanitarian settings to inform strategic recommendations to improve climate change adaptation practices for disaster preparedness and response.

The ERP initially identified nine low- and middle-income countries (LMICs) of focus across South Asia, the Caribbean, and Sub-Saharan Africa for this study: Pakistan, Bangladesh, Haiti, Mali, Burkina Faso, Niger, Ethiopia, Somalia, and the Democratic Republic of the Congo (DRC). To meet the project aim, we first quantified the number of peer-reviewed English-language literature that had been published about each country, with a goal to understand the landscape of literature on this topic as well as to select three countries on which to focus.

An initial, broad rapid review of the literature, published in PubMed/MEDLINE, was conducted to capture the recent and prominent cross sections of public health issues attributed to climate change events in humanitarian settings. This was done according to the *Preferred Reporting Items for Systematic Reviews and Meta-analyses* (PRISMA) guidelines [2]. As this was a rapid review, only peer review articles published in PubMed were reviewed. PubMed was chosen because it is a rich repository of medical and public health publications and covers over 24 million citations for biomedical literature [3].

To build our search strategy and identify eligible articles, the Population, Concept and Context (PCC) framework described by Aromataris & Munn was used [4]. The concept included climate-related extreme weather events and associated health issues. We designated climate-related extreme weather events as hydrometeorological events like extreme storms, hurricanes and typhoons, extreme precipitation events, extreme heat events, extreme cold events, and wildland fires, and climatic events like droughts. The context included our geographic focus of nine low-and-middle income countries. Medical Subject Heading (MeSH) vocabularies and search strings were developed based on the PCC framework and used to conduct the search on October 13th, 2023.

The study team designed a data extraction instrument and populated it after reviewing all relevant literature. For each article, team members entered information on the country, climate-related events, associated public health issues, key populations, and humanitarian responses. We formed our country-level syntheses based on the most significant and burdensome climate-related events we identified for each country. An extensive, narrative review approach was used, utilizing web search engines, snowballing, and examination of relevant grey literature and scientific reports to present an updated and comprehensive overview of the impact of climate change on public health issues in humanitarian settings for the countries of interest.
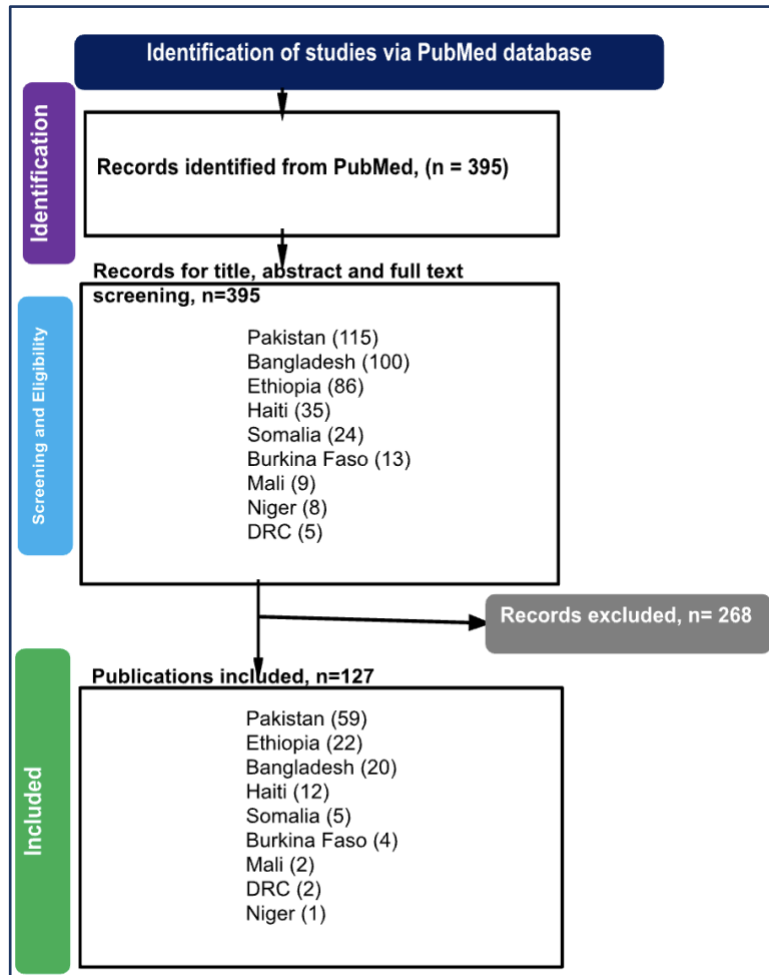
Preliminary Results of Broad Search

Figure 1: Flowchart for data extraction from relevant peer-reviewed studies from PubMed.

A total of 395 articles were identified from our initial literature search, and the distribution of the articles in our countries of interest is shown in Figure 1. After title, abstract and full text screening, 268 records were excluded, and 127 articles were included.

Based on the results of the broad search, we narrowed the focus to four priority countries reflecting geographic diversity, the highest number of articles, and evidence of well-documented climate change events leading to worsening public health impacts. The countries with the highest distribution of relevant articles were Pakistan (59), Ethiopia (22), Bangladesh (20), and Haiti (12). As Bangladesh and Pakistan are in the same geographic region and have similar patterns of climate events and public health burden of disease, Bangladesh was excluded. Despite the lower number of articles for Haiti, in comparison to Bangladesh, Haiti was included in the set of priority countries to capture geographic diversity and extreme vulnerability compounded by frequent natural disasters. After narrowing the countries, the project team constructed heatmaps to assess and visualize the distribution of public health conditions associated with specific climate change events for each priority country. The heat maps were used to identify a single climate event type and attributable public health concern (Figures 2-4).

Haiti: Among the 12 articles reviewed for Haiti, a majority of the studies linked hurricanes to infectious diseases (Figure 2), thus forming the basis for the country level synthesis in Haiti.
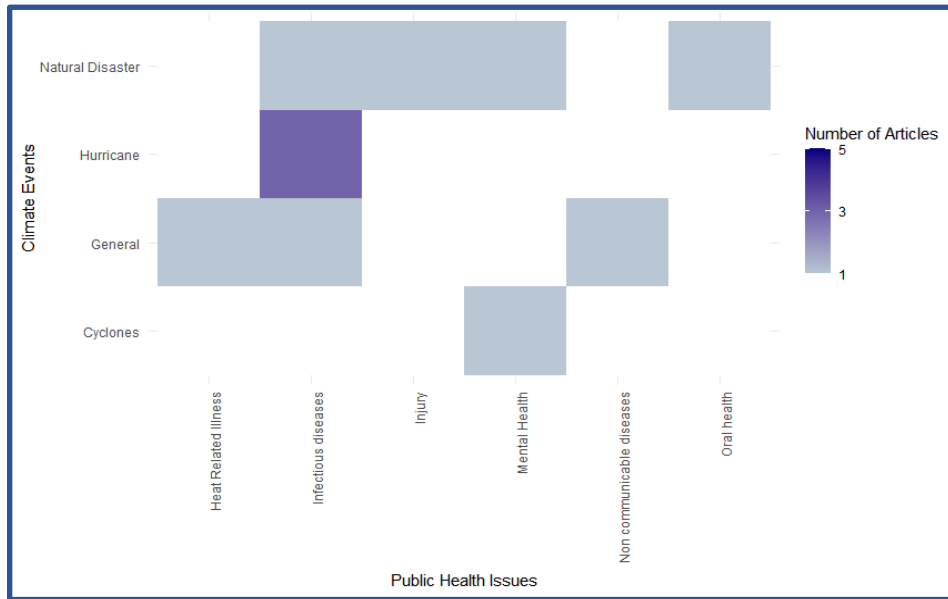

Figure 2: Heatmap of public health issues associated with climate events in Haiti.

Ethiopia: Among the 22 articles reviewed for Ethiopia, a high volume of literature centered on the intersection of drought and food and water insecurity (Figure 3). Therefore, we focused on drought and food/water insecurity, forming the basis for the country-level synthesis in Ethiopia.
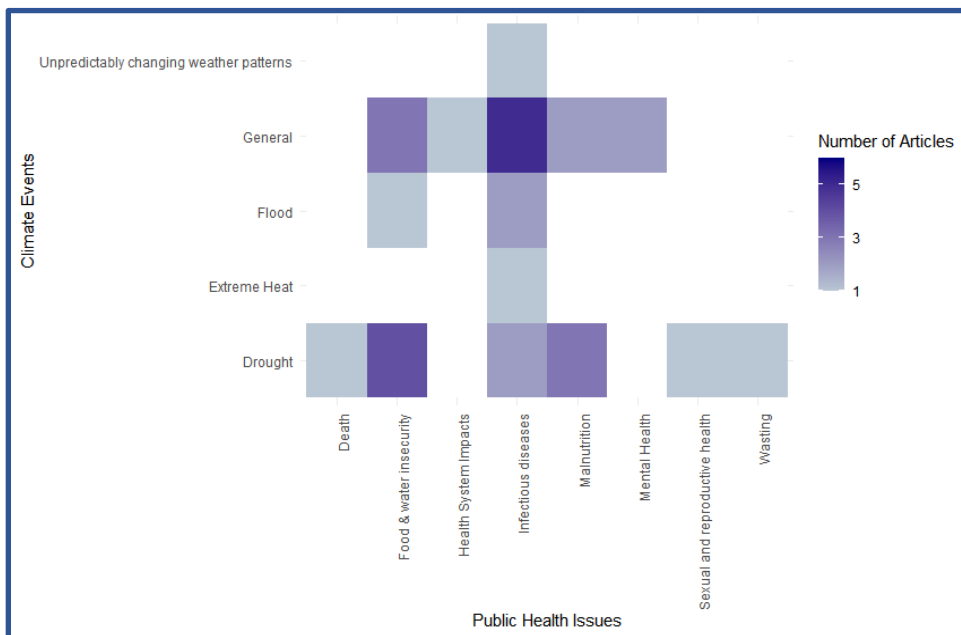

Figure 3: Heatmap of public health issues associated with climate events in Ethiopia.

Pakistan: Among the 59 articles reviewed for Pakistan, the most common intersection between climate events and public health was flooding and infectious diseases (Figure 4). This formed the basis for the country-level synthesis in Pakistan.
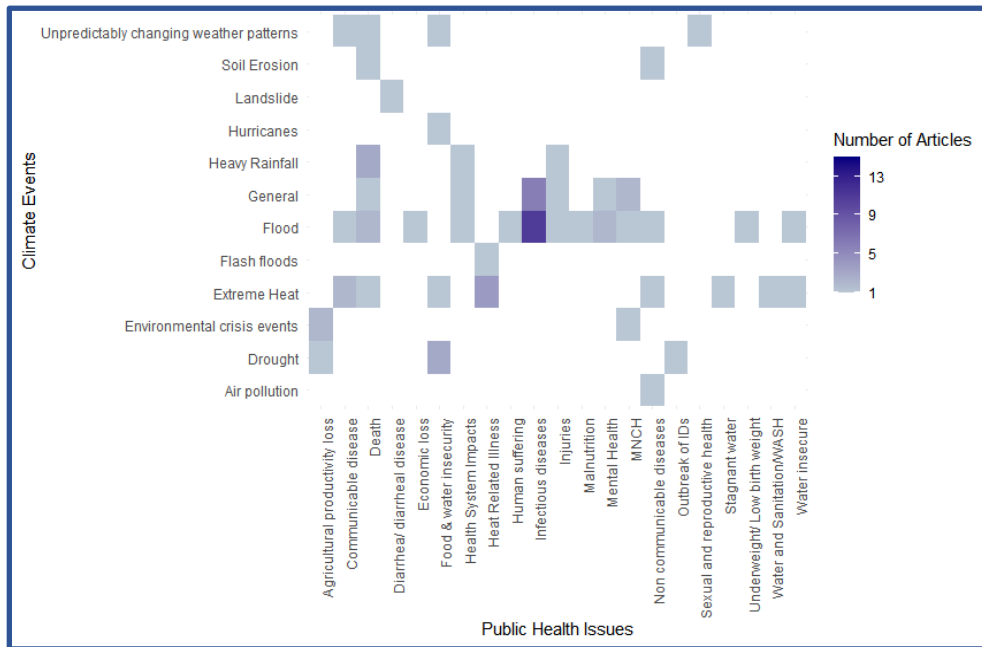

Figure 4: Heatmap of public health issues associated with climate events in Pakistan.

Country-Level Results Framework

Lastly, to meet our aim of synthesizing lessons learned and best practices for climate adaptation in a set of three focus countries (Haiti, Ethiopia, and Pakistan), we used the Intergovernmental Panel on Climate Change (IPCC) Disaster Risk Framework to assess and organize the peer reviewed, grey, and scientific literature for each country. The framework comes from a special report, entitled Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation and colloquially known as the SREX, that outlines the relationship between climate-sensitive hazards, vulnerability, and population exposure and the potential for recurrent climate-related disasters to undermine development over time. In this project, the framework provides a structure for classifying adaptation and response strategies as related to vulnerability, exposure, or weather and climate events to identify well-resourced domains as well as gaps in research and implementation (Figure 5) [5].
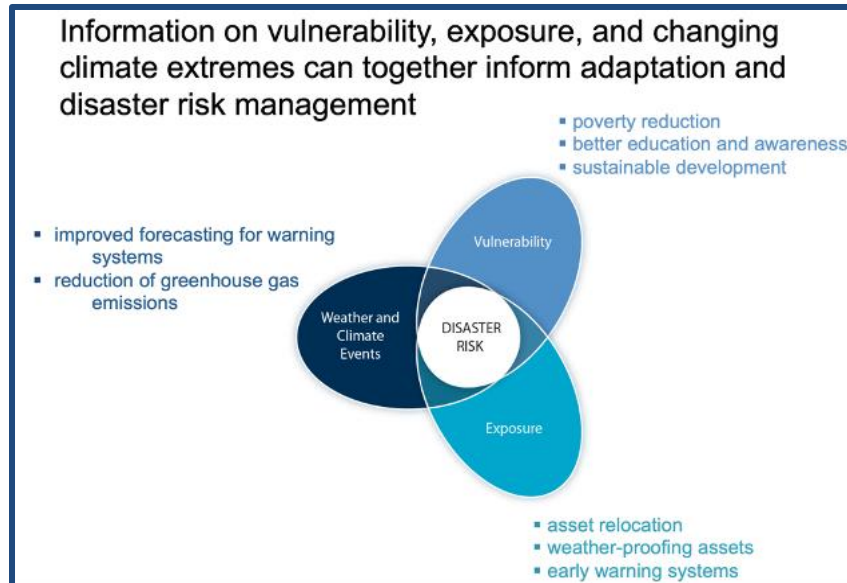
Figure 5: IPCC SREX Disaster Risk Framework. [5]

Each country-level summary provides a brief background, including a summary of the burden of disease associated with the climate event for that country. Findings are summarized using the IPCC framework to demonstrate how the specific strategy addresses prevention or response for weather and climate events, vulnerability, or exposure. For each country, detailed findings and lessons learned are organized by prevention, response, or both.

Results: Country Level Summaries

Hurricanes and Infectious Diseases in Haiti

BACKGROUND

Haiti is considered the most vulnerable country to climate change in Latin America and the Caribbean [6]. Haiti, located on the island of Hispaniola in the Caribbean, has an estimated population of 11.4 million people [7], and was ranked 163rd (of 188 countries) in the Humanitarian Development Index [8]. About 80% of Haitians are estimated to live below the international poverty line, lacking access to safe drinking water, health care services, and sanitation [6]. Unlike other countries in the Caribbean region, Haiti has suffered recent declines in almost all strategic socio-economic sectors [7, 9]. In the past 20 years, climate disasters have occurred almost every year. Figure 6 from the World Bank below shows a timeline of natural hazard events in Haiti since 1980 and highlights the frequent occurrence and impact of extreme storm events [10]. A key component of Haiti's vulnerability, interacting with and compounding the impact of natural hazards, is international debt. Since declaring independence from France in 1804, Haiti has faced colonial extortion resulting in overwhelming debt that has dictated the country's history of poverty and underdevelopment [11]. While many lenders canceled Haiti's debt following the earthquake in 2010, Haiti's total public debt remains high and has consistently risen, in part due to expenses associated with disaster losses. At the end of the 2021 fiscal year, Haiti had a total public debt of $5 billion, amounting to nearly 30% of its annual GDP [12].
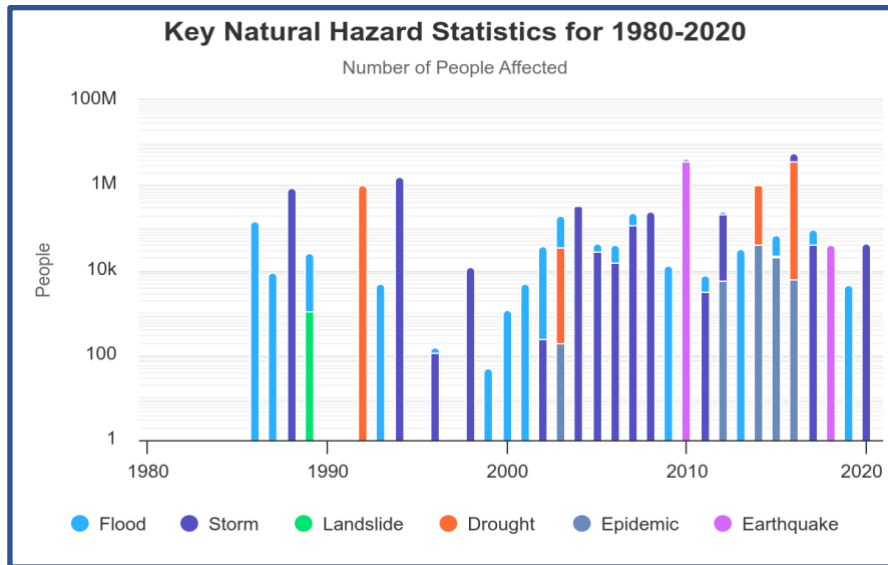
Figure 6: Number of people affected by key natural hazards in Haiti from 1980 through 2020 [10].

The World Bank estimates that 96% of the population is exposed to natural hazards, including floods, hurricanes, and earthquakes [9, 10]. Haiti is located within the "hurricane belt", a Caribbean region known to experience frequent hurricanes. Exacerbated by environmental degradation, including deforestation, hurricanes often result in significant flooding and landslide events [7]. The majority of the population live in particularly exposed, low lying areas such as dense coastal cities and floodplains which offer little protection from hurricane winds and rain [7].
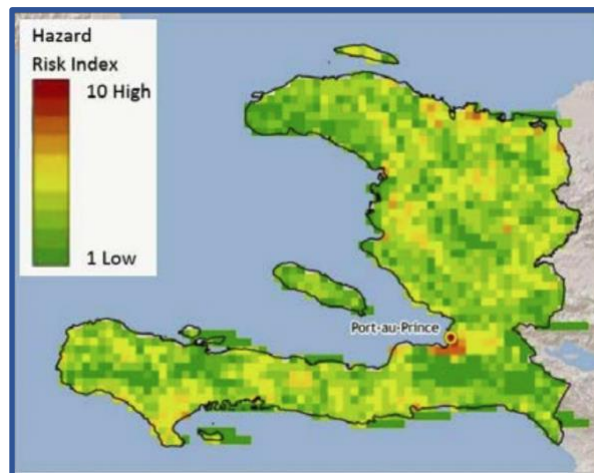
Figure 7: Tropical cyclone risk index across Haiti as of 2017 [7]

The IPCC has indicated that the frequency of tropical cyclone events is unlikely to increase with greenhouse warming, globally; nevertheless, storms are likely to intensify, both in terms of rainfall and wind speed [5, 13]. By 2050, hurricane intensity and associated rainfall in Haiti is projected to increase by 5-10% and 2%, respectively [7], which will further exacerbate fragile societal systems and increase climate-change induced public health issues. Figure 7 shows the current estimated risk index for tropical cyclones across Haiti, illustrating the difference in risk across the country [7].

BURDEN

Haiti has experienced several extreme storms in the past 30 years, including Hurricane Jeanne which killed over 3000 people in 2004, four hurricanes in 2008 which destroyed more than 60% of agricultural crops and killed more than 1000 people, and Hurricane Matthew in 2016 which resulted in 1.5 million people requiring humanitarian relief [7, 10, 14].

Damages from Hurricane Matthew equated to 32% of Haiti's 2015 GDP [7]. Destroyed roadways and damage to the health facility infrastructure particularly hampered response and relief efforts, making it difficult for the general population to seek health treatments [7]. Beyond immediate injuries and deaths, hurricanes and associated flooding increase the incidence of waterborne diseases, such as cholera [7, 8], and exacerbate pressure on drinking water resources. Haiti's capital, Port-au-Prince, is the largest city in the world without a functioning sewage system, and the country has the lowest rates of access to clean drinking water and safe sanitation in the Western Hemisphere [7]. While specific estimates of increased risk of infectious diseases in Haiti following hurricanes are unavailable, Haiti's experiences provide robust evidence of the re-emergence of infectious diseases, including cholera, following catastrophic natural disasters that disrupt health and sanitation infrastructure [15].

In many contexts, climate change can cause disastrous consequences through a series of smaller events impacting highly vulnerable populations who have little time and resources to recover, in addition to larger events that overwhelm even substantially resourced systems [5]. Unfortunately, Haiti experiences both recurring major disasters and regular social, political, and weather-related insecurities, all of which overwhelm any capacity to prepare for, and respond to, crises [5]. The considerable resources required for disaster recovery are often diverted from the finite resources available to support sustainable growth and development, impacting the government's capacity and focus to provide basic services to its population [7]. The following sections will describe findings from a review of peer-reviewed and grey literature discussing strategies that are being explored and implemented in Haiti to support disaster risk reduction and reduce the increased burden of infectious diseases following hurricane events.

FINDINGS FROM THE LITERATURE: LESSONS LEARNED FOR HURRICANE RESILIENCE IN HAITI'S PUBLIC HEALTH SECTOR

HAITI: KEY TAKEAWAYS

- About 96% of Haiti's population is exposed to natural hazards including hurricanes, floods, and earthquakes. Haiti's climate and socioeconomic vulnerabilities result in high population risk of infectious disease outbreaks following cascades of disasters.

- Limited adaptive strategies were discussed in peer-reviewed literature. The most well-documented adaptations were storm early warning systems and cholera outbreak tracking methodologies, however implementation gaps for these strategies remain.

- Prioritizing construction of climate-resilient health infrastructure and roads is necessary to mitigate population risk of infectious diseases following extreme weather events such as hurricanes.

- There are clear implementation gaps for strategies addressing population vulnerabilities and exposures to hurricanes and infectious disease outbreaks, in particular scaling evidence-based interventions.

After conducting a review of peer-reviewed and grey literature related to hurricanes and infectious diseases in Haiti, several strategies to prevent and respond to outbreaks were identified. We

summarized findings from 7 academic studies using the IPCC Risk Framework. Figure 8 highlights the activities identified in peer-reviewed studies, mapped to whether they address weather and climate events, vulnerability, or exposure. As noted above, Figure 8 aims to visually display which domains strategic activities are currently being researched and implemented in Haiti, compared to domains with noticeable gaps in action. The figure does not present an exhaustive list of all strategies being researched and implemented in each category, rather it presents strategies discussed in the peer-reviewed literature that were explicitly relevant to a search on hurricanes and infectious diseases in Haiti.

Adaptation Strategy *literature indicates strategy is currently being implemented*	Weather and Climate Events		Vulnerability				Exposure		
	Improved Forecasting for Warning Systems	Reduction of GHG Emissions	Health System Strengthening	Poverty Reduction	Better Education and Awareness	Sustainable Development	Relocation (People + Assets)	Weather-Proofing Assets	Early Warning Systems
Early warning systems *	■				■		■		■
Climate resilient sanitation services *		■						■	
Modernizing veterinary services for outbreak resilience *			■		■				
Predicting and tracking cholera outbreaks	■		■						■
Monitoring potential for mosquito-borne illness outbreaks									■
Oral cholera vaccine campaign			■						
Ensuring TB treatment success *			■						

Figure 8: Categorization of identified adaptation and response strategies regarding hurricanes and infectious diseases in Haiti within the IPCC Disaster Risk Framework.

As shown in Figure 8, two well-documented efforts are 1) cholera monitoring and 2) weather forecasting. Though these two efforts have clear room for improvement, it appears that other actions noted in Figure 8 are less well-resourced at this time. In the following sections, details of the strategies visualized in Figure 8 are described and categorized as either prevention, response, or prevention and response activities, with **key takeaways written in bold**.

PREVENTION: EARLY WARNING SYSTEMS

The World Bank's 2011 Climate Risk and Adaptation Country Profile for Haiti identified that an effective early warning system to help farmers confront extreme weather events could reduce the impacts of such events on Haiti's agriculture sector [7, 9]. Haiti has already installed networks of weather monitoring stations to predict extreme weather events and inform preparedness and response activities:

- In 2011 Haiti launched a program to create a network of more than 100 hydro-meteorological gauges and warning stations that could provide necessary data to inform decision-making on flooding risk. However, **many regions were still left uncovered by this system of meteorological data collection** [7, 9].

- In 2016, the World Meteorological Organization installed a new network of automatic stations and trained the Ministry of Agriculture's Hydrometeorological Unit (HMU) to interpret and disseminate weather forecasts and alerts [16]. Similar to the previous system, **weather forecasts are only available at the department level and Haiti's topography means that meteorological conditions vary even within a single department** [17].

- Staub et al. (2020) conducted focus groups to provide insights on local decision processes and potential pathways for discussing climate information with farmers [17]. The study found that **farmers generally receive weekly weather and hurricane forecasts over the radio and via text messages** which helps them decide when it is necessary to take their animals to a shelter.

Even with a perfectly running system, the effectiveness of the existing weather stations is limited by government capacity to initiate rapid response efforts [7]. For example, before Hurricane Matthew struck in 2016, the HMU forecasters accurately predicted the approach of the hurricane and, combined with previously developed disaster risk reduction plans and early warning systems, many people in the affected regions were alerted and evacuated, thus saving thousands of lives [16, 18]. Despite these successful forecasting efforts, Hurricane Matthew still had devastating consequences in the affected regions, highlighting the need to continue to improve and extend coverage of Haiti's early warning systems to all regions and at all administrative and community levels [16].

PREVENTION: CLIMATE RESILIENT SANITATION SERVICES

Given the link between hurricanes, flooding, and the subsequent spread of waterborne diseases, container-based sanitation (CBS) service is another relevant intervention being implemented in northern Haiti. **CBS is a non-sewered sanitation strategy through which excreta is captured in sealable containers and transported to facilities for treatment. This system could be key to achieving timely and equitable sanitation coverage in Haiti's cities where permanent infrastructure is impractical or damaged** [19, 20]. Beyond providing safe sanitation to vulnerable households, the CBS service chain also produces fewer greenhouse gas emissions than other common sanitation systems, such as waste stabilization ponds. Thus, CBS service not only reduces community risk of infectious diseases but also contributes to reductions in Haiti's greenhouse gas emissions [21].

PREVENTION: MODERNIZING VETERINARY SERVICES FOR OUTBREAK RESILIENCE

Beyond the scope of peer-reviewed literature investigating the impacts of hurricanes on infectious disease in Haiti, Millien 2017 argues that frequent natural disasters in Haiti, namely earthquakes, hurricanes, floods, and droughts, have increased the country's overall vulnerability to "biological threats" (i.e. infectious disease epidemics). Millien explores Haiti's efforts to adopt a One Health approach to develop resilience against outbreaks by applying animal health standards and guidelines of the World Organisation for Animal Health (OIE) to their veterinary services. At the time of the article, **five draft bills were prepared, including action to establish an epidemiological surveillance system of animal diseases and an animal health contingency fund for deployment of rapid response teams to address potential outbreaks** [22]. It is unclear if the bills were successfully passed and if implementation of these mechanisms has commenced.

PREVENTION AND RESPONSE: PREDICTING AND TRACKING CHOLERA OUTBREAKS

Three different methodologies have been piloted in Haiti to predict and inform cholera outbreak response efforts:

1. Khan et al. (2017) used satellite-derived data on precipitation, air temperature, and hurricane paths, alongside spatial water, and sanitation (WASH) infrastructure data, to track environmental conditions that are conducive to cholera pathogen growth [23].

2. Pasetto et al. (2018) implemented computational modeling and data assimilation methods to produce near real-time projections of cholera incidence during the cholera outbreak in 2016 following Hurricane Matthew. The team used the model to quantitatively estimate the efficacy of an ongoing vaccination campaign [24].

3. Chunara et al. (2012) explored the use of monitoring social and news media to estimate cholera epidemiological patterns in the initial 2010 cholera outbreak. The authors argue that release of official data collected by health institutions is often delayed, thus hindering real-time interventions. The study found that trends in the volume of informal sources discussing cholera are correlated with official case data and were available up to 2 weeks earlier [25].

The methodologies from the above-described studies could be implemented to help cholera outbreak response efforts in Haiti:

- Both Khan et al. (2017) and Pasetto et al. (2018) argue that their methodologies can be used to monitor ground conditions and guide real-time public health decision-making for cholera outbreak control, specifically **by targeting provision of access to vaccines and WASH infrastructure based on the analyses** [23, 24].

- Chunara et al. (2012) argues that trends in the volume of **informal sources discussing cholera during an outbreak could be used alongside official data to get timely estimates of outbreak progression** [25].

- The literature does not indicate why these methodologies are not being implemented at scale, though it is presumably due to lack of resources to train and sustain such programs in-country.

PREVENTION AND RESPONSE: MONITORING POTENTIAL FOR MOSQUITO-BORNE ILLNESS OUTBREAKS

Beatty et al. (2004) conducted a surveillance study of mosquito-borne illnesses, namely malaria, West Nile virus, Saint Louis encephalitis, and dengue, following Hurricane Jeane in 2004. At the time, the United States Centers for Disease Control and Prevention provided assistance to expand epidemiologic surveillance in Haiti, as there was particular concern that flooding, loss of shelter, and general destruction of infrastructure following a hurricane could result in increased risk of mosquito-borne illnesses. The surveillance program did not end up detecting signs of a mosquito-borne illness outbreak, which is consistent with previous literature indicating that very unique conditions, beyond solely post-disaster contexts, are required for such an event [26]. **While water-related climate disasters do not necessarily result in mosquito-borne illness outbreaks, post-disaster surveillance should continue to monitor for increased risk of mosquito-borne diseases** [27].

RESPONSE: ORAL CHOLERA VACCINE CAMPAIGN

During a cholera outbreak following Hurricane Matthew in 2016, the International Coordinating Group (ICG) for oral cholera vaccine (OCV) provision approved Haiti's request for 1.6 million doses of OCV for a reactive vaccination campaign [15]. Sharp et al. (2020) assessed vaccine coverage achieved by the campaign, which implemented door-to-door, fixed-site, and mobile team delivery strategies to cover both convenient and hard-to-reach communities. The follow-up cluster survey of over 9000 people found that, even among hard-to-reach communities, high vaccine coverage was achieved in all campaign areas as a result of combining the different vaccine delivery strategies alongside community mobilization. The study concluded that **emergency OCV campaigns that employ multiple delivery strategies are a viable option for outbreak control** [28]. However, given a global cholera vaccine shortage, this may not always be an available intervention in Haiti [29].

RESPONSE: ENSURING TB TREATMENT SUCCESS

Charles et al. (2021) assessed the impact of Hurricane Matthew on TB treatment success among patients in regions affected by the climate event. The study identified that, despite major challenges, including health facility damage due to the hurricane, a high percentage of patients receiving TB treatment before the hurricane were located and successfully treated. The authors indicate that **effective policies and guidelines are in place and being implemented for TB control after a natural disaster** [30].

FINDINGS FROM THE LITERATURE: PRIORITIES FOR HURRICANE RESILIENCE IN HAITI'S PUBLIC HEALTH SECTOR

While the peer-reviewed literature described above highlights certain priorities and gaps in the disaster preparedness and response sector, this section discusses the most up-to-date perspectives and priorities of relevant development and government actors operating in Haiti from supplemental grey literature and reports.

GENERAL IPCC SREX GUIDELINES

In addition to describing predicted global trends in tropical cyclone activity, the IPCC SREX highlights case studies of countries that have implemented cyclone preparedness and response strategies. While Haiti is not explicitly discussed as a case study in the document, the report does generalize lessons learned and suggests four adaptation priorities for countries facing tropical cyclones, such as Haiti [5]:

1. Improvement of forecasting capacity and implementation of improved early warning systems (including evacuation plans and infrastructure).
2. Protection of healthy ecosystems.
3. Post-disaster support services to dispersed communities.
4. Transparent management of recovery funds directly with the victims.

HAITI NATIONAL ADAPTATION PLAN

In 2010 the United Nations Framework Convention on Climate Change (UNFCCC) established the National Adaptation Plan (NAP) process, which facilitates strategic medium- and long-term country-led planning and preparedness for climate change adaptation. Haiti underwent the NAP process and, after much iterative collaboration and discussion across government departments and international partners, the final plan was launched in December 2022 [9]. Haiti's NAP identifies four priority sectors for strategic interventions:

- **Agriculture**: The revival of agriculture with particular emphasis on climate-resilient agri-food systems combined with the strengthening of human capital through training and research and the introduction of appropriate climate technologies.

- **Water**: The social and integrated management of water resources with particular emphasis on sector governance, monitoring the status of the resources, strengthening human capital, raising awareness, and adopting appropriate climate technologies.

- **Health**: Building infrastructure that is resilient to adverse weather conditions combined with training, research, improving the legal framework, promoting natural medicine, and providing affordable and appropriate insurance programs.

- **Infrastructure**: The development of infrastructure resilient to adverse weather conditions supported by a process of human capital building, development and adoption of appropriate building standards, and appropriate management of the upstream slope of critical infrastructure.

Across the four priority sectors, Haiti's NAP details a total of 340 actions, of which 21 are considered "priority actions" and would require an estimated $980 million to implement (Figure 8) [9]. Regarding hurricanes and infectious diseases specifically, it is recognized that underdeveloped infrastructure is vulnerable to damage by hurricanes and subsequent flooding increases health risks and reduces access to basic services [7]. The NAP highlights that **in order to strengthen the health sector as a whole, additional infrastructure needs to be built to withstand extreme weather conditions**

alongside affordable insurance programs, medical training, and implementation of new technologies [31].

A NAP Brief released in 2017 identified several main challenges to implementing the climate change adaptation approach in Haiti, namely [18] :

- Ineffective communication and dissemination of climate-related risks at the national and sub-national levels

- The majority of projects are funded by international donors and are therefore not sustainable beyond the lifespan of the project itself because government budgets do not currently support such initiatives

- Lack of systemic coordination and sharing of climate-related data and information

- Lack of synergy between disaster risk management and climate change adaptation efforts, including communications between government ministries

ADDITIONAL DEVELOPMENT PRIORITIES IDENTIFIED

Alongside the official NAP process, several international development organizations have been collaborating with different Haitian governmental departments to discuss disaster risk management actions. For example, the World Food Programme hosted a workshop in early 2023 that aimed to reflect on how anticipatory action can mitigate the risks and impacts associated with predictable rapid-onset hazards in Haiti, such as floods and hurricanes. The workshop helped participating partners identify several short-, medium-, and long-term activities to start implementing, including the following [32]:

- Strengthen and disseminate weather and hydrometeorological bulletins and alerts.

- Strengthen training on interpretation and understanding of hydro-meteorological information.

- Support the mechanism of cash-based transfers within a broader market-based ecosystem.

- Strengthen civil society and community-based organization (CBO) understanding and roles in the anticipatory actions system.

- Establish a national coordination platform on anticipatory actions to strength coordination among key actors and reinforce mobilization of stakeholders.

Similarly, in early 2022 the Inter-American Development Bank met with representatives from the government, the Caribbean Development Bank, and the Caribbean Disaster Emergency Management Agency. The workshop resulted in three main takeaways to boost resilience and disaster response in Haiti [33]:

1. **The severe impact of natural disasters will worsen in Haiti and the rest of the Caribbean region.** A wide range of extreme events, including hurricanes and floods, will likely increase in frequency and severity as will the corresponding consequences given the population's overall risk and vulnerability.

2. **Sovereignty is at the core of disaster preparedness and response efforts**. Further investment in capacity building and knowledge will be required, as well as the promotion of innovative financing instruments and better coordination of both private and public sector protection.

3. **Haiti is already part of a vast international institutional architecture designed to help respond to disasters.** The international architecture for preparedness and response is wide ranging and covers different phases of action. These partner institutions offer different layers of protection for countries and should thus be coordinated to maximize efficiency in Haiti.

These overarching conclusions paint a picture of where current literature and implementation organizations stand on climate adaptation for public health in Haiti, illustrating priority opportunities for action as well as for further research.

CONCLUSION: GAPS IN PREVENTION AND RESPONSE STRATEGIES IDENTIFIED FROM PEER-REVIEWED LITERATURE

- While a tropical storm early warning system is in place, weather forecasts are only available at the department level which is often not granular enough to be relevant to individuals deciding whether or not they should evacuate their homes.

- An innovative non-sewered sanitation service is available in one region; however, most of the population does not have access to safely managed sanitation systems. Various vulnerability analysis methods are available to help target provision of WASH infrastructure and vaccines.

- A One Health approach to reducing population vulnerability to biological threats was underway in 2017, when five draft bills were proposed to establish an epidemiological surveillance system of animal diseases and an animal health contingency fund for deployment of rapid response teams to address potential outbreaks. However, given the unstable political context, it is unclear whether these bills were actually implemented and acted upon by the government.

- Official outbreak data collection and dissemination is slow; therefore, estimates of outbreak progression are often delayed. Using informal sources, such as social media, alongside formal data may bolster timely responses. In general, improved data collection systems and sharing of information across organizations could improve timely outbreak response activities.

While several activities that address prevention and response have been identified across the literature, it is often unclear which of those activities have been adopted and continue to be implemented at scale. That said, two well-documented efforts are 1) cholera monitoring and 2) weather forecasting. Though those two campaigns have clear room for improvement, it seems other efforts outlined in the above sections are less well-resourced at present. This interpretation may be due to a genuine lack of activity and investment in certain efforts, a lack of coverage in the reviewed literature, or less advanced implementation due to lack of knowledge sharing and coordination across actors operating in this space.

Drought and Malnutrition in Ethiopia

BACKGROUND

Ethiopia, a country of diverse landscapes and ancient civilizations, is landlocked in the Horn of Africa. With a population of approximately 123 million, it is bordered by Eritrea, Djibouti, Somalia, Sudan, South Sudan, and Kenya [34]. The nation faces numerous challenges, including scarce water resources, limited access to healthcare services, rapid population growth, and frequent conflicts over natural resources. Compounded by an underdeveloped institutional framework, these issues contribute to Ethiopia's ranking of 175th on the Human Development Index, reflecting critical shortcomings in life expectancy, education, and income [8]. Ethiopia grapples with both conflict in the north and climate-related challenges in the south, leading to widespread devastation. With 4.5 million people in the north receiving aid since March 2021 and a total of 11 million targeted for assistance across the country, the situation highlights the need for support amidst escalating violence and drought-induced hardships [35].

Ethiopia's exposure and vulnerability to extreme climate events are significant concerns, as evidenced by its 57th ranking on the Climate Risk Index [36]. The country has historically faced a multitude of extreme weather events, such as droughts and floods, which are intensified by its variable rainfall patterns and the threat of rising temperatures. These climate-related challenges pose severe risks to the Ethiopian way of life, particularly in rural areas where the environment plays a crucial role in sustenance and livelihood [36].

The diverse Ethiopian climate and topography range from the rain-soaked equatorial rainforests in the south to the arid conditions of the northeastern lowlands. Despite this diversity, drought remains a principal environmental concern, with pronounced fluctuations in rainfall leading to periodic water scarcity [37]. The specter of drought in Ethiopia casts a long shadow over its development and public health, with the arid and semi-arid regions such as Afar, Somali, and Oromia being particularly vulnerable. The memory of the Horn of Africa drought in 2011, and the subsequent El Niño-induced droughts from 2015 to 2016 and in 2019, serve as grim reminders of the country's susceptibility to erratic climatic patterns [38].

Drought brings about more than just a shortage of water; it initiates a series of environmental transformations that compound the nation's challenges. Soil erosion, deforestation, desertification, and land degradation are but a few of the sequelae that stem from drought conditions, aggravating an already precarious situation [38].
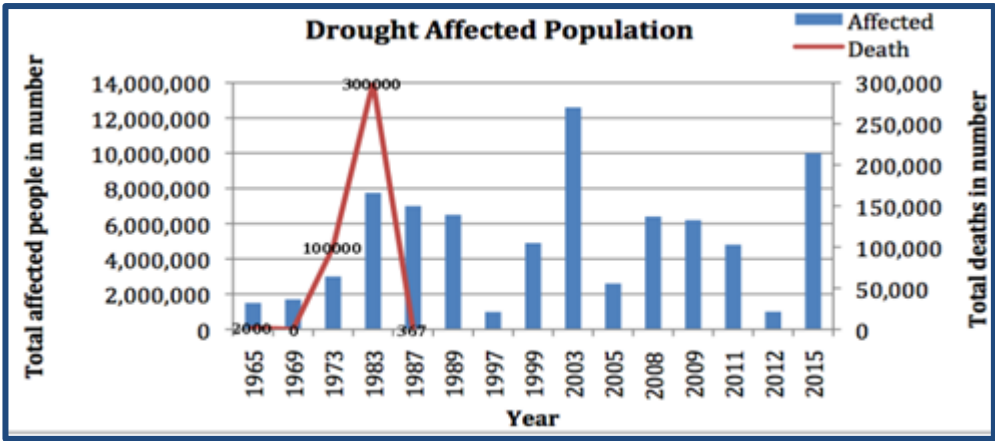
The impact of these conditions on agriculture and food security is profound, as evidenced by historical data documenting the significant number of people affected by major droughts between 1965 and 2015 (Figure 9).

Figure 9: Number of people affected by drought in Ethiopia from 1965 – 2015 [39].
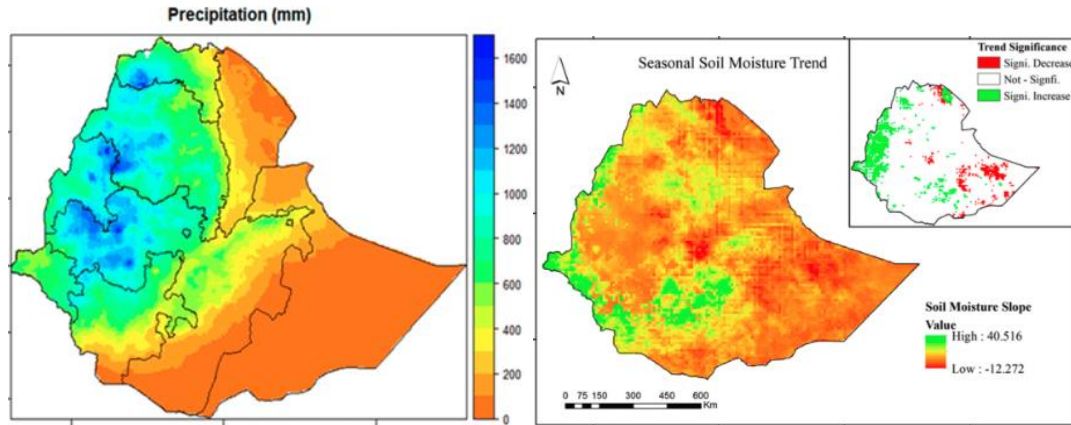
Figure 10: a) Long-term seasonal average of rainfall (mm) and b) Spatial and temporal trends of soil moisture in Ethiopia from 2001 to 2018.

Projected temperature increases of 1°C to 2°C by the year 2050 are expected to exacerbate the unpredictability of seasonal rains, further threatening the country's agricultural productivity and, by extension, its food security. Drought is identified as the most destructive climate-related natural hazard in Ethiopia, with the potential to reduce the nation's GDP by up to 10% by 2045 – a devastating blow to an economy heavily reliant on agriculture [37].

Drought and its environmental consequences also burden the public health sector as it bears the brunt of these environmental changes, grappling with a range of issues that escalate from deterioration of health systems, of safe hygiene practices, and more frequent illnesses, including intensified mental health problems [40].

BURDEN

A shared characteristic between Pakistan and, most likely, Ethiopia too, is that events such as droughts in Ethiopia lead to multiple challenges, encompassing not just one singular event but a series of climate-related disasters. The ramifications of drought in Ethiopia are profound, significantly affecting health and economic well-being with increasing child and adult morbidity and mortality rates, reduced agricultural outputs and incomes, and escalating food insecurity, famine, and malnutrition [40].

The Global Nutrition Report states that, in Ethiopia, 36.8% of children under 5 years of age are still affected by stunting, a form of malnutrition, which is higher than the average for the Africa region (30.7%) [41]. Furthermore, analyses found the burden of food insecurity in Ethiopia was measured at 22.25% of the population in 2023 [42].

The drought phenomenon also triggers mass displacement, with millions seeking shelter as refugees or internally displaced persons (IDPs) to escape the harsh realities of drought and floods [38]. Despite the implementation of various programs to mitigate micronutrient deficiencies and alleviate food insecurity among those vulnerable population, Ethiopia continues to struggle with these persistent issues, threatening the livelihoods of thousands reliant on agriculture as is illustrated in Figure 11 [43, 44].
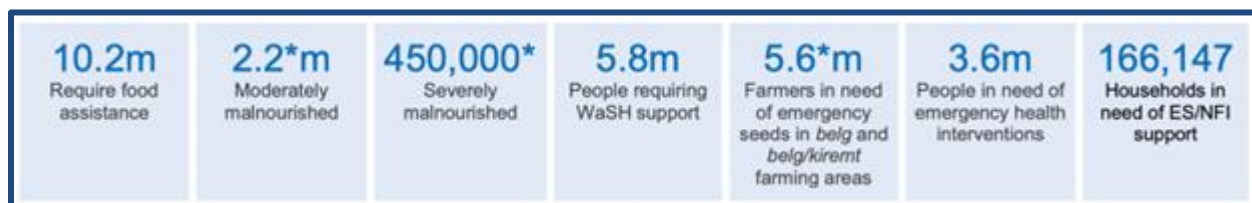
Figure 11: Burden of food insecurity and malnutrition in Ethiopia [45].

FINDINGS FROM THE LITERATURE: LESSONS LEARNED FOR DROUGHT RESILIENCE IN ETHIOPIA'S PUBLIC HEALTH SECTOR

ETHIOPIA: KEY TAKEAWAYS

- Ethiopia faces a severe threat from drought, which leads to food and water insecurity and has a dire impact on public health, specifically malnutrition among children and vulnerable populations.

- The research findings indicate that by integrating early warning systems for drought and malnutrition, along with climate-resilient agricultural practices, Ethiopia can significantly mitigate the adverse effects of these climate events.

- Social safety nets such as cash transfers, food fortification with essential micronutrients, and therapeutic feeding programs are identified as effective measures for addressing acute malnutrition in drought-stricken areas.

- Despite these strategies, there are gaps in implementation, especially in expanding the reach of these programs and ensuring their integration with other drought resilience strategies.

In-depth analysis of peer-reviewed and grey literature related to drought and its impact on food security and malnutrition in Ethiopia has found a multitude of strategies for preventing, mitigating, and responding to these issues.

The findings from academic studies are synthesized using the IPCC Risk Framework [5]. Figure 12 below offers a visual representation of the strategies identified in the literature, mapped according to whether they address weather and climate events, vulnerability, or exposure. It is important to note that this figure does not provide a comprehensive list of all strategies being researched and implemented in Ethiopia, but rather focuses on those strategies that are directly relevant to drought and its related impacts on food security and public health.

Adaptation Strategy	Weather and Climate Events		Vulnerability				Exposure		
	Improved Forecasting for Warning Systems	Reduction of GHG Emissions	Health System Strengthening	Poverty Reduction	Better Education and Awareness	Sustainable Development	Relocation (People and Assets)	Weather-Proofing Assets	Early Warning Systems
Disaster risk management program	■		■			■	□		■
Famine Early Warning System (FEWS)	■			□	□	■			■
Post drought agricultural support services				■		■	□	■	
Cash transfer programs				■			■		
Women's empowerment program				■	■	■			
Community health system, resilience, preparedness	■		■		■				■
Community's Emergency Preparedness	■		■			■			■
Health System Integration - Nutritional interventions	■	■	■		■			■	■

Figure 12: Categorization of identified adaptation and response strategies regarding drought and malnutrition in Ethiopia within the IPCC Disaster Risk Framework.

The details of the strategies depicted in Figure G are articulated and categorized as either prevention, response, or combined prevention and response activities in the subsequent sections. Key takeaways from each category are highlighted in **bold**.

PREVENTION: DISASTER RISK MANAGEMENT (DRM) PROGRAM

The government of Ethiopia is continuing to address the persistent issues of drought and food scarcity by adopting a strategic and holistic method to disaster risk management (DRM). In 2007, the establishment of the 'Disaster Management and Food Security Sector' within the Ministry of Agriculture marked a significant step forward. This was accompanied by the formulation and ratification of a National Policy and Strategy on Disaster Management, as well as the creation of a Strategic Program and Investment Framework for DRM that outlines the avenues for both government and donor contributions. Currently, the DRM Commission's initiatives encompass programs for early warning and response, risk reduction and rehabilitation, as well as humanitarian assistance following climate-related disasters [46]. Early warning systems for drought, along with initiation of therapeutic feeding programs for promptly managing acute malnutrition in drought-prone areas, represent significant advances in Ethiopia's disaster risk management [47].

These continuing programs from the Ethiopian government aids to mitigate the drought events and prevent malnutrition. Providing capacity building support and coordinating Regional States in order to strengthen and enhance the effectiveness of Disaster Management during drought and Food Security Program related activities [46]. The integration of drought early warning systems and therapeutic feeding initiatives within Ethiopia's unified disaster risk management approach has marked notable progress in addressing acute malnutrition swiftly in drought-affected regions [48].

PREVENTION: FAMINE EARLY WARNING SYSTEMS (FEWS)

Ethiopia's efforts to combat climate-related hazards, particularly recurrent droughts, are underscored by the implementation of the Early Warnings for All Initiative (EW4All) [49]. This strategy focuses on enhancing risk data utilization for early action and warning systems. The Ethiopian Disaster Risk Management Commission (EDRMC), with support from the United Nations Office for Disaster Risk Reduction (UNDRR - Regional Office for Africa) and international partners, is optimizing a risk information management system to better prepare and respond to crises. Key to these efforts is the digitalization of risk profiles and the integration of advanced technologies, such as Artificial Intelligence, for more effective exposure mapping [46, 50].

Complementing local efforts, the U.S. Agency for International Development's Famine Early Warning Systems Network (FEWS NET) contributes to the prediction and monitoring of food insecurity, utilizing diverse data sources and modeling techniques [51]. Additionally, understanding the impact of El Niño Southern Oscillation (ENSO) on drought patterns offers the potential for early warnings, providing governments with critical lead time to mitigate the impacts of drought [52]. Together, these systems represent a comprehensive approach to reducing the risks and impacts of climate-related food crises in Ethiopia.

RESPONSE: POST-DROUGHT AGRICULTURAL SUPPORT SERVICES

A critical component of Ethiopia's response to climate change, specifically drought, includes strengthening agricultural support services to maintain food security. In line with the Famine Early Warning Systems (FEWS) prevention efforts, Ardalan and colleagues have highlighted the significance of providing multifaceted agricultural support to households. **This support extends to the acquisition and application of chemical fertilizers, dissemination of information on weather patterns and climate events that can affect agriculture, as well as famine early warning systems to prevent food insecurity** [40]. Additionally, improving access to drought-resistant crop varieties, advocating for family planning to optimize household food security, creating agricultural employment opportunities, and encouraging participation in income-generating activities are integral to enhancing the resilience of households post-drought.

Key enhancements to post-drought agricultural support services include:

- Effectively sharing targeted information with households regarding weather forecasts, climate events, and market trends for agricultural inputs and outputs, which is crucial for informed decision-making.

- Broadening the availability and adoption of improved, drought-resistant crop varieties to safeguard harvests against climatic unpredictability.

- Promoting family planning initiatives to manage household sizes, thereby contributing to improved food security.

- Generating agricultural job opportunities, which can provide alternative sources of income and foster economic stability.

- Encouraging the development of agricultural income-generating activities to diversify and strengthen the economic base of rural communities.

RESPONSE: CASH TRANSFER PROGRAM

In a comparative study, Baye et al. (2014) showed that, in Ethiopia, cash transfer programs have proved to be effective safety nets, providing financial relief during severe environmental stresses like drought [53]. Pega et al. also advocated for the cash transfer program to mitigate climate changes, globally and mentioned the Ethiopian Productive Safety Net Program provides cash transfers to reduce food insecurity resulting from droughts [54]. Cash transfers could be used as a policy tool to address the adverse health consequences of climate change like malnutrition to other countries located in the horn of Africa [54]. The adoption of post-drought 'cash transfer programs' as effective safety-net measures are instrumental in alleviating the health consequences associated with malnutrition and food insecurity resulting from drought.

PREVENTION AND RESPONSE: WOMEN EMPOWERED PROGRAM

Building social capital has emerged as another potent strategy for both prevention and response, with initiatives like the "Women Empowered" (WE) groups fostering community resilience and enhancing disaster preparedness, revealed from Story et al. 2020 [55]. Social capital refers to the networks, relationships, and norms that enable collective action among community members. In this context, it includes elements like emotional support from the group, social network support, collective action, and trust. These aspects of social capital seem to bridge the gap between WE group membership and disaster preparedness, facilitating behaviors and attitudes that can better equip individuals and communities to face disasters. Specifically, the study found that emotional support from WE groups encourages members to take proactive steps towards preparing for disasters, while the broader support received through social networks, collective action, and trust contributes to a perception of being prepared for disasters. The implications of these findings are significant. **They suggest that empowering women through community-based programs that foster strong social ties can be an effective strategy in disaster risk reduction** [55]. Specifically, the Women Empower (WE) approach addresses drought-induced malnutrition and food insecurity through the following actions in Ethiopia:

- Bolstering social capital by supporting WE groups to foster community resilience and preparedness.

- Prioritization of disaster preparedness through collective action and trust-building within communities.

- Empowering women to lead in social capital development and disaster readiness initiatives.

- Implementing community-based programs that leverage social relationships for effective disaster response.

PREVENTION AND RESPONSE: COMMUNITY HEALTH SYSTEM, RESILIENCE, PREPAREDNESS, AND WORKFORCE

Ethiopia has been working on decentralizing its health care system since the 1990s, transferring responsibilities from the federal government to regional states and then further down to district (woreda) levels. This structure is intended to increase the efficiency and accessibility of health services by bringing decision-making closer to the communities that the system serves. The decentralized Ethiopian health system was challenged and then succeeded in building resilience in community-based health systems in Ethiopia during the drought. **In the face of drought and other climate adversities, investing in local health authorities and strengthening community health workforce and systems has proved to be a vital asset.** Ethiopia has a more resilient response to these drought and other climate event crises through an adaptable human resource structure and decentralized government decision-making [56]. More specifically, Ethiopia's 'Community health system, resilience, preparedness, and workforce' highlights the below best practices:

- Empowering local health authorities to customize solutions for malnutrition and food security depending on regional burden.

- Upgradation of community health facilities and establish local early warning systems for malnutrition.

- Developing community-specific emergency plans and maintaining stocks of essential nutrition supplies.

- Training community health workers in nutrition and emergency response, and ensuring they have the support of higher-level health authorities for scalability during crises.

RESPONSE: LESSONS LEARNED FROM COMMUNITY EMERGENCY PREPAREDNESS

- Responses to other climate related natural disasters provide some best practices for drought and its consequences. For example, community emergency preparedness measures, such as local committee formation, supporting house retrofitting, and establishing robust communication channels within the community, were successful in fortifying communities against hazards from the Dire-dawa floods [57]. **Investing in community preparedness in Ethiopia's northern and eastern drought-prone communities, could strengthen community resilience averting the consequence of drought in a similar way**. Specifically, in drought prone areas, the following approaches could be used:
  - Form local committees to lead and coordinate drought preparedness and response efforts. Retrofitting houses and community buildings to withstand drought-related issues, such as construction of food and water storage infrastructure.

  - Establishment of robust communication channels to disseminate information and warnings about drought conditions and resources swiftly.

PREVENTION AND RESPONSE: ENHANCING PUBLIC HEALTH MEASURES AND NUTRITIONAL INTERVENTIONS POST-DROUGHT

Public health initiatives, such as the strategic distribution of contraceptives in refugee and IDP camps, are essential for preventing unintended pregnancies, thereby reducing maternal health risks and the incidence of low-birth-weight infants who are more susceptible to malnutrition or mortality. Investing in family planning is a cost-effective strategy that yields long-term benefits for refugees and other vulnerable groups. These investments serve to prevent childhood malnutrition and contribute to adult health resilience during and after drought episodes in Ethiopia [58].

To address the specific nutritional needs of children in the face of climate-induced challenges like drought, targeted food and nutrition interventions are vital. These interventions must focus on the promotion, procurement, and consumption of vitamin-rich foods, particularly during times when the production of such foods might be compromised by drought conditions. Strategies should include the establishment of food banks, the distribution of vitamin-fortified foods, and education on the importance of a nutrient-dense diet [43].

Research indicates that in areas of Ethiopia affected by drought and conflict, the prevalence of wasting among children under the age of five is alarmingly high (OR: 1.34; 95% CI: 1.05-1.72) [59]. To counteract malnutrition and micronutrient deficiencies, it is crucial to promote foods enriched with vitamin A and iron. Additionally, implementing and scaling-up programs that distribute multiple micronutrient powders (MNP), provide iron and vitamin A supplements (VAS), and conduct deworming campaigns can significantly improve health outcomes. It is recommended to enhance the coverage of these programs and utilize health worker volunteers to ensure delivery even in the most drought-affected areas, aligning with Ethiopia's national nutrition strategy and providing context-specific support [43].

Furthermore, supplementing feeding programs within refugee camps and among vulnerable populations is of paramount importance. The Ethiopian government's DRM program is tasked with managing therapeutic feeding interventions for IDPs who are at risk of, or currently experiencing, malnutrition due to drought conditions.

Effective health and nutrition practices to combat post-drought malnutrition and food insecurity in Ethiopia include:

- Distribution of contraceptives in refugee/IDP camps or shelters to prevent unintended pregnancies and improve maternal health, reducing the risk of childhood malnutrition.

- Implementation of infant and young child supplementary feeding programs.

- Micronutrient supplementation programs, including MNP, iron, VAS, and deworming initiatives.

- Promotion and support of the consumption of vitamin-rich foods to alleviate malnutrition and micronutrient deficiencies in children impacted by climate change and drought.

- Continuation and enhancement of the Ethiopian government's DRM program, which encompasses therapeutic feeding for malnourished IDPs.

Adopting these measures can significantly reduce the impact of drought on malnutrition among vulnerable populations, with a particular focus on children in Ethiopia.

FINDINGS FROM THE LITERATURE: PRIORITIES FOR DROUGHT RESILIENCE IN ETHIOPIA'S PUBLIC HEALTH SECTOR

GENERAL IPCC SREX GUIDELINES

Ethiopia's public health sector faces significant challenges in preparing for and responding to natural disasters. The literature on Ethiopia's disaster risk management, particularly concerning drought resilience, suggests several priorities that are in line with the general guidelines of the Intergovernmental Panel on Climate Change (IPCC) Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX). The SREX report, while not specifically focusing on Ethiopia, offers broad adaptation priorities applicable to drought-prone countries. Drawing from these guidelines and the specific context of Ethiopia, the following priorities emerge:

1. **Enhancement of Drought Forecasting and Early Warning Systems**: These systems should include mechanisms for timely dissemination of information and preparation plans tailored to the unique challenges of drought.

2. **Sustainable Management and Conservation of Water Resources:** Ethiopia should prioritize sustainable water resource management practices and conservation strategies to maintain water availability during dry spells.

3. **Strengthening the Public Health Infrastructure:** This includes bolstering healthcare facilities, ensuring adequate supplies of medicines, and training healthcare workers in disaster response. It also includes strengthening community level services and health worker volunteers to provide support and essential health care to communities affected by drought.

4. **Support Services and Social Safety Nets for Affected Populations:** Ethiopia needs to establish robust social safety nets that provide cash transfers and access to essential services to communities affected by drought.

5. **Transparent Disaster Recovery and Resilience Funding:** Ethiopia should ensure that financial assistance for drought recovery and resilience building is managed transparently and reaches the intended beneficiaries promptly and effectively.

By incorporating these priorities into its public health sector strategies, Ethiopia can enhance its resilience to drought and safeguard the health and well-being of its population.

ETHIOPIA'S NATIONAL ADAPTATION PLAN

Ethiopia's National Adaptation Plan (NAP-ETH) is an extension of the country's sustained initiatives to integrate climate change adaptation into its developmental agenda [39]. The NAP-ETH is designed to foster a comprehensive incorporation of climate change mitigation strategies into Ethiopia's strategic plans for long-term growth. It identifies critical sectors that are highly susceptible to the impacts of climate change, including agriculture, forestry, health, transportation, energy, industry, water resources, and urban development. Within these identified sectors, 18 specific adaptation measures have been outlined for execution at various administrative levels. Pertinent to the discussion of alleviating the risks of drought resulting from climate change and, by extension, combating food insecurity and malnutrition in Ethiopia, the following measures from the NAP-ETH are particularly relevant:

- Enhancing food security by improving agricultural productivity in a climate-smart manner.
- Improving access to water and improving soil and water harvesting and water retention mechanisms.
- Improving ecosystem resilience through conserving biodiversity.
- Enhancing sustainable forest management.
- Building social protection and livelihood options of vulnerable people.
- Strengthening drought, livestock & crop insurance mechanisms.
- Improving early warning systems.
- Developing and using adaptation technologies.
- Reinforcing adaptation research and development.

ADDITIONAL DEVELOPMENT PRIORITIES AND COORDINATION IDENTIFIED

In addition to homegrown measures, various international development organizations are working in concert with Ethiopian government bodies to bolster disaster risk management and drought resilience. A notable event was the partnership between Ethiopia and the United Nations Development Program (UNDP) at a workshop in Stockholm in 2022, which aimed to weave drought mitigation efforts into the fabric of Ethiopia's sustainable development goals [60]. The workshop pinpointed several essential initiatives for immediate and future action, including:

- Expansion of drought-resilient agricultural practices.

- Enhancement of community-based early warning systems.

- Development of market-based solutions for drought adaptation.

- Capacity building for local non-governmental organizations (NGOs) and community-based organizations (CBOs).

- Establishment of a national drought resilience platform.

Moreover, the African Union's Climate Change and Resilient Development Strategy and Action Plan for 2022-2023 serves as a pivotal framework to encourage regional cooperation, with a particular focus on enhancing drought resilience in Ethiopia and across the Horn of Africa [61]. The strategy underscores the significant investment by African governments, including Ethiopia, in national adaptation measures like drought relief, agricultural support, and disaster management programs - averaging 3.4% of the GDP among African nations. It also advocates for increased power generation through regional river basins, which can simultaneously strengthen drought resilience and spur economic growth by bringing renewable energy to market.

A critical development in Ethiopia's adaptation and risk management is the engagement with the UNDRR. As part of the EW4All Initiative, Ethiopia is actively developing its Roadmap for Multi-hazard, Impact-based Early Warning and Early Action System (2023-2030). The EDRMC, together with UNDRR and the United Nations Country Team, has convened over 60 technical experts from more than 25 organizations and 12 regions to advance the implementation of this Roadmap, which includes leveraging risk data to optimize national, sub-national, and community-based early warning systems [50].

These efforts reflect a growing consensus among development stakeholders on the need for climate adaptation and public health prioritization in Ethiopia and the wider Horn of Africa region. However, a challenge that arises is the coordination of these multifaceted and multilateral efforts. To maximize the efficiency of time and financial resources, it is imperative to ensure alignment and minimize duplication between the actions of the UNDRR, the African Union, and other agencies. Enhanced collaboration and strategic planning among these entities will be crucial to achieving the most impactful and sustainable outcomes in Ethiopia's fight against drought and its broader development goals.

CONCLUSION: GAPS IN PREVENTION AND RESPONSE STRATEGIES IDENTIFIED FROM PEER-REVIEWED LITERATURE

Despite Ethiopia's considerable efforts to manage the impacts of drought on food insecurity and malnutrition, the literature reveals gaps in both prevention and response strategies that must be acknowledged and addressed to improve resilience.

1. There is a critical need for more sustainable water resource management and conservation strategies to ensure water availability during droughts, which are integral to agricultural productivity and food security.

2. The healthcare infrastructure in drought-prone areas remains insufficiently equipped to handle the surge in demand during drought-related health crises, including acute malnutrition and associated diseases.

3. Although community-based programs and emergency preparedness measures have been implemented in some settings, there is a need for wider adoption and integration of these approaches to build local resilience.

4. Interventions to combat malnutrition, such as the distribution of micronutrient supplements and promotion of vitamin-rich foods, need to be scaled up and better integrated with other drought resilience strategies.

5. There is a need for more transparent and effective allocation and management of funds dedicated to drought recovery and resilience to ensure they reach the intended beneficiaries.

While some strategies found from the literature have shown moderate degrees of promise, not all have been met with success, such as:

● Distribution of hygiene kits among internally displaced persons (IDPs) was found to be ineffective, indicating the importance of ongoing evaluation and refinement of adaptation strategies [62].

● The dire situation in the Afar region, with a deadly malnutrition crisis as a consequence of El Nino reported by MSF in June 2022, underscores the persistent and urgent need for effective interventions [63].

● The impact of the conflict in northern Ethiopia, which has exacerbated food insecurity and led to famine conditions in affected areas, necessitates urgent humanitarian aid and a coordinated response to address both war-related damages and the resultant hunger crisis.

Ethiopia's efforts to address the multifaceted challenges of drought-induced malnutrition and food insecurity showcase a variety of best practices and lessons learned. The country's focus on a combination of prevention and response strategies, along with a commitment to continuous improvement, is critical to enhancing resilience to climate change and safeguarding the health and nutrition of its population. By recognizing and bridging some gaps identified above, Ethiopia can strengthen its public health sector and enhance its capacity to prevent and respond to the consequences of drought, thereby securing the food supply and nutritional needs of its population. Finally, Ethiopia is working closely with a number of regional and multilateral efforts supported by the African Union, UNDP and coordination across these efforts will be needed to avoid duplication of efforts in a resource constrained setting.

Flooding and Infectious Diseases in Pakistan

BACKGROUND

Pakistan sits within the southeast Asia coast along the Arabian sea and the Gulf of Oman, and borders Afghanistan, Iran, India, and China. It has an estimated population of 250 million [64]. With high rates of poverty and historic internal conflicts, Pakistan is ranked as the 161st of 188 countries in the Human Development Index, based on life expectancy, mean years of schooling, and gross national income per capita [8].

This vulnerability is informed by, and contributes to, its rank as the 5th most likely country to experience increasingly severe extreme weather events [65]. Earthquakes, storms, landslides, and flooding have been documented regularly as shown in Figure 13. It is important to note that there are multiple forms of flooding, each with unique challenges, that vary in different parts of the country. Significant flooding includes glacial lake outburst floods in the north, riverine flooding and flash floods in the plains, and coastal flooding associated with cyclone events.

Disaster Type	Disaster Subtype	Events Count	Total Deaths	Total Affected	Total Damage ('000 US$)
Drought	Drought	1	143	2,200,000	247,000
Earthquake	Ground movement	35	144,116	7,435,786	5,376,755
Epidemic	Bacterial disease	3	142	11,103	0
	Parasitic disease	1	0	5,000	0
	Viral disease	2	130	56,338	0
	Others	5	131	371	0
Extreme temperature	Cold wave	3	18	0	0
	Heat wave	15	2,936	80,574	18,000
Flood	Flash flood	24	3,590	22,114,253	10,184,118
	Riverine flood	43	9,229	34,967,357	9,727,030
	Others	39	5,286	23,863,294	2,670,030
Landslide	Avalanche	12	567	4,435	0
	Landslide	9	222	29,707	18,000
	Mudslide	2	16	12	0
Storm	Convective storm	15	402	1,906	0
	Tropical cyclone	7	11,555	2,599,940	1,715,036
	Others	7	184	2,988	0

Figure 13: Summary of natural disasters in Pakistan and affected people.

Pakistan has an extremely diverse topography, ecosystems, and climate zones with three major geographic regions: mountainous highlands, plateaus, and the Indus River valley. Most of the population reside on the arable land along the Indus, as this fertile land has offered sustenance and livelihood to Pakistanis for millennia. Of late, monsoon seasons, between July and August, have seen record high rainfalls [66], such that river flood basins become saturated, unable to absorb large volumes of water and natural drainage is overwhelmed. The volume of water is driven not only by historic rains, but also glacial melting from Northern Mountainous areas which drain down into the valley as temperatures rise.

Currently, an estimated 714,000 people are affected by flooding every year, but that number is projected to rise as frequency and intensity of floods are projected to rise [67, 68]. A likely increase of around 5 million people exposed to extreme river floods by 2035–2044 is predicted, and an additional 1 million per year are projected to be exposed to coastal flooding between 2070–2100 [65]. Figure 14

below shows the intensity of flooding, by district, for the last 50 years, indicating risk for flood hazard across the country [69].
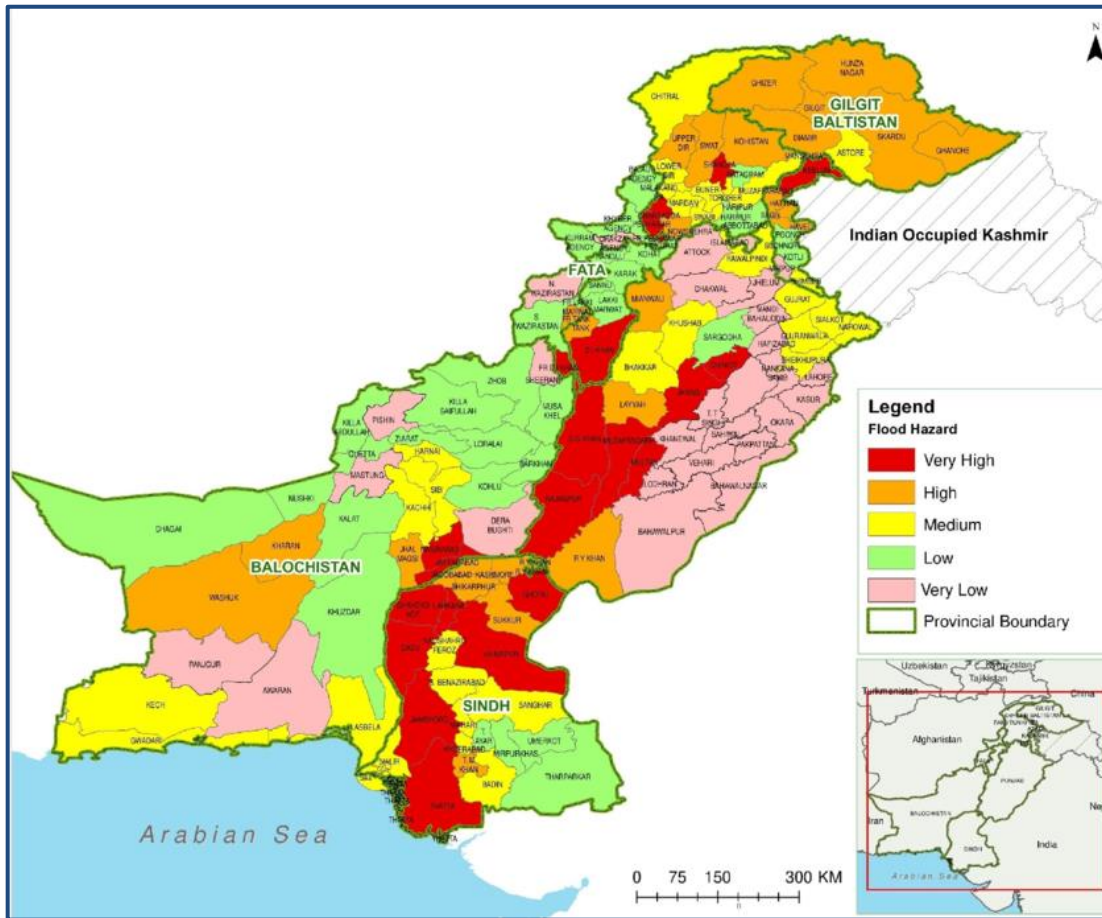

Figure 14: Pakistan Flood Hazard Map (1970-2020) [69].
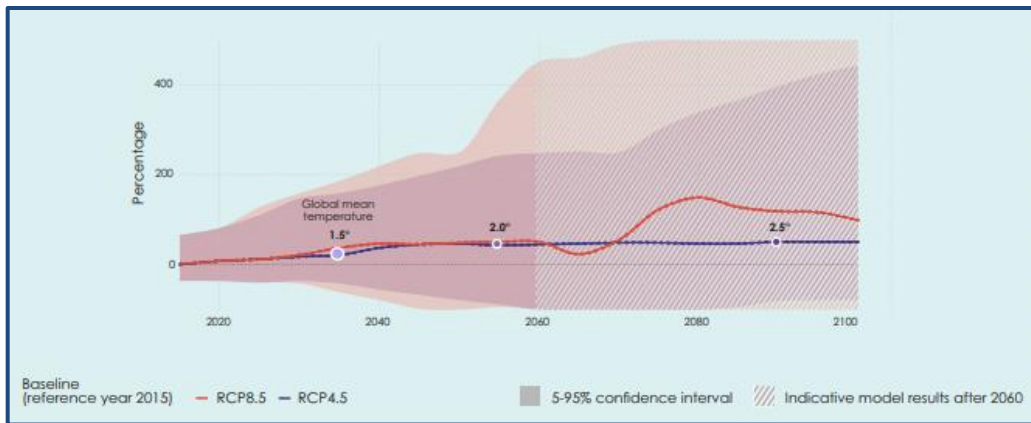

Figure 15: Annual Expected Damage (%) from River Floods [70].

BURDEN

In July 2010, Pakistan suffered nationwide floods after unprecedented monsoon rains overwhelmed the Indus basin, claiming a reported 1,985 lives, injuring 2,946 people, killing 10,000 cattle, affecting

over 20.2 million people, displacing 14 million people, and destroying 1.4 million acres of crops [71, 72]. In 2022, catastrophic flooding struck again, resulting in 1,730 reported deaths with even more wide scale health and social disruption, affecting 33 million people, 16 millions of which are children, and displacing 8 million persons [73].

These intensified floods have inflicted a compounded toll on both mortality and morbidity, and displacement and disruption of livelihoods have further exacerbated the socio-economic strain. The inundation of homes, destruction of infrastructure, and contamination of water sources led to an expected annual reduction of GDP at $1.7 billion [65] and to widespread public health risks. Immediate deaths and injuries were uncommon but 77.0% reported flood-related illnesses in their households within the six months following the floods [74].

Compromised sanitation infrastructure serves as a breeding ground for infectious diseases like cholera, typhoid fever, diphtheria, and hepatitis, while also exacerbating the prevalence of vector-borne illnesses such as malaria and dengue fever [75]. Moreover, the displacement and congestion in temporary flood-relief shelters precipitate the rapid transmission of infectious diseases, including fever, respiratory and gastrointestinal disease imposing an additional strain on already fragile healthcare systems ill-equipped to manage such crises [76]. Vulnerable populations such as babies and young children are particularly at risk given Pakistan has the third-highest number of unvaccinated children globally. Despite renewed vaccination campaigns, there has been a 42% decline in immunization rates since the onset of the COVID-19 pandemic and outbreaks of infectious disease correlated with flooding continue to persist as seen in Figure 16 [77, 78]:
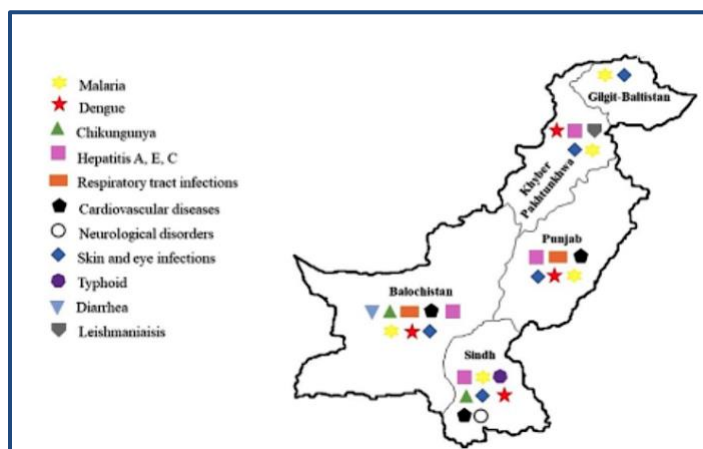

Figure 16: Outbreaks of infectious disease during COVID-19 in Pakistan.

While bigger picture social determinants of health and climate risk must be addressed, a peer-reviewed and grey literature review on riverine flooding made worse by climate-change and resulting infectious diseases in Pakistan, points to several lessons learned about prevention and response, particularly in the aftermath of the 2010 and 2022 flooding. In the following, we will present ways to make disaster recovery more human-centered to ease disease outbreak through health system strengthening, education and awareness, and exposure reduction.

FINDINGS FROM THE LITERATURE: LESSONS LEARNED FOR FLOOD RESILIENCE IN PAKISTAN'S PUBLIC HEALTH SECTOR

After conducting a comprehensive review of peer-reviewed and grey literature on floods and public health in Pakistan, various strategies to prevent, alleviate, and respond to public health challenges have been identified.

PAKISTAN: KEY TAKEAWAYS

- Pakistan is highly susceptible to flooding, which is exacerbated by monsoon rains and glacial melts, leading to a heightened prevalence of infectious diseases.

- Strengthening flood early warning systems, enhancing the healthcare system's capacity, and investing in water, sanitation, and hygiene infrastructure are pivotal strategies to prevent the spread of diseases following floods, particularly in riverine agrarian communities.

- The need for community-specific interventions, such as targeted vaccination campaigns and education on disease prevention, is highlighted to effectively manage health risks during and after flood events.

- The research findings reveal implementation gaps, particularly in local specificity of flood warnings and the provision of adequate sanitation systems, which are crucial for reducing infectious/waterborne diseases post-flood.

We provide a summary of key findings from multiple studies that apply a risk framework similar to that of the IPCC for flood-related risks. In particular, (Figure 17) illustrates the activities pointed in the academic research, mapped to whether they address hydrological events, population vulnerability, or exposure to flood risks. This figure is not an exhaustive inventory of all strategies being researched and implemented but instead showcase strategies specifically relevant to floods and public health in Pakistan.

Adaptation Strategy	Weather and Climate Events		Vulnerability				Exposure		
	Improved Forecasting for Warning Systems	Reduction of GHG Emissions	Health System Strengthening	Poverty Reduction	Better Education and Awareness	Sustainable Development	Relocation (People and Assets)	Weather-Proofing Assets	Early Warning Systems
GIS-Based Flood Hazard Mapping for Early	■		■	■			■	■	■
Designing Disaster Relief for Livestock Keepers				■			■		
Veterinary vaccination campaigns			■	■					
Increased support during Return to Flood Zones	■			■			■		
Zinc supplementation to Reduce Cholera Risk	■		■						
Vitamin A supplementation to Reduce Measles Risk	■		■						
Vitamin D supplementation to Reduce Respiratory Illness Risk	■		■					■	■
Malaria Management Tactics Specific to P. vivax	■		■						

Figure 17: Categorization of identified adaptation and response strategies regarding flooding and infectious diseases in Pakistan within the IPCC Disaster Risk Framework

The detailed strategies from the literature described and categorized as either prevention, response, or both prevention and response activities in subsequent sections. Key insights and practical recommendations would be highlighted in bold, drawing attention to the most impactful measures.

PREVENTION: GIS-BASED FLOOD HAZARD MAPPING FOR EARLY WARNING

Kashif et al. 2020, used relative frequency ratio to determine the correlation between eight flood parameters such as slope, land use, drainage density, and rainfall to create a flood hazard map of the Panjkora River Basin. The model was found reliable with an 82% success rate and 84% prediction rate. Its usability also, unlike other models used to map flood susceptibility, does not depend on the length of data sets used or interpretation by an expert; its inputs can be of any size and results obtained from it are easy to interpret [79]. The study can play a key role for proactive hazard management in the region, but also offers a model that may be of use in other geographies to aid local disaster management authority, researchers, planners, local government, and line agencies dealing with flood

risk management. The use of **this model of statistical analysis should be explored further for accurate flood hazard mapping in Pakistan.**

PREVENTION AND RESPONSE: VETERINARY VACCINATION CAMPAIGNS

Braam et al. 2021 spoke with live-stock keepers who noted that their livestock became sick with hand-foot-and-mouth disease as well as a swelling of the throat and nose, fever, and bloat but were provided few livestock vaccinations. In 2021, preventative Foot and Mouth Disease vaccination campaigns reached only about 10% of formally registered cattle according to local veterinarians [80]. The study noted that **better livestock vaccination practices before disasters, as well as during relief, could ease zoonotic disease burden** on victims of flooding.

PREVENTION AND RESPONSE: ZINC SUPPLEMENTATION TO REDUCE CHOLERA RISK

Abdullah et al, 2023, noted cholera spikes after monsoon floods. According to conservative estimates, as of late 2022, nearly 2000 confirmed cases of Cholera have been reported across all four provinces of Pakistan. **While vaccines are a primary priority, strengthening the guidance, health worker training logistics, cost, and distribution of micronutrients such as Zinc, can reduce the duration and severity of disease outbreaks.** When zinc is given as a supplement, it can also reduce the risk of recurrences in the short term. But, only 37% of children under five are deficient in zinc on a national level according to the Pakistan National Nutrition Survey 2011 [81].

- One method for Zinc supplementation is food fortification. Pakistan's National Agriculture Research System (NARS), the International Maize and Wheat Improvement Center (CIMMYT), and a private organization called HarvestPlus collaborated to develop a biofortified zinc wheat variety. Mahboob et al. 2022 noted that community perceptions of these zinc-fortified flours are positive, and that local storage, supply, distribution, and affordability of newly developed zinc-fortified flours should be invested in [82].

- Amin et al. 2023 offer guidelines for including supplementation into the organization and management of medical flood relief camps based on their experience of providing and witnessing medical flood relief after the 2022 floods. Their guidelines recommend the inclusion of zinc sulfate in medical supplies and prescribe specific dosages of Zinc be given for diarrhea [83].

- Nutrition International also conducts training sessions for district-level health facilities staff on zinc for diarrhea management [84].

PREVENTION AND RESPONSE: VITAMIN A SUPPLEMENTATION TO REDUCE MEASLES RISK

Tariq et al, 2022 note that the flooded state of Pakistan and subsequent mass movement of population, deterioration of health services and worsened living conditions contribute to high rise of Measles outbreaks. Measles cases surged to 10,399 in 2021 from 2,747 in 2020 due in part to flooding during that period [85]. Muzzamil et al, 2023 urgently note that nutritional deficiency has been linked to a more severe course of viral infections such as measles. Regular Vitamin A capsule supplementation in children aged 6–59 months has been demonstrated to reduce mortality by 12%–24% [86]. Since WHO recommends Vitamin A supplementation as a low-cost, highly efficient strategy for lowering child mortality and morbidity from measles in non-emergency settings, it is critical to maintain high supplementation rates for vulnerable populations exposed to flooding, especially since 56% of Pakistani children under five are deficient in vitamin A. Tariq et al, 2022 indicate that **raising awareness of the protective effects of Vitamin A** is crucial to increasing its usage as a prophylaxis against measles [85]. Amin et al, 2023 recommend using guidelines **for including vitamin supplementation into the organization and management of medical flood relief camps** based on their experience of providing and witnessing medical flood relief after the 2022 floods [83]. Their

guidelines recommend the inclusion of Vitamin A in medical supplies, and that specified dosages of Vitamin A be given alongside vaccinations and deworming medications to every child in camps over the age of 6 months.

PREVENTION AND RESPONSE: VITAMIN D SUPPLEMENTATION TO REDUCE RESPIRATORY ILLNESS RISK

In the aftermath of the 2010 floods the WHO reported that 113,981 cases of respiratory tract infections were reported in the flood-affected communities of Pakistan [87]. The WHO notes that vitamin D deficiency was linked to respiratory infections such as pneumonia, tuberculosis and bronchiolitis along with causing rickets [88]. About 41% of children under five are deficient in vitamin D on a national level according to the Pakistan National Nutrition Survey 2011 [89].

PREVENTION AND RESPONSE: MALARIA MANAGEMENT TACTICS SPECIFIC TO *PLASMODIUM VIVAX (P. VIVAX)*

By August 2022, reported cases of malaria in Pakistan after a significant surge in flooding surpassed the total for the entire year of 2021. In August 2022, there was a more than two-fold increase in cumulative cases across 62 high-burden districts in Pakistan compared to August 2021. Malaria is endemic to Pakistan and stagnant flood waters serve as a breeding ground for the mosquitoes that spread malaria. Tabassum et al, 2023 noted that *P. vivax was* the most prevalent form of malaria in this 2022 upsurge. **Controlling the transmission of *P. vivax* comes with its own host of challenges, however some solutions such as focusing on prophylactic treatment, improved diagnostics and screening to improve drug treatment options can help contain malaria in populations exposed to stagnant flood waters** [90]**.** More specifically:

- *P. Vivax* is spread via the Anopheles mosquito which is less easily controlled by long-lasting insecticidal nets and indoor residual spraying, as it bites at dawn and dusk, times when people are often outside of the home. Though nets and spraying remain important practices, *P. vivax* requires focus on prophylactic treatment and postexposure treatments more so than other species. This is especially true given that only 6% of households own mosquito nets [71], mosquito nets are often not available during displacement, and larvicidal preventive procedures are not as feasible in flood-affected areas.

- This form of malaria can also be more difficult to identify and diagnose. Tabassum calls for a considerable amount of further research to develop more precise diagnostic methods [90].

- The only drug approved for *P. vivax* is primaquine, which is contraindicated in G6PD deficient patients as it causes mild to severe hemolysis and anemia. G6PD deficiency is a genetic disorder in which the body does not produce enough of the G6PD enzyme. The percentage of incidence is extremely high in Pakistan and highly limits the management of Malaria. Thus, G6PD deficiency screening must be included in the long-term plan to mitigate the impact of malaria.

RESPONSE: DESIGNING DISASTER RELIEF FOR LIVESTOCK KEEPERS

Braam et al (2021) studied the relationship between disaster displacement and zoonotic disease dynamics in the wake of the 2010 floods [80]. Key informants from Singh Province shared that livestock, livelihoods, and key sources of fodder, are central to decision making about whether to evacuate, what transportation to use, and what destinations to head to, but that army-run formal relief camps did not provide space for their animals.

This caused households to split up as male family members stayed with the animals and were at increased risk for zoonotic diseases given the increased human-animal and animal-animal proximity. Zoonotic diseases are always of concern for livestock keepers, but substandard living conditions

during displacement can exacerbate the spread of disease. The act of moving, experiencing separation, and dealing with uncertainty can lead to fatigue, stress, and various psychosocial challenges that can negatively impact immunity, affecting both humans and animals alike [80].

These livestock keepers noted an increase in their own respiratory and gastrointestinal infections and attributed that at least partially to a lack of hygiene living close to livestock. The study concluded that **designing evacuation plans and relief camps with the lifestyles and needs of livestock keepers in mind could reduce the risk of zoonotic disease transmission** [80].

RESPONSE: INCREASED SUPPORT DURING RETURN TO FLOOD ZONES

Shabir et al, (2013) found that nationwide, around 77% of people reported illness within their household in the six months following the floods. Data from the health cluster showed acute respiratory infection (23%), skin diseases (11%) and acute diarrhea (9%) in flood-affected districts during this period [71]. Braam et al. (2021) also noted that the risk of disease outbreaks was greatest after displacement and during households return to flood zones. In particular, upon returning to their homes, many Pakistanis found their wells to be contaminated. Water testing after the 2010 floods confirmed an outbreak of cholera traced to hand-pumped water [80]. Braam et al (2021) recommended **increased investment, particularly in WASH resources, for those returning to their communities which could reduce disease burden during recovery.**

FINDINGS FROM THE LITERATURE: PRIORITIES FOR FLOOD RESILIENCE IN PAKISTAN'S PUBLIC HEALTH SECTOR

GENERAL IPCC SREX GUIDELINES

IPCC SREX report does generalize lessons learned from flooding seen in countries such as Pakistan as well as Kenya and Nairobi and suggests the following adaptation priorities for countries facing floods:

1. Measures to improve effectiveness of disaster risk management by government agencies.

2. Accuracy of forecast and timely delivery of warnings that are delivered to every person in an easy-to-understand way which are tailored to the specific needs and skills of the people.

3. Collaborative preparation and training of communities at risk.

4. Creation and development of effective and steadily functioning systems of hydrological monitoring and early warning systems at local regional and national levels.

5. Intensive programs to move people to safe areas, large resettlement programs for communities affected by floods, and ensured funds for those relocated. These programs are a last resort and have not been as well-received given that relocation areas are sometimes less desirable or livable than areas left behind.

6. Vulnerability in all sectors (social, infrastructure, environmental, etc.) must be well understood and resources available, or lack thereof, must also be considered in the formulation of preparedness and response mechanisms.

PAKISTAN NATIONAL ADAPTATION PLAN

In 2010 the UNFCCC established the National Adaptation Plan (NAP) process, which facilitates strategic medium and long-term country-led planning and preparedness for climate change adaptation [70]. Pakistan's NAP outlines priority initiatives focused on achieving four key objectives:

1. Incentivizing farmers to transition to climate-smart water and land management practices.

2. Modernizing surface and groundwater irrigation services to support transitions to climate-smart agriculture.

3. Developing a long-term agriculture growth strategy, with a focus on productivity improvement, climate resilience, and physical expansion

4. Developing a plan for managing projected river flow and rainfall variability under different climate scenarios

The NAP discusses how the 2010 floods led to the establishment of a comprehensive institutional framework of disaster risk management bodies at the national, provincial, and district levels, as well as the development of long-term disaster risk management policies. That said, it calls out that the floods of 2022 brought to the forefront the limitations within Pakistan's disaster risk management system, notably at the subnational and local levels, spotlighting areas that require further attention and improvement. The main challenges are:

- Poor coordination, particularly between federal and provincial governments, and the Government of Pakistan and international community.

- Suboptimal understanding of the roles and responsibilities of stakeholders, especially the multiple agencies at all levels of government mandated to manage disasters; and

- Weak capacity of all stakeholders, in both the public and private sectors, highlighted by their increased workload and overstretch.

CONCLUSION: GAPS IN PREVENTION AND RESPONSE STRATEGIES IDENTIFIED FROM PEER-REVIEWED LITERATURE

In the light of the lessons learned and best practices for enhancing flood resilience in Pakistan's public health sector, it is essential to recognize the gaps that exist in prevention and response strategies, as evidenced by peer-reviewed literature. Below are some areas that would benefit from additional research and action to address flood-related infectious diseases in Pakistan.

1. Current flood warnings are not geographically targeted, sometimes alerting the wrong people, and are not specific on what risks the community is facing in their decisions to stay or evacuate, thus hindering effective evacuation and preparedness at the community level and harming long term trust in communications overall. Communication specificity and accuracy is an opportunity for improved preparedness.

2. Due to the majority of the population's lack of access to adequate sanitation systems heightening the risk of waterborne diseases following floods, comprehensive vulnerability analyses are essential to effectively target the delivery of crucial services such as WASH (Water, Sanitation, and Hygiene) infrastructure and vaccinations.

3. Implementation of effective disease surveillance and rapid response systems is challenged by political and resource limitations. Therefore, enhanced coordination between government, NGOs, aid agencies, and communities is needed for effective knowledge sharing and disaster response.

4. Outbreak data reporting is slow, and integrating informal data sources with formal ones could improve response times. Improved inter-organizational data sharing is necessary.

5. The extent of adoption and scaling of identified activities is often unclear, necessitating better documentation and wider implementation.

Addressing these gaps requires focused efforts to ensure strategies are actionable, consistently applied, and scaled appropriately to protect the health of those vulnerable to floods.

In conclusion, Pakistan's journey towards robust flood resilience, particularly in its public health sector, is marked by identifiable gaps that require urgent attention. Addressing the need for more localized early warning systems, expanded access to sanitation, targeted vulnerability assessments, reliable disease surveillance, timely data dissemination, clear implementation of prevention and response strategies, and strengthened integration and coordination among stakeholders are crucial steps forward. By closing these gaps, Pakistan can better safeguard its population from the health impacts of flooding, ultimately building a stronger, more resilient nation.

Conclusion

Across the three case studies discussed in this report, several overarching themes and gaps arose despite focus on varying geographies, climate events, and public health outcomes:

1. **Given the overarching climate-related and socio-economic vulnerabilities in each country, the best way to improve climate resilience and emergency preparedness across all three contexts is to invest in economic development and health system strengthening with ongoing attention to building resilience to climate change**. For example, in Haiti the construction of climate-resilient roads and health infrastructure allows for sustained access to health services following natural disasters such as hurricanes. In Ethiopia, consistent agricultural support services strengthen farmers' ability to cope with shocks such as droughts and prevent subsequent widespread malnutrition. Finally, in the case of Pakistan, widespread vaccination campaigns in non-emergency times are one of the best outbreak prevention strategies following a flood event.

2. **Post-disaster response may be an opportune moment to implement adaptations to increase a community's climate resilience given the interruption to existing systems but should not preclude disaster risk reduction efforts in advance of disaster conditions**. Instead of applying resources to rapid "band-aid" responses, longer-term disaster risk reduction development priorities should be incorporated into relief activities. Haiti is a particular case of how recurring disasters and insecurity divert funds away from long-term sustainable development creating a dependance on international intervention as opposed to building up resilient local systems. In Ethiopia, improving women's empowerment is a key strategy to improve a community's overall resilience, therefore focusing on women's empowerment before, during, and after a drought is a long-term protective social intervention. Finally, in Pakistan, infectious disease outbreaks following a flood event typically occur beyond 6 months after the event itself, suggesting that a longer timeline of relief efforts, such as vaccination campaigns, needs to be considered. It is important to note that this approach may not always be possible in practice, as it can be seen as slowing down recovery and urgently needed opportunities to resume activities and livelihoods.

3. **Early warning systems for both weather events themselves and their consequences only work when people receive and trust the notices, have options for protective responses, and believe that acceptable evacuation and other options are available to them, their families, and their assets.** In Haiti, weather forecasting and associated early warning systems are not granular enough to be relevant to individuals at a local scale; therefore, people often do not trust alerts to evacuate even if they are truly at risk. In Ethiopia, early warning systems for drought coupled with those for malnutrition, could build trust by providing alerts and ensuring resilience against disasters. In Pakistan, the sites people get diverted to in the event of an evacuation are often not desirable or suitable for people and their livestock. Therefore, despite the risk of exposure to an extreme event such as a flood, a person may choose to stay and face the consequences.

4. **Interdisciplinary collaboration in prevention and response activities are key to ensuring appropriate intervention implementation and uptake.** In Haiti, there is very little information sharing across organizations and sectors, thus resulting in often redundant replication of data collection. Improving information sharing policies and practices could be a key strategy to improve timely response activities. In Ethiopia, collaborative efforts between nutritional supplement programs and the government's Disaster Risk Management program demonstrated effective prevention strategies, especially for the IDPs suffering from malnutrition. In Pakistan, relief camp services could consult with anthropologists to design relevant and acceptable service and supply provision.

5. As exemplified by comprehensive National Adaptation Plans (NAP) in each of the three countries, **governments are already aware of their vulnerabilities and have established priority areas for future development to improve climate resilience alongside estimates of the resources required to realize those priorities**. In Haiti, the four key priorities are:

   - Reviving climate-resilient agri-food systems

   - Social and integrated management of water resources

   - Building extreme weather-resilient health infrastructure and associated health professional training (relevant to hurricanes)

   - Adopting building standards to promote general extreme weather-resilient infrastructure (relevant to hurricanes)

   In Ethiopia, the four priority initiatives are:

   - Enhancing food security by improving agricultural productivity in a climate-smart manner

   - Improving access to water by improving soil and water harvesting and water retention mechanisms

   - Enhancing sustainable forest management, strengthening drought, livestock & crop insurance mechanisms

   - Building social protection and livelihood options of vulnerable people

   In the case of Pakistan, the four identified initiatives are:

   - Incentives for climate-smart water and land management

   - Modernizing irrigation systems

   - Developing a long-term agriculture growth strategy

   - Developing a plan for managing projected river flow and rainfall variability (relevant to flooding)

Specific activities within each of the four domains in all three countries are outlined in each respective NAP, presenting a clear roadmap to sustainable development in each context.

Haiti, Ethiopia, and Pakistan are vulnerable countries due to extreme weather events caused by climate change and recurring political, economic, and social insecurities. These vulnerabilities simultaneously build upon and exacerbate each other, in particular, as a country's climate change vulnerability increases so too do the borrowing rates on its debt [91]. Due to this phenomenon, in all these contexts, economic development and health system strengthening are key to improving climate resilience and reducing population risk to negative health outcomes. Each country has a climate adaptation strategy in place, with various development priorities outlined in their respective National Adaptation Plans. However, they do not necessarily have the resources and capacity to fulfill these plans on their own. Collaborations across sectors with an emphasis on community involvement and trust-building are necessary to implement appropriate and effective adaptation strategies.

Limitations

First, the prominent cross section of climate change and public issues were identified using the rapid review approach and using one database. This may have constrained the depth of the analysis and synthesis, potentially overlooking other relevant articles in other databases. Secondly, not considering unpublished findings may have resulted in the omission of emerging insights from grey literature related to climate events and their implications on public health. Thirdly, the literature search focused on specific hazards and locations, not generally on best practices related to disaster risk reduction for each of the hazards identified. For example, the literature on reducing health impacts associated with floods and how climate change might impact them is broader than the country-specific literature on the same topic. Finally, the study's broad scope, including various geographic regions and a complex subject matter, might have imposed constraints on the depth of exploration within each area.

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