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Climate-Induced Disasters: Preparedness and Adaptation Strategies

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Abstract

Climate change has become a critical global issue, significantly affecting population health, poverty, and development. Climate-induced disasters (CINDs), such as floods, droughts, and cyclones, exacerbate existing vulnerabilities, particularly in disadvantaged communities. The objective of this study was to conduct a thorough review of climate induced disaster through an analysis of existing literature. The literature was analyzed to identify techniques, challenges, and potential future directions in climate induced disaster. Data was gathered from research papers, reports, and case studies. The rising frequency and intensity of extreme weather events, driven by hydrological, meteorological, and climatological changes, challenge the resilience of cities and regions worldwide. This paper explores the impacts of climate change on ecosystems, human health, and economies, with a focus on Bangladesh and other vulnerable regions like Southern Africa and Sub-Saharan Africa. It delves into the preparedness and adaptation strategies employed by governments and organizations, highlighting flood mitigation, climate change adaptation, and disaster risk reduction (DRR) initiatives. Barriers to effective disaster management, such as resource limitations, complex stakeholder coordination, and policy gaps, are also discussed. The future of disaster management is likely to focus on innovative solutions involving predictive technologies, climate-resilient infrastructure, and collaborative, community-based approaches to enhance resilience against climate-induced disasters.

Key words: Climate, Climate induced disaster, Disaster preparedness, Climate change adaptation.

1. Introduction

Climate change has become a worldwide issue, and its effects on population, health, and poverty are undeniable. There is no question that climate change and climate-related disasters present a major obstacle to reducing poverty, improving health, and fostering development in many nations. However, the specific impacts of climate change and the susceptibility of disadvantaged communities vary significantly. In most cases, climate change compounds existing vulnerabilities (Patel, 2016). Climate-induced natural disasters (CINDs), such as droughts, floods, and cyclones, have emerged as major challenges for the economy (Nanda and Ghosh, 2017). The effects of climate change are evident in all areas of the global environment and economy (Weerasekara, 2021).

The growing intensity and frequency of climate-induced disasters (CID), particularly those resulting from hydrological, meteorological, and climatological changes, have been challenging the resilience of cities globally. According to the World Economic Forum's 2020 Global Risk Report, from 2018 to 2020, three of the top five risks in terms of likelihood and impact were climate-related, with extreme weather events ranking as the most probable threat (Haggag, 2021).

Climate change has been associated with a reduction in snow cover, faster sea level rise, more frequent heat waves and droughts, stronger hurricanes, and, most critically, a persistent and rapid increase in global temperatures (Callery S, 2018). Disasters have become more frequent and widespread, causing severe impacts on both people and the environment (Kamara, 2018).

In Bangladesh, several studies (Sikder & Xiaoying, 2014; Rokonuzzaman et al., 2018; Huq et al., 2015; Abedin & Shaw, 2013) have focused on the effects of climate change on the agricultural sector, with particular attention to vulnerability and adaptation strategies (Islam, 2020). Climate-induced disasters pose major challenges for vulnerable groups, particularly elderly individuals with disabilities, who encounter distinct obstacles in preparing for, responding to, and recovering from these catastrophic events (Matlakala et al., 2024).

Climate change is causing more frequent and intense disasters in Sub-Saharan Africa, with vulnerable populations being disproportionately affected. Extreme weather events such as floods, droughts, and heatwaves are endangering lives and livelihoods throughout the region (Codjoe & Atiglo, 2020; Thiede et al., 2022). The rise in global temperatures has led to more frequent and intense cyclones, hurricanes, and floods in various regions worldwide. These climate change-related water disasters (CCRWDs) severely affect communities and pose significant health risks to residents (Veenema et. al., 2017).

Global climate change will raise the likelihood of extreme weather events, which may be linked to either heavy precipitation (such as storms, floods, and landslides) or insufficient precipitation (Keim, 2008). The aim of this review paper is to analyze climate-induced disasters, preparedness, and adaptation strategies.

2. Methodology

This review article utilizes a comprehensive literature review approach to analyze climate-induced disasters, preparedness, and adaptation strategies. Relevant peer-reviewed articles, reports, and policy documents were sourced from academic databases such as Google Scholar, Science Direct, and Springer, focusing on the period from 2000 to 2024. Key search terms included “climate-induced disasters,” “disaster preparedness,” “climate change adaptation,” “disaster risk reduction,” and “resilience strategies.” The review covers diverse geographic regions, particularly vulnerable areas such as Bangladesh, Sub-Saharan Africa, and Southern Europe. Adaptation strategies were examined in terms of policy frameworks, technological innovations, and socio-cultural factors influencing resilience. Additionally, this methodology allowed for the comparison of climate change adaptation and disaster risk reduction, and future directions in preparedness and adaptation strategies.

3. Climate induced disaster

According to Lodhia (2011), It is now widely acknowledged that global temperatures are steadily increasing due to the rise in greenhouse gases, and this is evident in two main ways. The first, and most significant, is the rise in sea levels. Higher temperatures cause the thermal expansion of oceans, leading to a global increase in sea levels. Additionally, the melting of glaciers and ice sheets, driven by rising temperatures, contributes more water to the oceans, further exacerbating sea level rise. The second manifestation is observed in the growing frequency and intensity of extreme weather events.

The most significant effects of climate change on ecosystems, wildlife, and humans typically result from extreme events rather than gradual shifts in average climate conditions (Walsh, 2020).

Bangladesh's coastal region is extremely susceptible to climate change and climate-induced natural disasters. Each year, coastal communities experience various natural hazards, including floods, tropical cyclones, tornadoes, tidal surges, droughts, and significant river erosion (Faisal, 2024).

Southern Africa has historically been prone to climate-induced disasters, particularly droughts and floods. Since the early 1980s, the frequency and intensity of these events have escalated, gradually undermining livelihoods and prompting ongoing humanitarian interventions (Kamara, 2018).

Climate change is expected to lead to an increase in the frequency and intensity of extreme weather events across Europe, including heavy rainfall, flooding, and drought (Cacciotti, 2021). Climate-related disasters (CRDs) and hazards like droughts, floods, and storms are key natural events in long-term weather cycles that may be influenced by climate change (Azadi, 2022).

Climate change and climate-related disasters negatively impact mental health, with low- and middle-income countries (LMICs) being especially at risk. These countries often face significant challenges due to insufficient mental healthcare infrastructure to address the effects of such disasters (Sharpe, 2021).

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According to Warren (2010), There are two types of disasters that can be directly associated with the potential impacts of climate change. These include:

1. Climatological disasters, such as droughts (leading to food insecurity), extreme temperatures, and wildfires.
2. Hydrological disasters, such as floods (including waves and storm surges) and wet mass movements like avalanches, mudslides, landslides, rock falls, and subsidence caused by hydrological factors.
3. Additionally, a third category could be added that encompasses geographical events such as earthquakes and tsunamis, as well as mass earth movements and rock falls.

Extreme climate and weather events, including floods, droughts, heat waves, and bushfires, are becoming more frequent and severe in various regions around the globe.

4. Preparedness strategies for climate induced disaster

According to Cacciotto (2021), In Central Europe, a range of risk management strategies is being implemented to mitigate the effects of climate change on cultural heritage (ProteCHt2save Deliverable D.T2.1.1, 2018). These strategies fall into three primary categories:

1. **Preparedness and Risk Prevention:** This includes initiatives aimed at enhancing readiness and mitigating risks, such as training and awareness programs (e.g., seminars, media campaigns), as well as documentation efforts like mapping and maintaining inventories of heritage sites.
2. **Disaster Response:** This category focuses on responding to emergencies through specialized training, disaster simulations, and planning for emergency vehicle access.
3. **Recovery and Rebuilding:** These strategies are designed to restore operations after an event, addressing physical, social, environmental, and cultural losses while aligning with sustainable development principles to enhance resilience against future risks.

According to Shah Alam Khan (2008), Several key strategies for flood mitigation have been implemented:

1. **Embankment Construction**: Around 7,500 km of embankments have been built along major rivers, including loop embankments and polders to protect urban centers and coastal agriculture. While they help prevent floods, these structures have negatively affected fish migration, spawning grounds, and floodplain ecosystems.
2. **Improved Gravity Drainage**: Enhancing gravity drainage is crucial for quick floodwater recession. This involves excavating khals (canals) and selectively dredging rivers, especially post-monsoon when water levels are lower. However, draining wetlands for rice cultivation has led to environmental issues and user conflicts.
3. **Pumped Drainage**: Pumping facilities have been established in areas where gravity drainage is insufficient, effectively managing storm water in urban embankments. Yet, urban encroachment and unplanned development hinder their effectiveness. In rural projects, pumped drainage has proven to be cost-ineffective, leading to sedimentation and environmental harm.
4. **Flood Proofing**: This traditional method involves constructing homes and infrastructure on elevated ground above flood levels. Various projects have successfully raised these structures, minimizing environmental impact and risks.
5. **Flood Forecasting**: Recent advancements have improved the accuracy and lead times of flood forecasts at 44 locations, providing 24, 48, and 72-hour warnings. While the forecasts are reasonably accurate, longer lead times and better local interpretation of the data are necessary for enhanced preparedness and damage reduction.

5. Climate Change Adaptation

According to McBean & Rodgers (2010), In the context of climate change, adaptation refers to the process of adjusting natural or human systems to respond to actual or anticipated climatic changes or their impacts, with the goal of reducing harm or taking advantage of beneficial opportunities.

Adaptation measures to climate change can be categorized into several key strategies:
1. Bearing or Sharing Losses: In less developed regions, communities often have no choice but to endure the losses. However, in more developed societies, losses can be shared through public relief, reconstruction efforts, or insurance, whether public or private.
2. Modifying Threats or Preventing Effects: Threats like floods can be mitigated through physical interventions like dams or levees. In agriculture, changing management practices (e.g., increasing irrigation or using more fertilizers) can help address climatic threats. For climate change, mitigation efforts can slow its progression.
3. Changing Land Use or Location: Shifting crops or moving agriculture to new locations is a strategy, although it may be constrained by economic, political, or other factors.
4. Conducting Research: Research can bridge knowledge gaps and develop new technologies for adaptive strategies.
5. Promoting Behavioral Change: Education, information, and regulation can drive behavioral shifts. Historically underemphasized, this approach is gaining importance for effective adaptation (McBean & Rodgers, 2010).

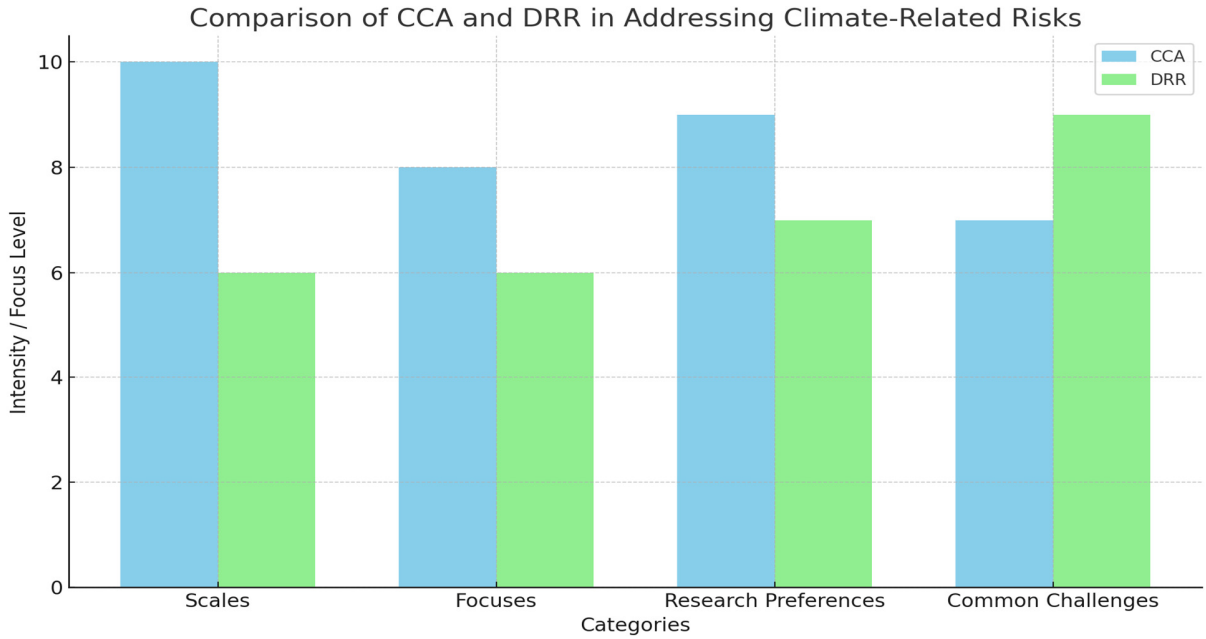
Comparison between Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR):
Table 1 summarizes the comparison between the two approaches, focusing on their scales, focuses, research preferences, and common challenges.

Table 1: Comparison between Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR)

Aspect	Climate Change Adaptation (CCA)	Disaster Risk Reduction (DRR)
Scales	Focuses on longer-temporal and larger-spatial scales	Works within relatively shorter and smaller scales
Focuses	Takes into account both positive and negative effects of climate-related changes	Primarily addresses the negative effects of climate-related hazards
Research Preferences	Tends to use a mostly top-down approach in planning and implementation	Utilizes a mostly bottom-up approach, engaging communities more directly
Common Challenges	Requires multi-stakeholder participation	Requires multi-scale coordination

Source: Lei & Wang, 2014.

Following Figure 1 compares Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR) across four categories: scales, focuses, research preferences, and common challenges. The chart visually shows how each approach addresses climate-related risks with different intensities across these aspects.



Source: Lei & Wang, 2014.

Figure 1: Comparison of Climate Change Adaptation (CCA) and Disaster Risk Reduction

According to Sarwar (2023), to tackle the effects of climate change, the Government of Bangladesh (GOB) has implemented various policy and institutional measures. These include the development of the National Adaptation Programs of Action (NAPA) in 2005 and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009. Additionally, the government has established a Climate Change Unit, created the Climate Trust Fund, and formed several high-level committees to support adaptation efforts. Key projects under the BCCSAP include the repair and maintenance of coastal polders, excavation of coastal rivers, and

the construction of numerous cyclone shelters. Table 2 simplifies the main points discussed, focusing on temporal and spatial dimensions, involvement strategies, stakeholder, and key challenges.

Table 2: Temporal and spatial dimensions, involvement strategies, stakeholder, and key challenges.

Dimension	Details
Temporal Dimension	• Short-term adjustments before, during, and after a disaster • Long-term adaptation strategy for future risks and climatic uncertainty • Balances present and future goals to assist decision-makers in strategic planning
Spatial Dimension	• Adaptation actions depend on participants (individual, local community, national, or international) • Multiscale participation and communication are essential for effective adaptation • Scale-differential criteria needed for adaptation effects assessment • Scientific vulnerability assessment and risk analysis face challenges due to spatial locality and uncertainty
Adaptation Strategies	• Should include educational, ecological, technological, and political considerations • Effective adaptation balances different adaptive approaches.
Stakeholder Involvement	• A wide range of stakeholders (scientists, policy makers, private firms, NGOs, media, educators, public) is needed • Coordination of different stakeholders' interests is a key challenge for effective adaptation
Example (Agricultural Drought)	• Farmers focus on drought impacts on livelihoods and incomes • Local government concerned with ecological issues like land degradation and water shortage • Central government focuses on yield losses and regional grain security • Discrepancy in interests makes it difficult to reach consensus on adaptation measures
Key Challenge	• Multi stakeholder participation and communication for decision-making are crucial for a reasonable adaptive solution

Source: Lei & Wang, 2014.

6. Barriers and Challenges to Effective Preparedness and Adaptation

According to Measham et al. (2011) in the context of climate change, the range of responsibilities faced by local governments presents several challenges. They share the duty, often with state governments, to identify potential natural hazards, including those linked to climate events, and to ensure these risks are considered in both formal and informal decision-making processes. Local governments have a "duty of care" to make sure development choices do not lead to significant unmanaged hazard exposure. Although this has always been a responsibility, climate change complicates the process by requiring attention not only to historical climate patterns but also to future changes. However, there is currently a lack of clear legislative guidance or established community practices on how to integrate climate risks and their uncertainties into local decision-making. This integration demands learning, resource allocation, and policy

development, all while local governments continue to address their existing duties. Consequently, climate adaptation is competing for priority on the policy agenda and in local government budgets (Measham et al., 2011).

One significant limitation on local institutions' ability to plan and adapt to climate change lies in their broader institutional context. Local governments often operate within a policy framework dictated by higher levels of governance, such as state, provincial, or national policies. In many instances, municipal authorities lack their own constitutional authority and function as agents of these higher powers, such as states in Australia or provinces in Canada. For example, in Sydney, Local Environmental Plans developed by individual councils are mandated under the New South Wales Environmental Planning and Assessment Act of 1979 (Section 53). However, the State Minister for Planning is not obligated to adhere to these plans when making decisions, such as those involving state infrastructure projects (Measham et al., 2011).

According to Khan et.al. (2023), different types of disasters, such as earthquakes, fires, and floods, each present specific challenges on top of the general issues that arise in disaster management.

General Challenges

Disaster management faces various broad challenges, including the allocation of limited resources (personnel, equipment, and funding), especially during multiple crises. Effective communication and coordination between diverse stakeholders are hindered by complex networks and language barriers. Timely access to accurate information is difficult due to limited data and misinformation. Engaging communities, adapting systems to climate change, fostering cross-disciplinary collaboration, and ensuring equitable recovery also present significant hurdles (Khan et.al, 2023).

Flood Management Challenges

Flood management requires constant improvement in modeling techniques and decision support tools. There is limited information on the computational time of flood models, and few studies compare the efficiency of simulation platforms (Khan et.al, 2023).

Earthquake Management Challenges

Earthquake management is challenged by the limited use of global models, insufficient integration with landscape management, and difficulty handling uncertainties in forecasting. There is also a lack of data analysis for real-time earthquake modeling (Khan et.al, 2023).

Wildfire Management Challenges

Wildfire management faces difficulties due to the lack of large datasets, challenges in acquiring landscape data, issues with overfitting in prediction models, and the need to bridge the gap between monitoring and decision-making (Khan et.al, 2023).

Remote Sensing in Disaster Management

Remote sensing is limited by the difficulty of selecting the most appropriate systems for different disasters, cloud coverage issues, lack of access to high-resolution data in developing countries, and insufficient research funding. New frameworks and algorithms for remote sensing in disaster contexts need to be developed (Khan et.al, 2023).

7. Future directions and innovations

Future directions and innovations in addressing climate-induced disasters will likely focus on enhancing predictive technologies, improving resilience, and fostering sustainable adaptation strategies. Advancements in remote sensing, artificial intelligence, and big data analytics can provide more accurate forecasts and early warning systems, enabling faster and more effective responses. Innovations in infrastructure, such as climate-resilient buildings and adaptive water management systems, will also be crucial in minimizing the impact of extreme weather events. Furthermore, integrating climate risk reduction into urban planning and development policies, alongside community-based approaches, will strengthen local resilience. Collaboration across sectors, such as engineering, social sciences, and policy-making, will be essential to develop comprehensive, sustainable, and innovative solutions to the growing threat of climate-induced disasters.

8. Conclusion

The increasing frequency and intensity of climate-induced disasters (CIDs) pose significant challenges to global communities, economies, and ecosystems. Climate change, driven by rising greenhouse gas emissions, has led to more frequent hydrological, meteorological, and climatological disasters such as floods, droughts, and cyclones. Vulnerable populations, especially in developing regions like Bangladesh and Sub-Saharan Africa, face heightened risks from these events. Preparedness strategies, such as improved infrastructure, flood forecasting, and climate change adaptation, are essential for mitigating these impacts. However, challenges remain in resource allocation, communication, and integrating climate risks into local governance. Future innovations in disaster management will likely focus on enhancing predictive technologies and fostering resilience through community-based adaptation and policy integration. Overall, a multi-stakeholder approach involving technological advancements, cross-disciplinary collaboration, and sustainable development will be crucial for addressing the evolving risks posed by climate-induced disasters. To effectively combat climate-induced disasters, it is vital to embrace innovations in technology, infrastructure, and community engagement. As climate change exacerbates vulnerabilities, integrated and forward-looking strategies, supported by global cooperation, will be essential to building resilient societies capable of withstanding future disasters.

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