International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 9 Issue 9 September - 2025, Pages: 86-101

Climate Change and Institutional Responses in Bangladesh: *Challenges and Pathways for Adaptation and Mitigation*

Nazifa Ifrit1, Imran Hossain2, A.K.M. Mahmudul Haque3

1Department of Political Science, University of Rajshahi, Rajshahi- 6205, Bangladesh
ifritnazifa@gmail.com
2Department of Political Science, Varendra University, Rajshahi- 6204, Bangladesh
imran.pol@vu.edu.bd
3Department of Political Science, University of Rajshahi, Rajshahi- 6205, Bangladesh
akmmahmudul@ru.ac.bd

***Abstract*—*Bangladesh is globally recognized as one of the most climate-vulnerable countries, facing recurrent cyclones, floods, salinity intrusion, droughts, and urban heat stress. These hazards pose severe threats to agriculture, water resources, health, and urban systems, compounding existing socio-economic inequalities. This manuscript critically examines the institutional responses to climate change in Bangladesh, highlighting national policies such as the Bangladesh Climate Change Strategy and Action Plan (BCCSAP), sectoral initiatives in agriculture and water management, and the role of local governments, NGOs, and community-based adaptation. Despite policy innovation and domestic climate financing mechanisms, governance challenges persist, including fragmented mandates, weak coordination, inadequate finance, and limited inclusion of marginalized groups. The paper proposes pathways for strengthening adaptation and mitigation through mainstreaming climate risks into development planning, decentralizing authority to local governments, ensuring financial transparency, and enhancing science–policy linkages. By situating vulnerability within socio-political contexts, the study underscores that sustainable climate resilience in Bangladesh requires integrated, inclusive, and multi-level governance frameworks with lessons for other climate-vulnerable nations.*

Keywords—Climate change; Bangladesh; Vulnerability; Adaptation; Governance

1. INTRODUCTION

Climate change has emerged as one of the most pressing challenges of the twenty-first century, exerting profound impacts on ecosystems, societies, and economies worldwide. Scientific consensus, as articulated by successive Intergovernmental Panel on Climate Change (IPCC) assessment reports, confirms that anthropogenic greenhouse gas (GHG) emissions have significantly altered global climatic systems, leading to rising average temperatures, sea level rise, shifting precipitation patterns, and more frequent extreme weather events (IPCC, 2014; IPCC, 2021). While the impacts of climate change are global in nature, their severity is unevenly distributed, with developing nations, particularly low-lying deltaic countries, bearing a disproportionate share of the burden due to their geographical exposure, socio-economic vulnerabilities, and limited adaptive capacities (Adger, 2006; Field et al., 2014).

Bangladesh is widely recognized as one of the most climate-vulnerable countries in the world. Located in the deltaic floodplains of the Ganges–Brahmaputra–Meghna river basin and intersected by an intricate network of rivers and coastal ecosystems, the country is exposed to recurrent floods, tropical cyclones, storm surges, salinity intrusion, riverbank erosion, and droughts (Ahmed and Haque, 2002; Karim and Mimura, 2008). Recent assessments indicate a consistent rise in mean annual temperature, irregular monsoon rainfall, and an increased frequency of climate-induced disasters, particularly after the 1970s (Karmakar and Shrestha, 2000; Debsarma, 2003). Projections suggest that by 2030 the mean temperature could rise by 1.3°C and by 2075 by as much as 2.6°C, accompanied by erratic precipitation patterns and accelerated sea level rise, threatening agriculture, water resources, food security, health, and livelihoods across the country (Haque et al., 1992; IPCC, 2007; MoEFCC, 2018). These vulnerabilities are not only biophysical but also deeply socio-economic, intersecting with high population density, poverty, and rapid urbanization.

The urgency of addressing climate change in Bangladesh is underscored by its consistent ranking among the topmost countries in the Global Climate Risk Index, reflecting both its high exposure to climate-induced hazards and its limited coping capacity (Germanwatch, 2010; Eckstein et al., 2021). Extreme events such as Cyclone Sidr in 2007 and Cyclone Aila in 2009 exemplify the devastating impacts on lives, livelihoods, and infrastructure, displacing millions of people and causing extensive economic damage. Beyond these sudden-onset disasters, slow-onset processes such as salinity intrusion in coastal areas, groundwater depletion in drought-prone regions like Barind, and urban heat stress in cities such as Dhaka and Rajshahi are progressively undermining the resilience of communities and ecosystems (Shahid and Behrawan, 2008; Green News BD, 2018). These dynamics highlight the multifaceted nature of climate vulnerability in Bangladesh, where local variations in geography and socio-economic structure create diverse risk profiles.

In response to these challenges, Bangladesh has demonstrated remarkable policy innovation and institutional commitment to climate change adaptation and mitigation. The formulation of the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009 represented one of the earliest national frameworks among developing countries to comprehensively address climate change. The strategy prioritizes disaster risk reduction, livelihood protection, low-carbon development, technology transfer, and access to international climate finance (MoEFCC, 2009). Complementary institutions such as the Bangladesh Climate Change Trust Fund (BCCTF) and the Bangladesh Climate Change Resilience Fund (BCCRF) have been established to mobilize domestic and international resources for resilience-building initiatives. In addition, line ministries, including the Ministry of Environment, Forest and Climate Change (MoEFCC), the Ministry of Disaster Management and Relief (MoDMR), the Ministry of Agriculture (MoA), and the Ministry of Water Resources (MoWR), have incorporated climate considerations into their mandates, while local government institutions have begun to integrate adaptation measures into development planning (Alam et al., 2020; Khan et al., 2019).

Despite these advances, Bangladesh continues to face critical governance and institutional challenges in climate action. Policy fragmentation, overlapping mandates, limited coordination among agencies, and inadequate enforcement of environmental regulations weaken the effectiveness of institutional responses (Siddiqui et al., 2020). Moreover, climate finance remains constrained, with heavy reliance on donor-driven projects and insufficient mobilization of private sector investment in renewable energy and green infrastructure. At the local level, municipalities and union parishads often lack technical expertise, resources, and data to effectively plan and implement adaptation strategies, leaving vulnerable populations, especially women, children, and marginalized groups, at disproportionate risk (Haque et al., 2019; Brouwer et al., 2007). These institutional gaps underscore the need for a more integrated, multi-level, and inclusive governance framework that bridges national policies with grassroots resilience efforts.

Against this backdrop, this paper critically examines climate change and institutional responses in Bangladesh, with a focus on identifying challenges and pathways for adaptation and mitigation. Drawing on scientific assessments, policy frameworks, and governance literature, it explores the country's vulnerability to climate impacts, evaluates the roles of key state and non-state actors, and highlights sectoral challenges in agriculture, water, health, and urban systems. The analysis also interrogates governance gaps and institutional barriers that constrain effective climate action. By synthesizing insights from national and local experiences, the paper aims to contribute to policy debates on strengthening institutional capacity, mainstreaming climate adaptation into development planning, and fostering inclusive, multi-level governance. In doing so, it not only addresses the urgent needs of Bangladesh but also offers lessons for other climate-vulnerable countries seeking to build resilience in the face of an uncertain climatic future.

2. CLIMATE CHANGE AND VULNERABILITY IN BANGLADESH

The impacts of climate change are globally pervasive, but their manifestations are often place-specific, shaped by local geographies, socio-economic conditions, and institutional capacities. Bangladesh presents one of the most compelling cases of vulnerability due to its unique location in the world's largest delta, its high population density, and its dependence on climate-sensitive sectors such as agriculture, fisheries, and water resources. Scientific evidence demonstrates that climatic parameters in Bangladesh have already undergone measurable changes, with increasing trends in both temperature and rainfall irregularities observed across decades. Studies have shown that the decadal mean annual temperature has risen significantly since the 1960s, with more pronounced warming after 1970, reflecting both global warming trends and local climatic shifts (Karmakar and Shrestha, 2000; Debsarma, 2003). Climate modeling projections suggest that mean annual temperature will increase by 1.3°C by 2030 and 2.6°C by 2075 (Table 1), while monsoon rainfall is expected to intensify, potentially amplifying flood hazards and crop damage (Haque et al., 1992; IPCC, 2007). At the same time, sea level rise is anticipated to be between 31 cm and 85 cm by the end of the century, posing existential threats to the country's extensive low-lying coastal belt (IPCC, 2014; MoEFCC, 2018).

The biophysical vulnerability of Bangladesh is multifaceted, combining exposure to sudden-onset disasters with long-term, slow-onset processes that erode resilience over time. Cyclones and storm surges remain the most visible hazards, with devastating events such as Cyclone Sidr in 2007 and Cyclone Aila in 2009 killing thousands and displacing millions while destroying critical infrastructure and livelihoods (Paul, 2009; Mallick et al., 2011). These disasters are becoming more intense as warming sea surface temperatures contribute to stronger tropical cyclones with higher wind speeds and heavier precipitation (IPCC, 2014). Flooding, both riverine and flash, is another recurrent hazard, exacerbated by changing monsoon dynamics and Himalayan glacier melt, which increase river discharge during peak seasons. Salinity intrusion in the southwest coastal regions, driven by sea level rise and upstream freshwater withdrawal, is degrading soil fertility and contaminating drinking water sources, thereby compounding health and livelihood challenges (Shahid and Behrawan, 2008; Dasgupta et al., 2014). In drought-prone areas such as the Barind Tract, groundwater depletion due to over-extraction and declining rainfall is undermining agricultural productivity and household water security, reflecting the vulnerability of inland regions that often receive less attention than coastal zones (Green News BD, 2018; Jamat, 2010).

Urban areas are increasingly emerging as critical sites of climate vulnerability in Bangladesh. Rapid and unplanned urbanization, coupled with inadequate infrastructure, has made cities such as Dhaka, Chattogram, and Rajshahi particularly susceptible to climate-induced hazards. Urban flooding due to intense rainfall events and poor drainage systems has become a recurrent phenomenon, disrupting economic activity and exacerbating public health crises. Additionally, the urban heat island effect is intensifying heat stress,

especially among low-income communities living in congested settlements with poor housing and limited access to healthcare (Harlan et al., 2013; Klanenberg, 2015). The concentration of population, assets, and economic functions in urban centers means that climate shocks in these areas have disproportionately high social and economic costs.

The social dimensions of climate vulnerability in Bangladesh are as critical as the biophysical ones. Vulnerability is not distributed evenly across populations but is stratified by income, gender, age, and access to resources. Poor households, smallholder farmers, landless laborers, women, and marginalized groups often bear the brunt of climate impacts because they have fewer adaptive capacities and limited access to protective infrastructure (Adger, 2006; Brouwer et al., 2007). For example, studies show that households with lower income and limited access to productive assets are more likely to suffer livelihood losses and displacement following floods and cyclones, and their recovery trajectories are slower compared to wealthier groups (Ahmed et al., 2009). Social vulnerability is further reinforced by institutional weaknesses, where governance systems often fail to effectively integrate marginalized voices into planning processes or deliver timely adaptation support (Yamin et al., 2005).

Sectoral vulnerabilities further illustrate the multi-dimensional risks of climate change in Bangladesh. Agriculture, which employs a significant portion of the labor force, is highly climate-sensitive. Erratic rainfall, salinity intrusion, prolonged droughts, and flooding threaten both subsistence and commercial crop production, leading to food insecurity and loss of livelihoods (Sikder, 2010; Hossain, 2010). Fisheries and aquaculture, vital sources of nutrition and income, are being undermined by salinity shifts and water quality degradation. Water resources, already under stress due to over-extraction, are being further destabilized by climatic changes, with cascading effects on irrigation, drinking water, and sanitation. Health outcomes are also being shaped by climate variability, with increased incidences of heat stress, vector-borne diseases, and water-borne illnesses recorded in recent years (Ahsan, 2010; Begum, 2020).

The compounded vulnerabilities of Bangladesh place immense pressure on the nation's development trajectory. Climate-induced damages are estimated to cost the economy billions annually, undermining gains in poverty reduction, infrastructure development, and social welfare (MoEFCC, 2018; Khan et al., 2020). Climate risks also interact with broader structural challenges such as rapid population growth, urban migration, and environmental degradation, creating a complex nexus of pressures that threaten long-term sustainability. For instance, migration from climate-affected areas to urban centers is intensifying the stress on already overburdened cities, generating new forms of urban poverty and social tensions (Islam, 2006; Ericksen et al., 1994).

Despite widespread recognition of these challenges, research and policy discourse have historically focused disproportionately on coastal vulnerabilities, while non-coastal regions such as the drought-prone northwest and the heat-stressed urban centers remain comparatively underexplored (Siddiqui et al., 2020). This uneven focus risks obscuring the diverse and localized manifestations of climate vulnerability, which require tailored adaptation strategies. Importantly, while the biophysical impacts of climate change cannot be eliminated, their socio-economic consequences can be mediated through effective governance, institutional strengthening, and proactive adaptation measures. The task, therefore, is to move beyond documenting vulnerabilities towards building resilience that is inclusive, equitable, and grounded in both scientific evidence and local knowledge systems.

Table 1. Climate Change Trends and Projections for Bangladesh

Climate Variable	Observed Trends (Past 30–50 years)	Projected Changes (Mid- to Late 21st Century)	Sectoral Implications	Governance Imperatives
Temperature	Mean annual temperature increased by ~0.6°C since 1960; rise in warm days/nights.	Expected rise of 1.5–2.4°C by 2050; up to 4°C by 2100 under high-emission scenarios.	Heat stress on crops and labor productivity; rising urban heat island effects.	Integrate heat-resilient agriculture, expand green urban planning, and enforce heat-health action plans.
Rainfall Patterns	Increasing variability; higher intensity rainfall during monsoon, longer dry spells.	Monsoon precipitation projected to rise 5–10%; longer droughts in north-west regions.	Drought risk in Barind areas; increased flash flooding in urban centers.	Adopt adaptive water governance, strengthen rainwater harvesting, and climate-proof drainage infrastructure.

Sea-Level Rise	~3–7 mm/year rise observed along coastal belt.	0.4–0.8 m rise by 2100 (IPCC AR6), with significant risk of saline intrusion.	Loss of arable land in coastal districts; displacement of ~13 million people by 2050.	Enhance coastal embankment integrity, scale climate-resilient housing, and prioritize planned migration.
Cyclones & Storm Surges	Increase in intensity though frequency remains stable; Sidr (2007), Aila (2009), Amphan (2020) caused major losses.	More frequent intense cyclones; higher surges amplified by sea-level rise.	Loss of lives, assets, and livelihoods; long-term salinization of coastal soils.	Strengthen early warning systems, expand cyclone shelters, and promote climate insurance for recovery.
River Flooding	Monsoon floods affect ~20% of land annually; extreme floods (1988, 1998, 2007) exceeded 60%.	Flood intensity projected to increase with Himalayan glacier melt and erratic rainfall.	Damage to agriculture, infrastructure, and rural livelihoods; rising health risks.	Integrate basin-wide flood governance, enforce zoning laws, and develop resilient rural infrastructure.

3. CONCEPTUAL FRAMEWORK: VULNERABILITY, ADAPTATION, AND GOVERNANCE

Understanding climate change in Bangladesh requires a clear conceptual grounding in the interrelated notions of vulnerability, adaptation, and governance (Table 2). The concept of vulnerability has evolved within the climate change literature to capture the differential capacities of societies and ecosystems to cope with climatic stressors. The IPCC defines vulnerability as a function of exposure, sensitivity, and adaptive capacity, thereby recognizing that risks are not solely determined by physical hazards but are mediated through socio-economic structures, institutional arrangements, and access to resources (IPCC, 2001; Adger, 2006). Exposure refers to the degree to which a system experiences climatic stimuli, such as floods, cyclones, or droughts. Sensitivity reflects the extent to which these stimuli affect the system, for example, the high dependence of rural households on agriculture in Bangladesh that makes them highly sensitive to rainfall variability. Adaptive capacity denotes the ability of individuals, households, and institutions to adjust to these stresses, drawing on economic resources, knowledge, technology, and social networks (Smit and Wandel, 2006; O'Brien et al., 2007).

Within this framework, vulnerability in Bangladesh is shaped not only by geography but also by deeply entrenched socio-economic inequalities. Coastal populations exposed to cyclones and salinity intrusion, for instance, are vulnerable because of both their physical location and their socio-economic conditions, including poverty, lack of land tenure, and limited institutional support (Islam and Winkel, 2017). Similarly, urban slum dwellers are vulnerable not just to the physical hazard of urban heat islands or flash floods but also to inadequate housing, limited access to healthcare, and exclusion from formal decision-making processes (Harlan et al., 2013). This perspective underscores that climate vulnerability is socially constructed and politically mediated, rather than being merely an outcome of biophysical exposure.

Adaptation has emerged as a central response to climate vulnerability. Defined broadly, adaptation refers to adjustments in natural or human systems in response to actual or expected climatic stimuli to moderate harm or exploit beneficial opportunities (Smit et al., 2000). Adaptation in Bangladesh has taken diverse forms, ranging from infrastructural measures such as cyclone shelters and embankments to community-based strategies like rainwater harvesting, crop diversification, and mangrove restoration (Huq and Ayers, 2008; Pouliotte et al., 2009). Scholars distinguish between reactive adaptation, undertaken after climate impacts are felt, and anticipatory adaptation, which is proactive and planned in advance (Burton et al., 2002). In practice, both forms are evident in Bangladesh: households often cope reactively with floods through temporary migration, while the government invests in anticipatory measures such as the Cyclone Preparedness Programme and the Bangladesh Climate Change Strategy and Action Plan. Importantly, adaptation is not a neutral process but one that is shaped by power relations, resource distribution, and institutional priorities. This recognition has led to growing emphasis on socially just adaptation, which seeks to ensure that marginalized groups, including women and the poor, are not excluded from adaptation benefits (Ribot, 2014).

While adaptation is indispensable, it is not sufficient without attention to mitigation. Mitigation refers to interventions aimed at reducing greenhouse gas emissions or enhancing carbon sinks, thereby addressing the root causes of climate change (IPCC, 2014). Although Bangladesh's contribution to global emissions is negligible, the country has increasingly recognized the co-benefits of low-carbon development pathways, particularly in renewable energy expansion, energy efficiency, and sustainable urban planning (Alam et al., 2020). The interplay between adaptation and mitigation is crucial, as some interventions, such as afforestation or sustainable agriculture, contribute to both. This integrated perspective allows Bangladesh to align national development objectives with global climate goals under frameworks such as the Paris Agreement.

Governance provides the institutional lens through which vulnerability and adaptation are understood and operationalized. Climate governance refers to the processes of decision-making and implementation that shape collective responses to climate change across scales, from local to global (Jordan et al., 2010). In Bangladesh, governance is multi-level, involving national ministries, local governments, international donors, NGOs, and community-based organizations. The Ministry of Environment, Forest and Climate Change leads national strategy development, while local government institutions are increasingly tasked with integrating climate resilience into development planning. Yet, governance challenges are pervasive, including overlapping mandates, fragmented coordination, weak enforcement, and limited inclusion of marginalized voices (Siddiqui et al., 2020). These gaps undermine the effectiveness of climate policy, highlighting the importance of institutional reforms and stronger accountability mechanisms.

Non-state actors also play a significant role in governance. International and national NGOs, community-based organizations, and private sector actors are often at the forefront of implementing adaptation projects, piloting innovations, and mobilizing resources (Pelling, 2011). For instance, NGOs have introduced participatory vulnerability assessments and community-based adaptation initiatives in coastal areas, while the private sector is gradually engaging in renewable energy solutions. The involvement of non-state actors reflects the broader trend of polycentric governance, in which multiple centers of authority interact and overlap, offering potential for innovation but also risks of fragmentation and duplication (Ostrom, 2010).

The conceptual nexus of vulnerability, adaptation, and governance underscores that climate change is not merely an environmental problem but a governance challenge embedded in socio-political systems (Table 2). Vulnerability reveals who is at risk and why; adaptation reflects how societies respond to those risks; and governance determines whose voices count in decision-making and how resources are allocated. For Bangladesh, this triad provides a useful analytical framework to evaluate institutional responses, identify governance deficits, and chart pathways for strengthening resilience. By situating vulnerability within social structures, adaptation within equity considerations, and governance within institutional capacity, this framework enables a comprehensive understanding of the country's climate challenges and the necessary pathways for sustainable and just responses.

Table 2. Key Concepts in Climate Change Governance

Concept	Definition (Scholarly)	Relevance for Climate Action in Bangladesh	Governance Implications
Vulnerability	Degree to which a system is susceptible to, or unable to cope with, adverse climate impacts (IPCC, 2001; Adger, 2006).	High in coastal zones (cyclones, salinity), drought-prone Barind areas, and among urban poor populations.	Requires context-specific interventions targeting social inequities, resource access, and institutional support.
Adaptation	Adjustments in natural or human systems to reduce harm or exploit beneficial opportunities (Smit & Wandel, 2006).	Evident in cyclone shelters, stress-tolerant crops, rainwater harvesting, and community-based adaptation.	Calls for mainstreaming adaptation into sectoral policies, scaling local innovations, and ensuring inclusivity.
Mitigation	Efforts to reduce greenhouse gas emissions or enhance carbon sinks (IPCC, 2014).	Bangladesh contributes <0.5% of global emissions, yet pursues renewable energy, afforestation, and efficiency.	Integration of low-carbon strategies with development goals; leveraging co-benefits in agriculture and urban planning.
Multi-level Governance	Decision-making distributed across international, national, and sub-national actors (Jordan et al., 2010; Ostrom, 2010).	Seen in global–local linkages: UNFCCC negotiations, national policies (BCCSAP), and local disaster committees.	Demands coordination, accountability, and vertical integration across scales to avoid fragmentation.
Polycentricity	Overlapping centers of authority and action that foster innovation but risk duplication (Ostrom, 2010).	Evident in NGO, donor, private sector, and government projects on adaptation and resilience.	Needs strong coordination mechanisms to harmonize diverse actors and ensure sustainability of interventions.

4. INSTITUTIONAL RESPONSES IN BANGLADESH

Bangladesh has developed a diverse array of institutional responses to address the growing threat of climate change, ranging from national-level ministries and specialized agencies to local government bodies, donor-supported financial mechanisms, and an active network of non-state actors. These institutional arrangements reflect both the urgency of climate impacts and the recognition that climate resilience requires an integrated, multi-sectoral response. Yet they also reveal gaps in coordination, accountability, and resource mobilization that constrain the effectiveness of interventions. Understanding these institutional dynamics is critical to evaluating Bangladesh's climate governance and identifying pathways for reform.

4.1 National Institutions

At the national level, climate governance in Bangladesh is led by the Ministry of Environment, Forest and Climate Change (MoEFCC), which serves as the focal ministry for the United Nations Framework Convention on Climate Change (UNFCCC) and coordinates national climate policy. The MoEFCC played a central role in formulating the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009, which remains a cornerstone policy framework for climate action in the country. The strategy outlines six pillars of intervention, including food security, social protection and health, infrastructure, mitigation and low-carbon development, research and knowledge management, and institutional strengthening (MoEFCC, 2009). The ministry has also overseen the preparation of National Adaptation Programmes of Action (NAPAs) and the National Adaptation Plan (NAP), aligning Bangladesh's domestic priorities with global frameworks such as the Paris Agreement (Alam et al., 2020). However, the MoEFCC often faces challenges of limited staffing, technical expertise, and financial resources, which hinder its ability to coordinate effectively across multiple ministries (Siddiqui et al., 2020).

The Department of Environment (DoE), under the MoEFCC, is responsible for implementing environmental regulations and conducting environmental impact assessments (EIAs). The DoE has developed guidelines for integrating climate change into EIAs and has promoted pollution monitoring and control. Despite these initiatives, the department suffers from weak enforcement capacity and limited monitoring infrastructure, leading to gaps in ensuring that development projects are climate-sensitive and environmentally sustainable (Rahman et al., 2018).

Beyond the MoEFCC and DoE, other line ministries are crucial to climate governance. The Ministry of Disaster Management and Relief (MoDMR) has a long history of managing natural hazards, particularly through the Cyclone Preparedness Programme (CPP), which is globally recognized for saving lives during cyclones (Paul, 2009). The MoDMR has also integrated disaster risk reduction with climate adaptation, emphasizing early warning systems, emergency shelters, and community-based disaster management committees (Mallick et al., 2011). Nevertheless, the ministry's disaster-focused mandate often overshadows long-term resilience planning, creating a reactive rather than proactive institutional culture.

The Ministry of Agriculture (MoA) has been increasingly engaged in promoting climate-smart agriculture (CSA). Through the development of stress-tolerant crop varieties, dissemination of adaptive farming techniques, and strengthening of extension services, the MoA has attempted to cushion the agricultural sector from the adverse effects of salinity, drought, and flooding (Sikder, 2010; Alam et al., 2020). However, resource limitations and weak coordination with research institutions and local governments often constrain the reach of CSA programs. Similarly, the Ministry of Water Resources (MoWR) is tasked with managing the country's extensive water systems, including flood control, drainage, irrigation, and riverbank protection. Large-scale projects such as embankments and polders have provided critical protection against flooding and saline intrusion, though they have also been criticized for unintended consequences such as waterlogging, ecosystem disruption, and inequitable access (Hossain, 2010). The MoWR's activities highlight the tensions between infrastructural approaches to climate adaptation and the need for integrated water resource management (IWRM).

Despite these initiatives, one of the persistent challenges at the national level is inter-ministerial fragmentation. Overlapping mandates, insufficient coordination, and competition for resources among ministries often lead to duplication of efforts and inefficiencies in implementation (Khan et al., 2019). While the MoEFCC is formally designated to provide leadership, its limited authority relative to more powerful ministries, such as agriculture, water resources, and finance, dilutes its influence. Consequently, climate change remains partially mainstreamed rather than fully integrated into national development planning.

4.2 Local Government and Decentralized Responses

Local government institutions (LGIs) play a critical role in translating national climate strategies into context-specific interventions. Union parishads, upazila parishads, municipalities, and city corporations are the frontline actors in delivering public services, coordinating disaster preparedness, and engaging communities in adaptation initiatives. These institutions are often the first responders to climate-induced disasters, providing relief and mobilizing local resources. For instance, city corporations in coastal cities such as Khulna and Barisal have integrated climate resilience into urban development plans, including drainage improvement, road elevation, and the development of protective embankments (Khan et al., 2020).

However, the capacity of LGIs to address climate change is constrained by structural and financial limitations. Local governments in Bangladesh remain heavily dependent on central government allocations, with limited autonomy to mobilize revenue for climate initiatives (Shah and Shah, 2006). This dependency restricts their ability to plan and implement proactive adaptation measures. Moreover, technical expertise in climate risk assessment, project design, and monitoring is often lacking at the local level, resulting in reliance on donor-funded projects and NGOs for implementation (Haque et al., 2019). The absence of systematic integration of climate change into local development planning further weakens the effectiveness of decentralized responses.

Community-based disaster management committees (CBDMCs) and local volunteer networks have demonstrated the potential of decentralized governance, particularly in cyclone-prone areas where early warning dissemination and evacuation have saved lives. Yet, these initiatives are unevenly distributed across regions, with more donor presence in coastal areas compared to drought-prone inland regions such as Rajshahi and the Barind Tract (Green News BD, 2018). This unevenness reflects broader challenges of equity and inclusiveness in climate governance, whereby localized vulnerabilities are not always matched by proportional institutional attention and resources.

4.3 Climate Finance Mechanisms

Financing adaptation and mitigation has emerged as a central pillar of Bangladesh's climate governance. Recognizing the inadequacy of donor dependency, the government established the Bangladesh Climate Change Trust Fund (BCCTF) in 2009, financed through national budgetary allocations. This fund was designed to support projects aligned with the BCCSAP, ranging from infrastructure development to capacity-building and research (MoEFCC, 2009). Between 2009 and 2017, the BCCTF allocated more than US$400 million to over 400 projects (Khan et al., 2019). While the fund reflects strong political commitment, concerns have been raised about project selection, transparency, and accountability, with some studies pointing to misallocation and politicization (Alam et al., 2020).

In parallel, the Bangladesh Climate Change Resilience Fund (BCCRF) was established in 2010 as a multi-donor trust fund, supported by the World Bank, UK, EU, and other partners. The BCCRF sought to harmonize donor contributions and channel them into resilience-building projects, particularly those benefiting vulnerable communities (World Bank, 2012). However, bureaucratic complexities and donor-government tensions limited the fund's effectiveness, and its operations gradually declined. These experiences highlight the difficulties of aligning national ownership with donor accountability in climate finance.

Bangladesh has also sought to access international climate funds such as the Green Climate Fund (GCF) and the Least Developed Countries Fund (LDCF). Successful projects have included investments in coastal embankments, resilient agriculture, and renewable energy. Yet, accessing these funds requires extensive proposal development and monitoring frameworks, which often exceed the technical capacities of national and local institutions (Siddiqui et al., 2020). Private sector investment in climate finance remains minimal, reflecting the absence of incentives and enabling frameworks for green finance. Thus, while Bangladesh has pioneered domestic climate financing mechanisms, scaling and sustaining these efforts require stronger governance, enhanced transparency, and diversification of funding sources.

4.4 Role of Non-State Actors

Non-state actors, including NGOs, community-based organizations (CBOs), research institutions, and the private sector, have played indispensable roles in advancing climate resilience in Bangladesh (Table 3). International NGOs such as CARE, BRAC, and ActionAid have been instrumental in piloting community-based adaptation (CBA) projects, ranging from the construction of raised homesteads and water-harvesting systems to the promotion of climate-resilient livelihoods (Huq and Ayers, 2008). These initiatives have demonstrated the value of participatory approaches that incorporate local knowledge and priorities, complementing state-led interventions that are often top-down in design.

National NGOs and CBOs have extended these efforts by building local capacities, facilitating access to microfinance, and supporting women's empowerment in adaptation practices (Haque et al., 2019). For instance, community-based water management groups in the Barind region have experimented with water-sharing arrangements and low-cost irrigation technologies to cope with groundwater scarcity. Similarly, women's groups in coastal areas have pioneered salt-tolerant vegetable cultivation and home gardening, strengthening household food security while reducing gender disparities in adaptation.

Research institutions and universities have contributed by generating climate data, modeling future scenarios, and evaluating the effectiveness of adaptation strategies. Their role in linking science with policy has been crucial, though often underutilized due to limited collaboration with government agencies (Alam et al., 2020). The private sector, while less active, has begun to explore renewable energy investments, with solar home systems representing one of the largest decentralized renewable energy programs in the world (Barua, 2017). However, the broader potential of private sector engagement in climate-resilient infrastructure, insurance schemes, and green technologies remains largely untapped.

Despite these achievements, the proliferation of non-state actors has also created challenges. The lack of coordination between NGOs, donors, and government agencies sometimes results in duplication of projects and uneven geographic coverage, with coastal areas receiving disproportionate attention relative to inland drought-affected regions (Shahid and Behrawan, 2008). Moreover, donor dependency raises questions about sustainability, as projects often terminate once external funding ends. Ensuring the scalability and institutionalization of successful community-based initiatives remains a key governance challenge.

Table 3. Mapping Key Climate Institutions and Their Roles

Institution/Actor	Mandate/Role	Key Achievements	Challenges
MoEFCC	National climate policy and international negotiations	BCCSAP (2009), NAPA, NAP preparation	Limited authority, resource and capacity constraints
DoE	Environmental regulation and EIA	Pollution monitoring, EIA guidelines	Weak enforcement, limited technical staff
MoDMR	Disaster risk reduction and management	Cyclone Preparedness Programme, shelters	Reactive focus, resource gaps
MoA	Climate-smart agriculture and food security	Stress-tolerant crops, extension services	Weak coordination, limited coverage
MoWR	Water resources management	Embankments, polders, irrigation	Maintenance issues, ecosystem disruption
LGIs (municipalities, union parishads)	Local service delivery and adaptation planning	Community-based disaster management, drainage improvement	Financial dependency, weak technical expertise
BCCTF & BCCRF	Climate finance mechanisms	Mobilized domestic and donor resources	Transparency and accountability issues
NGOs/CBOs	Community-based adaptation, advocacy	Piloted innovative local projects, women's empowerment	Fragmentation, donor-dependency
Research institutions	Knowledge generation and policy advice	Climate data, modeling, impact studies	Limited integration into policymaking
Private sector	Renewable energy, green technology	Solar home system dissemination	Low investment incentives, weak policy support

5. Sectoral Impacts and Adaptation Challenges

Climate change in Bangladesh manifests across multiple sectors, disrupting agriculture, water resources, health systems, and urban environments. The cross-sectoral nature of these impacts complicates adaptation, as vulnerabilities in one sector often cascade into others. While institutions have attempted to mainstream adaptation into development planning, the extent and effectiveness of sectoral responses remain uneven. Examining the sectoral dimensions of climate change therefore provides insights into the country's adaptive challenges and the pathways required to strengthen resilience.

5.1 Agriculture and Food Security

Agriculture is the backbone of Bangladesh's economy and livelihoods, employing nearly 40 percent of the labor force and contributing significantly to food security (MoA, 2020). However, it is also among the most climate-sensitive sectors. Changes in temperature, rainfall variability, salinity intrusion, flooding, and drought are exerting cumulative stresses on crop production. Evidence suggests that rice yields, which form the staple food of the nation, are highly vulnerable to both drought and flooding. For example, Aman rice, which depends on monsoon rainfall, suffers from erratic precipitation and submergence, while Boro rice, cultivated in the dry season, is increasingly constrained by groundwater depletion and energy-intensive irrigation (Hossain, 2010; Shahid, 2011). Salinity intrusion in the coastal districts of Khulna, Satkhira, and Bagerhat is reducing soil fertility and undermining crop diversity, with farmers shifting to salt-tolerant varieties or abandoning agriculture altogether (Karim and Mimura, 2008).

Climate change also disrupts food security beyond crop yields, affecting fisheries, livestock, and horticulture. Rising water temperatures and salinity shifts alter fish breeding cycles, reducing productivity in both freshwater and coastal aquaculture systems

(Allison et al., 2009). Livestock face heat stress and fodder shortages during prolonged droughts, while fruit and vegetable cultivation is jeopardized by irregular rainfall and increased pest outbreaks. These dynamics translate into reduced household incomes, higher food prices, and heightened risks of malnutrition, particularly among women and children (Hossain, 2010; Begum, 2020).

Adaptation in agriculture has focused on climate-smart agriculture (CSA), including the development of stress-tolerant crop varieties, crop diversification, and conservation agriculture practices (MoA, 2019). Research institutions and NGOs have piloted salt-tolerant rice and drought-resistant wheat, while farmers have adopted floating gardens and mixed cropping in flood-prone areas (Huq and Ayers, 2008). Yet the diffusion of CSA technologies remains limited by weak extension services, inadequate financial support, and the reluctance of farmers to adopt unfamiliar practices without guaranteed returns (Sikder, 2010). Moreover, adaptation efforts tend to be localized pilot projects rather than scaled-up programs, creating uneven access across regions. These gaps highlight the pressing need for sustained investments, institutional support, and integration of local knowledge into agricultural adaptation strategies.

5.2 Water Resources

Bangladesh's water resources are increasingly under pressure from climate change, with critical implications for agriculture, health, and livelihoods. The country's dependence on surface and groundwater for irrigation and drinking water makes it highly vulnerable to shifts in precipitation, river flows, and salinity intrusion. The northwest Barind Tract has witnessed a sharp decline in groundwater levels due to over-extraction, compounded by reduced rainfall and prolonged droughts (Shahid and Behrawan, 2008). Farmers in Rajshahi and Chapai Nawabganj have faced irrigation crises, forcing them to abandon high-yielding crops or switch to less water-intensive varieties. This has not only reduced productivity but also exacerbated rural poverty (Green News BD, 2018).

Coastal water systems face distinct challenges. Rising sea levels and tidal surges are increasing salinity in rivers and aquifers, contaminating drinking water supplies and reducing agricultural viability (Dasgupta et al., 2014). Women and children in coastal communities often travel long distances to collect fresh water, highlighting the gendered burdens of water stress. In urban areas, waterlogging caused by heavy rainfall and poor drainage disrupts livelihoods, contaminates water sources, and increases the incidence of waterborne diseases such as diarrhea and cholera (Khan et al., 2020). Riverbank erosion, another climate-induced hazard, displaces thousands of households annually, further compounding pressures on water availability and settlement patterns (Islam and Winkel, 2017).

Adaptation in the water sector has centered on infrastructural measures such as embankments, polders, and flood control projects, alongside community-based rainwater harvesting and small-scale irrigation schemes (MoWR, 2018). While embankments provide protection, they also create long-term ecological and social trade-offs, including waterlogging, siltation, and inequitable distribution of benefits (Hossain, 2010). Community-based approaches such as pond sand filters and rainwater harvesting have shown promise in addressing drinking water scarcity but remain limited in scale and sustainability (Mallick et al., 2011). These challenges underscore the need for integrated water resource management (IWRM) that balances infrastructural development with ecosystem restoration and community empowerment.

5.3 Health and Livelihoods

The health impacts of climate change in Bangladesh are profound, with both direct and indirect consequences for morbidity and mortality. Rising temperatures contribute to heat stress, particularly among the elderly, children, and outdoor laborers. Heat waves in the northwestern regions, including Rajshahi and Khulna, have been linked to increased hospital admissions and heat-related deaths (Begum, 2020). Extreme weather events, such as cyclones and floods, cause injuries, deaths, and psychological trauma while disrupting healthcare delivery systems. Vector-borne diseases such as dengue, malaria, and chikungunya are expanding due to changing rainfall and temperature patterns that influence mosquito breeding habitats (Ahsan, 2010).

Waterborne diseases remain pervasive, particularly in flood-prone and waterlogged areas. Outbreaks of diarrhea, dysentery, and skin infections often follow major flooding events, overwhelming healthcare facilities (Ahmed et al., 2009). Salinity intrusion in coastal areas has also been linked to hypertension and reproductive health complications among women (Khan et al., 2019). The nutritional implications of climate change are equally concerning, as declining crop yields and fisheries productivity increase food insecurity and malnutrition, particularly among children (Ericksen et al., 1994).

Livelihood impacts are equally severe, as climate change erodes income opportunities across sectors. Farmers, fishers, and agricultural laborers are increasingly exposed to livelihood insecurity, leading to seasonal or permanent migration. Migration from climate-affected coastal areas to urban centers such as Dhaka and Chattogram is straining housing, services, and labor markets, creating new urban vulnerabilities (Islam, 2006). Women and marginalized groups often face compounded challenges, as they are more likely to rely on informal or climate-sensitive livelihoods and have less access to adaptation resources (Yamin et al., 2005). While social protection programs such as food-for-work and cash transfers provide temporary relief, they are insufficient to address the long-term structural drivers of livelihood vulnerability (Alam et al., 2020).

Adaptation in the health and livelihood sectors has included awareness campaigns, early warning systems, mobile health clinics, and the promotion of diversified income sources. However, these initiatives are often fragmented, project-based, and inadequately funded. The health system remains under-resourced and poorly equipped to handle climate-induced disease burdens, while livelihood diversification is constrained by limited access to credit, training, and markets. Addressing these gaps requires systemic investments in healthcare infrastructure, targeted support for vulnerable groups, and the integration of health and livelihood considerations into broader climate planning.

5.4 Urban Climate Challenges

Urbanization in Bangladesh is accelerating, with more than 40 percent of the population projected to live in cities by 2030 (BBS, 2020). This demographic shift amplifies the intersection between climate change and urban vulnerabilities. Urban areas face multiple climate-induced hazards, including flooding, waterlogging, heat stress, and air pollution. Dhaka, one of the fastest-growing megacities in the world, experiences recurrent flooding due to heavy rainfall combined with inadequate drainage and encroachment on wetlands (Khan et al., 2020). Similar challenges are evident in Chattogram, where hilly areas face landslides triggered by intense rainfall, and in Rajshahi, where heat waves exacerbate public health risks (Begum, 2020).

The urban heat island effect is an emerging challenge, intensifying heat stress among low-income populations living in poorly ventilated housing without access to cooling systems (Harlan et al., 2013). Informal settlements are particularly exposed, as they are often located in low-lying or environmentally fragile areas and lack access to adequate water, sanitation, and health services (Klanenberg, 2015). Climate-induced migration from rural areas further adds to the pressures on urban infrastructure, employment, and housing, generating new forms of urban poverty.

Adaptation responses in cities include drainage improvements, elevated road construction, urban greening, and the establishment of community shelters. City corporations in Khulna and Barisal have developed climate-resilient infrastructure projects with donor support, while Dhaka has piloted green roof initiatives and urban tree planting to mitigate heat stress (Khan et al., 2019). Yet these initiatives remain fragmented and limited in scope. Urban climate governance is weakened by institutional overlaps, lack of coordination between planning agencies, and insufficient financing for climate-resilient infrastructure (Alam et al., 2020). Moreover, urban planning often prioritizes short-term development goals over long-term climate resilience, perpetuating vulnerabilities.

Table 4. Climate Impacts across Sectors in Bangladesh

Sector	Climate Threats	Adaptive Responses	Gaps and Challenges
Agriculture	Droughts, floods, salinity, irregular rainfall	Stress-tolerant crops, floating gardens, crop diversification	Limited extension services, uneven adoption, financing constraints
Water	Groundwater depletion, salinity intrusion, flooding, erosion	Embankments, rainwater harvesting, irrigation schemes	Waterlogging, ecosystem disruption, limited scalability
Health	Heat stress, vector- and waterborne diseases, malnutrition	Early warning, mobile clinics, social protection	Under-resourced health system, fragmented interventions
Livelihoods	Crop loss, fishery decline, migration pressures	Diversified income sources, microfinance	Limited access to credit, weak market integration
Urban	Flooding, waterlogging, heat islands, landslides	Drainage upgrades, green roofs, shelters	Institutional fragmentation, inadequate planning, weak finance

6. Governance Gaps and Institutional Challenges

The persistence of climate vulnerability in Bangladesh, despite significant institutional and policy innovations, underscores the structural governance gaps that undermine effective adaptation and mitigation. Governance challenges are deeply intertwined with the socio-political and institutional fabric of the country, shaping how climate policies are designed, implemented, and evaluated. These challenges span across multiple scales, from national policy frameworks to local government actions, and intersect with the very sectoral vulnerabilities highlighted in Table 4, where agriculture, water, health, livelihoods, and urban systems remain exposed despite targeted interventions (Table 4). Understanding these governance gaps is therefore essential for identifying the institutional bottlenecks that continue to limit the resilience of Bangladesh.

One of the most pressing governance gaps lies in the fragmentation of policy and institutional responsibilities. Multiple ministries share overlapping mandates on climate-related issues, including the Ministry of Environment, Forest and Climate Change (MoEFCC), the Ministry of Agriculture (MoA), the Ministry of Water Resources (MoWR), and the Ministry of Disaster Management and Relief (MoDMR). Although the MoEFCC is formally designated as the lead institution for climate governance, it often lacks the authority

and resources to coordinate across more powerful sectoral ministries (Khan et al., 2019). This imbalance weakens the integration of climate adaptation into core development planning. For instance, while the MoA has advanced climate-smart agriculture initiatives, weak coordination with extension services and research institutes has hampered their diffusion, reflecting how institutional fragmentation translates into sectoral gaps in agriculture (Sikder, 2010). Similarly, the MoWR's focus on large-scale embankment projects often proceeds without adequate consultation with the MoEFCC or local governments, leading to unintended ecological consequences such as waterlogging and reduced soil fertility (Hossain, 2010).

Another critical challenge is the limited capacity of local government institutions (LGIs) to implement climate adaptation. Municipalities, city corporations, and union parishads are the frontline actors in responding to localized climate impacts, yet they remain heavily dependent on central government allocations and donor-driven projects (Shah and Shah, 2006). This dependency not only restricts financial autonomy but also delays timely responses to climate shocks. In urban areas, where drainage failure, flooding, and heat islands are intensifying, city corporations often lack the financial and technical resources to implement large-scale climate-resilient infrastructure (Khan et al., 2020). The gaps in local governance directly mirror the vulnerabilities outlined in Table 4, where urban adaptation measures such as drainage upgrades and green roofs are insufficiently implemented due to fragmented planning and inadequate finance. The mismatch between responsibilities and resources at the local level thus represents a major institutional bottleneck.

Financial constraints more broadly represent a systemic governance challenge. Although Bangladesh has pioneered domestic mechanisms such as the Bangladesh Climate Change Trust Fund (BCCTF), transparency and accountability concerns have undermined its credibility (Alam et al., 2020). International climate finance, including the Bangladesh Climate Change Resilience Fund (BCCRF), has also been hindered by bureaucratic delays and donor-government tensions. Accessing global funds such as the Green Climate Fund (GCF) requires technical expertise in project design and monitoring that many national and local institutions lack (Siddiqui et al., 2020). As a result, climate finance often remains project-based, short-term, and donor-driven, limiting sustainability. This pattern is particularly evident in the water sector, where rainwater harvesting and small-scale irrigation projects are piloted by NGOs but rarely scaled up due to limited and inconsistent funding. The financing gap not only slows down adaptation but also perpetuates geographic inequities, as coastal regions with donor presence receive more resources than drought-prone inland areas (Shahid and Behrawan, 2008).

Weak enforcement of regulations further compounds governance challenges. The Department of Environment (DoE) is tasked with ensuring environmental compliance through tools such as environmental impact assessments (EIAs). However, limited staffing, technical expertise, and political influence often weaken enforcement capacity (Rahman et al., 2018). Development projects, including industrial expansion and urban construction, frequently proceed without adequate climate risk assessments, exacerbating vulnerabilities. For example, unregulated urban expansion into wetlands has intensified flooding and waterlogging in Dhaka, undermining urban resilience measures outlined in Table 4. The absence of robust monitoring and accountability mechanisms creates a governance environment where short-term economic gains often outweigh long-term climate resilience.

Inclusion and equity also remain significant governance challenges. Climate change disproportionately affects marginalized groups, such as women, the poor, and ethnic minorities, yet their voices are often underrepresented in policy design and implementation (Adger, 2006; Yamin et al., 2005). Community-based adaptation projects have demonstrated the potential of participatory approaches, but these initiatives are not systematically integrated into national or local planning. For example, women's groups in coastal areas have pioneered salt-tolerant vegetable cultivation, directly addressing agricultural vulnerabilities identified in Table 4, yet such grassroots innovations rarely receive institutional support for scaling. This exclusionary tendency risks reinforcing social vulnerabilities and undermines the legitimacy of governance responses.

The gap between science and policy further constrains effective climate governance. Research institutions and universities in Bangladesh have produced valuable data on climate projections, vulnerability assessments, and adaptation options (Alam et al., 2020). However, this knowledge often remains underutilized due to weak linkages between researchers and policymakers. Climate policy is frequently shaped by donor priorities or political considerations rather than empirical evidence, resulting in mismatches between adaptation needs and interventions. For instance, while scientific studies highlight groundwater depletion in the Barind region as a pressing threat, national adaptation resources continue to prioritize coastal embankments, leaving inland drought-prone areas underfunded (Green News BD, 2018). Bridging this science-policy divide is essential for ensuring that adaptation strategies are evidence-based and context-specific.

Finally, the proliferation of non-state actors, while valuable in piloting innovations and mobilizing communities, has introduced its own governance challenges. NGOs and CBOs often operate independently of government structures, leading to duplication, inefficiency, and uneven geographic coverage (Pelling, 2011). Projects are frequently donor-driven and time-bound, raising questions about sustainability once external funding ends. Moreover, the absence of robust coordination mechanisms between NGOs, donors, and government agencies limits the institutionalization of successful practices. For example, while NGOs have introduced community-based water management systems in the Barind region, these remain isolated initiatives rather than being mainstreamed into national

water policies. The challenges of coordination, sustainability, and integration reflect the difficulties of polycentric governance, where multiple actors with overlapping authority coexist without strong mechanisms of alignment (Ostrom, 2010).

Taken together, these governance gaps create a paradoxical situation in Bangladesh. On one hand, the country has established pioneering policy frameworks, mobilized domestic climate finance, and gained international recognition for disaster preparedness. On the other, fragmented institutions, weak enforcement, financial dependency, inequitable participation, and limited integration of science continue to undermine resilience. The sectoral vulnerabilities summarized in Table 4, spanning agriculture, water, health, livelihoods, and urban systems, are thus less a reflection of inadequate awareness than of systemic governance challenges. Addressing these gaps will require not only technical solutions but also institutional reforms that enhance coordination, accountability, inclusiveness, and long-term financing. Without such reforms, Bangladesh risks remaining trapped in a cycle of reactive adaptation, where each climate shock is met with short-term responses rather than sustained resilience-building.

7. PATHWAYS FOR STRENGTHENING ADAPTATION AND MITIGATION

Bangladesh's climate future depends not only on the severity of global warming but also on the ability of its governance institutions to close existing gaps and strengthen adaptive and mitigative capacities. The institutional challenges outlined earlier demonstrate that while policy frameworks exist, they often lack operational coherence, accountability, and long-term sustainability. Moving beyond fragmented interventions requires the articulation of clear pathways that align governance reforms with sectoral needs, finance mechanisms, and community-based innovation. These pathways must integrate both adaptation and mitigation, recognizing the dual imperatives of reducing vulnerability while simultaneously addressing emission sources and environmental degradation. Table 5 synthesizes potential pathways for strengthening adaptation and mitigation across key sectors, highlighting the governance actions required for their effective implementation.

A central pathway involves mainstreaming climate adaptation into national development planning. Although Bangladesh has introduced policies such as the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) and the National Adaptation Plan (NAP), these frameworks often operate parallel to sectoral development agendas (Alam et al., 2020). Stronger integration is needed to ensure that agricultural modernization, urban planning, and water management are inherently climate-sensitive. For example, incorporating climate-smart agriculture into the national food security strategy would facilitate the diffusion of salt-tolerant and drought-resistant crop varieties, directly reducing sectoral vulnerabilities noted in Table 5. Similarly, embedding climate risk assessments into infrastructure planning would prevent maladaptation, such as the construction of embankments that exacerbate waterlogging. The mainstreaming approach requires not only technical guidelines but also institutional reforms that empower the Ministry of Environment, Forest and Climate Change (MoEFCC) to play a coordinating role across ministries.

Another pathway concerns strengthening local government capacity. Decentralization remains an untapped resource for climate resilience, as local governments are closest to the populations most affected by climate impacts. Providing fiscal autonomy and technical training to city corporations, municipalities, and union parishads would enable them to implement locally tailored adaptation measures (Khan et al., 2020). Urban climate challenges, such as flooding and heat stress, can only be addressed through locally driven solutions like improved drainage, urban greening, and resilient housing programs. As Table 5 illustrates, decentralization not only enhances sectoral responsiveness but also allows for participatory governance, where communities are actively involved in identifying priorities and monitoring outcomes. However, decentralization must be accompanied by safeguards against elite capture and corruption, necessitating robust accountability frameworks.

Financing mechanisms also form a critical pathway for enhancing adaptation and mitigation. While Bangladesh has mobilized domestic resources through the Climate Change Trust Fund, ensuring transparency and efficiency in fund allocation remains a challenge (Alam et al., 2020). Future pathways must expand innovative financing, such as green bonds, climate insurance schemes, and public–private partnerships, to supplement donor contributions. Direct access modalities to international funds like the Green Climate Fund (GCF) should be prioritized, supported by building technical capacity in proposal development and monitoring. Sector-specific financing, as reflected in Table 5, is essential to ensure that agriculture, health, water, and urban systems receive tailored investment packages. For instance, agriculture requires investments in resilient seed research, while urban areas demand financing for low-carbon transport and green infrastructure. Linking adaptation financing with co-benefits for mitigation, such as promoting renewable energy in irrigation, creates synergies that maximize returns.

A further pathway is improving knowledge integration and science–policy linkages. Although research institutions in Bangladesh have produced extensive data on climate change, the translation of this knowledge into policy remains inconsistent (Siddiqui et al., 2020). Strengthening platforms for science–policy dialogue, such as climate knowledge hubs and stakeholder forums, would enhance evidence-based decision-making. Real-time climate data should inform early warning systems, crop planning, and disease surveillance, addressing vulnerabilities across agriculture, water, and health sectors. Table 5 emphasizes that knowledge integration is not only about producing new research but also about ensuring that local and indigenous knowledge systems are valued. For example, coastal communities' knowledge of saline agriculture and indigenous water harvesting techniques can provide low-cost, contextually relevant adaptation models.

Equity and inclusion also form indispensable pathways for sustainable adaptation. Governance must deliberately address the differential impacts of climate change on marginalized groups, including women, the poor, and ethnic minorities (Adger, 2006). Inclusive decision-making structures, gender-responsive budgeting, and targeted social protection schemes can ensure that adaptation benefits are equitably distributed. Table 5 highlights that gender-sensitive adaptation in agriculture, health, and livelihoods not only reduces vulnerability but also builds long-term community resilience. For instance, empowering women in agricultural extension services strengthens household food security while expanding adaptive capacity. Without deliberate inclusion, climate interventions risk reinforcing existing inequalities, thereby weakening resilience at both household and societal levels.

Finally, non-state actors, including NGOs, community-based organizations, and the private sector, must be systematically integrated into national adaptation and mitigation strategies. Their innovative approaches, ranging from community-based disaster preparedness to private sector investment in renewable energy, demonstrate the potential of polycentric governance (Pelling, 2011; Ostrom, 2010). The challenge lies in institutionalizing these contributions into policy frameworks rather than leaving them as isolated pilot projects. As Table 5 indicates, scaling up successful NGO interventions, such as micro-insurance schemes for farmers or decentralized solar energy systems, can fill gaps left by the state. Creating multi-stakeholder platforms that foster coordination between government, NGOs, donors, and the private sector would enhance synergy and reduce duplication.

Taken together, these pathways suggest that strengthening adaptation and mitigation in Bangladesh requires a systemic transformation of governance structures, financial instruments, and participatory mechanisms. Climate resilience cannot be achieved through fragmented interventions; rather, it requires a coherent strategy that bridges sectors, scales, and actors. Table 5 provides a synthesis of how pathways align with sectoral challenges, illustrating that effective governance reforms must simultaneously address technical, financial, and social dimensions. By institutionalizing these pathways, Bangladesh can transition from reactive adaptation to proactive resilience-building, ensuring that climate change becomes not only a challenge but also a catalyst for sustainable transformation.

Table 5. Pathways for Strengthening Adaptation and Mitigation Across Sectors in Bangladesh

Sector	Key Climate Impacts (from Table 4)	Adaptation Pathways	Mitigation Co-Benefits	Governance/Institutional Actions
Agriculture	Salinity, drought, flood-induced crop loss	Climate-smart agriculture, resilient seeds, irrigation innovation	Reduced methane from rice, renewable energy for irrigation	Integrate CSA into MoA programs; scale NGO pilots
Water Resources	Scarcity, flooding, groundwater depletion	Rainwater harvesting, integrated water resource management	Energy-efficient pumping systems	Empower MoWR & LGIs; strengthen basin-level planning
Health	Heat stress, vector-borne diseases, malnutrition	Early warning systems, climate-sensitive health infrastructure	Reduced hospital energy use via solar systems	Mainstream health-climate link in MoHFW strategies
Livelihoods	Coastal displacement, income loss, informal sector vulnerability	Livelihood diversification, micro-insurance, migration planning	Low-carbon livelihoods (solar SMEs, eco-tourism)	Gender-sensitive social protection, NGO–govt partnerships
Urban Systems	Flooding, drainage failure, urban heat islands	Green infrastructure, resilient housing, low-carbon transport	Emissions reduction in transport & housing	Fiscal autonomy for city corporations; enforce urban climate plans

8. CONCLUSION

Climate change represents an existential challenge for Bangladesh, a country already struggling with high population density, poverty, and environmental degradation. The preceding analysis has demonstrated that Bangladesh is uniquely vulnerable to both sudden-onset hazards such as cyclones and floods and slow-onset processes including salinity intrusion, groundwater depletion, and urban heat stress. These impacts cut across critical sectors such as agriculture, water resources, health, and urban systems, threatening not only development gains but also the very sustainability of livelihoods. As the literature and empirical evidence consistently underscore, climate change in Bangladesh is not merely a biophysical phenomenon but one deeply embedded in governance structures, socio-economic inequalities, and institutional capacities.

The country has taken significant steps to address these vulnerabilities through institutional innovations and policy frameworks. The Bangladesh Climate Change Strategy and Action Plan (BCCSAP) and subsequent national adaptation programs illustrate the government's recognition of climate risks and its commitment to proactive responses. Domestic financing mechanisms such as the Bangladesh Climate Change Trust Fund (BCCTF) have further signaled political will, while non-state actors including NGOs and research institutions have piloted innovative community-based adaptation strategies. At the global level, Bangladesh has emerged as a vocal advocate for climate justice, consistently emphasizing the disproportionate burdens borne by low-emission countries in international negotiations.

Yet these achievements are tempered by persistent governance gaps. Fragmented mandates across ministries, weak coordination, and insufficient enforcement undermine the coherence of climate policy. Local governments, which are best positioned to implement adaptation at the community level, lack the financial autonomy and technical capacity necessary to deliver meaningful results. Climate finance, though mobilized domestically and internationally, remains constrained by issues of transparency, donor dependency, and inequitable distribution. Knowledge produced by research institutions often remains disconnected from policy, while community-based innovations are rarely scaled up due to institutional inertia. These gaps explain why sectoral vulnerabilities, such as those in agriculture and water resources, remain acute despite decades of interventions.

The analysis in this manuscript highlights the centrality of governance in shaping the success or failure of climate action. Vulnerability in Bangladesh is not solely a matter of exposure to natural hazards but a function of adaptive capacity, which is in turn determined by the effectiveness of institutions, the inclusiveness of decision-making, and the adequacy of resource mobilization. For example, the continued challenges of salinity intrusion in coastal agriculture are not just ecological problems but governance problems tied to water management, agricultural extension, and transboundary river negotiations. Similarly, urban flooding in Dhaka is less a product of rainfall intensity than of unplanned urbanization, weak enforcement of land use regulations, and inadequate drainage management. Recognizing this governance dimension is essential for moving beyond reactive coping strategies toward systemic resilience-building.

The pathways outlined earlier underscore that strengthening adaptation and mitigation requires systemic reforms that cut across sectors and institutions. Mainstreaming climate risks into national development planning, empowering local governments, enhancing climate finance transparency, and improving science–policy linkages are critical for addressing structural deficits. Equally important is the integration of equity and inclusion into adaptation, ensuring that the poorest and most marginalized are not left behind. Evidence from community-based adaptation projects demonstrates that when local voices are integrated, adaptation is more effective, sustainable, and socially just. These lessons suggest that climate governance in Bangladesh must become not only more efficient but also more democratic, participatory, and inclusive.

At the same time, mitigation should not be overlooked. While Bangladesh's contribution to global emissions is negligible, pursuing low-carbon development offers multiple co-benefits, from reducing air pollution in urban areas to promoting energy security through renewables. Investments in solar energy, green infrastructure, and low-carbon transport can simultaneously reduce emissions and build adaptive capacity, creating synergies between the two pillars of climate response. Such co-benefits are essential for aligning national development goals with international commitments under the Paris Agreement.

Looking ahead, Bangladesh's experience offers important lessons for other climate-vulnerable nations. The country demonstrates both the possibilities and limitations of adaptation in resource-constrained settings. Its successes in disaster preparedness, particularly the Cyclone Preparedness Programme, highlight the value of early warning systems and community mobilization. At the same time, the persistence of vulnerabilities despite progressive policies underscores the importance of addressing governance deficits. Bangladesh thus serves as both a model and a cautionary tale: a model in terms of institutional innovation and global advocacy, and a cautionary tale in terms of the difficulties of translating policy ambition into local resilience.

In conclusion, climate change will remain a defining challenge for Bangladesh throughout the twenty-first century. While the risks are immense, they are not insurmountable. By embracing systemic reforms, strengthening institutions, ensuring inclusivity, and fostering innovation, Bangladesh can transform vulnerability into resilience. The challenge is not only to survive in the face of climate change but to chart a development trajectory that is sustainable, equitable, and adaptive. Achieving this transformation requires a shift from reactive responses to proactive governance, where climate resilience is embedded in all aspects of national planning and societal development. If pursued with determination and inclusiveness, these efforts can secure a climate-resilient future for Bangladesh and offer valuable lessons for other nations navigating the turbulent waters of a changing climate.

9. REFERENCES

[1] Adger, W. N. (2006). Vulnerability. Global Environmental Change, 16(3), 268–281.

[2] Ahmed, A. U., & Haque, N. (2002). Climate change and sustainable development: Vulnerabilities and needs of Bangladesh. Proceedings of the OECD Workshop on Climate Change and Development. OECD.

[3] Ahmed, S. A., Diffenbaugh, N. S., & Hertel, T. W. (2009). Climate volatility deepens poverty vulnerability in developing countries. Environmental Research Letters, 4(3), 034004.

[4] Ahsan, M. N. (2010). Heat stress, climate change and human health in Bangladesh. Journal of Bangladesh Health, 2(1), 15–28.

[5] Alam, K., Alam, M., & Huq, S. (2020). National climate change governance in Bangladesh: Institutional arrangements, financing and planning. Routledge.

[6] Allison, E. H., Perry, A. L., Badjeck, M. C., Adger, W. N., Brown, K., Conway, D., … Dulvy, N. K. (2009). Vulnerability of national economies to the impacts of climate change on fisheries. Fish and Fisheries, 10(2), 173–196.

[7] Barua, D. C. (2017). Scaling up renewable energy in Bangladesh: Lessons from solar home systems. Energy Policy, 109, 662–670.

[8] Begum, H. (2020). Climate change, heat stress and health vulnerabilities in Bangladesh. Asian Journal of Environment and Disaster Management, 12(2), 77–92.

[9] Brouwer, R., Akter, S., Brander, L., & Haque, E. (2007). Socioeconomic vulnerability and adaptation to environmental risk: A case study of climate change and flooding in Bangladesh. Risk Analysis, 27(2), 313–326.

[10] Burton, I., Huq, S., Lim, B., Pilifosova, O., & Schipper, E. L. (2002). From impacts assessment to adaptation priorities: The shaping of adaptation policy. Climate Policy, 2(2–3), 145–159.

[11] Dasgupta, S., Hossain, M. M., Huq, M., & Wheeler, D. (2014). Climate change, soil salinity, and the economics of high-yield rice production in coastal Bangladesh. World Bank Policy Research Working Paper No. 7140.

[12] Debsarma, S. K. (2003). Simulated changes in climate over South Asia using regional climate model. Theoretical and Applied Climatology, 76(1–2), 61–78.

[13] Eckstein, D., Künzel, V., & Schäfer, L. (2021). Global Climate Risk Index 2021. Germanwatch.

[14] Ericksen, N. J., Ahmad, Q. K., & Chowdhury, A. R. (1994). Socioeconomic implications of climate change for Bangladesh. Bangladesh Unnayan Parishad (BUP).

[15] Field, C. B., Barros, V., Stocker, T. F., Qin, D., Dokken, D. J., Ebi, K. L., … Midgley, P. M. (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Cambridge University Press.

[16] Germanwatch. (2010). Global Climate Risk Index 2010. Germanwatch.

[17] Green News BD. (2018). Barind region faces deepening water crisis. The Daily Star.

[18] Haque, M. A., Yamamoto, K., Malik, A. A., & Ashikuzzaman, M. (2019). Climate change and local adaptation strategies of shrimp farmers in coastal Bangladesh. Sustainability, 11(23), 6664.

[19] Haque, S. A., Chowdhury, A. K., & Ahmed, A. U. (1992). Climate scenarios for Bangladesh. Climate Research, 2(2), 83–90.

[20] Harlan, S. L., Declet-Barreto, J. H., Stefanov, W. L., & Petitti, D. B. (2013). Neighborhood effects on heat deaths: Social and environmental predictors of vulnerability in Maricopa County, Arizona. Environmental Health Perspectives, 121(2), 197–204.

[21] Hossain, M. (2010). Adaptation measures for sustainable agriculture in Bangladesh under climate change. Environmental Hazards, 9(1), 95–111.

[22] Huq, S., & Ayers, J. (2008). Critical adaptation to climate change: Community-based adaptation in Bangladesh. IDS Bulletin, 39(4), 30–39.

[23] IPCC. (2001). Climate Change 2001: Impacts, Adaptation, and Vulnerability. Cambridge University Press.

[24] IPCC. (2007). Climate Change 2007: Impacts, Adaptation, and Vulnerability. Cambridge University Press.

[25] IPCC. (2014). Climate Change 2014: Synthesis Report. Cambridge University Press.

[26] IPCC. (2021). Climate Change 2021: The Physical Science Basis. Cambridge University Press.

[27] Islam, M. N. (2006). Managing natural disasters in Bangladesh. Natural Hazards, 37(2), 201–223.

[28] Islam, S. N., & Winkel, J. (2017). Climate change and social inequality: The case of Bangladesh. UN DESA Working Paper No. 152.

[29] Jamat, T. (2010). Water scarcity and agricultural challenges in northwestern Bangladesh. Journal of Rural Development, 34(2), 45–63.

[30] Jordan, A., Huitema, D., Van Asselt, H., Rayner, T., & Berkhout, F. (2010). Climate Change Policy in the European Union: Confronting the Dilemmas of Mitigation and Adaptation? Cambridge University Press.

[31] Karim, Z., & Mimura, N. (2008). Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh. Global Environmental Change, 18(3), 490–500.

[32] Karmakar, S., & Shrestha, M. L. (2000). Recent climate changes in Bangladesh. Bangladesh Meteorological Department Report.

[33] Khan, M. R., Ahmed, A. U., & Alam, K. (2019). Institutionalizing climate change in Bangladesh: Learning from two decades of policy and practice. Sustainability, 11(24), 6891.

[34] Khan, S. R., Rahman, M., & Islam, M. M. (2020). Climate change, urbanization and sustainable development in Bangladesh. Environmental Research, 183, 109183.

[35] Klanenberg, F. (2015). Urban heat stress in South Asian cities: Emerging risks and responses. Asian Journal of Urban Environment, 7(1), 51–70.

[36] Mallick, B., Rahaman, K. R., & Vogt, J. (2011). Coastal livelihood adaptation under natural disaster risks in Bangladesh: A case of shrimp farming in Satkhira district. Ocean & Coastal Management, 54(3), 201–211.

[37] Ministry of Agriculture (MoA). (2019). Climate Smart Agriculture Strategy for Bangladesh. Dhaka: Government of Bangladesh.

[38] Ministry of Agriculture (MoA). (2020). Statistical Yearbook of Agriculture 2020. Dhaka: Government of Bangladesh.

[39] Ministry of Environment, Forest and Climate Change (MoEFCC). (2009). Bangladesh Climate Change Strategy and Action Plan. Dhaka: Government of Bangladesh.

[40] Ministry of Environment, Forest and Climate Change (MoEFCC). (2018). Third National Communication of Bangladesh to the UNFCCC. Dhaka: Government of Bangladesh.

[41] Ministry of Water Resources (MoWR). (2018). National Water Policy Implementation Report. Dhaka: Government of Bangladesh.

[42] O'Brien, K., Eriksen, S., Nygaard, L. P., & Schjolden, A. (2007). Why different interpretations of vulnerability matter in climate change discourses. Climate Policy, 7(1), 73–88.

[43] Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. Global Environmental Change, 20(4), 550–557.

[44] Paul, B. K. (2009). Why relatively fewer people died? The case of Bangladesh's Cyclone Sidr. Natural Hazards, 50(2), 289–304.

[45] Pelling, M. (2011). Adaptation to Climate Change: From Resilience to Transformation. Routledge.

[46] Pouliotte, J., Smit, B., & Westerhoff, L. (2009). Adaptation and development: Livelihoods and climate change in Subarnabad, Bangladesh. Climate and Development, 1(1), 31–46.

[47] Rahman, M., Siddiqui, S., & Alam, K. (2018). Environmental regulation and industrial compliance in Bangladesh. Environmental Policy and Governance, 28(2), 90–102.

[48] Ribot, J. (2014). Cause and response: Vulnerability and climate in the Anthropocene. Journal of Peasant Studies, 41(5), 667–705.

[49] Shah, A., & Shah, S. (2006). The new vision of local governance and the evolving roles of local governments. World Bank Policy Research Working Paper 3169.

[50] Shahid, S. (2011). Impact of climate change on irrigation water demand of dry season Boro rice in northwest Bangladesh. Climatic Change, 105(3–4), 433–453.

[51] Shahid, S., & Behrawan, H. (2008). Drought risk assessment in the western part of Bangladesh. Natural Hazards, 46(3), 391–413.

[52] Siddiqui, S., Khan, M. R., & Alam, K. (2020). Climate finance in Bangladesh: Governance, transparency and accountability challenges. Climate Policy, 20(3), 271–286.

[53] Sikder, M. (2010). Farmer perceptions of climate change and adaptation in Bangladesh. Asian Journal of Agriculture and Development, 7(2), 41–55.

[54] Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. Global Environmental Change, 16(3), 282–292.

[55] Smit, B., Burton, I., Klein, R. J. T., & Wandel, J. (2000). An anatomy of adaptation to climate change and variability. Climatic Change, 45(1), 223–251.

[56] World Bank. (2012). Implementation Completion and Results Report on the Bangladesh Climate Change Resilience Fund. Washington, DC: World Bank.

[57] Yamin, F., Rahman, A., & Huq, S. (2005). Vulnerability, adaptation and climate disasters: A conceptual overview. IDS Bulletin, 36(4), 1–14.