International Journal of Applied Research
Journal HP: www.intjar.com; ISSN: 2411-6610

Community-Based Adaptation and Climate Risk Reduction in Bangladesh

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ARTICLE INFO

Article history

Received: 26 April 2025
Accepted: 27 May 2026

Keywords

Climate change, BCCTF, resilience, adaptation, mitigation, Bangladesh, risk management, sustainability, ROAD framework

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ABSTRACT

Bangladesh is recognized as one of the countries most vulnerable to climate change because of its low-lying deltaic geography, high population density, dependence on climate-sensitive livelihoods, and recurring exposure to floods, cyclones, droughts, salinity intrusion, and waterlogging. In response to these challenges, the Government of Bangladesh established the Bangladesh Climate Change Trust Fund (BCCTF) to finance climate adaptation and mitigation initiatives under the Bangladesh Climate Change Strategy and Action Plan (BCCSAP). This study evaluated the sustainability, risk management approaches, and climate resilience outcomes of selected BCCTF-funded projects implemented in climate-vulnerable regions of Bangladesh. A mixed-methods research design was employed using household surveys, focus group discussions (FGDs), key informant interviews (KIIs), case studies, and secondary document analysis. Data were collected from 230 respondents across Sirajganj, Satkhira, and Kushtia districts. The study applied the Risks and Options Assessment for Decision-making (ROAD) framework to assess project implementation, risk reduction strategies, adaptation measures, mitigation interventions, and sustainability mechanisms. Findings indicated that BCCTF-supported projects significantly improved environmental management, food security, renewable energy access, climate-sensitive health resilience, and local adaptive capacity. Solar-powered irrigation systems reduced production costs and greenhouse gas emissions, drainage and water management interventions reduced urban waterlogging, and community health adaptation programs decreased the prevalence of waterborne diseases in flood-prone areas. Despite these achievements, challenges remain regarding long-term institutional sustainability, stakeholder participation, monitoring systems, and community awareness regarding BCCTF initiatives. The study concludes that climate-resilient development in Bangladesh requires integrated governance, strengthened local participation, improved monitoring frameworks, and long-term investment in adaptation and mitigation measures.

1. Introduction

Climate change has emerged as one of the most significant global environmental and developmental challenges of the twenty-first century. Increasing atmospheric concentrations of greenhouse gases (GHGs) have resulted in rising global temperatures, changing precipitation patterns, sea-level rise, and a growing frequency and intensity of extreme weather events such as floods, droughts, cyclones, and heatwaves (IPCC, 2014; IPCC, 2023).

Rising global temperatures, sea-level rise, altered precipitation patterns, and increasing frequency of extreme weather events are affecting ecosystems, economies, food systems, water resources, and public health worldwide (IPCC, 2014). Developing countries are disproportionately vulnerable to these impacts because of limited adaptive capacity, high dependence on climate-sensitive sectors, and socio-economic constraints (Stern, 2007; UNDP, 2022).

Bangladesh is widely recognized as one of the most climate-vulnerable countries in the world due to its unique geographical location, low-lying topography, dense population, and dependence on agriculture and natural resources (Ahmed, 2006; IPCC, 2014). The country is situated within the Ganges–Brahmaputra–Meghna (GBM) delta, one of the largest river deltas globally, where approximately 80% of the land area consists of floodplains (Huq and Ayers, 2007). Approximately 80% of the country consists of floodplains formed by the Ganges, Brahmaputra, and Meghna river systems. Consequently, millions of people remain exposed to recurrent floods, cyclones, storm surges, riverbank erosion, salinity intrusion, droughts, and waterlogging. The interaction of geographic exposure, high population density, poverty, and dependence on climate-sensitive livelihoods further increases the country's

Cite this article: *Raihan, M.M., & Kamal, M.M. (2026). Community-based adaptation and climate risk reduction in Bangladesh. International Journal of Applied Research, 12 (1): 29-42. DOI: 10.5281/zenodo.21054787*

vulnerability to climate change impacts (Islam and Winkel, 2017).

The impacts of climate change in Bangladesh are multidimensional. Rising temperatures and erratic rainfall patterns are reducing agricultural productivity, increasing food insecurity, and threatening water availability (Stern, 2007; Basak et al., 2010; Aryal et al., 2020). Coastal communities face severe salinity intrusion and sea-level rise that threaten freshwater resources, agricultural production, fisheries, and public health (Karim and Mimura, 2008), while northern regions frequently experience drought and heat stress. Urban areas are increasingly affected by drainage congestion, flooding, and infrastructure damage associated with rapid urbanization and climate variability (Rahman et al., 2019).

To address these growing climate risks, the Government of Bangladesh formulated the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009. The BCCSAP provides a comprehensive framework for climate-resilient development through six thematic pillars, including food security, disaster management, infrastructure development, research and knowledge management, mitigation and low-carbon development, and capacity building (MoEF, 2009). As part of this strategy, the Bangladesh Climate Change Trust Fund (BCCTF) was established to finance adaptation and mitigation projects using domestic resources. The BCCTF has funded projects related to disaster management, renewable energy, climate-resilient agriculture, water management, health adaptation, and environmental protection. Since its establishment under the Climate Change Trust Act 2010, the BCCTF has supported hundreds of climate-related projects across vulnerable regions of Bangladesh (BCCTF, 2023).

Although BCCTF-funded projects have contributed substantially to climate adaptation and mitigation, limited empirical studies have comprehensively assessed their effectiveness, sustainability, and risk management mechanisms. Previous studies have emphasized the importance of climate finance, community participation, and locally led adaptation approaches in enhancing resilience outcomes (Huq et al., 2015; Rai et al., 2019). However, systematic evaluations of BCCTF-funded interventions at the community level remain limited, particularly regarding long-term sustainability, risk reduction effectiveness, and institutional resilience. Therefore, this study evaluates selected BCCTF-funded projects to understand their contributions to climate-resilient development in Bangladesh. Using the Risks and Options Assessment for Decision-making (ROAD) framework, the study examines adaptation and mitigation outcomes, stakeholder engagement, sustainability mechanisms, and climate risk management practices to generate evidence-based recommendations for strengthening climate finance governance and resilience planning in Bangladesh.

2. Literature review

2.1. Climate change and vulnerability in Bangladesh

Bangladesh is highly vulnerable to climate change due to its geographical and socio-economic conditions (Huq & Ayers, 2007). Studies indicate that sea-level rise, increased cyclone intensity, and erratic monsoon rainfall threaten food security, livelihoods, and infrastructure (Ali, 1999; Islam & Winkel, 2017). Coastal salinity intrusion has already affected agricultural production and freshwater availability in southwestern Bangladesh.

According to the Intergovernmental Panel on Climate Change (IPCC, 2014), South Asia will experience intensified heat waves, flooding, and climate-related displacement in the coming decades. Bangladesh may lose significant portions of coastal land because of sea-level rise, potentially displacing millions of people.

2.2. Climate-resilient development

Climate-resilient development refers to development processes that simultaneously reduce climate risks, strengthen adaptive capacity, and promote sustainable livelihoods (IPCC, 2022). Resilience frameworks emphasize the ability of communities and systems to absorb disturbances, adapt to changing conditions, and recover from climatic shocks (Folke, 2006).

Adaptation strategies in Bangladesh include climate-resilient agriculture, flood protection infrastructure, renewable energy promotion, water resource management, and community-based disaster preparedness (Huq et al., 2004).

2.3. Bangladesh Climate Change Trust Fund (BCCTF)

The BCCTF was established under the Climate Change Trust Act, 2010, to support climate adaptation and mitigation initiatives in Bangladesh. The fund operates under the Ministry of Environment, Forest and Climate Change and finances projects aligned with the six thematic pillars of the BCCSAP:

- Food security, social protection, and health
- Comprehensive disaster management
- Infrastructure development
- Research and knowledge management
- Mitigation and low-carbon development
- Capacity building and institutional strengthening

Previous studies suggest that BCCTF-funded projects have improved local adaptation capacity; however, concerns remain regarding transparency, sustainability, monitoring, and stakeholder participation (TIB, 2017).

3. Materials and methods

3.1. Study design

A mixed-methods approach integrating quantitative and qualitative methods was used to evaluate selected BCCTF-funded projects. The study combined household surveys, FGDs, KIIs, case studies, and secondary data review.

3.2. Study areas

Three completed BCCTF-funded projects from different thematic sectors were selected:

Project Title	Major Intervention	Study Area
Risk reduction and adaptive measures in the context of climate change impacts on health sector	Health adaptation and climate resilience	Sirajganj
Introduction of solar-powered irrigation pump and power distribution system	Renewable energy and irrigation adaptation	Satkhira
Infrastructural and environmental improvement of Mirpur Pourashava	Urban drainage and waterlogging management	Kushtia

3.3. Sampling procedure and sample size

The study population included beneficiaries of BCCTF-funded projects. A probability sampling approach was employed. Sample size was calculated using a standard statistical formula with 95% confidence level and 5% margin of error.

The final sample size consisted of 230 respondents.

3.4. Data collection methods

Quantitative Methods

- Household surveys using semi-structured questionnaires
- Socio-economic and demographic assessment
- Climate adaptation and livelihood indicators

Qualitative Methods

- Focus Group Discussions (FGDs)
- Key Informant Interviews (KIIs)
- Participatory observation
- Case studies

3.5. Analytical framework

The study applied the Risks and Options Assessment for Decision-making (ROAD) framework to evaluate:

- Climate risks
- Adaptive responses
- Mitigation interventions
- Sustainability mechanisms
- Institutional decision-making

3.6. Data analysis

Quantitative data were analyzed using SPSS software. Descriptive statistics, frequency distributions, and comparative analyses were

conducted. Qualitative data were analyzed through thematic interpretation and triangulation.

4. Results and discussion

4.1. Socio-demographic characteristics of the study population

The socio-demographic characteristics of respondents provide important insights into the adaptive capacity, livelihood conditions, and resilience potential of communities benefiting from BCCTF-funded climate adaptation projects. Variables such as age, gender, education, occupation, and household income influence the ability of individuals and communities to respond to climate-related risks and to benefit from adaptation interventions.

Information was collected from respondents belonging to different age groups ranging from 21 years to above 65 years. Among the respondents, 13.2% were aged between 21–25 years, whereas only 3.1% were aged 65 years and above. The highest proportion of respondents belonged to the 26–30 years age group (15.6%), followed by the 31–35 years age group (14.3%) and the 36–40 years age group (13.9%) (Figure 1A). The predominance of young and middle-aged respondents indicates that economically productive populations constituted the majority of project beneficiaries. These age groups are generally more capable of adopting new technologies, participating in community-based adaptation activities, and implementing climate-resilient livelihood practices. Similar observations have been reported in climate adaptation studies in Bangladesh, where younger and economically active populations demonstrated greater participation in resilience-building initiatives and disaster preparedness programs (Huq and Reid, 2007; Islam et al., 2014).

Regarding gender distribution, male respondents represented 60.3% of the sample, while female respondents accounted for 39.7%. No transgender respondents were identified in the study areas. Although male participation was comparatively higher, the substantial involvement of women indicates that project activities reached both genders. Women's participation is particularly important in climate adaptation because women often play key roles in household food security, water management, caregiving, and disaster response. Previous studies have shown that gender-inclusive adaptation programs enhance community resilience and contribute to more sustainable development outcomes (Ayers and Huq, 2009; UN Women, 2022). The relatively high representation of female respondents suggests that BCCTF-supported interventions promoted broader community engagement in adaptation processes.

Education was identified as an important determinant of adaptive capacity and awareness regarding climate change. The educational profile of respondents revealed that the largest proportion (20.8%) had completed higher secondary education (Grades 11–12), followed by 19.5% who had attained secondary education (Grades 6–10). The presence of a relatively educated population may have facilitated awareness of climate risks, participation in project activities, and adoption of adaptation measures. Education enhances access to information, strengthens decision-making capacity, and improves the ability to respond to environmental changes (Muttarak and Lutz, 2014). Therefore, the educational status of respondents likely contributed to the successful implementation of project interventions and the sustainability of adaptation outcomes.

Although religion was not a primary focus of the study, efforts were made to include respondents from different religious backgrounds. The majority of respondents were Muslim (78.2%), followed by Hindu respondents (20.6%), while Christians accounted for only 1.2% of the sample and were exclusively located in Satkhira district. No Buddhist respondents were identified during the survey. This distribution generally reflects the demographic characteristics of the selected project areas. The participation of different religious communities suggests that BCCTF-funded interventions were accessible across diverse social groups. Social inclusion and community cohesion are widely recognized as important components of resilience-building and collective adaptation efforts in climate-vulnerable regions (Adger, 2003).

Occupation was found to be an important factor in understanding livelihood diversification and community empowerment resulting from project interventions. Respondents were engaged in a wide range of occupations, including farming, day labor, fishing, rickshaw pulling, agricultural labor, begging, small trading, NGO service, government service, religious service, and honey collection. Before project implementation, agriculture was the dominant occupation, involving 27.4% of

respondents. However, this proportion declined slightly to 24.2% after project implementation (Figure 1B). Conversely, participation in small trading activities increased from 8.6% before the project to 12.4% after implementation. This trend was particularly evident in Kushtia, where improvements in drainage systems and flood management infrastructure under the Pourashava project enhanced accessibility, reduced waterlogging, and created favorable conditions for small-scale commercial activities.

Similarly, the proportion of respondents engaged in rickshaw pulling increased from 2.0% to 5.2% after project implementation. This occupational shift was mainly observed in Sirajganj, where the climate-sensitive health adaptation project improved community well-being but had limited direct influence on agricultural productivity and income generation. Consequently, some households diversified their livelihood strategies by seeking alternative income sources in the transport and informal service sectors.

The observed changes in occupational patterns indicate that BCCTF-supported interventions indirectly contributed to livelihood diversification. Diversification of income sources is widely recognized as an effective adaptation strategy that reduces vulnerability to climate-related shocks by decreasing dependence on climate-sensitive sectors such as agriculture (Ellis, 2000; IPCC, 2022). Improved infrastructure, enhanced mobility, and reduced environmental risks may have created opportunities for beneficiaries to engage in alternative economic activities, thereby strengthening household resilience and adaptive capacity.

Household income and expenditure were used as indicators to assess the economic impacts of project interventions. The results indicate a noticeable improvement in the economic status of beneficiary households following project implementation. Before the project, 45.3% of respondents reported monthly incomes ranging between 5,000 and 10,000 BDT, while 48.5% reported monthly expenditures within the same range. Following project implementation, 59.1% of respondents reported monthly incomes and 60.4% reported expenditures within this income category (Figure 1D). Furthermore, the proportion of households earning more than 25,000 BDT per month increased from 3.1% before implementation to 7.8% afterward.

The increase in household income may be attributed to multiple project-related benefits, including improved agricultural productivity, reduced disaster-related losses, enhanced access to markets, improved public infrastructure, and greater livelihood opportunities. Similar findings have been reported in climate adaptation and resilience studies, where investments in climate-resilient infrastructure and community-based adaptation programs contributed to income growth, livelihood security, and poverty reduction among vulnerable populations (World Bank, 2021; FAO, 2022). Although household expenditures also increased, this trend may reflect improved purchasing power and living standards rather than economic hardship. Increased expenditures on education, healthcare, food, and household assets are commonly associated with improved socioeconomic conditions and enhanced resilience.

Overall, the socio-demographic findings suggest that BCCTF-funded projects contributed not only to climate risk reduction but also to broader socioeconomic development. The predominance of economically active respondents, moderate educational attainment, increased livelihood diversification, and improved household income collectively indicate enhanced adaptive capacity among beneficiary communities. These findings support the growing evidence that climate adaptation investments can generate multiple co-benefits, including livelihood improvement, social inclusion, economic empowerment, and long-term community resilience. Consequently, the socio-demographic profile of respondents provides an important foundation for understanding the effectiveness and sustainability of BCCTF-supported climate-resilient development initiatives in Bangladesh.

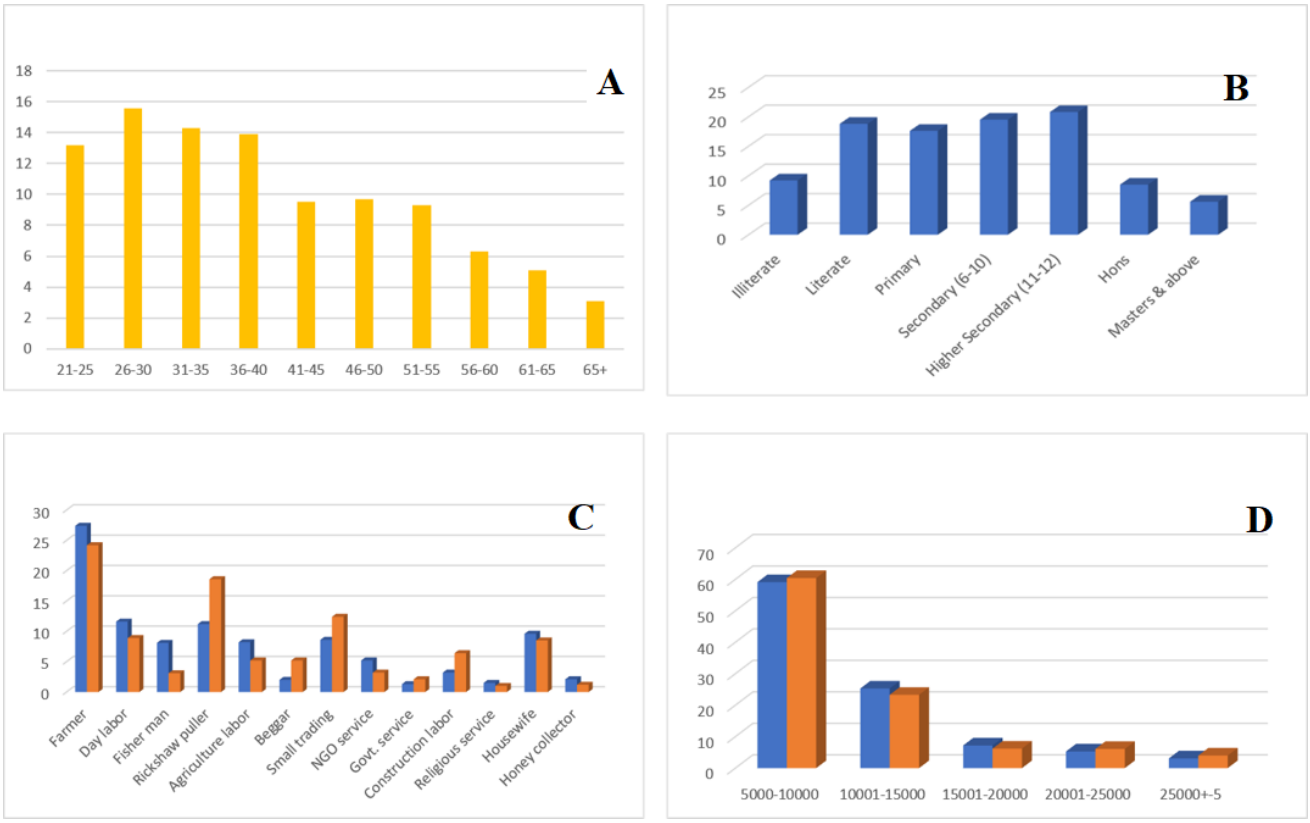

Figure 1. Socio-demographic characteristics of participants. (A) Age, (B) Education, (C) Occupation. C) Monthly income and expenditures beyond the projects of the respondents.

4.2. Climate risks identified in study areas

The assessment of climate-related risks revealed that communities in the selected project areas face multiple environmental hazards that directly affect livelihoods, public health, agricultural productivity, and overall resilience. Although the nature and intensity of risks varied across locations, flooding, salinity intrusion, water scarcity, drainage congestion, and climate-sensitive health challenges emerged as the most significant threats reported by respondents (Table 1). These findings are consistent with previous studies that identified Bangladesh as highly vulnerable to diverse climate hazards due to its geographic location, deltaic landscape, and dependence on climate-sensitive economic activities (Ahmed, 2006; IPCC, 2022).

The climate risks identified in the study areas reflect the distinct ecological and socio-economic characteristics of each region. In Satkhira, respondents identified salinity intrusion, water scarcity, and cyclone impacts as the most severe climate-related challenges. The district is located in the coastal zone of southwestern Bangladesh and is highly exposed to sea-level rise, tidal flooding, and storm surges. Increased salinity in soil and freshwater sources has adversely affected agricultural production, livestock rearing, fisheries, and household water supply. Many respondents reported difficulties in accessing safe drinking water, particularly during the dry season when saline intrusion intensifies. Similar observations have been documented by Karim and Mimura (2008) and Rahman et al. (2019), who reported that salinity intrusion poses a significant threat to food security, human health, and rural livelihoods in coastal Bangladesh. Cyclone-induced damage to infrastructure, agricultural land, and housing further increases the vulnerability of coastal communities and limits their adaptive capacity.

In Sirajganj, flooding and waterborne diseases were identified as the primary climate-related risks. Located along the Jamuna River floodplain, the district experiences frequent seasonal flooding and riverbank erosion. Respondents indicated that recurrent floods damage crops, disrupt transportation systems, contaminate drinking water sources, and negatively affect household income. Flood events also increase the incidence of waterborne diseases such as diarrhea, dysentery,

and skin infections, particularly among children and elderly populations. Previous studies have demonstrated that flood-prone communities in Bangladesh experience substantial economic losses and heightened public health risks due to prolonged inundation and poor sanitation conditions (Few et al., 2004; Alam and Collins, 2010). The findings highlight the interconnected nature of climate risks and health outcomes in flood-affected regions.

In Kushtia, urban waterlogging and drainage congestion were identified as the dominant climate-related challenges. Respondents reported that intense rainfall events, combined with inadequate drainage infrastructure and rapid urban expansion, frequently result in prolonged waterlogging in residential and commercial areas. Waterlogging disrupts economic activities, damages roads and public infrastructure, restricts mobility, and creates favorable conditions for vector-borne and water-related diseases. Similar challenges have been observed in many secondary cities of Bangladesh, where urban growth has outpaced investments in climate-resilient drainage systems (Roy et al., 2021). The increasing frequency of extreme rainfall events associated with climate change is expected to further exacerbate urban flooding and waterlogging problems in the future.

Table 1. Major climate risks in the study areas

Study area	Major climate risks
Satkhira	Salinity intrusion, water scarcity, cyclone impacts
Sirajganj	Flooding, waterborne diseases
Kushtia	Urban waterlogging, drainage congestion

The findings demonstrated that climate risks in the study areas are highly location-specific, requiring tailored adaptation and risk management strategies. Coastal areas such as Satkhira require interventions focused on salinity management, freshwater security, and cyclone resilience, whereas flood-prone regions such as Sirajganj require improved flood management and climate-sensitive health services. In contrast, urban areas such as Kushtia require investments in drainage infrastructure and integrated urban water management systems. These results support the growing consensus that effective climate-resilient development depends on context-specific adaptation measures that address the unique vulnerabilities of different ecological and socio-economic settings (IPCC, 2022; Huq and Ayers, 2007).

4.3. Adaptation and mitigation interventions

The assessment of BCCTF-funded projects revealed that a diverse range of adaptation and mitigation interventions were implemented to address location-specific climate risks and strengthen community resilience. The interventions were designed to reduce vulnerability to climate-related hazards while simultaneously promoting sustainable resource management, environmental protection, and low-carbon development. Findings from household surveys, Focus Group Discussions (FGDs), Key Informant Interviews (KIIs), and case studies indicate that these interventions generated substantial environmental, social, and economic benefits across the study areas.

4.3.1. Adaptation interventions

The BCCTF-funded projects implemented several adaptation measures tailored to the climatic and environmental challenges of the respective regions. Major adaptation interventions included climate-resilient agriculture, urban drainage development, water management systems, climate-sensitive health adaptation measures, salinity management, and community awareness programs.

In Satkhira, adaptation efforts primarily focused on salinity management and water resource conservation. Improved water management systems enhanced access to freshwater for domestic and agricultural use, reducing the vulnerability of communities affected by saline intrusion. Beneficiaries reported that improved water availability contributed to better agricultural productivity and reduced health risks associated with saline water consumption. Similar findings have been reported in coastal Bangladesh, where freshwater management interventions significantly enhanced adaptive capacity and livelihood security (Karim and Mimura, 2008; Rahman et al., 2019).

In Kushtia, urban drainage development and waterlogging reduction constituted major adaptation interventions. The rehabilitation and expansion of drainage infrastructure improved stormwater management, reduced flooding during

heavy rainfall events, and enhanced mobility within urban areas. Respondents reported reduced damage to roads, residential areas, and commercial establishments, leading to improved economic activities and living conditions. Previous studies have highlighted that climate-resilient urban infrastructure plays a crucial role in reducing the impacts of extreme rainfall and enhancing urban resilience (Roy et al., 2021).

In Sirajganj, climate-sensitive health adaptation measures were implemented to address health risks associated with recurrent flooding. These interventions included awareness campaigns, health service improvements, and preventive measures targeting waterborne diseases. Beneficiaries reported improved access to healthcare services and increased awareness regarding disease prevention during flood events. Such interventions are increasingly recognized as critical components of climate adaptation strategies because climate change significantly influences public health outcomes, particularly in flood-prone regions (Watts et al., 2021).

Community awareness and capacity-building programs were implemented across all project sites. These activities enhanced knowledge regarding climate risks, adaptation practices, disaster preparedness, and environmental conservation. Increased awareness contributed to greater community participation and strengthened local adaptive capacity. Similar studies have shown that community-based adaptation approaches are more effective when local stakeholders actively participate in planning and implementation processes (Huq and Reid, 2007; Adger et al., 2005).

4.3.2. Mitigation interventions

In addition to adaptation measures, BCCTF-funded projects incorporated several mitigation initiatives aimed at reducing greenhouse gas emissions and promoting low-carbon development pathways. The major mitigation interventions included solar-powered irrigation systems, renewable energy promotion, reduced dependence on fossil fuels, and adoption of low-carbon energy technologies.

Among these interventions, solar-powered irrigation systems emerged as one of the most significant mitigation achievements. Beneficiaries reported that solar irrigation reduced dependence on diesel-powered pumps, lowered production costs, and ensured a more reliable energy supply for agricultural operations. The replacement of fossil fuel-based energy sources with renewable energy technologies contributed to reductions in greenhouse gas emissions while simultaneously improving agricultural productivity and profitability. Similar benefits have been documented in climate-smart agriculture programs across South Asia, where solar irrigation has been identified as an effective strategy for achieving both adaptation and mitigation objectives (FAO, 2022; IPCC, 2022).

The promotion of renewable energy technologies also increased community awareness regarding sustainable energy use and environmental conservation. By encouraging the adoption of low-carbon technologies, the projects contributed to Bangladesh's broader climate change mitigation commitments and sustainable development goals.

4.3.3. Environmental outcomes of BCCTF interventions

The projects implemented in Kushtia (Mirpur Pourashava) and Satkhira Sadar generated significant environmental improvements through ecosystem conservation, ecological restoration, and sustainable natural resource management. According to findings from FGDs, KIIs, and case studies, project beneficiaries perceived substantial improvements in environmental quality and ecosystem health following project implementation (Figure 2).

At the physical level, respondents reported improvements in both surface and groundwater quality due to enhanced water management practices and reduced environmental contamination. Improved drainage systems and water conservation measures contributed to more efficient utilization of water resources and reduced environmental degradation. Beneficiaries also reported enhanced soil fertility, improved land-use practices, better waste management systems, and reduced exposure to climate-induced natural hazards. These findings are consistent with previous studies showing that integrated water and land management interventions can strengthen ecosystem resilience and improve environmental sustainability (UNEP, 2021).

At the biological level, the projects contributed to the conservation of terrestrial flora and fauna and supported habitat restoration efforts.

Environmental restoration activities enhanced ecosystem functions and strengthened biodiversity conservation within project areas. Healthy ecosystems provide important ecosystem services, including flood regulation, soil conservation, water purification, and climate regulation, which are essential for long-term climate resilience (Millennium Ecosystem Assessment, 2005).

At the socioeconomic level, respondents reported improvements in occupational health and safety, community well-being, and public health conditions. Environmental improvements reduced exposure to environmental hazards and enhanced overall quality of life. Beneficiaries also highlighted positive impacts on vulnerable groups, including women and marginalized populations. Increased participation of women in project activities contributed to improved gender equity and social inclusion. These findings support previous research indicating that climate adaptation projects often generate significant social co-benefits beyond their primary environmental objectives (IPCC, 2022).

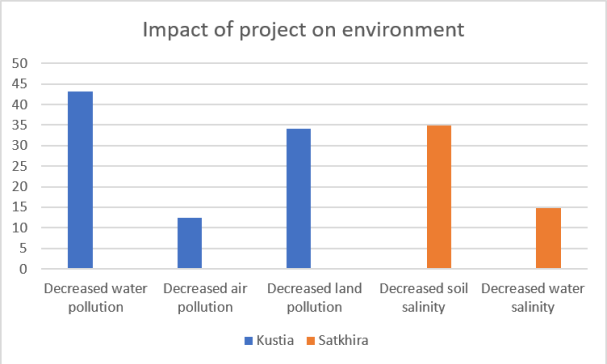

Figure 2. Impact of BCCTF project on environment

The findings demonstrate that BCCTF-funded interventions generated multiple environmental benefits while simultaneously strengthening community resilience and supporting sustainable development objectives. The observed improvements highlight the importance of integrated adaptation and mitigation strategies in achieving climate-resilient development outcomes.

4.3.4. Environmental management and risk mitigation frameworks

Findings from KIIs and case studies revealed that both projects incorporated comprehensive environmental management frameworks to ensure that project activities were implemented sustainably and in compliance with environmental safeguards. These frameworks played a critical role in minimizing adverse environmental impacts and maximizing project benefits.

The projects operated within established policy, legal, and administrative frameworks, ensuring compliance with national environmental regulations, standards, and institutional requirements. Such compliance enhanced accountability and promoted environmentally responsible project implementation.

A detailed baseline environmental assessment was conducted before project implementation to document existing environmental and socioeconomic conditions. These baseline data provided an important foundation for evaluating project impacts and monitoring environmental changes over time.

The projects also undertook systematic impact and risk assessments, examining potential physical, biological, and socioeconomic impacts associated with project activities. These assessments considered institutional capacities and identified mitigation measures to address potential environmental risks.

An Environmental Management Plan (EMP) was developed to guide implementation. The EMP specified mitigation measures, institutional responsibilities, monitoring procedures, performance indicators, capacity-building activities, and implementation timelines. The existence of a structured EMP facilitated adaptive management and enhanced project effectiveness.
Stakeholder consultation and participation formed another important component of project implementation. Local communities, civil society organizations, and other stakeholders were actively engaged throughout project planning and implementation processes. Meaningful participation increased project ownership, improved transparency, and enhanced the sustainability of project outcomes. Community participation has consistently been identified as a critical determinant of successful climate adaptation initiatives (Adger et al., 2005; Huq et al., 2015).

Furthermore, both projects established a Grievance Redress Mechanism (GRM) to systematically receive, evaluate, and address complaints raised by

affected individuals and communities. The GRM strengthened transparency, accountability, and responsiveness while ensuring that stakeholder concerns were appropriately managed. Particular attention was given to protecting vulnerable groups, including poor households, women, and marginalized populations, from potential adverse environmental and social impacts.

The integration of environmental safeguards, stakeholder participation, and risk management mechanisms significantly enhanced the effectiveness and sustainability of BCCTF-funded interventions. These findings demonstrate that successful climate-resilient development requires not only technical adaptation measures but also robust governance frameworks, inclusive participation processes, and effective environmental management systems.

4.4. Impact on food security and livelihoods

Improving food security and livelihood resilience was a key objective of the BCCTF-funded projects. The interventions focused on enhancing agricultural productivity, reducing climate-related production constraints, improving water management, and strengthening household income opportunities (Figure 3).

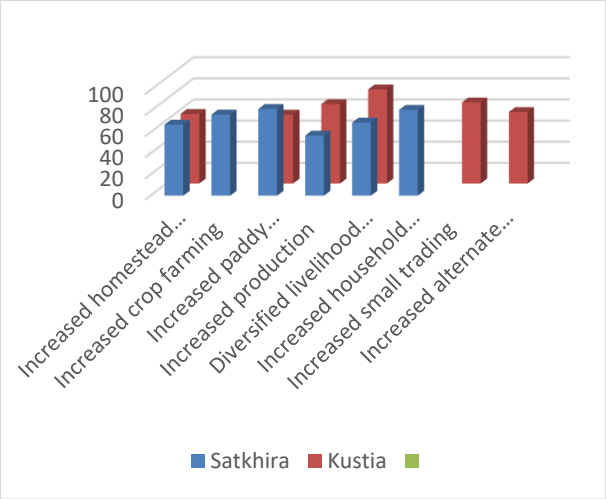

Figure 3. Food security and livelihood improvements resulting from BCCTF interventions.

The findings from household surveys, FGDs, KIIs, and case studies indicate that the projects positively affected food production, income generation, and livelihood security across the study areas. In Satkhira, salinity intrusion and freshwater scarcity had severely constrained dry-season agriculture. The introduction of groundwater-based irrigation systems improved access to irrigation water, resulting in higher crop yields, increased cropping intensity, and improved food availability. Beneficiaries reported reduced production risks and enhanced agricultural productivity, consistent with previous studies highlighting the importance of irrigation and water management for climate adaptation in coastal Bangladesh (Karim and Mimura, 2008).

In Kushtia, chronic waterlogging and inadequate drainage infrastructure had negatively affected agricultural production and economic activities. Drainage improvement interventions reduced waterlogging, increased cultivable land use, and improved access to markets and services. Respondents reported higher agricultural productivity and reduced economic losses associated with seasonal flooding. Similar benefits of climate-resilient infrastructure have been reported in other adaptation studies in Bangladesh (World Bank, 2021).

The projects also generated broader livelihood benefits by increasing labor demand, improving resource-use efficiency, and reducing climate-related losses. Household-level assessments indicated that project benefits substantially exceeded implementation costs. Although increased production occasionally resulted in lower market prices, farmers compensated through higher production volumes and diversified income sources, resulting in improved economic stability and resilience.

The interventions significantly strengthened food security and livelihoods by addressing key climate-related constraints such as salinity intrusion, water scarcity, and waterlogging. Increased agricultural productivity, improved income opportunities, and reduced vulnerability to climate shocks contributed to enhanced resilience among beneficiary households. These findings support previous evidence that climate adaptation investments can simultaneously improve food security, livelihood outcomes, and community resilience (IPCC, 2022; FAO, 2022).

4.5. Impact on energy

The promotion of renewable energy, particularly solar power, was one of the notable achievements of the BCCTF-funded project in Satkhira. The

installation of solar-powered systems generated significant economic, social, and environmental benefits for beneficiary households and communities.

Households using solar energy reported a substantial reduction in monthly energy expenditures, decreasing from approximately BDT 400 to BDT 150. The availability of reliable and affordable energy improved household welfare and supported agricultural activities, particularly irrigation, in areas where access to conventional electricity was limited. Similar findings have shown that renewable energy technologies can reduce production costs while improving energy security in climate-vulnerable rural communities (IRENA, 2021).

The adoption of solar energy also contributed to local economic development. Between 2013 and 2017, employment opportunities increased by approximately 20%, largely due to the expansion of irrigated agriculture and increased crop diversification. Improved energy access further supported the development of small businesses and income-generating activities in off-grid areas, thereby strengthening local livelihoods and resilience.

From an environmental perspective, solar energy reduced dependence on fossil fuels and contributed to lower greenhouse gas emissions. Beneficiaries recognized solar power as a clean and sustainable energy source with minimal environmental impacts. The transition to renewable energy not only supported climate change mitigation efforts but also contributed to improved environmental quality through reduced air pollution and enhanced ecosystem protection.

The findings demonstrate that BCCTF-supported solar energy interventions generated multiple co-benefits, including reduced energy costs, increased employment opportunities, improved agricultural productivity, and lower carbon emissions. These outcomes highlight the important role of renewable energy technologies in promoting climate-resilient and low-carbon development in Bangladesh.

4.6. Impact on health

Strengthening health resilience was a key objective of the Community-Based Health Adaptation Project implemented in Sirajganj under BCCTF funding. Health resilience refers to the ability of individuals and communities to anticipate, cope with, and recover from climate-related health risks while enhancing their capacity to respond to future challenges.

The findings indicate that the project significantly improved community health outcomes, particularly in flood-prone areas where waterborne diseases are common. Prior to project implementation, approximately 78% of schoolchildren suffered from climate-sensitive diseases such as diarrhea, cholera, and dysentery. Following project interventions, the prevalence of these diseases declined substantially to about 21%, demonstrating the effectiveness of community-based health adaptation measures.

The observed improvements were attributed to a combination of capacity-building activities, health awareness campaigns, improved access to safe drinking water, and enhanced sanitation facilities. Training programs increased knowledge of disease prevention and hygiene practices among community members, particularly schoolchildren, thereby reducing exposure to waterborne pathogens. Similar studies have shown that climate-sensitive health interventions, combined with improved water, sanitation, and hygiene (WASH) services, can substantially reduce disease burdens in flood-affected communities (WHO, 2021; IPCC, 2022).

In addition to reducing disease prevalence, the project strengthened community preparedness and adaptive capacity by promoting preventive health practices and increasing awareness of climate-related health risks. Beneficiaries reported improved health security, reduced healthcare expenditures, and fewer disruptions to education and livelihoods caused by illness.

The findings demonstrated that BCCTF-supported health adaptation interventions significantly enhanced health resilience in vulnerable communities. By reducing the incidence of waterborne diseases and improving access to essential health services, the project contributed to broader climate resilience and community well-being in flood-prone areas of Bangladesh.

5. Risk management and sustainability

Effective risk management was a key component of the BCCTF-funded projects and contributed substantially to project implementation and sustainability. The projects adopted a range of risk management strategies, including disaster preparedness planning, flexible implementation approaches, stakeholder engagement, institutional coordination, community participation, and environmental management planning. These measures enabled project activities to continue despite climatic, social, and institutional challenges.

The analysis identified several major risks that could affect project performance and long-term outcomes (Table 2). Political instability and natural disasters were assessed as medium-level risks, while low community awareness and social resistance were identified as high-priority challenges. To address these risks, project authorities implemented awareness campaigns, community mobilization activities, adaptive implementation schedules, and close coordination with local stakeholders and government institutions.

Table 2. Major risks and mitigation measures.

Risk	Likelihood	Mitigation Strategy
Political instability	Medium	Coordination with local stakeholders
Natural disasters	Medium	Adaptive implementation planning
Low community awareness	High	Awareness and communication programs
Social resistance	High	Community mobilization and sensitization

The findings further indicate that project sustainability was strongly influenced by the level of participation of local government institutions and community stakeholders. Projects with active involvement of local authorities, community organizations, and beneficiary groups demonstrated greater ownership, improved maintenance of project outputs, and stronger prospects for long-term sustainability. These findings support previous studies emphasizing the importance of institutional capacity, stakeholder participation, and local ownership in sustaining climate adaptation outcomes (Adger et al., 2005; Huq et al., 2015).

Overall, the findings demonstrate that BCCTF-funded projects significantly contributed to climate-resilient development in vulnerable regions of Bangladesh. The projects improved environmental sustainability, adaptive capacity, renewable energy utilization, public health resilience, and livelihood security.

The solar irrigation initiative in Satkhira aligns with previous findings showing that renewable energy technologies can strengthen agricultural adaptation while reducing greenhouse gas emissions (Rahman et al., 2018). Similarly, urban drainage improvements in Kushtia reduced waterlogging and improved local environmental conditions.

Community health adaptation initiatives in Sirajganj also demonstrated the importance of integrating climate change into public health planning. Previous studies have highlighted that flood-prone communities in Bangladesh remain highly vulnerable to diarrheal and waterborne diseases during extreme weather events (Hashizume et al., 2008).

Despite positive outcomes, several institutional and operational challenges were identified. Many respondents lacked awareness regarding BCCTF-funded projects, indicating gaps in community engagement and communication. Sustainability also remains a concern because long-term maintenance depends heavily on local institutions.
The study further highlights the importance of participatory climate governance, stakeholder involvement, and locally driven adaptation planning for ensuring long-term resilience.

6. Conclusion

This study evaluated selected BCCTF-funded projects focusing on climate resilience, sustainability, adaptation, and risk management in Bangladesh. Findings suggest that the projects positively contributed to environmental protection, renewable energy promotion, food security, public health resilience, and livelihood improvement.

Socio-economic and demographic characteristics are important components of social research, as they provide insights into social class, economic conditions, gender distribution, and overall social structure within a community. This study analyzed the age, gender, education, occupation, monthly income, and expenditure patterns of project beneficiaries. The findings indicate noticeable socio-economic changes among respondents following project implementation, particularly in terms of occupational diversification and improved income levels.

The study highlights that integrated adaptation and mitigation interventions can significantly strengthen local resilience in climate-vulnerable regions. However, sustaining long-term impacts requires stronger institutional coordination, enhanced stakeholder participation, effective monitoring systems, and greater community awareness.

As climate risks continue to intensify in Bangladesh, the BCCTF remains an important national mechanism for climate-resilient development. Future climate interventions should prioritize participatory governance, sustainability planning, and locally adaptive strategies to enhance resilience among vulnerable populations.

7. Policy recommendations

Based on the findings of this study, several policy recommendations are proposed to enhance the effectiveness, sustainability, and impact of BCCTF-funded projects:

1. Strengthen monitoring and evaluation systems to assess long-term project performance, sustainability, and resilience outcomes.
2. Increase community participation throughout project planning, implementation, monitoring, and post-project management to improve local ownership.
3. Enhance transparency and accountability in climate finance governance through improved reporting, auditing, and stakeholder engagement mechanisms.
4. Scale up renewable energy interventions, particularly solar-powered technologies, in climate-vulnerable and off-grid regions.
5. Strengthen local institutional capacity to ensure effective operation, maintenance, and sustainability of project investments.
6. Integrate climate change and public health planning by expanding climate-sensitive health adaptation programs in vulnerable districts.
7. Promote locally adapted climate-resilient agricultural technologies to improve food security and reduce vulnerability to climate variability.
8. Increase investments in urban drainage, flood management, and water resource infrastructure to address growing climate-related risks in urban and peri-urban areas.
9. Expand climate awareness and public education programs to improve risk perception, behavioral change, and community preparedness.
10. Promote evidence-based climate policy formulation through systematic research, impact evaluation, and knowledge-sharing among government agencies, researchers, and development partners.

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