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Adopting the Local Knowledge of Coastal Communities for Climate Change Adaptation: A Case Study From Bangladesh

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Bangladesh has a unique coastal system with both proximity of climatic vulnerability and opportunity, having rich coastal resources. The upkeep of people's livelihoods in the coastal zone largely depends on the degree to which key stakeholders at all levels of decision-making can participate in climate adaptation planning and implementation processes. These facts are well recognized in Bangladesh's Integrated Coastal Zone Management Plan (ICZM), National Adaptation Program of Action (NAPA), and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP), which emphasize the need for integrated multi-level decision-making at all stages of the adaptive management cycle. The aim of this article is to assess the value of coastal community engagement in Bhola and Satkhira districts of Bangladesh and highlight priority programs that may increase adaptive capacity in the face of climate change. To this end, interviews were conducted involving local farmers, fishers, women householders, businessmen, and other local leaders, thus yielding a total 240 participants who informed this empirical research. Case studies of villages of these districts highlight helpful examples of adaptation initiatives that may increase people's capacity to respond to the adverse effects of climate change, both autonomously as villagers, and as part of a coordinated program to reduce vulnerability. Issues flagged for urgent attention include water management, socioeconomic conditions, and migration away from coastal districts. The findings point to both potential interventions and a need to better prioritize adaptation options and strategies that are suitable for local contexts. In some cases, these options reflect existing Indigenous and local knowledge (ILK) and adaptation practices which may be both supported and leveraged through the coordinated implementation of different aspects of government policies.

Keywords: Bangladesh, climate adaptation, coastal zone, priority adaptation options, national plans, decision-making process, local knowledge, case study research

INTRODUCTION

According to the Intergovernmental Panel on Climate Change (IPCC, 2007), "Adaptation" to climate changes involves "initiatives and measures to reduce the vulnerability … against … climate change effects" (p. 76). As such, adaptation may be most appropriately understood to encapsulate alterations in natural or human systems made necessary by present or future climatic stimuli or their effects. While remaining subject to limits and constraints, adaptation seeks to moderate harm or exploit beneficial opportunities (Leal Filho et al., 2021a). In consequence, reducing coastal vulnerability to natural hazards and climate change is a form of adaptation (Klein et al., 2001; Luetz, 2008; Doust et al., 2021). Coastal environments constitute a high priority for adaptation. Although they produce goods and services of economic and social value, the interface of land, sea and air also embodies a highly dynamic and potentially treacherous natural environment. As such, coastal zones typically manifest both significant economic investments and high population densities (McGranahan et al., 2007). In synthesis, coastal zones tend to be both densely settled and highly sensitive to common coastal hazards such as storm surges and coastal erosion (Klein et al., 2001; Luetz, 2008; Ewing, 2015).

Bangladesh's coastal area stretches across an active river delta system that is rich in land and water resources. Being characterized by a very dynamic geographic and geomorphologic environment (Sarker and Thorne, 2006; Sarker et al., 2011; Luetz, 2015), Bangladesh's coastal zone is vulnerable to both natural and human-induced calamities (Saroar and Routray, 2011; Momtaz and Shameem, 2016; Luetz, 2018). Furthermore, in this region land ownership can be more skewed than elsewhere in Bangladesh. Compared to urban areas there is also a comparatively lower prevalence of government and NGO services in rural areas, with varying levels of coordination between active organizations. In this socioeconomic context law-and-order can be tenuous. The materially poor tend to be socioeconomically eclipsed and/or politically marginalized, with the elite remaining firmly in control of political influence and most economic and social resources (World Bank, 2007; McAdam and Saul, 2010; Luetz, 2018; Luetz and Sultana, 2019). Although in some parts of coastal Bangladesh mangrove forests and coastal vegetation have been irrecoverably damaged by human intervention, in other parts this natural resource base is still largely intact and available to underpin robust coastal protection, sustainable development, and poverty reduction (Datta et al., 2003; Luetz, 2008, 2018; Sarker et al., 2011; Kelman et al., 2018).

The purpose of this article is to show how the decision-making practices of different levels (policy making, implementation and beneficiaries) in relation to coastal management and climate change adaptation plans can be reoriented toward adaptive governance for two coastal regions. This article discusses the need for coastal societies to adapt to climate change and the importance of adaptation options selected through diverse coastal communities according to their adaptive capacity to climate change. Based on local-level research, available decision-making components and adaptation options will assist in executing national policy, plans and strategies in the individual coastal districts in a sustainable manner. As such, the two main objectives of this article are:

a. To assess the indicators of adaptive capacity for the coastal communities against climate change to observe the present conditions and formulate them for the future decision-making process.
b. Compare and contrast between two coastal districts with their local priority components aligned with the coastal development strategies, plans and programs available.

The motivation for this research arose from a desire to re-examine Bangladesh's existing adaptation frameworks in the context of coastal communities to enhance their adaptive capacity to climate change. To this end, the study relates grassroots level priorities for adaptation to the country's Integrated Coastal Zone Management Plan (ICZM), the Bangladesh Climate Change Strategies and Action Plan (BCCSAP), and the National Adaptation Program of Action (NAPA). In doing so, the study extends previous research by bringing to the attention of duty bearers the expressed adaptation requirements and priorities of local communities that need to be heeded and implemented to increase their adaptive capacity (Ellis, 2000; Nelson et al., 2007; Younus and Harvey, 2014; Zamudio and Parry, 2016; Younus and Kabir, 2018). The analysis of this study synthesizes what projects and programs need to be implemented on a priority basis. It also appreciates some of the complexities involved in implementing the national plans and conceptualizes options and opportunities for future research.

This article is organized as follows: First, we explore adaptation to climate change and national and international policy response options and frameworks in Bangladesh, including the country's ICZM, BCCSAP, and NAPA. Next, we introduce the field research sites where data collection took place. This is followed by an explanation of methodological considerations and approaches relating to the study's empirical data collection and analysis. Next, we provide a detailed presentation of the results, which is followed by a critical discussion of the main study findings in light of Bangladesh's demographic and geomorphological context. Finally, we offer a succinct concluding synthesis that frames the local knowledge-informed findings in terms of their usefulness for climate change adaptation policy and practice in Bangladesh.

RESEARCH CONTEXT AND LITERARY FRAMEWORK

The Process and Priority of Adaptation to Climate Change in Coastal Contexts

The vulnerabilities of coastal areas to climatic issues are amply documented in the literature and may include a range of impacts (McGranahan et al., 2007; Luetz, 2008). There is robust support in the literature that natural coastal impacts tend to be aggravated under climate change (Knutson et al., 2020). Risks may comprise cyclones, sea level rises, flooding events, storm surges, and corresponding soil salinization, among others

(Woodroffe et al., 2006; Kelman et al., 2018). While climate-related costs and challenges are not unique to the Bay of Bengal (Sterner, 2015), compounding impacts may be concentrated in Bangladesh (Nicholls, 2006; Nicholls et al., 2018).

Since the late 1980s, when climate change first entered mainstream scientific consciousness, most research emphasis was directed to mitigation (i.e., reducing atmospheric greenhouse gas emissions) rather than adaptation (i.e., preparing to live with climate change already in motion). However, over recent decades attention has gradually shifted toward adaptation to climate change, chiefly because climate system inertia implies that a considerable amount of climate change will be inevitable even under scenarios that envisage swift and significant global mitigation efforts (Hansen et al., 2013). This situation makes it beneficial to manage the synergies between existing problems and available opportunities for adaptation (Younus, 2014; Leal Filho et al., 2021b). More specifically, integrated coastal policies are needed that may minimize and redress any potential for conflict between sustainable development objectives and unalterable adaptation requirements (Tobey et al., 2010).

As coastal zones typically accommodate competing sectoral activities, to date coastal technologies have been mostly conceived with specific sectoral exigencies in mind (Nicholls et al., 2018). However, given the significant challenges that climate change poses to coastal zones, it is imperative to devise and implement holistic coastal technologies and management approaches that are more comprehensive (Woodroffe et al., 2006; Doust et al., 2021). To this end, it is critical that all concerned stakeholders—national and local governments, non-governmental organizations, the private sector, universities, think tanks, laboratories, and local communities—are jointly informed and collaborating to mitigate coastal vulnerabilities to climate change impacts. Furthermore, effective and enduring coastal zone management mandates the meticulous conception and implementation of adaptation options that are based on reliable information, regular monitoring, and fastidious performance evaluation over time (Ford and Berrang-Ford, 2015). Relatedly, Klein et al. (1999) have described coastal adaptation to climate change as a four-step process that comprises awareness raising, planning and design, implementation, and continuous monitoring and evaluation.

National and International Policy Responses in Bangladesh

Bangladesh does not have a stand-alone comprehensive national policy in place that single-handedly encapsulates all climate change risk (Huq and Jessica, 2008; Sultana, 2015). This is also noted by McAdam and Saul (2010) with reference to migration-as-adaptation to climate change (see also Luetz, 2019; Luetz and Merson, 2019). Notwithstanding, the government is keenly aware of the country's significant sensitivity to both climate-related vulnerability and its propensity to experience severe and recurrent disaster events (Momtaz and Shameem, 2016). Hence there are several climate change policies and schemes in operation that directly target, mitigate and/or manage the country's multidimensional vulnerability to climate variability, extreme events, and disaster risk reduction (Younus and Kabir, 2018). These efforts aim to mainstream climate change into national policies and sectoral plans. Furthermore, relevant initiatives tend to intersect with other existing endeavors that target poverty alleviation, employment generation, and crop diversification, among others (Huq and Jessica, 2008).

Bangladesh's Participatory Disaster Management Program (PDMP) emphasizes relevant objectives, including disaster preparedness, prevention and management, and also adaptation to climate change. It principally promotes a portfolio of "soft" measures, including awareness raising, capacity building to strengthen national disaster management, knowledge dissemination and skills acquisition to raise disaster response capability, implementing disaster action plans in disaster prone areas, propagating risk reduction strategies to limit disaster losses, and improving early warning systems, among others (Kelkar and Bhadwal, 2007; Islam et al., 2010). Apart from these measures several important national plans have been prepared and established in Bangladesh since 2005, including the country's Integrated Coastal Zone Management Plan (ICZM).

Bangladesh's Integrated Coastal Zone Management Program

As in the case of other countries that established ICZM programs over the course of several years, three key steps informed and guided the inception and progressive implementation of Bangladesh's ICZM plan when it was initiated in 2005 (PDO-ICZMP, 2003). Key issues include policy development, strategic planning, and matters related to implementation (Islam and Rob, 2003; Shamsul Huda, 2004; Roy et al., 2017).

Policy Formulation

Propagating perspectives that balance environmental conservation, economic development, and social equity as mutually compatible objectives, ICZM aims to prevent piecemeal approaches in favor of holistic coastal development prospects.

Strategic Planning

Considering challenges and opportunities conjointly, including in areas of managing natural resources, economic development, and social equity, ICZM aims to devise strategies that concurrently aspire to attain the following two objectives:

- First, given that past national development strategies have overwhelmingly considered single sectors in isolation (i.e., apart from taking into account relevant impacts on other sectors), strategic planning must ensure that development activities will stimulate and sustain cross-cutting equilibrium across sectors. This will foster conditions for consensus on ICZM.
- Second, strategic planning must integrate national economic planning processes by aligning the constituent components of resources planning, land use planning, and economic planning. Such integration will ensure that ICZM will cohere and harmonize with broader national development aspirations.

Implementation

To stand a good chance of being successful and sustainable, ICZM programs require the involvement of all levels of government. On the one hand, local authorities are indispensable

because as they oversee local-level development projects and resource use. Furthermore, they are also closest to the people in terms of supporting their recovery from the impacts of disasters or helping them to adapt to the effects of climate change. On the other hand, the central government is imperative in governing national-level resource use, offering technical support, and overseeing regional or international matters of concern (CDS, 2006).

Bangladesh Climate Change Strategies and Action Plan and National Adaptation Program of Action

Over recent decades Bangladesh has leveraged its significant knowledge, institutional preparedness, and policy response capabilities for substantial reductions in human fatalities from disaster events (Luetz, 2008, 2018; Kelman et al., 2018). This success was largely predicated on and supported by the recognition that climate change is a formidable threat to Bangladesh's aspiration to attain the status of a middle-income country by 2021 (GOB, 2006). At the national level, the Government of Bangladesh spearheaded the Bangladesh Climate Change Strategy and Action Plan (BCCSAP, 2009) by establishing a trust fund that would enable donors to finance its implementation post-2007. This plan attracted attention for two reasons. First, the BCCSAP (2009) is poised and envisioned to facilitate future sustainable development and coastal land use in a country that is vulnerable to significant climate-related risks. Second, the plan provides Bangladesh vital access and linkages to international policy fora and intergovernmental climate change diplomacy (Alam et al., 2011).

In comparison to previous climate change-related initiatives such as Bangladesh's National Adaptation Program of Action (NAPA, 2005), the BCCSAP (2009) is notably different in both nature and scope. Compared to NAPA (2005), which emphasized mainly urgent and pressing priorities for adaptation to climate change, the BCCSAP (2009) is far more comprehensive and envisions both medium and long-term adaptation options. Moreover, actions are to be taken in conjunction with post-2012 UNFCCC negotiations. This entails comprehensive long-term commitments to reduce emissions of greenhouse gasses, mainstream adaptation initiatives at all levels, and facilitate the transfer and financing of technology (Alam et al., 2011).

Area Descriptions

This study took place in two coastal districts of Bangladesh, which over recent decades have received significant impacts from intense and frequent climatic hazards. The two different case study locations enable the research to test the robustness of ICZM as a theory and a practice in two coastal areas that manifest significant economic and sociocultural dissimilarities between communities, including in areas of water quality and availability, agriculture, and livelihoods, among others. This sort of comparative case study between two island villages (Bhola; **Figure 1**) and two estuary villages (Satkhira, **Figure 2**) could be gainfully replicated in similar regions of other developing countries.

South Central Coastal Island: Bhola (A)

The first grassroots case study was conducted in Muslimpara Village and Shabajpur Village in Char Kukri Mukri Union of Char Fasson Subdistrict of Bhola District (**Figure 1**). Geographical position, natural environment, mining wealth and on the other hand natural disasters-all combine to describe Bhola district as an independent area in the coastal zone. Bhola is associated with high economic value and diverse income generation opportunities. Unplanned use of coastal resources may be the cause of destruction of ecological balance, pollution and degradation of land and water quality (Paul et al., 1994). This part of the coastal zone, like many other parts of the country, is full of natural resources, but unlike most other areas it faces multipronged vulnerabilities like cyclones, storm surges, coastal erosion, etc. in an intense and frequent manner (Kelman et al., 2018).

South Western Coastal Estuary: Satkhira (B)

The second grassroots case study was conducted in Mathurapur Village and Dakshin Kadamtali Village in the Munshigang Union of Shyamnagar Subdistrict of Satkhira District (**Figure 2**). The southwestern coastal estuary is influenced by considerable tidal and other river-flow effects. Most of the land is located within one meter of mean sea level, and a significant proportion of which falls below high-tide levels (Islam, 2005). This estuary region has long been vulnerable to a plenitude of hydro-geo-morphological hazards. These include recurrent flooding events, high rates of riverbed sedimentation coupled with acute low-flow conditions and moisture stress during dry seasons, poor river system drainage and salinity ingress along rivers, and propensity for cyclonic storm surges that are progressively exacerbated by local-level land subsidence and corresponding rises in sea level (HALCROW-WARPO, 2001; Hanebuth et al., 2013).

METHODS AND TECHNIQUES

In coastal communities, bodies of local knowledge tend to be empirically based, pragmatic and/or behavior-oriented, thus providing the means to harvest coastal resources or ensure safety (Shipman and Stojanovic, 2007). Recognizing the salience of local expertise, this research seeks to highlight bottom-up contributions to climate change adaptation policy that reflect local people's knowledge, needs and capacities. Local perspectives are cogitated from two in-depth coastal case studies. As a mixed methods study the research broadly followed an exploratory paradigm of inquiry that sought to leverage the well-known and manifold benefits of case study research (Creswell and Plano Clark, 2011; Creswell, 2013, 2014; Punch, 2014). The design of this study is mainly based on qualitative research and a range of data-gathering tools involving observation, personal in-depth interviews with relevant stakeholders, and the review and analysis of primary and secondary information (Punch, 2014; Bryman, 2016). Semi-structured interviews and surveys were undertaken in two villages of Char Kukri Mukri union of Bhola district (**Figure 1**) and another two villages Munshigang union of Satkhira district (**Figure 2**). From each village 60 local

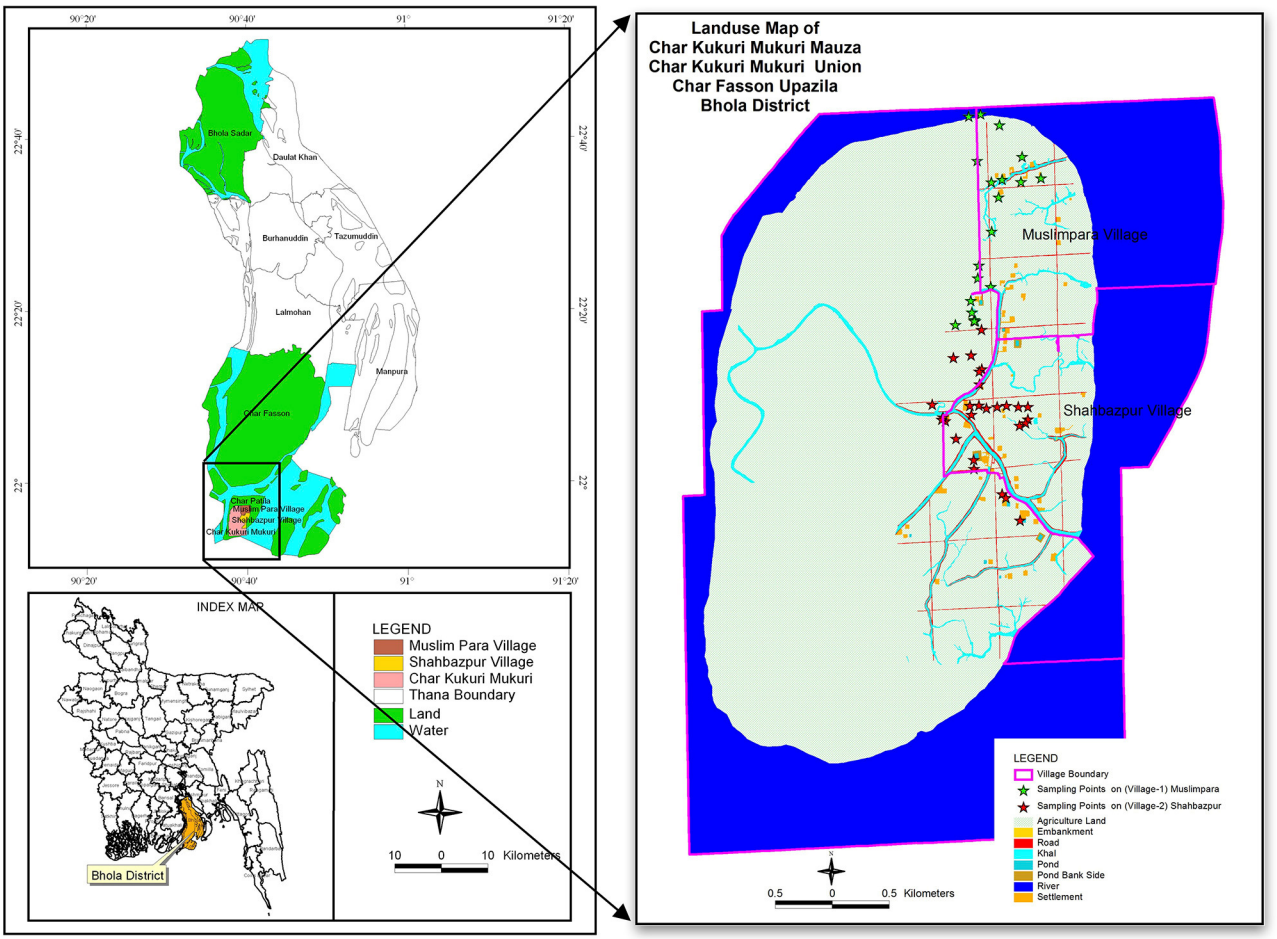


FIGURE 1 | Bhola District of Bangladesh **(left)**; Land use map of Char Kukri Mukri Union of Bhola District with the sampling points (location of interviewees) of Muslimpara Village and Shabajpur Village **(right)**. Created by authors using GIS.

community members were randomly recruited to participate: farmers (12), fishers (12), women householders (12), local businessmen (12), and local leaders (12), thus yielding a total 240 research participants for the two districts. Interviews and surveys were performed in 2011 and 2012, respectively. The nature of the questions also provided an opportunity to generate new ideas on how ICZM, NAPA, and BCCSAP could be improved for better coastal protection in the future. Furthermore, to support the validation of the study's findings (elaborated in Section Limitations and Opportunities for Future Research), the research incorporated several focus group discussions held in 2012 at the case study villages of both districts; participant groups comprised 20 to 25 of the same participants who had previously participated in the semi-structured interviews and surveys. There is support for such multi-input research approaches in the peer reviewed literature (Islam et al., 2021).

The Comprehensive Disaster Management Program (CDMP) was established in Bangladesh in 2013, with the aim of refocusing the government toward greater emphasis on disaster preparedness and risk reduction (DoE, 2008). The first author of this article benefited from CDMP support while conducting the local case studies in the two coastal districts. Support received comprised using available work stations and accessing existing grassroots level partnerships.

Since data collection no other studies have been done in coastal Bangladesh that have engaged the same study framework, research questions, analysis and/or case study sites. For this reason, the original data and analysis presented in this study represents the best available synthesis of the state of the art in coastal Bangladesh to date.

Assessment of adaptive capacity of people's livelihoods was undertaken following The Rural Livelihoods Analysis Framework (Ellis, 2000) at the local (policy beneficiary) level, which essentially helped to offer recommendations on how important it is to incorporate adaptation needs and options in present decision-making processes with active participation of stakeholders. Adaptive capacity and the five points of capital depend on the balance between the five capitals from which rural livelihoods are derived (after Carney, 1998). This example could represent the relative adaptive capacity of two households, regions, industries or even nations. The advantages of this method include the opportunity to engage

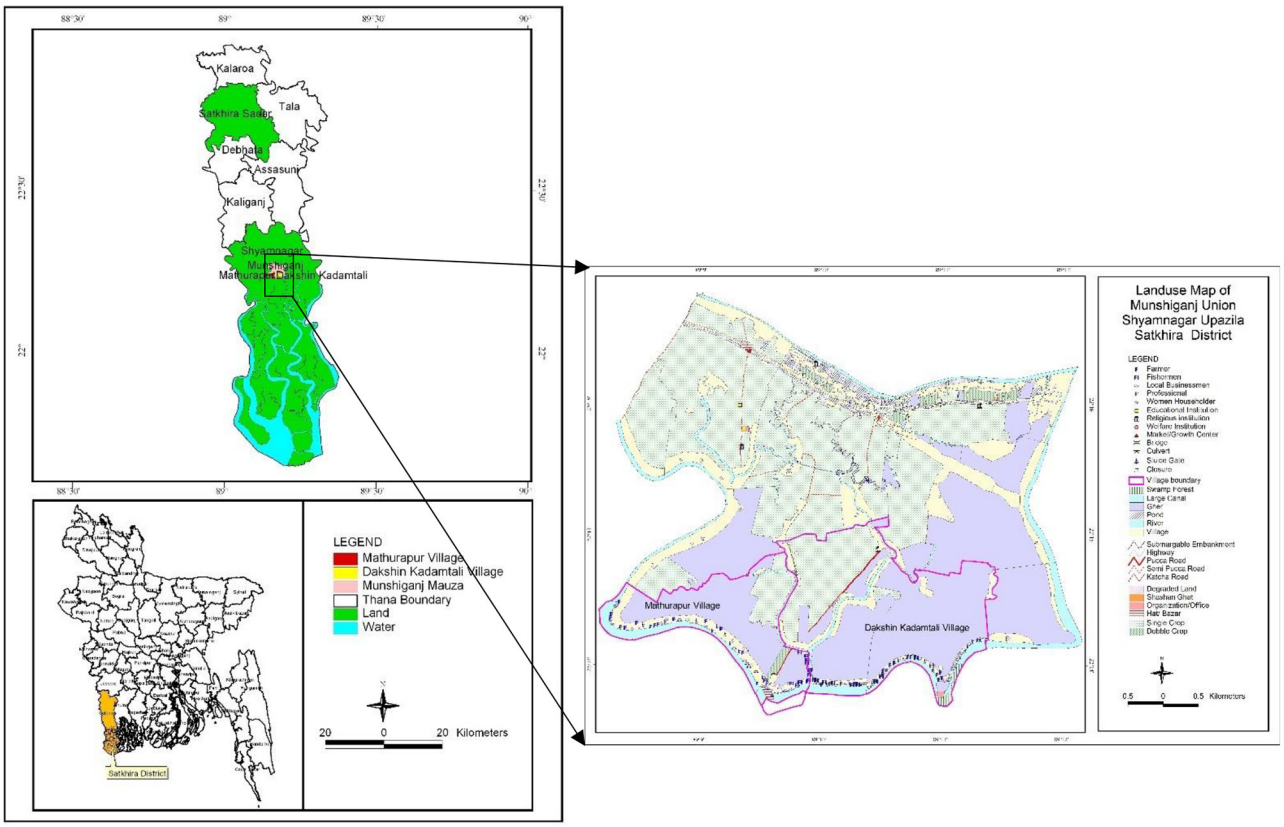


FIGURE 2 | Satkhira District of Bangladesh **(left)**; Land use map of of Munshigang Union of Satkhira District with the sampling points (location of interviewees) of Mathurapur Village and Dakshin Kadamtali Village **(right)**. Created by authors using GIS.

with local people who act as natural resource managers, to examine significant issues relating to adaptive capacity, and to identify practical and collectively implemented adaptation options (Brown et al., 2010). The collective nature of the decisions provides scope for shared responsibility and joint ownership of the causes of and solutions to low adaptive capacity. For the comparison and contrast of the two coastal study areas, mapping and data analysis were done using Geographical Information System (GIS) and statistical software tools (SPSS), respectively. This participatory approach with local stakeholders resulted in the systematic documentation of knowledge surrounding local problems and the impacts of climate change (**Figure 3**).

The process began with analyzing existing local problems and prioritizing them based on their importance and urgency. Consequently, villagers were asked to suggest and explore better adaptation practices involving both structural (hardware) and behavioral or management-related (software) considerations. This framework afforded villagers the space to generate systematic knowledge. It also revealed that individual community members were very knowledgeable about their own situation. By systemizing, synthesizing, and organizing this knowledge, what was already known became tangible information that villagers could then act on collectively. In this manner the research sought to support bottom-up adaptation practices, which complemented and blended in with other existing top-down policy approaches in Bangladesh.

RESULTS AND DISCUSSION

The effectiveness of coastal adaptation is largely predicated on local socioeconomic, institutional, and legal contexts (van Aalst et al., 2008; Younus and Harvey, 2014). Hence climate change adaptation strategies can succeed most readily if they are implemented as part of broader, integrated coastal zone management frameworks that recognize both near-term and long-term sectoral conditions. Furthermore, coastal zone development initiatives will be most effective and sustainable if they can recognize the diversified and incongruous adaptive capacity of coastal communities with different demographic compositions (Tobey et al., 2010).

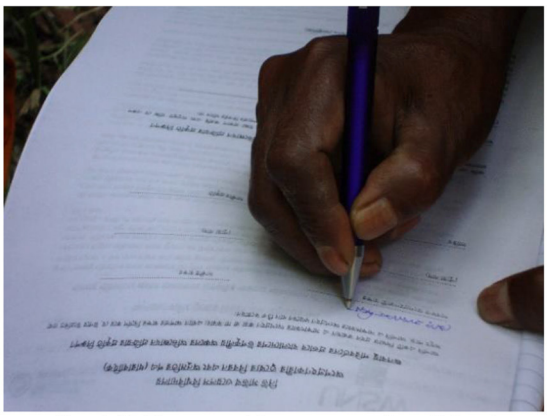
Adaptive Capacity

The self-assessments of adaptive capacity were calculated by using particular indicators within the 5 capitals (human; social; natural; physical and financial; see Ellis, 2000) shown in **Table 1** and **Figure 4** that local stakeholders considered important in terms of adapting to climate change. Each indicator is scored (self-assessed) on the basis of its current adequacy for adaptation potential under climate change (transformation) in each of

A **Step 1: Char Kukri Mukri Union Map of Bhola District placed upon Mouza (villages) plot maps of that Union for matching the village's names and locations.**

B **Step 2: Visit to Union Parisad Office of Char Kukri Mukri Union to collect the voter names and occupations list of local people who were to be interviewed.**

C **Step 3: Geographical Positioning System (GPS) meter taking and saving the longitude and latitude location of each interview conducted in the two villages of the Bhola and Satkhira Districts for GIS analysis to create maps and locate the interviewer's position.**



D **Step 4: Taking consent from a research participant before the start of the interview. The consent form was translated into the local language (Bengali) for interviewees to read and understand.**

FIGURE 3 | (A–D) Scoping, scanning, collecting, sampling—Steps undertaken before the start of interviews for both Bhola and Satkhira District of Bangladesh during October 2011 to January 2012 (Photographs by Authors).

the villages of the coastal district. The assessment therefore helps to build the ability of a household to operate in their own occupation to adapt to climate change through asset transformation. This will be expressed as the priority that should be accorded to enhance the dimension of adaptive capacity represented by each indicator rather than as an estimate of its stock. Hence a score of "5" would not imply an abundance or high level of a particular component of adaptive capacity, but rather it would mean that effective support of asset transformation is available to adapt to climate change. Conversely, a score of "0" would not imply a complete absence of a component, but rather that the indicator was currently not effectively supporting adequate asset transformation to adapt to climate change and therefore is a high priority for action. The rating system was explained to the research group participants so that they were able to score the indicators consistently. This type of subjective scoring has limitations in terms of precision, and can run into legitimacy issues if some of the more passive participants in larger groups acquiesce to scores that they ultimately disagree with (as outlined in Nelson et al., 2007).

According to **Figure 4** (left), financial, physical, and human capital are low to medium in villages of the coastal island, which indicates that presently those components of adaptive capacity are not effectively supporting adequate asset transformation to adapt to climate change. Hence those indicators reflect a high priority for action through the local government to national level government and NGOs working on the area. On the other hand, indicators of social and natural capital were judged as having a high value to support adequate asset transformation to adapt to climate change. Hence no immediate action is required to enhance adaptive capacity in these areas.

In contrast, the coastal estuary district assessed indicators of natural, financial, and physical capital as having a comparatively low value for local-level climate change adaptation (**Figure 4**, right). Therefore, to enhance the adaptive capacity of this district adequate asset transformation emerges as a high priority for

TABLE 1 | Assessment of adaptive capacity of a Coastal Island (Bhola District; left) and a Coastal Estuary (Satkhira District; right) of Bangladesh.

		Bhola			Satkhira		
Capital	**Indicators**	**Village 1**	**Village 2**	**Median**	**Village 1**	**Village 2**	**Median**
Human	Enthusiasm and optimism	2.00	3.00	2.50	4.00	4.00	4.00
	Aged and women's representative	1.00	2.00	1.50	2.50	1.00	1.75
	Willingness to take risks and change	1.50	2.50	2.00	3.00	4.00	3.50
	Resilience and health	0.00	1.00	0.50	2.00	3.00	2.50
	Total human	**1.13**	**2.13**	**1.63**	**2.88**	**3.00**	**2.94**
Social	Volunteering—participation	5.00	4.00	4.50	2.50	5.00	3.75
	Volunteering—climate action	5.00	4.00	4.50	3.50	5.00	4.25
	Young people in coastal management	4.00	4.00	4.00	2.50	5.00	3.75
	Climate change education in schools	2.00	0.00	1.00	2.00	2.00	2.00
	Fear of policy	4.00	4.00	4.00	2.50	3.00	2.75
	Total social	**4.00**	**3.20**	**3.60**	**2.60**	**4.00**	**3.30**
Natural	Rice cultivation	4.50	2.00	3.25	0.00	2.00	1.00
	Water security	1.50	1.00	1.25	2.00	3.00	2.50
	Biodiversity	4.00	5.00	4.50	2.00	0.00	1.00
	Soil health	2.50	0.00	1.25	1.50	1.00	1.25
	Total natural	**3.13**	**2.00**	**2.56**	**1.38**	**1.50**	**1.44**
Physical	Conservation farming equipment	2.00	1.50	1.75	1.50	1.00	1.25
	Fisheries equipment	1.00	2.00	1.50	3.50	2.00	2.75
	Low input local business	0.00	1.00	0.50	3.00	2.00	2.50
	Total physical	**1.00**	**1.50**	**1.25**	**2.67**	**1.67**	**2.17**
Financial	Off-farm investment	2.00	1.50	1.75	2.00	1.00	1.50
	Off-farm employment	2.50	2.00	2.25	3.00	4.00	3.50
	Availability of cash to adapt	0.00	0.00	0.00	1.50	0.00	0.75
	Total financial	**1.50**	**1.17**	**1.33**	**2.17**	**1.67**	**1.92**

This scoring table of indicators for each capital should be read in conjunction with ***Figure 4****. The scale of 0–5 is also shown and elaborated in* ***Figure 4*** *(after Nelson et al., 2007).*

action to adapt to climate change. Conversely, the district reflects social and human capital as having a high value. Therefore, no immediate action is required for asset transformation toward these components.

Priority Components From Local Communities Relating to National Plans

Prioritized adaptation options or strategies of local communities were a key finding that emerged after detailed analyses of the issues by participants and the identification of key problems and potential interventions. Whilst the participants prioritized the interventions as a group, the priorities in reality were different for every person depending on their circumstances, including their capacity or resilience and vis-à-vis their vulnerability. Nonetheless, after much deliberation and negotiation a final prioritized list of adaptation options at both local community levels was identified as they related to the three national plans (**Tables 2**, **3**). The following two tables highlight bottom-up adaptation options that communities have either prioritized or which they may have self-implemented in some cases, based on survey results and focus group findings. In some cases, these options reflect existing Indigenous or local knowledge and adaptation practices which could be supported by the implementation of different aspects of government policies.

Table 2 (see below) represents the priority adaptation options raised by local community participants of Bhola district. They are cross checked in the table with Bangladesh's three national plans and programs for coastal climate adaptation. The Priority Investments Programs of ICZM (2005) were met with the most recommended priority options, and the local community wishes to enact them immediately. More specifically, this includes ensuring coastal water supply and sanitation, building cyclone shelters and rehabilitation centers, and enhancing coastal livelihoods by creating diversified opportunities. NAPA (2005) was also met with some important action plans to be implemented on a priority basis, which includes capacity building though climate change projects, promoting adaptation knowledge, especially Indigenous knowledge, and providing drinking water facilities in coastal communities. BCCSAP (2009) comprises a more diverse range of plans driven by the

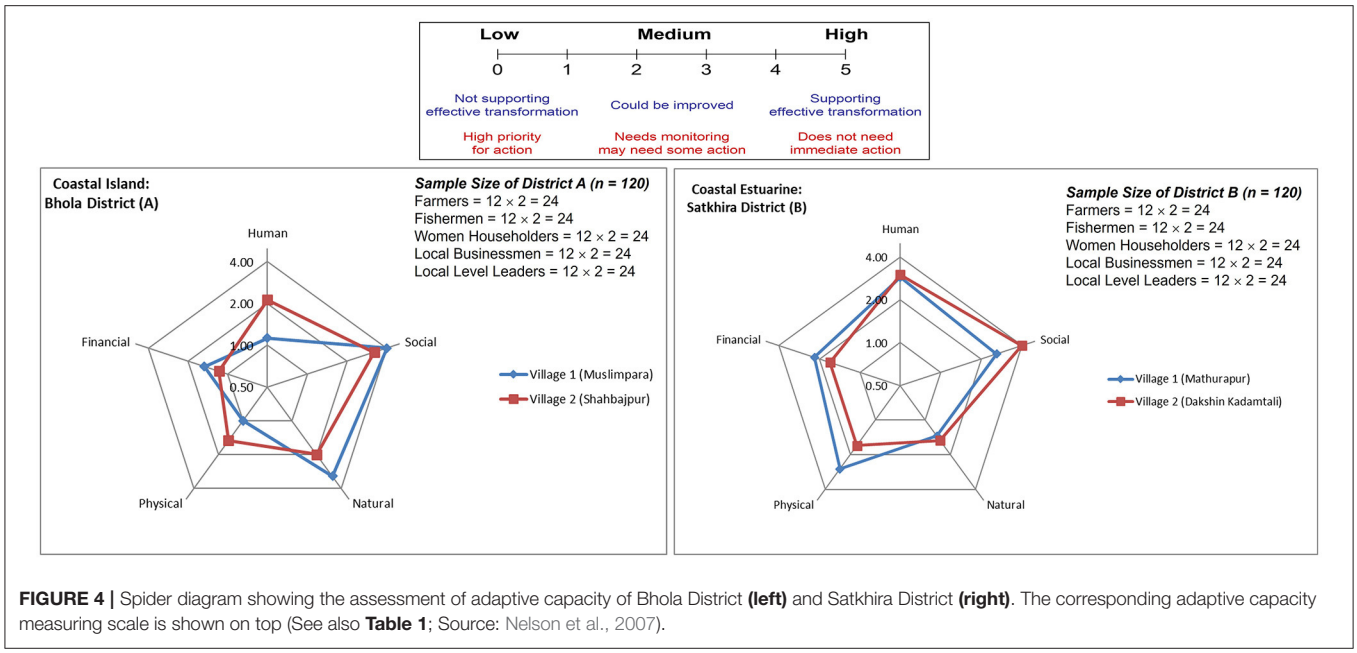


FIGURE 4 | Spider diagram showing the assessment of adaptive capacity of Bhola District **(left)** and Satkhira District **(right)**. The corresponding adaptive capacity measuring scale is shown on top (See also **Table 1**; Source: Nelson et al., 2007).

local community, including development of climate resilient cropping systems, livelihood protection mechanisms, education, health care, cyclone shelters, climate migration, water supply, and sanitation. Altogether local participants of this district emphasized 10 very important priority components which are relevant to the national plans and programs addressed in the article. These components should be considered in national and regional decision-making processes, so that they can be promptly implemented to safeguard local livelihoods against climate change impacts.

Table 3 (see below) represents the priority adaptation options raised by local community participants in Satkhira district. They are also cross checked in the table against Bangladesh's three national plans and programs that are relevant for coastal climate adaptation. Like Bhola district, the Priority Investments Programs of ICZM (2005) were met with the most recommended priority options by the local community of Satkhira district. Some of the highlights are groundwater management which has a link with agricultural development of the district, strengthening of coast guard and building multipurpose cyclone shelters, improving drainage systems and coastal water infrastructure, water supply and sanitation, local women empowerment, and capacity building of local government. Local demand of Satkhira district is also in support of the action plan of NAPA (2005). These include promoting adaptation to coastal crops by combating salinity and adaptation measures for coastal fisheries, awareness raising, coastal afforestation, construction of flood shelter, inclusion of climate change issues in curriculum at secondary and tertiary educational institutions. Among the BCCSAP (2009) plans most of the recommendations driven from the local community are similar with ICZM (2005) and NAPA (2005). Apart from them some of the options are improvement of cyclone and storm surge warning systems, monitoring of ecosystem and biodiversity changes and their impacts, strengthening gender consideration in climate change management etc. Altogether local participants of this district emphasized 11 much needed components which are relevant with the national plans and programs addressed in the article. These components should be considered in the national and regional decision-making process of coastal estuary districts like Satkhira, to be implemented on priority basis.

Adopting Indigenous and Local Knowledge

Although some local knowledge is becoming outdated, invalid, and/or unusable, local people are reported in the literature as sensible and perceptible observers who are able to accurately compare how the climate used to be against what they are currently experiencing (Raihan et al., 2010). They are also remarkably resilient and creative when it comes to adapting to their changing environments and circumstances. Facilitating scientific and technical knowledge jointly is crucial for effective and sustainable local adaptation and can help people at the grassroots relate the changes they are experiencing to their context of progressive or escalating climate change. Importantly, such holistic knowledge promotes a better understanding of "what" is happening around them, and to some extent "why", and may raise more appropriate options for adaptation to climate change that are aptly suited to unique local community contexts (Raihan et al., 2010). This is reflected in **Tables 2**, **3**, which identify significant existing local adaptation strategies that are based on local demand in both Bhola and Satkhira district (**Figures 5**, **6**).

An important factor to be considered in the decision-making process is whether Indigenous knowledge is adopted and valued in decision-making, especially when climate change adaptation is concerned. Unfortunately, this is not the case in either district.

TABLE 2 | Prioritized adaptation options at local community level (Bhola District) as related to national plans and frameworks.

	Bhola district		
Local community-reported adaptation options and priorities	**Linking local adaptation options and priorities to Bangladesh's national adaptation frameworks**		
	(ICZM, 2005)	**(NAPA, 2005)**	**(BCCSAP, 2009)**
1. Construction of "Beribadh" (embankment) around the island is needed urgently for the purpose of adaptation to climate change.	• Integrated management of coastal water infrastructures. • Strengthening and rehabilitation of sea dykes.	• Capacity building for integrating climate change in planning, designing of infrastructure, conflict management and land-water zoning for water management institutions.	———————–
2. Start producing "Rabi Crops" (winter season crops) which was not possible due to saline water intrusion on the land. And installation of more deep tube wells is needed for saline free water for irrigation purposes.	• Development of coastal agriculture in Bangladesh.	• Promoting adaptation to coastal crop agriculture to combat increased salinity. • Promotion of research on drought, flood, and saline tolerant varieties of crops to facilitate adaptation in future.	• Development of a climate resilient cropping system.
3. Enhance the adaptive capacity of livelihoods against the disasters that occur during October-November and again in March-April of almost every year.	• Enhancement of livelihoods in the coastal char area. • Reduction of severe vulnerability in the coastal zone through multi-purpose cyclone shelters, including coping mechanisms	• Development of eco-specific adaptive knowledge (including Indigenous knowledge) on adaptation to climate variability to enhance adaptive capacity for future climate change.	• Livelihood protection in ecologically fragile areas.
4. Saline free drinking water (especially in the winter season) should be available by installing more deep-water tube wells between houses.	• Strengthening sanitation and safe water supply programs in arsenic and salinity affected areas.	• Providing drinking water to coastal communities to combat enhanced salinity due to sea level rise.	———————–
5. Proper sanitation facilities in the villages are needed.	• Strengthening sanitation and safe water supply programs in arsenic and salinity affected areas.	———————–	• Water and sanitation program in climate vulnerable areas.
6. More schools needed for children's education with recruitment of teachers. There is only one public primary school in Char Kukri Mukri Union with no teacher.	• Implementation of District Development Plan at Bhola district	———————–	• Awareness raising and public education toward climate resilience
7. More health centers and recruitment of doctors are needed. There is only one health center with no doctor. Training on family planning is required.	• Promotion of coastal community services through establishment of community radio	———————–	• Adaptation in health sector
8. Construction of more cyclone shelters in the villages is highly recommended.	• Reduction of severe vulnerability in the coastal zone through multi-purpose cyclone shelters, including coping mechanisms.	• Climate change and adaptation information dissemination to vulnerable communities for emergency preparedness measures and awareness raising on enhanced climatic disasters.	• Improvement of cyclone and storm surge warning. • Repair and maintenance of cyclone shelters

(Continued)

TABLE 2 | Continued

Bhola district			
Local community-reported adaptation options and priorities	**Linking local adaptation options and priorities to Bangladesh's national adaptation frameworks**		
	(ICZM, 2005)	**(NAPA, 2005)**	**(BCCSAP, 2009)**
9. The roads toward the school need to be reconstructed soon to enable children to get safely to school.	• Integrated development of remotely located Islands.	———————	———————
10. There should be more job opportunities in the villages, Unions and Upazilas, so that post-disaster, people are willing to stay in the district rather than migrate.	• Enhancement of coastal livelihood through Small and Medium Enterprise development. • Tourism development in the coastal zone for improvement of livelihoods and poverty reduction. • Marine fisheries and livelihood development program.	———————	• Monitoring of internal and external migration of adversely impacted populations and providing support to them through capacity building for their rehabilitation in new environments.

There is evidence of an extensive body of local knowledge regarding adaptation to extreme weather and other activities that would be relevant to climate change adaptation. However, this information has never been systematically sought or valued. At the same time this knowledge is becoming lost over time as data literally dies with older generations. During interviews, most people referred to their grandparents and their knowledge about the warning signs of natural disasters. They also stated that people used to have a lot of prior indications of floods, storm surges, or even cyclones. But over time this knowledge is seemingly being lost. Climate change, in addition to causing rises in sea level, is likely to increase the frequency and severity of severe weather events. The case study sites, due to their latitude and low-lying nature, have endured countless severe weather events over time. Whilst such events are likely to worsen under climate change, benefits can be reaped from examining historical events and the underlying reasons why some events have led to catastrophic outcomes whilst others did not. Statistically, there is a significant association between the two districts and the value placed on Indigenous knowledge in the decision-making process, with Bhola only slightly more positive about the way this role is perceived (**Figure 7**).

Local government service providers can be seen as the responsible and optimally positioned duty bearers to disseminate scientific and technical knowledge on issues like agriculture, livestock, and fisheries through local extension officers. Set within their local context, villagers stand to benefit from being empowered and enabled to enact and implement their preferred bottom-up approaches rather than feeling constrained to passively await the execution of top-down schemes and strategies. In this manner, villagers may also overcome certain limitations that may arise from their sense that local government offices are understaffed, and/or that officials rarely visit them. Local level empowerment harmonizes with the aims and objectives of this research, which sought to raise options to leverage existing Indigenous and local knowledge (ILK) toward the coordinated implementation of government strategies and policies that are aptly suited to facilitate grassroots adaptation in the context of progressive climate change in Bangladesh.

Limitations and Opportunities for Future Research

This article is focused on strategic policy, the decision-making role of stakeholders, and valuing their local knowledge. It draws on place-based case studies to illustrate points rather than provide a detailed analysis of statutory environmental and planning law. As with other place-based case studies this empirical research has geographical limitations in that it selected only four sites (villages) at two locations (districts) in Bangladesh to conduct the research. The findings reflect wide gaps within ICZM (2005), NAPA (2005), and BCCSAP (2009) approaches to coastal planning and management, and the decision-making functions between local stakeholders and policy makers. The research recognizes the importance of assessing adaptive capacity and sustainable decision-making processes for diverse yet comparatively small socio-economic groups in Bangladesh. Even so, despite these geographical limitations the research makes a valid contribution by exploring vital cross-cutting implications and thus raising options to enhance adaptive capacity in other similar parts of the developing world. Moreover, the validation of the local level findings integrates an adaptation model that correlates the input-output dynamics from local level to central decision management level (bottom-up approach). As noted in Section Methods and Techniques, the findings were validated during a second visit to the case study sites in 2012. This subsequent visit saw the presentation of key research findings

TABLE 3 | Prioritized adaptation options at local community level (Satkhira District) as related to national plans and framework.

Satkhira districts			
Local community-reported adaptation options and priorities	**Linking local adaptation options and priorities to Bangladesh's national adaptation frameworks**		
	(ICZM, 2005)	**(NAPA, 2005)**	**(BCCSAP, 2009)**
1. Water storage needs to be constructed underground and more tube wells need to be installed for saline free irrigation water. The existing tube wells provide saline water because of "Gher" shrimp and crab cultivation over most of the land.	• Groundwater management in the coastal zone of Bangladesh. • Development of coastal agriculture in Bangladesh. • Environmental and social responsive shrimp farming.	• Promoting adaptation to coastal crop agriculture to combat increased salinity. • Promoting adaptation to coastal fisheries through culture of salt tolerant fish species in coastal areas of Bangladesh.	• Adaptation in the fisheries sector.
2. More cyclone shelters needed to be installed and response to disasters should be quicker—without delay.	• Reduction of severe vulnerability in the coastal zone through multi-purpose cyclone shelters, including coping mechanisms.	• Climate change and adaptation information dissemination to vulnerable communities for emergency preparedness measures and awareness raising on enhanced climatic disasters.	• Improvement of cyclone and storm surge warning. • Repair and maintenance of cyclone shelters
3. The roads and transport system needs to be improved.	• Integrated development of remotely located Islands.	——————–	——————–
4. Measures should be taken to protect people from tigers of Sundarbans Forest. And the trees of the forest should not be cut down for firewood, this is transforming the forest into a bare field.	• Strengthening of Coast Guard for improvement of coastal safety and security, coordination with other law enforcing agencies.	• Reduction of climate change hazards through Coastal afforestation with community participation.	• Livelihood protection in ecologically fragile areas. • Monitoring of ecosystem and biodiversity changes and their impacts. • Afforestation and reforestation program.
5. The riverside embankments need to be built stronger and bigger to prevent salinity intrusion.	• Strengthening and rehabilitation of sea dykes. • Integrated management of coastal water infrastructure.	• Capacity building for integrating climate change in planning, designing of infrastructure, conflict management and land, water zoning for water management institutions.	• Repair and maintenance of existing flood embankments.
6. Re-excavation of canals and ponds and drainage systems needed to be improved so that the lands will not be submerged or flooded during storm surges.	• Integrated drainage improvement of tidal influenced south-west region of Bangladesh.	• Construction of flood shelter, and information and assistance center, to cope with enhanced recurrent floods in major floodplains.	• Planning, design and implementation of resuscitation of river and khals through dredging and desilting work.
7. The sanitation systems need to be well managed and constructed for everybody.	• Strengthening sanitation and safe water supply programs in arsenic and salinity affected areas.	——————–	• Water and sanitation program in climate vulnerable areas.
8. Government should take initiatives about adaptation to climate change impacts caused by high temperature, excess or no rainfall on coastal zones.	• Capacity building of the local government institutions for integrated coastal resources management	• Mainstreaming adaptation to climate change into policies and programs in different sectors (focusing on disaster management, water, agriculture, health and industry).	• Revision of sectoral policies for climate resilience.

(Continued)

TABLE 3 | Continued

Satkhira districts			
Local community-reported adaptation options and priorities	**Linking local adaptation options and priorities to Bangladesh's national adaptation frameworks**		
	(ICZM, 2005)	**(NAPA, 2005)**	**(BCCSAP, 2009)**
9. More jobs and opportunities need to be increased for women.	• Empowerment of women members/commissioners of local government institutions of the coastal zone.	———————–	• Livelihood protection of vulnerable socio-economic groups (including women) • Strengthening gender consideration in climate change management.
10. The education system is developing, but it needs to be more developed. Environment and climate change subjects should be included and emphasized in the education system.	• Integrated development of remotely located islands. • Promotion of coastal community services through establishment of community radio.	• Inclusion of climate change issues in curriculum at secondary and tertiary educational institutions.	• Awareness raising and public education toward climate resilience. • Preparatory studies for adaptation against sea level rise.
11. The racial discrimination needs to be stopped and access of law and order should increase in the coastal areas. Relief and funds are not being distributed correctly. People who have money are getting more. People who need the support are not getting anything.	• Strengthening of Coast Guard for improvement of coastal safety and security, coordination with other law enforcing agencies.	———————–	———————–

being presented to the local community members who had previously participated in the data collection process in 2011. The focus group participants validated the results and offered valuable suggestions on the outcomes of the research findings.

Demand for more specific adaptation information has been growing in tandem with awareness-raising campaigns about present and future climate change impacts in Bangladesh (Momtaz and Shameem, 2016). Even so, tools for assessing both potential climate change impacts and evaluating available adaptation options have been limited. There is currently a need to make information available to coastal communities in a manner and format that is more accessible and user-friendly. Furthermore, information needs to be made practical in respect of time and space to ensure that effective and sustainable adaptation solutions can be developed with the backing of robust policy support.

Building on previous research (Ellis, 2000; Huq and Khan, 2006; Nelson et al., 2007; Younus and Harvey, 2014; Zamudio and Parry, 2016; Younus and Kabir, 2018), the synthesis of this study points to opportunities for adaptation that may be implemented on a priority basis. The literature concurs that more research is needed that links and conjointly analyses both primary and secondary data sources (Yasmin, 2018). Moreover, development partners should come forward to scale up critical adaptation projects. At the implementation period and in later phases such projects play an important role in tackling climate change issues in Bangladesh. Importantly, and in order to ensure that relevant projects will be both effective and sustainable, project maintenance should be underwritten by multiple stakeholders, including government, donors, and implementing agencies (Yasmin, 2018). Furthermore, and accounting for the likelihood of progressive or even escalating changes in climatic conditions, future studies stand to benefit from incorporating modeling approaches within their research designs. Relatedly, relevant modeling approaches may integrate hybrid design features, wherein environmental and socio-economic parameters are conjointly adopted and analyzed. In synthesis, this research conceptualizes pertinent opportunities for future research that may include:

- Investigating sustainable decision support systems for Bangladesh's coastal zone.
- Examining the wider influence of power, politics, and corruption in relation to coastal developments.

A **Cyclone shelter in Muslimpara village on one of the islands.**

B **Almost dried up canal in Shabajpur village due to tidal effects during the winter season.**

C **A deep tube well installed by Coast Trust NGO for the villagers to get fresh drinking water (Muslimpara village).**

D **A local adaptation strategy to fight against sudden storm surges by building clay steps higher than the ground level (Shabajpur village).**

FIGURE 5 | (A–D) Local policy beneficiary level: Char Kukri Mukri Union, Char Fasson Sub-District of Bhola District. November 2011 (Photographs by Authors).

- Researching participatory community processes in coastal zone management and regularly reviewing progress in face of evolving climate change.
- Applying the framework of this case study to analyze other national adaptation frameworks [e.g., National Plan for Disaster Management (NPDM)].

CONCLUSION

This empirical study was informed by 240 local farmers, fishers, women householders, businessmen, and other local leaders in Bhola and Satkhira districts. Set within the wider climate change adaptation discourse, this case study has sought to identify features and success factors that may facilitate more effective and sustainable climate change adaptation initiatives in Bangladesh's coastal zone. The study did not presume or hypothesize any specific variables that may represent risk exposure, climate sensitivity, or adaptive capacity, but intentionally purposed to identify relevant issues empirically from the local communities involved in this research. In this sense, the case study focused expressly on those prevailing issues and conditions that are deemed important for climate change adaptation by the surveyed communities themselves rather than those matters indicated as relevant by local authorities or

A **Agricultural land converted for shrimp and crab cultivation (Mathurapur village).**

B **Sundarbans Forest as seen from the other side of the river, where people and livestock are under continuous threat of tiger attacks arising from habitat loss and food stress (Dakshin Kadamtali village).**

C **Newly built settlements on the embankment of the river (Mathurapur village).**

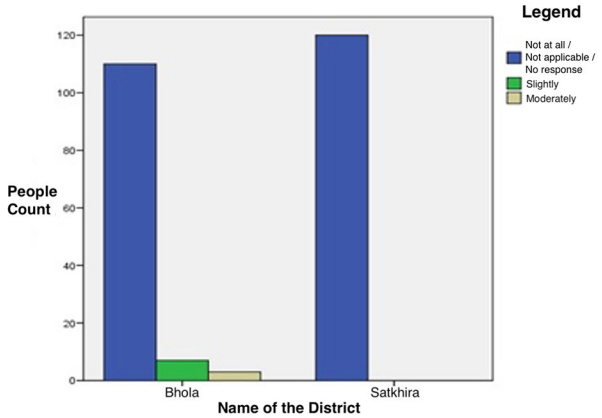
D **Drinking water tank built by a local NGO (Dakshin Kadamtali village).**

FIGURE 6 | (A–D) Local policy beneficiary level: Munshigang Union, Shyamnagar Sub-District of Satkhira District, January 2012 (Photographs by Authors).

for which data are effortlessly available. It thus surveyed and engaged the experience and knowledge of coastal community members to build their resilience toward sustainable coastal management. It identified and documented the decision-making processes into which adaptations to climate change may be merged and integrated within the existing Integrated Coastal Zone Management (ICZM, 2005) framework. This modus operandi has been called a bottom-up approach in contrast to scenario-based top-down approaches and is known to have effectively engaged Indigenous knowledge toward effective climate change adaptation in local communities elsewhere in the developing world (Smit and Wandel, 2006; Leal Filho et al., 2021c).

As shown in **Tables 2**, **3** above, most adaptation options and strategies discussed and identified by research participants in both coastal districts are addressed by the Priority Investment Program of the ICZM Plan for Bangladesh (**Appendix 1**). This indicates that to adapt to climate change and improve the adaptive capacity of local communities, especially post-disaster, ICZM (2005) addresses the most urgent issues and offers solutions in terms of strategic priorities and programs. Relatedly, if those programs can be implemented in a timely manner in those areas where this research took place, people's livelihoods may be substantially enhanced to help them face the challenges of climate change more effectively. Like ICZM (2005), the projects under NAPA (**Appendix 2**) also address many adaptation options discussed by the local people. However, the BCCSAP (**Appendix 3**) addresses the options at macro scale. The action plans and programs are mainly focused on broad themes of adaptation to climate change in Bangladesh, but also raise some significant issues like strengthening gender equity and institutional capacity for climate change management. The adaptation options for coastal island and estuary communities can be effectively addressed by the proper implementation of the projects and programs of the national plans. These programs may also be useful with some

Is the Indigenous knowledge in your community valued and included in decision-making processes?



District	Not at all / Not applicable No response	Slightly	Moderately	Total
Bhola	110	7	3	120
Satkhira	120	0	0	120
Total	230	7	3	240

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.435[a]	2	.005
Likelihood Ratio	14.298	2	.001
Linear-by-Linear Association	9.199	1	.002
N of Valid Cases	240		

a. 4 cells (66.7%) have expected count less than 5. The minimum expected count is 1.50.

FIGURE 7 | Cross Table Analysis and Chi-Square Tests on participant's perception of Indigenous knowledge is valued in decision-making, by district.

modification in other developing countries that have similarly large coastal regions and therefore present similar climate change adaptation needs.

In synthesis, this case study underscores the need to better prioritize adaptation options and strategies that are suitable for local contexts. It seeks to capitalize on options and opportunities that may leverage existing Indigenous and local knowledge (ILK) toward the coordinated implementation of government strategies and policies. It adds to the literature by theoretically and empirically cross-checking local grassroots perspectives against existing adaptation frameworks, namely Bangladesh's Integrated Coastal Zone Management Plan (ICZM, 2005), the National Adaptation Program of Action (NAPA, 2005), and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP, 2009). By aiming to engage the local knowledge of coastal communities more effectively toward sustainable climate change adaptation processes and outcomes, the study makes a timely practice-oriented contribution to the current body of research on coastal climate change adaptation.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Human Research Ethics Advisory Panel B Arts, Humanities and Law Ref No. 11076 University of New South Wales (UNSW), Sydney, and Commonwealth Scientific and Industrial Research Organization (CSIRO) EcoSystem Sciences, Canberra. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

NS: conceptualization, formal analysis, data curation, writing—original draft preparation, and project administration. NS and JL: methodology, investigation, resources, writing—review and editing, visualization, coordination, and funding acquisition. Both authors read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2022.823296/full#supplementary-material

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