LOCAL ENVIRONMENT
2021, VOL. 26, NO. 8, 967–984
https://doi.org/10.1080/13549839.2021.1937970

Routledge
Taylor & Francis Group

Check for updates

Lessons from local indigenous climate adaptation practices: perceptions and evidence from coastal Bangladesh

Md Nurul Amin [a,b], Md Asaduzzaman[b], Alamgir Kabir [c], Shaila Sharmin Snigdha[d] and Md Sarwar Hossain [e]

[a]School of Environmental and Rural Science, University of New England, Australia; [b]Department of Environmental Science, Patuakhali Science and Technology University, Bangladesh; [c]Department of Environmental Science, Bangladesh University of Professionals, Bangladesh; [d]Bangladesh Betar, Ministry of Information, Khulna, Bangladesh; [e]Environmental Science and Sustainability, School of Interdisciplinary Studies, The University of Glasgow, Dumfries, Scotland

ABSTRACT

Lessons of local-scale climate change adaptations through indigenous techniques and knowledge practices (ITKPs) are imperative for climate adaptation policies. This study focused on the benefits of ITKPs and the potential of integrating them into climate adaptation and development activities through focus group discussions (FGDs) (n = 4) (involving persons over 18 years old, had recent disaster experience, and had lived at least 12 years in the area) and household surveys (n = 130) in the southern coastal areas of Bangladesh. We used household surveys to examine the importance of the ITKPs in terms of livelihood development and climate change adaptations, and qualitative syntheses of the FGDs information to reveal the causality of the ITKPs and development activities. Our study revealed that households perceived ITKPs to have higher economic security (64%), livelihood risk reduction (75%) and food security (62%). The majority of households (70%) in the agriculture profession perceived the higher economic potential of ITKPs, depending on the climate-adaptive co-benefits and taking into account their dependencies on climatic events. Agriculture dependent households who perceived the higher benefits of ITKPs were willing to pay 300 BDT/person/year for the improvement and restoration of those in the study areas. Our proposed DPSIR (driver, pressure, state, impact and response) framework implies the potentials of the incorporation of ITKPs into the national climate change adaptation policy in order to ensure sustainable climate change adaption for the coastal community of Bangladesh.

ARTICLE HISTORY
Received 11 June 2020
Accepted 24 May 2021

KEYWORDS
Indigenous knowledge practices; perceptions; climate adaptation; DPSIR framework

1. Introduction

Adaptation to climate change has received increasing attention in policy and research in recent decades, considering its impacts across the world (Arezki et al. 2018; Klein et al. 2005). Considering the heterogeneity of climate change impacts and their social and ecological characteristics, communities, researchers, and policymakers have developed and adopted various adaptation practices in response to the impacts of climate change (Kihila 2018; Leal Filho et al. 2019). Climate change adaptations are the activities that reduce the adverse effect of climatic events (e.g. floods, drought) or extend the beneficial opportunities to offset the negative impact of climate change (Sloat et al.

CONTACT Md Nurul Amin mamin8@myune.edu.au School of Environmental and Rural Science, University of New England, Australia

© 2021 Informa UK Limited, trading as Taylor & Francis Group

Box 1. Definition of some key terminologies

Adaptation
Climate change adaptations are the activities that reduce the adverse effect of climatic events (e.g. floods, drought) or extend the beneficial opportunities to offset the negative impact of climate change.
Local indigenous climate adaptations
Local indigenous climate adaptations are structural or non- structural measures adopted by the local community irrespective of ethnicity as a long term practices perceived to be effective for adaptation processes.
Indigenous adaptation techniques and knowledge practices (ITKPs)
Indigenous adaptation techniques are the structural measures e.g. intercropping, rainwater harvesting and knowledge practices are the non-structural measures e.g. appropriate fishing scheduling by fishermen, changes in farming practices, diversifying alternative livelihoods.

2020). Among these adaptation practices, indigenous adaptation techniques and knowledge practices (ITKPs) are key components for climate change adaptation in the world's developing countries. ITKPs have mainly evolved from years of collective learning experience through a practice of experiential observation and the consequences of practical engagement of everyday life (Makondo and Thomas 2018; Reid et al. 2014; Shaw, Sharma, and Takeuchi 2009). They are handed down from one generation to the next. In this study, indigenous climate change adaptation techniques are the structural measures (e.g. intercropping, rainwater harvesting) and knowledge practices are the non-structural measures (e.g. appropriate fishing scheduling by fishermen, changes in farming practices, and diversifying alternative livelihoods) of climate change adaptation (Barua and Rahman 2017; Kihila 2018) adopted by the local community irrespective of ethnicity (Box 1). The main difference between indigenous and modern adaptation and knowledge practices is the nature of the techniques used. Indigenous adaptation techniques and knowledge practices are highly practical, experience-based, and adjusted within the community (e.g. duck rearing) (Kihila 2018), whereas scientific knowledge of adaptation (e.g. resilience of species to climate change) is experimentally proven and highly technical in nature (Fuentes et al. 2013). ITKPs are used by community for weather forecasting, monitoring, alternative livelihood development, resource protection, ensuring nutritional facilities during adverse climatic events, and securing food production potential (Altieri and Nicholls 2017).

In addition to modern scientific knowledge, incorporation of indigenous climate change adaptation knowledge into development policies ensures participatory and cost-effective measures for climate adaptation and offers sustainability for the procedure in many cases (Nyong, Adesina, and Osman Elasha 2007). According to the Working Group II (WGII) of the 5th Assessment Report (AR5), indigenous knowledge systems were marked as very important for climate change adaptation, monitoring impacts, and vulnerability (Ebi 2012). Many disaster risk reduction specialists have highlighted ITKPs as an important component for creating robust adaptation techniques for the coastal vulnerable community (Nyong, Adesina, and Osman Elasha 2007; Reid et al. 2014). Similar to other coastal areas, ITKPs are the most commonly practiced mechanism for adapting to the climate change induced hazards in the Bangladesh delta (Al Masud et al. 2018; Alam et al. 2017; Ur-Rahman et al. 2011). Considering these facts, ITKPs need to be part of the nation's broader policy perspective, in order to ensure more effective adaptation and the social-ecological resilience of the vulnerable coastal community in Bangladesh (Haque, Rahman, and Rahman 2016).

At present, the sustainable development agenda is addressing different challenges, and many of these challenges could be efficiently managed by ITKPs (Magni 2017). However, undermining the incorporation of ITKPs into the sustainable development initiative will mean that the specified targets are not reached as quickly as targeted. The Intergovernmental Panel on Climate Change (IPCC) is the prominent international body for assessing climate change and creating a good science policy interface. Unfortunately, the 5th Assessment Report of the IPCC underrepresented the indigenous knowledge issue. While it was discussed in Working Group II, it was less focused in scope and had little critical engagement with the indigenous knowledge system (Ford et al. 2016). Bangladesh was one of the first countries to develop a community-adaptation project in the coastal area to cope with the effect of climate change. However, the National Adaptation Program of Action (NAPA) and the Climate Change Strategy and Action Plan (BCCSAP) of Bangladesh did not focus indigenous adaptation practices, as NAPA 2005 and 2009 and BCCSAP 2009 only concerned about indigenous species of agriculture and fishery while planning for adaptation to climate change (Haque, Rahman, and Rahman 2016; BCCSAP 2009; NAPA 2005, 2009). NAPA documented 15 climate change adaptation initiatives, some of which indicated community (e.g. community involved coastal afforestation) involvement (Anik and Sayed Arfin Khan 2012), but only one was broadly indicative of ITKPs (i.e. development of eco-specific adaptive knowledge including indigenous knowledge (BCCSAP 2009; NAPA 2005).

Many studies have identified ITKPs as a prerequisite for developing effective climate change adaptation and social-ecological resilience (Ford et al. 2016; Hiwasaki, Luna, and Shaw 2014; Magni 2017; Nyong, Adesina, and Osman Elasha 2007). Several studies around the world showed the success of the integration of ITKPs at different context e.g. the integration of local and indigenous knowledge practices with science for hydro-meteorological disaster risk reduction (Hiwasaki, Luna, and Shaw 2014), the influence of indigenous approach to climate change adaptation and poverty reduction (Leal Filho et al. 2019), the value of indigenous strategies for climate change mitigation and adaptation (Nyong, Adesina, and Osman Elasha 2007), and the profitability of indigenous adaptation to climate change (Enete, Madu, and Onwubuya 2012). However, the extent of benefits of ITKPs at a local scale has been investigated on a limited scale to ascertain the influence of climate change adaptation and livelihood development. A study on indigenous climate change adaptation examined the implication of indigenous knowledge practices for different aspects such as policy and livelihood but did not measure the level of its contribution (Alam et al. 2017). In addition, a very recent study has proposed a conceptual framework for measuring the sustainability impact of regional indigenous climate adaptation knowledge such as "Tidal River Management" (Al Masud et al. 2018). This framework implied to reveal the main temporal and spatial scale impacts for each indicators of ecosystem services of the tidal river management. The conceptual framework would explain the scientific prerequisite and pathway for overcoming barriers to climate change adaptations and ensuring sustainable solutions for vulnerability and risk exerted due to climate change-induced disasters (Moser and Ekstrom 2010). Thus, a comprehensive framework for conceptualizing local-level indigenous practices and development activities is a prerequisite for ensuring a sustainable solution to climate change adaptation for a vulnerable and affected region like Bangladesh (Ayers et al. 2014; Moniruzzaman 2019).

However, previous studies on climate change adaptation in Bangladesh have not conceptualized the integration of ITKPs-based climate change adaptations into development activities using a comprehensive framework. In addition, previous studies on ITKPs and climate adaptation practices in Bangladesh have focused on vulnerability and natural hazards at local scale (Makondo and Thomas 2018) and agricultural sustainability in the coastal areas (Islam and Shigeru 2019) and wetlands (Monwar et al. 2018) of Bangladesh. Therefore, taking into consideration the future implications of studying the contribution of indigenous climate adaptation practices to livelihood development and adaptation to climate change at local scale (Alam et al. 2017), this study makes a first attempt to develop a comprehensive conceptual framework for integrating ITKPs into climate change adaptation practices. In addition, the study also provides policy implication for indigenous climate change adaptation knowledge based on the lessons from the local indigenous climate adaptation practices in coastal (Alimabad Union in Barishal) Bangladesh. In order to achieve the overall objective of this study, we aimed to answer the following questions:

(1) What are the current indigenous knowledge and technology practices at the local scale?
(2) How are they contributing to livelihood development and adapting to climate change at the local scale?
(3) Can we develop a conceptual framework for integrating ITKPs and development activities?
(4) What can we learn in terms of policy implications from the local evidence of ITKPs?

2. Materials and methods

2.1. Study area

Our study focused on four randomly selected coastal villages (char lands): "Char Penua"; Char Mahisha"; "Elisha Koralia"; and "Sreepur", in the Alimadad Union of Mehendigonj sub-district of Barisal district, Bangladesh (Figure 1). Char lands are formed through the accumulation of lands/sediments in a river course or estuary. The studied villages are located between 90^0 31′50″ east to 90^0 34′10″ east and 22^0 40′50″ north to 22^0 44′20″ north (Figure 1). The socio-economic context and bio-physical characteristics of the study areas mostly similar as those all are Char lands located near to the estuarine coast in the identical geographical location (Fakhruddin and Rahman 2015; Azam et al. 2019). However, inhabitants of those locations typically use various indigenous or locally adopted techniques in order to minimize the loss of resources due to climate-induced disasters (Azam et al. 2019). Considering the above facts, the main criterion for selecting these villages were the geographical location in the southern coastal floodplain of Bangladesh, which is possibly one of the most climate-vulnerable areas in the world (Hossain et al. 2010; Hossain et al. 2015), and the potential use of indigenous techniques by the local community of these types of char lands (Alam et al. 2017; Amin et al. 2018). In these villages, the coastal community and natural resources are highly affected by climate change-induced hazardous events in most years (Hossain and Roy 2012). The natural ecosystem and inhabitants of these villages have been greatly affected by climate change-induced disasters at different times (Amin et al. 2018). Unlike in other coastal parts of Bangladesh, the most common climate change-induced disasters in this area are cyclones (e.g. SIDR and AILA), tidal floods, river bank erosion, and droughts.

2.2. Outline of the methodologies

Both qualitative (i.e. focus group discussions) and quantitative (i.e. household surveys) methods (Figure 2) have been used in this study in order to examine the contribution of ITKPs to livelihood development, adaptation processes, and to develop a conceptual framework for understanding the role of integrating ITKPs into adaptation and development activities.

The general approach of this research has comprised six steps: (1) identification of existing ITKPs through a reconnaissance survey, literature review, and verification through focus group discussions (FGDs); (2) categorization (very high, high, moderate, low, or very low) of the monetary benefits of ITKPs to livelihood development and adaptation processes at the local scale using FGDs; (3) estimation of the willingness to pay (WTP) for livelihood development and climate adaptive co-benefits using FGDs; (4) examination of the perceived benefit and WTP of ITKPs for livelihood development and adaptation processes through household surveys; (5) conceptualizing a DPSIR (driver, pressure, state, impact and response) framework through FGDs and synthesized information based on steps 2, 3, and 4 in order to understand the role of ITKPs in livelihood development and adaptation processes.

2.3. Interpretations of the data collection methodologies and data analysis

2.3.1. Focus group discussions (FGDs)

At the initial stage, a list of available ITKPs were identified using a reconnaissance survey and literature review. The literature review was conducted in August and September 2017 using the Web of Science and Scopus databases. This narrative literature review considered scientific studies that focused on indigenous knowledge and technology for climate change adaptation in coastal Bangladesh. The literature review resulted a comprehensive list of potential ITKPs in the coastal areas of Bangladesh. The characteristic (e.g. long collective learning experience from observation, practical engagement of daily life, and transferred from one generation to another) of the ITKP was explained

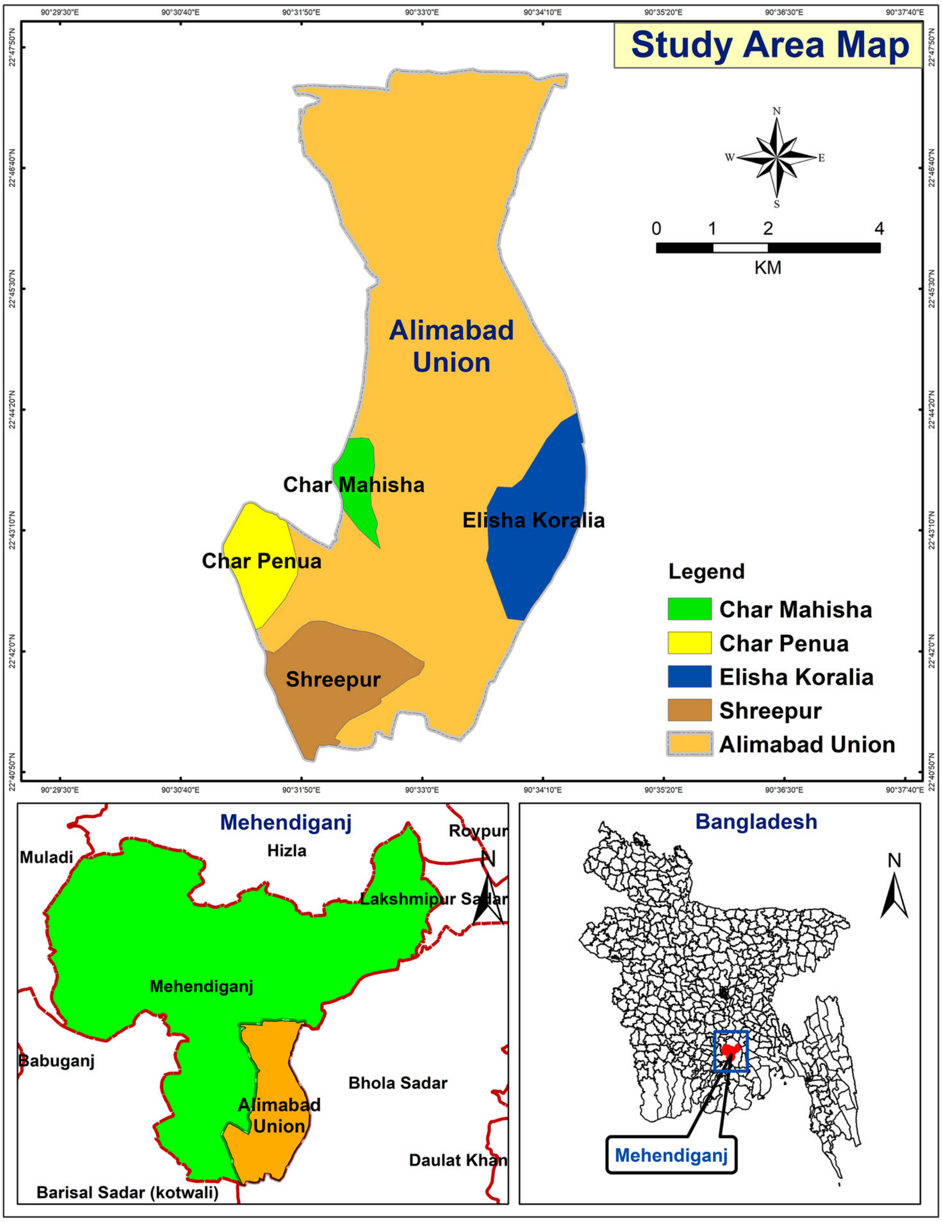

Figure 1. Alimabad Union within Mehendigonj sub-district of Barisal district in Bangladesh. The four surveyed villages are located in Alimabad Union.

to the FGD participants. Then the list of ITKPs from the review were verified through FGDs to select the indigenous knowledge practices that were in continuous local practices irrespective of ethnicity in these areas (Box 1). Four FGDs were conducted in four villages in order to finalize the list of practiced ITKPs for climate change adaptation and the estimation of the categorized (very high, high, moderate, low, or very low) monetary benefits of ITKPs to livelihood development and climate change adaptation on the local scale. The monetary benefits for each category were also calculated (Table 1). The perceived monetary benefits of the climate change adaptations were estimated on the basis of four selected climate adaptation co-benefits parameters (economic security, restored soil

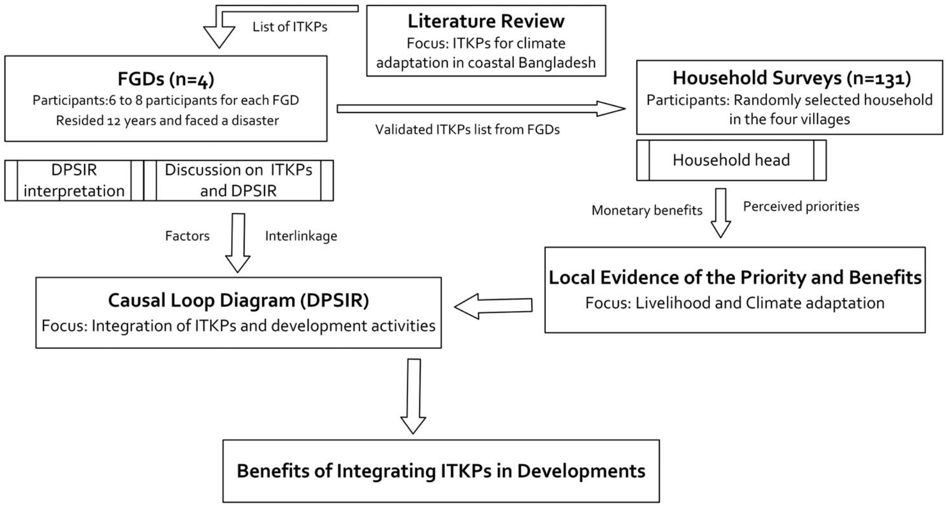

Figure 2. Flowchart showing the complete process of this research. The link between the information collected from the focus group discussions, household surveys, and literature review is shown in this diagram.

health, food security, and livelihood risk reduction). These parameters of climate adaptation co-benefits were purposively selected from FGDs to answer research question 3. According to the Pachauri et al. (2014), co-benefits are the positive effect of a policy or measures irrespective of the net effect on total social wellbeing. In this study, we assumed climate adaptive co-benefits to be a simple understanding of the benefits of practices for adapting with climate induced disasters in the coastal areas of Bangladesh. Eventually, to calculate the perceived adaptive monetary benefits, each of the four identified co-benefits were calculated using the same category as the climate adaptive co-benefits in Table 1. The perceived WTP ranges were estimated on the basis of the two categories (livelihood development and climate adaptive co-benefits) from the FGDs (Table 1). On average, there were six to eight participants in each FGD. The participants were heads of their families (over 18 years old, had lived in the area for at least 12 years, and had experienced disasters (e.g. cyclones or tidal floods). The FGD participants were selected based on practical disaster experience (i.e. before, after, and during) and taking into account the fact that a couple of recent cyclones (SIDR and AILA) had hit the coastal part of Bangladesh within the last 12 years. The participants were selected with the help of the Union Council Office. In this study, FGDs were conducted in order to rationalize information on the unique characteristics of the existing ITKPs and their pre-categorized perceived monetary benefits in different contexts (i.e. livelihood benefits

Table 1. Categorized perceived monetary benefits, willingness to pay for livelihood development, and climate adaptation co-benefits.

Category	Level of Benefits	Amount (BDT/Person/Year)
Livelihood benefits	Very high	25,000
	High	16,000
	Moderate	10,000
	Low	8,000
	Very low	5,000
Climate adaptation co-benefits	Very high	6,000
	High	4,000
	Moderate	2,000
	Low	1,200
	Very low	600
Willingness to pay (WTP)	Livelihood development	100–400
	Climate adaptive co-benefits	50–300

and climate adaptation benefits). Another major use of FGDs in this study was in the attempt to create a DPSIR-based framework in order to understand the role of ITKPs and the development activities of climate change adaptation in these areas (Section 2.3.3).

2.3.2. Household surveys

We conducted household surveys in order to collect information on the available ITKPs, the contribution of ITKPs to livelihood development and climate adaptation, and the household WTP for the contribution of ITKPs between October and December 2017 in the study area. For the household survey, 130 households were randomly selected from the four villages (Figure 1). The household survey included 12% of the total of 1121 household (n=130) in the selected four villages. The survey mostly targeted household heads, using a structured questionnaire to collect information on ITKPs. If the household head was unavailable, an active member (not less than 18 years old) of the family was selected for the survey. In most of the case household heads were mainly the active elderly person in the family, and in few cases main earning person of the family. Verbal consent was requested before the aim and objective of the research were explained. On average, each survey lasted for approximately an hour.

A percentile representation of the socio-economic profile of the respondents is presented in Table 2. In this study, around half (52%) of the respondents were young people (18–39 years old), and the other half (48%) were middle-aged and elderly people (40+ years old). A large number (40%) of the respondents were both household workers and landowners, and also leased their lands to other farmers (15%). Around 18% of the respondents were engaged in fishing activities. Most of the fishermen leased their fishing gear from the household workers. Among our respondents, almost 28% were employees and small business holders. In this study, we considered farmers, fishermen fishing in coastal water, and household workers to be members of the agricultural profession, and the rest of the respondents to be in non-agricultural professions. About half (48%) of the respondents had no schooling experience (although some of them could sign their names), and 45% had school education, while only 6% had higher education (Table 2). More than 75% of the respondents' income level was below 10,000 BDT/month; less than a quarter of them had an income level of above 10,000 BDT/month (Table 2).

The questionnaire included questions about available local ITKPs at home and workplaces and the benefits of ITKPs for livelihood development and climate change adaptation. In this study, benefits refer to the avoided cost (i.e. value of damage avoided by using ITKPs) and additional economic outputs (i.e. extra monetary gain in addition to usual business) of ITKPs. In addition,

Table 2. The socio-economic profile of the respondents.

ITEM	GROUP	PERCENTAGE (%)
AGE	Young (18–39)	52
	Middle-aged (40–59)	34
	Elderly (60+)	15
GENDER	Male	58
	Female	42
PROFESSION	Farmers	15
	Fishermen	18
	Household workers	40
	Employees	15
	Small business owners	13
EDUCATION	No schooling	48
	1–5 years of schooling	27
	6–10 years of schooling	18
	More than 10 years of schooling	6
INCOME/MONTH	Less than 5000 BDT	17
	5000–8000 BDT	35
	8000–10,000 BDT	25
	More than 10,000 BDT	23

respondents were asked to rank the ITKPs that were beneficial for their livelihood development and for adapting to climate change induced disasters. In addition to the ranking of ITKPs, questions were also asked about the categorically perceived (i.e. very high, high, moderate, low, or very low) monetary benefits of ITKPs. These categorically perceived monetary contexts of ITKPs were estimated in terms of profession and classified into two categories (agriculture and non-agriculture) to examine the effect on prominent agricultural-related professions (Table 2) in the coastal study areas. The professional categorization of the respondents is discussed in section 3.1. In all cases, the perceived monetary contribution of the livelihood development of ITKPs was within the five categories (very high, high, moderate, low, and very low) defined during the FGDs. A similar approach was used for estimating the perceived climate adaptation co-benefits of the ITKPs (i.e. economic security, restored soil health, food security, and livelihood risk reduction). Finally, questions were asked about the willingness to pay (WTP) for livelihood development and climate adaptation co-benefits in the area. In all of the cases, the categories were then translated to real monetary values (Bangladeshi Taka – BDT) estimated during the FGDs (Table 1). The monetary value estimates of the livelihood benefits, climate adaptation co-benefits, and WTP were calculated by multiplying the mean value for each of the components (livelihood benefits, climate adaptation co-benefits, and WTP) by the total number of respondents. Negative responses (i.e. people who responded "NO" to the questions about livelihood benefits, climate adaptation co-benefits and WTP) were excluded from the calculations. For instance, the total proportion of non-responses to the question about livelihood benefits of ITKPs was 8%, therefore the data on total livelihood benefits were taken from the average responses of 92% of the respondents. An explorative percentage analysis of the household survey data was conducted to answer the research questions 1 and 2, and visualization of the data was performed using the package ggplot2 of Rstudio version 1.1.456. We synthesized and documented (where relevant) the key dimensions of ITKPs described during the FGDs e.g. farmers used the mulch of water hyacinths to retain moisture in soil and provide organic nutrients to the crops.

2.3.3. Conceptual framework. We developed a conceptual framework based on the DPSIR framework and FGDs in order to understand the role of ITKPs and the development activities of climate change adaptation in these areas. DPSIR is a causal framework for delineating the interrelationship between the societal act and nature (Kristensen 2004; Tscherning et al. 2012). We chose the DPSIR framework for its wider use in different contexts (e.g. coastal wetlands developments, fisheries management) and its effectiveness for detailed analysis of interdisciplinary issues e.g. developing management responses, environmental changes, and policy responses (Hossain et al. 2015). The DPSIR framework of this study depicts the potential cause–effect relationships of the ITKPs and development activities in the study area created during the FGDs. In our framework: "drivers" indicate the needs that lead to changes in societal actions; "pressures" are human involvement that minimize the social effects; "states" are indicative of changes in the environmental context due to human actions; "impacts" are the result of human actions; and "responses" are the feedback from human actions (Kristensen 2004).

After collecting the targeted information based on the different components of DPSIR, a comprehensive framework for ITKPs and its subsequent phases in influencing climate-adaptive development activities were developed. During the FGDs, the DPSIR framework was briefly described to the participants before collecting information related to ITKPs for climate change adaptation, taking into consideration each of the components of the DPSIR framework. For example, discussion was initiated by explaining the "drivers" (i.e. the need for ITKPs to enable the reduction of disaster-induced loss) of climate change adaptation. This was followed by listing and discussing the main drivers of indigenous knowledge and technology practices for climate change adaptation in the study area. Similarly, each of the other components of the DPSIR framework (pressure, state, impact and response) were collected in order to conceptualize the role of ITKPs and other development activities in climate change adaptation. After listing all the information under each of the components of the DPSIR framework, the causal relationship among the DPSIR components was mapped based on the discussion with the participants of the FGDs. Our study synthesized all of the information collected from the four FGDs to finalize DPSIR components and combined all of the perceived connections proposed in the FGDs. We used Microsoft Visio2016 to visualize the final output of DPSIR framework.

3. Results

3.1. Summary of local indigenous techniques and knowledge practices (ITKPs)

The list of ITKPs and percentages of respondents adopting these ITKPs is provided in Table 3. The survey results revealed that 82.05% were practicing homestead gardening to add to their daily supply of food and as alternative sources during flooding seasons. They practiced this gardening in relatively high land areas, or by using "Macha" (an elevated structure above land, mainly made of bamboo or wood). In general, local people had traditional ways of ascertaining suitable practice times and structures for gardening, depending on their experience. For example, the vegetables were cultivated mainly during the dry winter, while some crops (e.g. gourd) were cultivated during summer.

Around 82% of household members were highly involved in free-range duck rearing, which provides a very good source of nutrition. These local varieties of ducks are more susceptible to various types of disasters (e.g. survive without shelters during frequent tidal floods) and need less food supply as they collect foods from the local natural wetlands. The ducks can survive tidal floods in the rainy season, but droughts or cyclones can cause severe damage to their numbers. The plantation of trees on high land is called "Aat" locally. "Aat" is usually a relatively higher lands prepared with low (e.g. wetlands) and plain land soil. Soils from low and plain lands in the "Aat" provide nutrients to plants, protect root damage from decay, and provide proper drainage from floodwater. Using this technique, local people (98%) planted different kinds of trees (e.g. fruit trees, trees used for fuelwood, and trees for medicinal purposes) to fulfill their various household needs during disaster and non-disaster prone months. Pigeon rearing was another popular technique, with most households (97%) engaged in the practice. Pigeons are safe from climatic events (e.g. floods, heavy rain, storm surges) as they are usually reared just under the rooftop. The use of "Macha" (relatively high places) for storing fuelwood was another technique commonly used by households (98.7%) to protect the wood from rain and floods.

Most of the households (84.3%) in the study areas had elevated their homestead areas after recent cyclones (SIDR and AILA) and tidal floods which was one of the prominent practices identified by the participants during FGDs. Community members also highlighted that two-layer homestead platforms and four-sided verandas were more effective at protecting against the force of the water. The household survey and FGDs revealed that around 14% of households tied the four

Table 3. Percentile distribution of livelihood-based (agriculture and non-agriculture) indigenous technology and knowledge practices for climate change adaptation in the coastal area of Bangladesh.

Sl. No	Livelihood-Based Adaptive Strategies	Used (%)	Not Used (%)
Agricultural-based adaptation strategies			
1	Mulching	70.83	29.17
2	Integrated cropping	40.00	60.00
3	Vegetable bag cultivation technique	52.00	48.00
Adaptation strategies for both agriculture and non-agriculture			
4	Homestead gardening	82.05	17.95
5	Free-range duck rearing	82.20	17.80
6	Plantation of trees on high land ("Aat")	98.00	02.00
7	Pigeon rearing	97.30	02.70
8	Fuelwood storage in "Macha"	98.70	01.30
9	Elevated homestead area	84.30	15.70
10	Houses tied to trees	98.00	02.00

corners of their houses to the nearest trees in order to protect the houses from strong cyclonic winds. This precautionary practice can save the main structure of a house, although roofs are often blown away by a heavy storm.

The practice of mulching was very common (used by 70% of households) in the crop fields of the study area. Farmers used the mulch of water hyacinths to retain moisture in soil and provide organic nutrients to the crops. In the study area, 40% of respondents practiced integrated cropping techniques. Since this area is affected by various natural calamities, people usually cultivate different varieties of crops in the same field in the same season. Integrated cropping was practiced on the elevated land by digging canals around the land. Another technique was cultivating vegetables in bags; 52% of households cultivated vegetables in bags full of soil, hanging them on trees to protect the vegetables from inundation by high tide.

Our results revealed that ITKPs have been considered the most prevalent adaptive measurers used for adapting to adverse climate change induced events in coastal areas of Bangladesh. During this study, we examined this important discourse around the essence of ITKPs by investigating their priority in terms of livelihood development and climate adaptations. Figure 3 summarizes the priority of the essences of ITKPs on a five-point scale (i.e. extremely high, very high, high, low, and very low) within livelihood categories (agriculture and non-agriculture ITKPs) and climate adaptation. Here, agricultural ITKPs were directly related to agricultural crop production (Figure 3(A)), and according to the household survey, homestead gardening, free-range duck rearing, pigeon rearing, mulching, integrated cropping, vegetable bag cultivation techniques and wood storage in the "Macha" all effectively influenced the livelihood development of the local people. The importance

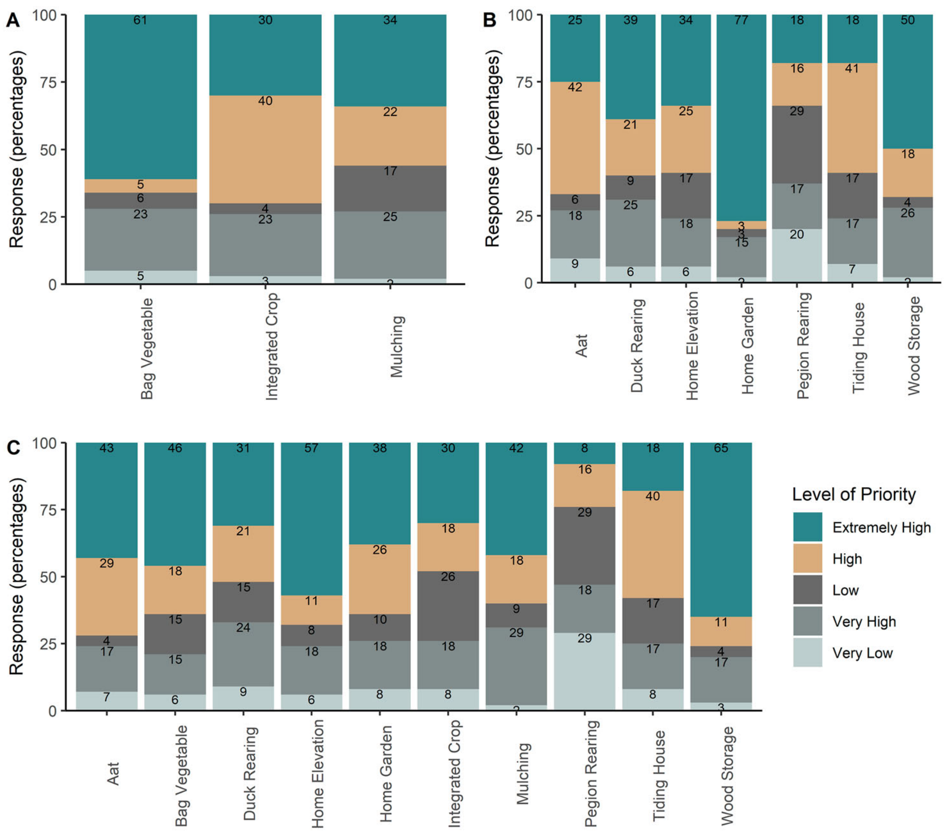

Figure 3. Level of importance of indigenous technology and knowledge practices (ITKPs) considering (A) agricultural livelihood benefits; (B) all other livelihood benefits; and (C) climate change adaptation in the coastal areas of Bangladesh.

of ITKPs to agricultural livelihood development was perceived to be extremely high (61%) for vegetable bag cultivation, mainly due to its importance in helping to adapt with climate change induced flooding in the studied areas (Figure 3(A)). According to the FGD results, vegetable bag cultivation was perceived to have greater potential for food security as it restored vegetable production during inundation by floods and supplementary income during disaster-prone seasons. Mulching (34%) and integrated cropping (30%) were also perceived as extremely high-essence ITKPs for agricultural livelihood development in terms of moisture retention during the frequent summer droughts and sustainable agricultural production (Figure 3(A)).

According to the household survey, homestead gardening (77%) was perceived as an extremely high priority technique for livelihood improvement (Figure 3(B)). Homestead gardening in the high land homestead area potentially supplies food during flood-prone seasons and provides income support for women. The highest-essence ITKP, according to the survey, was fuelwood storage (50%) in the "Macha" (Figure 3(B)). Fuelwood storage provides secure and low-cost cooking facilities during disaster periods, especially in the case of floods and heavy rain. About 34% and 39% of respondents, respectively, perceived homestead elevation and duck rearing to be extremely important for livelihood development. Planting trees on high lands using "Aat" (42%) and securing houses using trees (41%) were also perceived as highly important ITKPs in relation to livelihood security (Figure 3(B)).

According to the household survey, the plantation of trees on high lands, fuelwood storage in the "Macha", elevation of the homestead area, mulching, integrated cropping, and vegetable bag cultivation techniques were the most important ITKPs for adapting to climate change induced disasters (e.g. cyclones, floods, droughts) and untimely climatic events (e.g. prolonged summers, high rainfall). The survey revealed that vegetable bag cultivation (46%), fuelwood storage in the "Macha" (65%), elevation of the homestead area (57%), and mulching (42%) were perceived as extremely high priorities when adapting to climate change induced disasters and untimely climatic events (Figure 3(C)). The next highest-essence disaster adaptation (Figure 3(C)) techniques were homestead gardening (38%), duck rearing (31%) and integrated cropping practices (30%) (Figure 3(C)).

3.2. Contribution of ITKPs to livelihood development and climate adaptation

This part of the study explored the contribution of ITKPs to livelihood development and climate change adaptation in terms of perceived monetary benefits. The monetary benefits of ITKPs were estimated on the basis of the summary values extracted from the FGDs (Table 1). Our household survey found that around 85% of respondents used ITKPs and more than 80% of households perceived ITKPs to have higher potential for climate change adaptation and livelihood development. The respondents not keen on ITKPs were mostly the high-income group (Table 2) and those whose professions were less dependent on avoiding climatic events (e.g. employees). Most high-income people were non-agriculture dependent and lived in brick houses with good protection from disasters. Respondents who were not keen on ITKPs also perceived them to have less economic potential for livelihood development and climate adaptation. Our survey results revealed that a remarkable proportion of households (more than 80%) were willing to pay for the improvement and restoration of indigenous technology.

3.2.1. Contribution to livelihood development

The households were asked about currently practiced ITKPs in order to categorize such techniques on the basis of their influence on livelihood development. It was found that most respondents in the agriculture profession (farmers, fishermen, and household workers) perceived ITKPs to have high (32%) to very high (38%) livelihood benefits (Figure 4(A)). However, around 15% of respondents in this profession perceived ITKPs to be less economically beneficial (Figure 4(A)) which might be because of their multiple livelihood activities and challenges in the scale of production possibly due to lack of technical skill. In the non-agriculture profession, around 70% of respondents perceived

ITKPs to have moderate to very high livelihood benefits (Figure 4(A)). From the household survey, we estimated that ITKPs had high to very high monetary benefits for the livelihood development of the 70% of respondents who worked in the agriculture profession, ranging from 16,000–25,000 BDT/year/person (Figure 4(A), Table 1). However, 30% of the households working in the agriculture profession were estimated to have the lowest to moderate monetary benefits, i.e. 5000–10,000 BDT/year/person (Figure 4(A), Table 1). Interestingly, perceptions of monetary benefits for livelihood development were considerably lower in the non-agriculture profession than in the agriculture profession. The survey responses revealed that this lower monetary perception in the non-agriculture profession was mainly due to their lower dependence on climatic factors (e.g. rainfall, temperature). The perceived livelihood benefits of ITKPs for the non-agriculture profession were estimated between 16,000 BDT/year/person (13%) and 5000 BDT/year/person (7%) (Figure 4(A), Table 1). We have estimated that the majority of households in the non-agriculture profession (70%) perceived their livelihood benefits from ITKPs to be very low (5000 BDT/year/person) to moderate (10,000 BDT/year/person) (Figure 4(A), Table 1).

3.2.2. Contribution to climate adaptation

The households were asked about currently practiced indigenous technologies in order to categorize them on the basis of climate change adaptation. More than 80% of households assumed that most current ITKPs are climate-adaptive in terms of livelihood security and adaptation to climate change induced adverse climatic events. It was found that economic security and livelihood risk reductions were the most prioritized options for ITKP adaptations, while restoration of soil health and food security were considered co-benefits of ITKPs. According to the household survey, more than 60% (Figure 4(B)) of households perceived the use of ITKPs during adverse climatic events to provide high to very high economic security. This perceived monetary value ranged from 4000 BDT/year/person (32%) to 6000 BDT/year/person (33%) (Figure 4(B), Table 1). Again, about 75% of households perceived ITKPs to have the potential for (Figure 4(B)) high (4000 BDT/year/person) to very high (6000 BDT/year/person) livelihood risk reduction (Table 1). The resource protection potential of the ITKPs in terms of monetary value was perceived as high to very high by 65% of households (Figure 4(B)). It was also found that 62% of households perceived high to very high monetary potential for food security assurance (Figure 4(B)). Furthermore, almost 50% of respondents perceived ITKPs to provide a higher economic potential for soil health restoration (Figure 4(B)).

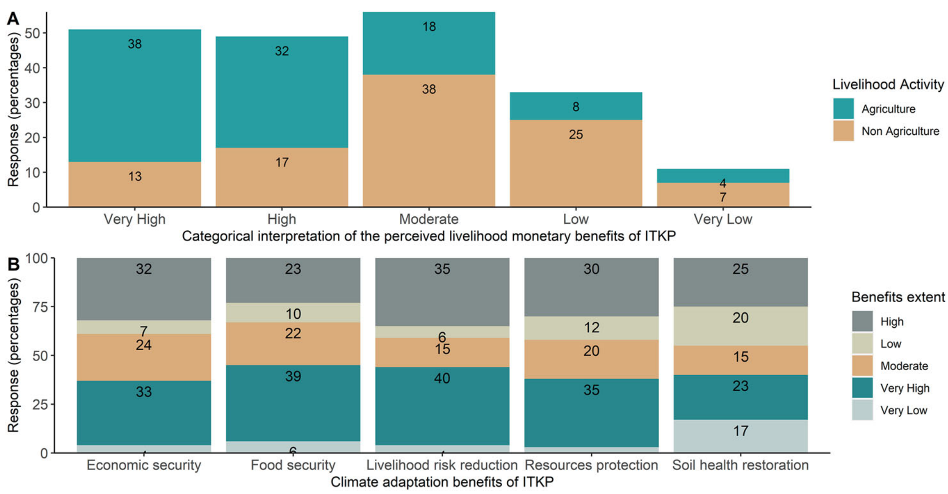

Figure 4. Categorical perception of (A) the livelihood monetary benefits of ITKPs and (B) the monetary benefits of the climate adaptive co-benefits of ITKPs in coastal areas of Bangladesh.

3.2.3. Perceived monetary benefits of ITKPs and willingness to pay

Our study also estimated the perceived monetary co-benefits of climatic disaster damage reduction from the use of ITKPs, which might be considered as the avoided cost in this case. In this study, the perceived avoided cost, i.e. the climate adaptation co-benefits of ITKPs, was estimated at 19,600 BDT/person/year. We also calculated the perceived livelihood benefit of ITKPs according to the household survey, with the estimated value of livelihood benefits being 20,500 BDT/person/year.

The study found that 75% of households were willing to pay for the protection and improvement of ITKPs considering the context of their contribution to livelihood development and climate adaptations. Furthermore, our study also estimated perceived willingness to pay on the part of different professions (agriculture and non-agriculture). We calculated a higher WTP in the agriculture profession (307 BDT/person/year) than in the non-agriculture profession (136 BDT/person/year) (Figure 5(A)). In this study, WTP was also estimated in terms of climate adaptation benefits and livelihood benefits, and according to the survey, WTP for livelihood developments (290 BDT/person/year) was higher (Figure 5(B)) than for climate adaptation benefits (205 BDT/person/year).

3.3. Components of the conceptual framework (Driver-pressure-state-impact-response, DPSIR)

The DPSIR framework was used in this study to explore the benefits of local ITKPs (Figure 6). In general, DPSIR framework provides an idea about potential cause–effect relationships of the ITKPs and development activities in the study area. In particular, implies the drivers of changes, pressure and state due to changes in the drivers and possible impacts and response to mitigate and adapt with impacts in the community. In order to do that, FGDs were used to examine the drivers, pressures, states, impacts, and responses for ITKPs. The main driving forces for local ITKPs were frequent disasters (e.g. SIDR in 2007, AILA in 2009, Mahasen in 2013, and frequent tidal floods in the monsoon) that induced losses in the coastal areas. Poor socio-economic conditions and poverty (Table 2) lead to the adoption of low-cost, socially and culturally acceptable ITKPs to ensure food and livelihood security for better climate change adaptation. The leading pressure to use local ITKPs were disaster risk reduction, and cost-effective techniques used for the climate adaptation processes. Other pressures included alternative livelihood generation and nutritional arrangements during and after disasters. According to participants, local indigenous techniques and knowledge practices change the state of the environment by restoring soil health, thus ensuring water and nutrient retention in soil (e.g. mulching) and facilitating plant production in adverse situations (e.g. the plantation of trees on high land ("Aat"). Moreover, ITKPs interpolate easily repeatable ecosystem-based alternatives and simple technical know-how (e.g. integrated cropping) to ensure better production and

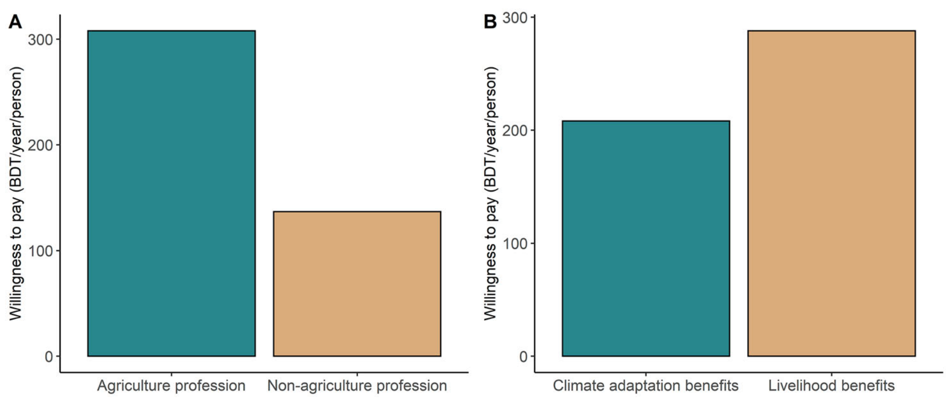

Figure 5. Willingness to pay on the part of (A) agriculture and non-agriculture profession for (B) the climate adaptive co-benefits and livelihood benefits of ITKPs in coastal areas of Bangladesh.

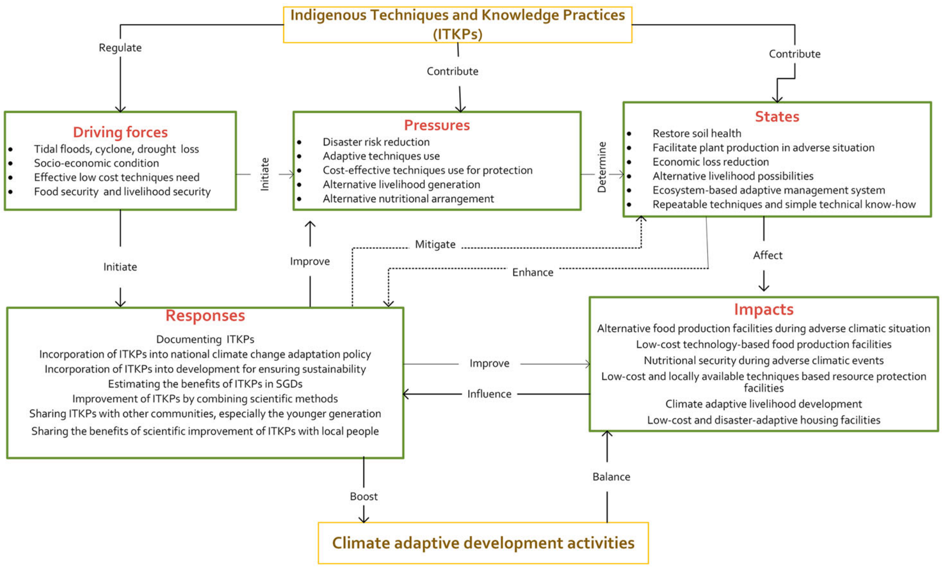

Figure 6. Driver-pressure-state-impact-response (DPSIR) framework, based on ITKPs use, for integrating climate change adaptations and development activities.

environmentally friendly use of natural resources (for instance, integrated cropping minimizes the use of chemical fertilizer and pesticides). This environmental state, resulting from ITKPs, ensures alternative food production facilities (e.g. vegetable bag cultivation techniques, homestead gardening), livelihood opportunities (e.g. free-range duck rearing, pigeon rearing), and low-cost housing and other resource protection facilities (e.g. fuelwood storage in the "Macha", securing houses to trees) in disaster situations. According to the FGD participants, documenting these structural (e.g. elevation of the homestead area) and non-structural (e.g. integrated cropping) ITKPs benefits in the national climate adaptation policy is essential for ensuring the protection and potential use of these techniques. In their view, elderly indigenous people are the main facilitators and users of ITKPs in their areas, thus sharing the benefits of these ITKPs with the younger generation and incorporating it into scientific examination will ensure future protection and greater benefits in terms of livelihood development and climate adaptation (Figure 6).

4. Discussion

The study results suggested that people use ITKPs for economic security and livelihood risk reduction in the study area. This study presented substantial perceived economic securities of ITKPs in terms of climate change adaptations and livelihood risk reduction. People in study areas use many local indigenous techniques and forms of knowledge for resource protection and livelihood security during disasters. Our study showed that ITKPs are very important for cost-effective and location-specific climate adaptation processes in the coastal areas of Bangladesh. In relation to the socio-economic and livelihood status of these areas, ITKPs are the most easily accessible mechanisms to adapt with the changing climate. The perceived co-benefits of ITKPs are restoration of soil health, ensuring food security, and protecting resources from disasters (Figure 4(B)). This study revealed the priorities of ITKPs in terms of livelihood activities and extents of benefits, thus provide the prevalent understanding of the importance in agriculture and non-agriculture sector (Figure 4(A)), and relative importance in terms of co-benefits (Figure 4(B)) for effective adaptation processes. This outcome could be useful for similar coastal areas when considering crucial decisions (e.g. agricultural extension department decision on crop rotation program) on coastal adaptations process to make it effective in terms of the existing livelihoods and acceptance to the local inhabitants. The study suggests that documenting ITKPs and integrating their scientific techniques through the participation of local people may enhance the effectiveness of these ITKPs in coastal Bangladesh. The process of integration of the science and ITKPs requires a comprehensive understanding of the causal links among the factors in ITKPs use, impacts and responses. A comprehensive DPSIR framework helped to develop a systematic approach for detecting the role of indigenous climate change adaptation techniques, and ascertaining the context and concerns in order to overcome the barriers to using existing techniques in policy and practice.

4.1. Conceptual framework (DPSIR) for climate-adaptive development activities

This study explored different components of the DPSIR framework based on ITKPs in order to examine its potential to integrate climate change adaptations and development. The interrelations of the DPSIR components extracted from the FGDs showed that ITKPs regulated driving forces such as disaster-induced property and economic losses. Other drivers regulating the use of ITKPs were the socio-economic conditions of the coastal areas and the issue of ensuring food and livelihood security using low-cost techniques. According to the FGDs, these driving forces initiate the pressure of climate-induced disaster risk reduction using ITKPs (Figure 6). Moreover, they initiate responses such as documenting ITKPs, incorporation of ITKPs into national climate adaptation policies, improvement of ITKPs by combining them with scientific methods, and estimating the benefits of ITKPs in SDGs (Figure 6). According to the participants, use of ITKPs contributed to disaster risk reduction, which ultimately determined soil health and thus facilitated food production in adverse climatic situations. Moreover, ITKPs ensured alternative livelihood possibilities and ecosystem-based adaptive management systems (i.e. those that were easily repeatable with simple technical know-how). Eventually, a positive response towards the improvement and protection of ITKPs could help to mitigate the state of the environment during and after climate induced disaster events, which may ultimately decrease the pressure of disaster risks. Enhanced responses using communication and understanding the benefits of ITKPs, as well as incorporating them into national policy and SDGs, would boost climate-adaptive development activities in the coastal areas of Bangladesh. In recent decades, there has been growing evidence that ITKPs are positively related to livelihood development and climate change adaptation in these coastal areas (Das et al. 2016). The household perceptions of substantial economic potential of ITKPs of this study validated this statement (section 3.2). In addition, climate adaptive development could balance the positive impact of ITKPs, helping to ensure climate change adaptations. Enhanced responses to ITKP development will improve this positive impact and help to adapt to climate change events, which will improve timely action for responses and thus provide a positive feedback loop between responses and impacts (Figure 6).

4.2. Lessons for national and Global climate adaptation practices

Most coastal areas of Bangladesh are vulnerable to climate change-induced disasters and many ITKPs are practiced in these areas for climate change adaptation (Ahmed and Atiqul Haq 2019). The uncertainties related to rainfall (e.g. untimely rain, erratic rainfall), incidence of pest and degradation of farming lands have shown the need for ITKPs in order to adapt with climatic events (Enete, Madu, and Onwubuya 2012). Like other parts of the world, the full sets of location-based ITKPs are not listed for Bangladesh by date, although within the NAPA projects “Livelihood Adaptation to Climate Variability and Change in Drought-prone Areas of Bangladesh” and “The Reducing Vulnerability to Climate Change (RVCC) Project”, some general ITKPs were documented in Bangladesh for adapting to climate change (NAPA 2005). The contribution of ITKPs to climate change adaptation is still playing a vital role in Bangladesh (Ahmed and Atiqul Haq 2019). Despite the growing demand for ITKP-focused climatic change adaptations to cope with the frequent adverse climatic events in the global context, the requirements of estimating the local-scale perceptions of the livelihood and climate adaptation benefits of ITKPs have been ignored in policy documents (BCCSAP 2009; MoP 2018). The main initiative for NAPA was building capacity and awareness in order to develop eco-specific adaptive knowledge including indigenous knowledge on future climatic variability adaptations; however, it was highly focused on nation-specific adaptation techniques rather than local scale adaptations (NAPA 2005).

NAPA 2005 and 2009; and BCCSAP 2009 only concerned about indigenous species of agriculture and fishery while planning for adaptation to climate change (BCCSAP 2009; NAPA 2005, 2009). This study has shown that ITKPs are very important to the coastal agricultural community as they reduce agricultural production loss. Moreover, the non-agricultural community are also potentially dependent on ITKPs for their food security and livelihood protection during disaster-prone seasons. This study revealed that due to the lack of quality infrastructure (e.g. roads, poultry disease treatment facilities, poultry processing) and disaster probability, maintaining a modern poultry system is challenging in the study area, thus local people were practicing local verity of duck rearing. Considering this importance of ITKPs to livelihood development and climate change adaptations, the local coastal communities were willing to pay for the protection and conservation of ITKPs; this willingness to pay was higher among people in the agricultural profession, who are most vulnerable to climate change effects in coastal areas (Figure 4(A and B)).

The ITKP-based adaptations also have some limitations, as many of them are specific to the context and condition of the environment (e.g. floating gardens). In many cases, ITKP-based adaptations are not the only solution (local early hazard warnings are another example), and the integration of scientific techniques is a prerequisite for their effectiveness. There are opportunities provided through a better understanding of indigenous knowledge, but it is not always all good or useful or better than modern interventions. Moreover, many of these adaptation techniques depend on nature (e.g. rainwater harvesting) and are thus not applicable in dry climatic conditions. This study was limited to examining the importance and benefits of ITKPs for development activities without focusing on any specific occupational group such as fishermen and without any specific recommendation to a particular study site of this research. Our local evidence-based DPSIR framework (Figure 6) implies that integration of ITKPs with scientific improvement into adaptation to climate change, would enhance the process of low-cost, socially accepted and easily repeatable mechanisms in order to adapt with the future climate change-induced disaster events.

5. Conclusions

This study has examined the importance of indigenous techniques and knowledge practices in terms of sustainable livelihood development and adaptation to climate change in southern coastal areas of Bangladesh. The potential benefits of ITKPs for livelihood risk reduction and resource protection were perceived as very high, as they ensure food security and soil health improvement during changing climatic conditions in the coastal areas of Bangladesh. We made the first attempt to propose a DPSIR framework based on ITKPs for integrating climate change adaptations and development. Our proposed DPSIR framework implies the potential of incorporating ITKPs into the national climate change adaptation policy in order to ensure effective and sustainable climate change adaptation for the coastal community of Bangladesh.

Acknowledgments

We acknowledge all the participants of the FGDs and household survey. We also acknowledge Sourav Karmakar, for his help in preparing the map of the study area.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research received no external funding

ORCID

Md Nurul Amin http://orcid.org/0000-0002-4620-0273
Alamgir Kabir http://orcid.org/0000-0002-0782-5967
Md Sarwar Hossain http://orcid.org/0000-0001-6101-659X

References

Ahmed, M. N. Q., and S. M. Atiqul Haq. 2019. "Indigenous People's Perceptions About Climate Change, Forest Resource Management, and Coping Strategies: a Comparative Study in Bangladesh." *Environment, Development and Sustainability* 21 (2): 679–708. doi:10.1007/s10668-017-0055-1.

Alam, GM Monirul, Khorshed Alam, Shahbaz Mushtaq, and Michèle L Clarke. 2017. "Vulnerability to Climatic Change in Riparian Char and River-Bank Households in Bangladesh: Implication for Policy, Livelihoods and Social Development." *Ecological Indicators* 72: 23–32.

Al Masud, Md Mahedi, Nurun Naher Moni, Hossein Azadi, and Steven Van Passel. 2018. "Sustainability Impacts of Tidal River Management: Towards a Conceptual Framework." *Ecological Indicators* 85: 451–467.

Altieri, Miguel A, and Clara I Nicholls. 2017. "The Adaptation and Mitigation Potential of Traditional Agriculture in a Changing Climate." *Climatic Change* 140 (1): 33–45.

Amin, M. N., H. M. Solayman, S. S. Snigdha, and J. Sultana. 2018. "Climate Resilient Livelihood Activity in the South Central Coastal Region of Bangladesh." *Journal of Science, Technology and Environment Informatics* 6 (01): 421–430.

Anik, Sawon Istiak, and Mohammed Abu Sayed Arfin Khan. 2012. "Climate Change Adaptation Through Local Knowledge in the North Eastern Region of Bangladesh." *Mitigation and Adaptation Strategies for Global Change* 17 (8): 879–896.

Arezki, Rabah, Patrick Bolton, Karim El Aynaoui, and Maurice Obstfeld. 2018. *Coping with the Climate Crisis: Mitigation Policies and Global Coordination*. New York: Columbia University Press.

Ayers, Jessica, Saleemul Huq, Helena Wright, Arif M Faisal, and Syed Tanveer Hussain. 2014. "Mainstreaming Climate Change Adaptation Into Development in Bangladesh." *Climate and Development* 6 (4): 293–305.

Azam, Gausul, Mohammad Emadul Huda, Mohammad Amir Hossain Bhuiyan, Mohammad Mohinuzzaman, Md Bodrud-Doza, and S. M. Didar-Ul Islam. 2019. "Climate Change and Natural Hazards Vulnerability of Char Land (Bar Land) Communities of Bangladesh: Application of the Livelihood Vulnerability Index (LVI)." *Global Social Welfare* 8: 93–105.

Barua, Prabal, and Syed Hafizur Rahman. 2017. "Indigenous Knowledge Practices for Climate Change Adaptation in the Southern Coast of Bangladesh." *IUP Journal of Knowledge Management* 15 (1): 44–62.

BCCSAP. 2009. "Bangladesh Climate Change Strategy and Action Plan." In. Ministry of Forest and Environment, Dhaka Bangladesh.

Das, R., A. Hanglem, K. Pradhan, and V. Sarkar. 2016. "Refocusing the Perceived Conception of Farmers Regarding Their Livelihood Under the Changed Climate Situation." *Ecology, Environment and Conservation* 22: S21–SS4.

Ebi, Kristie L. 2012. "Key Themes in the Working Group II Contribution to the Intergovernmental Panel on Climate Change 5th Assessment Report." *Climatic Change* 114 (3-4): 417–426.

Enete, Anselm A., Ignatius A. Madu, and Elizabeth A. Onwubuya. 2012. "Climate Change and the Profitability of Indigenous Adaptation Practices in Smallholder Agriculture in South East Nigeria." *Outlook on Agriculture* 41 (3): 179–185. doi:10.5367/oa.2012.0092.

Fakhruddin, S. H. M., and Juma Rahman. 2015. "Coping with Coastal Risk and Vulnerabilities in Bangladesh." *International Journal of Disaster Risk Reduction* 12: 112–118.

Ford, James D, Laura Cameron, Jennifer Rubis, Michelle Maillet, Douglas Nakashima, Ashlee Cunsolo Willox, and Tristan Pearce. 2016. "Including Indigenous Knowledge and Experience in IPCC Assessment Reports." *Nature Climate Change* 6 (4): 349–353.

Fuentes, Mariana MPB, David A Pike, Andrew Dimatteo, and Bryan P Wallace. 2013. "Resilience of Marine Turtle Regional Management Units to Climate Change." *Global Change Biology* 19 (5): 1399–1406.

Haque, Md Asirul, Dilara Rahman, and Md Habibur Rahman. 2016. "The Importance of Community Based Approach to Reduce sea Level Rise Vulnerability and Enhance Resilience Capacity in the Coastal Areas of Bangladesh: A Review." *Journal of Sustainability Science and Management* 11 (2): 81–100.

Hiwasaki, Lisa, Emmanuel Luna, and Rajib Shaw. 2014. "Process for Integrating Local and Indigenous Knowledge with Science for Hydro-Meteorological Disaster Risk Reduction and Climate Change Adaptation in Coastal and Small Island Communities." *International Journal of Disaster Risk Reduction* 10: 15–27.

Hossain, Md Sarwar, Lars Hein, Frans I Rip, and John A Dearing. 2015. "Integrating Ecosystem Services and Climate Change Responses in Coastal Wetlands Development Plans for Bangladesh." *Mitigation and Adaptation Strategies for Global Change* 20 (2): 241–261.

Hossain, Sarwar, and Kushal Roy. 2012. "Community Based Risk Assessment and Adaptation to Climate Change in the Coastal Wetlands of Bangladesh." *International Journal of Environment* 2 (2): 95–105.

Hossain, M. S., K. Roy, M. Hauqe, and H. M. Khan. 2010. Climate change and development: a research on mainstreaming of climate change in National Policy Development using Environmental Impact Assessment (EIA) in Water Resource Management at Narail, Bangladesh. Paper presented at the Ulashi Sreejony Sangha (USS) and NGO Forum on ADB.

Islam, Md. Rashedul, and Shigeru Tabeta. 2019. "Shrimp vs Prawn-Rice Farming in Bangladesh: A Comparative Impacts Study on Local Environments and Livelihoods." *Ocean & Coastal Management* 168: 167–176. doi:10.1016/j.ocecoaman.2018.11.004.

Kihila, Jacob M. 2018. "Indigenous Coping and Adaptation Strategies to Climate Change of Local Communities in Tanzania: a Review." *Climate and Development* 10 (5): 406–416. doi:10.1080/17565529.2017.1318739.

Klein, Richard JT, E. Lisa, F. Schipper, and Suraje Dessai. 2005. "Integrating Mitigation and Adaptation Into Climate and Development Policy: Three Research Questions." *Environmental Science & Policy* 8 (6): 579–588.

Kristensen, Peter. 2004. *The DPSIR Framework. Workshop on a Comprehensive/Detailed Assessment of the Vulnerability of Water Resources to Environmental Change in Africa Using River Basin Approach*. Nairobi: UNEP Headquarters.

Leal Filho, Walter, Abdul-Lateef Balogun, Olawale Emmanuel Olayide, Ulisses M Azeiteiro, Desalegn Y Ayal, Pastor David Chavez Muñoz, Gustavo J Nagy, Paulette Bynoe, Otienoh Oguge, and N. Yannick Toamukum. 2019. "Assessing the Impacts of Climate Change in Cities and Their Adaptive Capacity: Towards Transformative Approaches to Climate Change Adaptation and Poverty Reduction in Urban Areas in a set of Developing Countries." *Science of The Total Environment* 692: 1175–1190.

Magni, Giorgia. 2017. "Indigenous Knowledge and Implications for the Sustainable Development Agenda." *European Journal of Education* 52 (4): 437–447.

Makondo, Cuthbert Casey, and David S. G. Thomas. 2018. "Climate Change Adaptation: Linking Indigenous Knowledge with Western Science for Effective Adaptation." *Environmental Science & Policy* 88: 83–91. doi:https://doi.org/10.1016/j.envsci.2018.06.014.

Moniruzzaman, Shaikh. 2019. "Crop Diversification As Climate Change Adaptation: How Do Bangladeshi Farmers Perform?" *Climate Change Economics* 10 (02): 1–22.

Monwar, Md Mostafa, Md Golam Mustafa, Niaz Ahmed Khan, M. Shahadat Hossain, Mohammad Mosarof Hossain, Monoj Kumar Majumder, Ruhul Mohaiman Chowdhury, Mohammad Amirul Islam, Moniruzzaman Chowdhury, and Mohammed Shahidul Alam. 2018. "Indigenous Adaptation Practices for the Development of Climate Resilient Ecosystems in the Hail Haor, Bangladesh." *Global Social Welfare* 5 (2): 125–136.

MoP. 2018. "SDG 13: Climate Action." In Sustainable Development Goals: Bangladesh Progress Report 2018, 129–136. Dhaka, Bangladesh: Ministry of Planning (MoP), Government of the People's Republic of Bangladesh.

Moser, Susanne C, and Julia A Ekstrom. 2010. "A Framework to Diagnose Barriers to Climate Change Adaptation." *Proceedings of the National Academy of Sciences* 107 (51): 22026–22031.

NAPA. 2005. "National Adaptation Plan of Action." In. Dhaka Bangladesh.

NAPA. 2009. National Adaptation Programme of Action (NAPA)." In, edited by Ministry of Environment and Forests. Government of the People's Republic of Bangladesh.

Nyong, Anthony, Francis Adesina, and B. Osman Elasha. 2007. "The Value of Indigenous Knowledge in Climate Change Mitigation and Adaptation Strategies in the African Sahel." *Mitigation and Adaptation Strategies for Global Change* 12 (5): 787–797.

Pachauri, Rajendra K, Myles R Allen, Vicente R Barros, John Broome, Wolfgang Cramer, Renate Christ, John A Church, Leon Clarke, Qin Dahe, and Purnamita Dasgupta. 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva: Ipcc.

Reid, Michael G, Colleen Hamilton, Sarah K Reid, William Trousdale, Cam Hill, Nancy Turner, Chris R Picard, Cassandra Lamontagne, and H. Damon Matthews. 2014. "Indigenous Climate Change Adaptation Planning Using a Values-Focused Approach: a Case Study with the Gitga'at Nation." *Journal of Ethnobiology* 34 (3): 401–424.

Shaw, Rajib, Anshu Sharma, and Yukiko Takeuchi. 2009. *Indigenous Knowledge and Disaster Risk Reduction: From Practice to Policy*. New York: Nova Science Publishers, Inc.

Sloat, Lindsey L, Steven J Davis, James S Gerber, Frances C Moore, Deepak K Ray, Paul C West, and Nathaniel D Mueller. 2020. "Climate Adaptation by Crop Migration." *Nature Communications* 11 (1): 1–9.

Tscherning, Karen, Katharina Helming, Bernd Krippner, Stefan Sieber, and Sergio Gomez y Paloma. 2012. "Does Research Applying the DPSIR Framework Support Decision Making?" *Land use Policy* 29 (1): 102–110.

Ur-Rahman, Mahabub, Md Nurul Amin, Richard Haigh, Dilanthi Amaratunga, and Udayangani Kulatunga. 2011. "People's perception of climate change vulnerability and adaptation: Chila Union, Mongla Upazila, Bagerhat District, Bangladesh.".

Copyright of Local Environment is the property of Routledge and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.