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Climate change risk perceptions and agricultural adaptation strategies in vulnerable riverine *char* islands of Bangladesh

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ABSTRACT

Farmers in the riverine *char* islands of Bangladesh are frequently affected by climate change due to their proximity to the river and heavy reliance on agriculture for their livelihoods. The present study evaluates *char* dwellers' risk perceptions and agricultural adaptations to climate change. Survey data were collected from 98 households, and focus group discussions were conducted using a semi-structured questionnaire from Rydas Bari *char* under the Gaibandha District of Bangladesh. A standardized risk perception index was created using a four-point Likert scale against sixteen climatic events. In addition, a binary logit model was used to estimate the influence of socioeconomic characteristics of sample households on the decision to choose climate change adaptation strategies. Findings suggest that droughts, river erosion, and floods are the major climatic risks perceived by *char* dwellers. Additionally, results from a climate vulnerability index portray similar findings that *char* respondents are more exposed to diverse climatic hazards. The study further investigates local adaptation mechanisms in agriculture with regards to major climatic events. In response to the existing climate change risks, the *char* inhabitants employ several adaptation strategies in agriculture such as implementing new or alternative farming practices, changing planting times, and cultivating short-duration varieties. The llogit analysis suggests that household age, family size, annual income, farm size, farm ownership and farming experience have a significant influence on farmers' adaptation choices. Household access to education, early warning by extension agents, information on improved agricultural technologies, access to off-farm sources of income and incorporating *char* people during policy design can effectively enhance farmers' resilience and help reduce vulnerability.

1. Introduction

The current pattern of climate change is an important concern for many socio-economic and climate-sensitive sectors such as agriculture and food production (Amedie, 2013). Approximately 1.2–1.5 billion hectares of global land area is under crop production (Howden et al., 2007). However, with the occurrence of climate change and global warming, accomplishing global food security targets is expected to be a continuing major challenge (Misra, 2014). Bangladesh is one of the nations that is likely to face the brunt of climate change impacts. It is a country widely known to be amongst the foremost climate-vulnerable nations, globally (Sarker et al., 2020; Alam et al., 2019; Kabir et al., 2016). However, households in the *char*[1] areas are more vulnerable to climate change due their proximity to flood-prone riversf (Sarker et al., 2020; Alam et al., 2017).

Char lands can be described as sunken river islands and sand bars, predominantly existing in the deltaic plains of river systems (Alam et al., 2017). They occasionally develop from the riverbed as a result of accretion. They are shaped and restructured every year through silt deposition and erosion. *Chars* are of two types: attached *chars* and island *chars* (Roy et al., 2015). The attached *chars* are linked to the mainland under normal flow conditions. During the dry seasons, attached *chars* can be accessed without crossing a river channel. During the floods, many attached floods become island *chars*. For island *chars*, throughout the year, they are surrounded by water and can only be accessed from the mainland by crossing the main channel even through the dry season. Riverine *chars* exist mostly in Northern Bangladesh, although some coastal *char* occur in the southern region of Bangladesh. *Chars*

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[1] *Char* land is the Bengali term; its English meaning is Riverine Island.

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comprising 100 Upazillas (which as a sub-province administrative unit) in 32 districts (8854 km^2) accommodate a total population of around 6 million people (Conroy et al., 2010).

Regardless of their geographic connection to the mainland and distance from the growth centers, *char* land regions are exceptionally susceptible to flood, drought, and river erosion. Because of the unpredictable location of the *char*s, the perpetual variations in river currents occasionally wash them away. The fragile nature of the physical environment upon which the *char*s are located makes them not only risky but also disaster prone when it comes to human settlement. Besides, shortage and challenges of access to food, health, education, habitation, and empowerment serve to make it almost impossible for the poor *char* dwellers to rise above the poverty cycle (Sarker et al., 2020; Alam et al., 2019, 2017, Lahiri-Dutt and Samanta, 2007).

Agriculture is the main livelihood for *char* dwellers in Bangladesh. Most of the *char* inhabitants are directly or indirectly involved in agricultural operations (World-Bank, 2013). *Char* livelihood largely depends on agricultural production. Cropping systems in *char* are quite different from the other land areas because of sandy soil texture and environmental variability (Kabir, 2006). Only a few specific crops are grown in the *char* area such as maize, groundnut, seasonal paddy, and some vegetables. Most of the *char* farmers keep their lands fallow during the main cropping season: Kharif (May to October) because of high evaporation which is renders cultivation impossible without irrigation. Instead, the Rabi season (November to April) is the main cropping season in the *char* area, when temperatures are lower which is best for vegetable cultivation (Lahiri-Dutt and Samanta, 2007).

Climate change adaptation in the human dimension context refers to a planning and decision process. The action taken in a structure (household, community, group, region, country) to better deal with, tackle or modify action due to some adverse condition such as environmental hazard, risk, or opportunity (Intergovernmental Panel on Climate Change, 2007b). Adaptation is often done to mitigate problems caused by certain hazards or perceived risk, e.g. climate change or extreme weather events. There are various definitions of climate change adaptation found in the literature which are based on a common theme. In this study, the term adaptation and mitigation are used interchangeably. Smit et al. (2000) describes adaptation as–adjustments in ecological-socio-economic systems in response to actual or expected climatic stimuli, their effects, or impacts. Pielke (1998) also defines adaptation in the climate change context as the –adjustments in individual groups and institutional behavior in order to reduce society's vulnerability to climate. Nowadays, the climate change adaptation concept has been widely used in the study of social sciences, ecology, agriculture, and food security domains (Smit and Wandel, 2006). As climate change impacts are often geographically specific, it is important that large-scale climate change adaptation initiatives that support smallholder farmers should consider local priorities and integrate lessons from successful autonomous adaptation efforts (Forsyth, 2013).

Riverine char communities in Bangladesh face growing concerns resulting from climate change and socio-economic vulnerabilities. However, few studies (Alam et al., 2016, 2017; Islam et al., 2015; Rahman, 2010; Roy et al., 2015; Sarker et al., 2020) have investigated the linkages among climate change risk perceptions, vulnerability and adoption of adaptation technologies or strategies. Addressing the agricultural risks from natural hazards in these *char* areas is necessary to reduce poverty and vulnerability of the *char* dwellers and to achieve food self-sufficiency. As adaptation is location specific, it is very important to understand and document *char* farmers' perceptions, vulnerability, and local strategies to adapt agricultural practices toward resilience to environmental change. Thus, the main objectives of the present study are to understand and document *char* farmers' perceptions of changing climatic conditions, knowledge of climate change vulnerability, and local adaptation strategies in agricultural management. In this study, we have developed a standardized index-based metric to evaluate *char* dwellers' climate change risk perceptions and assess their local adaptation strategies specifically for major climatic events: droughts, river erosion, and floods. Furthermore, we also identify the socio-economic drivers for adoption of those adaptation strategies. The results of the study can be used for policy formulation and the same strategy can be applied and replicated in similar geographic areas facing rapid environmental changes.

2. Methodology

2.1. Key feature of the study area

The study area Raydas Bari *Char* is under Kamarjani Union, Gaibandha District of Northern Bangladesh (Fig. 1). The study area was selected purposefully based on its representativeness of other *char* islands in Bangladesh and ease of access for data collection. Qualitative information and data about the study area was obtained by expert-opinion from government agricultural offices, past climatic history perception from older farmers, and literature review from non-governmental sources. It is surrounded by the river Brahmaputra. The soil is sandy to loamy in texture. More than 80 percent of people are directly or indirectly involved with agricultural production. Average total cultivable land area is approximately 25 ha. Major crops include maize, jute, paddy rice, pumpkin, and peanuts, among other common household vegetables. Drought, riverbank erosion and flooding are very common hazards in the area because of proximity to the Brahmaputra River and the sandy soil texture.

2.2. Sampling and data collection

The study used both a household survey questionnaire and focus group discussions (FGDs) for collecting data from the study area. The questionnaires were sent for field testing before starting the final data collection. The sample size was determined using a probabilistic sample size calculator from the web and then simple random sampling methodology was used during data collection. The total population (households) of the study area was 130 households. Among them, 98 households (sample size) were selected for the survey based on availability. For qualitative information, two FGDs have been carried out. Prior to interviewing, informed consent was obtained from the respondents and no personally identifiable information was collected. Based on the questionnaire, data were collected on: demographic information for the household head and family members, land used patterns and land types, frequency and types of hazards and vulnerabilities, and climate change perceptions and adaptation strategies in agriculture. Data collection was conducted from 22nd February to 28th February 2019.

Historical (30 years) monthly temperature and rainfall data were collected from the nearest weather station (ID: 418830−99999) using R Statistical Software via the package Global Surface Summary of the Day (GSODR) Weather Data Client (Sparks, A. 2017). The datasets were generated from year 1990–2020 within the 50 km radius of latitude 25.343974 and longitude 89.629931 (study area center). For the year 2020, we have used the data from January to August, 29. The results from the weather data analysis were used for triangulation and to compare findings with the local *char* dwellers risk perceptions to improver understanding of the local *char* context and interpretation.

2.3. Climate change risk perception measurement and index

A four-point Likert scale was constructed to collect climate change risk perception data against 16 climatic events from respondents. The scale ranges from "no perception" to "high perception" and in between these two lower and upper boundaries, "low perception" and "medium perception" were incorporated. For ease of analysis, we have denoted values to respective perception scale in increasing order such as 0 for no perception, 1 for low perception, 2 for medium perception and 3 for high

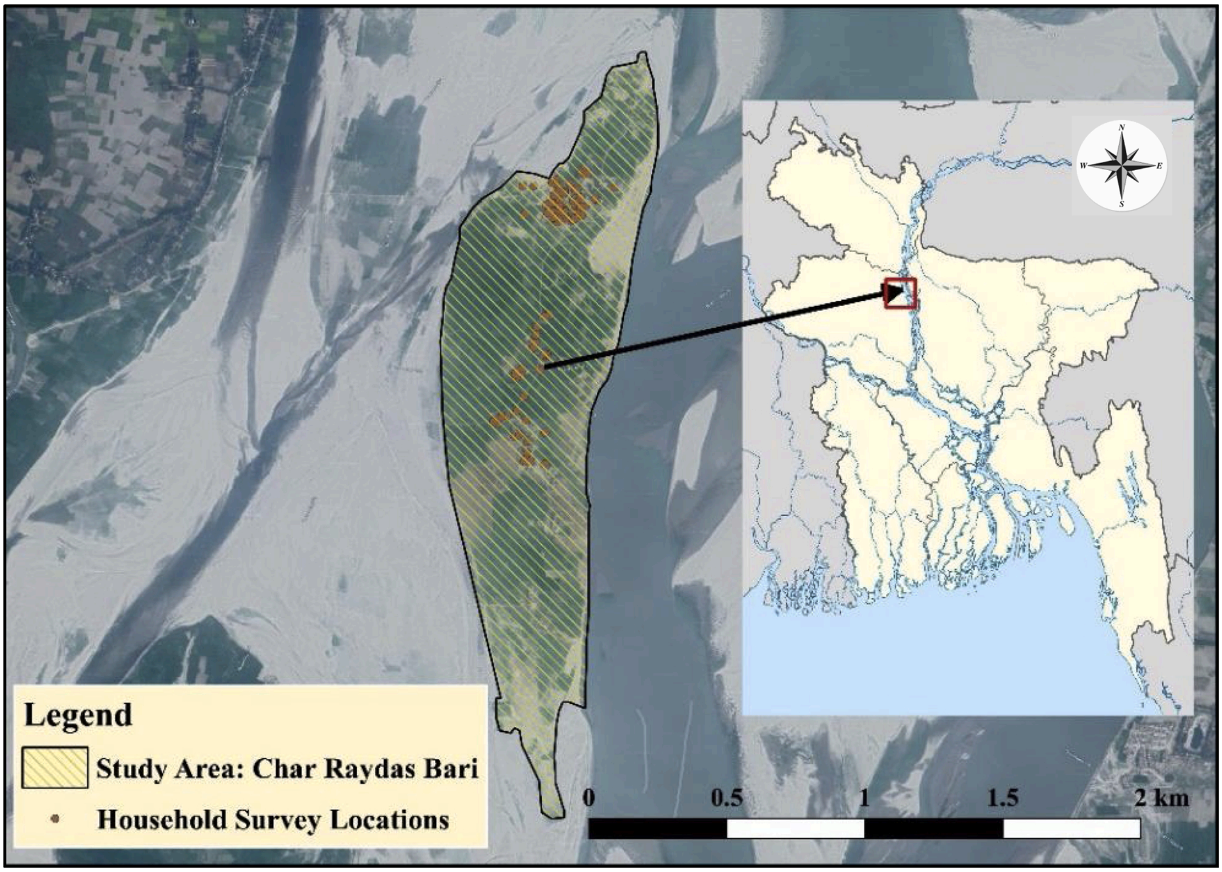

Fig. 1. The study area (Raydas Bari *Char*).
Source: Author's mapping using Google Earth application.

perception. Finally, the cumulative perception score of the respondents were obtained.

In this study, we introduced the Climate Change Risk Perception Index (CCRPI) for measuring *char* dwellers' climate change risk perception against any climatic events based on their personal experience. The respondents were asked to evaluate their opinion on 16 climatic event statements to have an understanding about the comparative perception of the respondents on the 16 selected climatic events. A Climate Change Risk Perception Score (CCRPS) was calculated to satisfy the purpose using the following equation (Eq. (1)).

$$\text{Climate Change Risk Perception Score (CCRPS)} = CCRPn*0 + CCRPl*1 + CCRPm*2 + CCRPh*3 \tag{1}$$

Where CCRPn is the number of respondents having no perception, CCRPl is the number of respondents having low perception, CCRPm is the number of respondents having medium perception, CCRPh is the number of respondents having high perception of risk.

Since we have a total of 98 respondents, the Climate Change Risk Perception Score (CCRPS) for any given climatic event could range from 0 to 294, meaning the lower boundary would be minimum 0 and the higher boundary would be maximum 294, where 0 indicates a minimum level of risk perception and 294 indicates a maximum level of risk perception. After that we converted the CCRPS to a standardized index for further interpretation of the results. To standardize the CCRPS, we have used the following equation (Eq. (2)).

$$\text{Standardized Climate Change Risk Perception Index (SCCRPI)} = (Total\ CCRPS\ Value)/(Respective\ Highest\ CCRPS\ Value)*100 \tag{2}$$

Where the *Total CCRPS Value* was calculated by multiplying respective perception values with total perception frequency against each climatic event, and the *Respective Highest CCRPS Value* was calculated by dividing total CCRPS value with the highest maximum boundary value and multiplying by 100.

SCCRPI provides a means to understand and classify climate change risk perceptions (Akanda, 2015). The SCCRPI value can range from 0 to 100, where 0 indicates a minimum level of risk perceived and 100 indicates a maximum level of risk perceived of climate change by *char* dwellers within their community.

2.4. Climate vulnerability index

Vulnerability is considered to be an exposure to a group or individual stresses due to change in climatic conditions (Frank et al., 2011). According to (Intergovernmental Panel on Climate Change, 2007a), vulnerability is a function of three dimensions, exposures, sensitivity and adaptive capacity. In this study, the IPCC Climate Vulnerability Index (IPCC-CVI) was used to establish a linkage between farmers climate change risk perception and perceived vulnerability. The respondents were asked to give score on 16 climatic event statements to have an understanding about their vulnerability perception on the 16 selected climatic events. For this study, exposure is the duration and magnitude of different types of climatic events that *char* dwellers faces. Sensitivity is the degree to which the *char* dwellers is affected by the climatic exposure and finally, the adaptive capacity is the *char* dwellers ability to withstand or recover from the climatic exposure.

An IPCC Climate Vulnerability Index (IPCC-CVI) was calculated using the index value for exposure, sensitivity and adaptive capacity (Eq. (3)).

$$\text{IPCC} - \text{CVI} = (\textit{Exposure Index} - \textit{Adaptive Capacity Index})\ x\ \textit{Sensitivity Index} \tag{3}$$

Where, the value of each dimension (exposure, sensitivity and adaptive capacity) will attain a maximum value of 1 and minimum of 0, but the range for IPCC-CVI varies from −1 to +1, where −1 denotes least vulnerable (adaptive capacity > exposure), 0 denotes moderately vulnerable (adaptive capacity = exposure) and +1 denotes extremely vulnerable (exposure > adaptive capacity).

2.5. Identifying drivers of the adoption of climate adaptation strategies

After analyzing nineteen local adaptation strategies which were practiced by the *char* farmers, we grouped them into five major categories, including (i) Climate resilient crop varieties, (ii) Crop diversification, (iii) Improved agronomic practices, (iv) Income diversification, and (v) Irrigation improvement. Each category was used as a separate response variable against farmer's socio-economic characteristics. A binary logistic regression model was used to analyze the relationship between the farmers' adoption of adaptation strategies and socio-economic characteristics. The study separately used the five above-mentioned major adaptation categories as binary dependent variables. The dependent variables Y_{i-v} (adoption of adaptation strategies) were binary and their values were 1 if a farmer used any of the strategies separately, 0 otherwise. We hypothesized that a farmer is more likely to adopt a climate change adaptation practice if the farmer had resources need and education level needed to understand the benefits of adaption to their household.

A binary logit model specification was employed to model climate change adaptation strategies of farmers involving dummy dependent variables with binary choices (Saguye, 2016; Delaporte and Maurel, 2016). The logit function for the farmers' likelihood of adopting a climate adaptation strategy can be specified as:

$$Logit\ (P) = \log\left(\frac{P}{1-P}\right) \tag{4}$$

$$\text{Let, } P_i = P_r\left(\frac{Y = 1}{X = x_i}\right) \tag{5}$$

Then, the model can be written as:

$$P_r\left(y = \frac{1}{x}\right) = \frac{exp^{x^{'}b}}{1 + e^{x^{'}b}} = \log\left(\frac{P_i}{1-P_i}\right) = Logit\ (P_i) = \beta_0 + \ldots + \beta_i\, x_i \tag{6}$$

Where, P_i is the probability to adopt an adaptation strategy (response variable), x_i' s are the explanatory variables, β_0 is the intercept and β_i are the regression coefficients for socio-economic variables (Table 1).

After transformation, the logistic regression equation can be simplified in terms of an odds ratio as:

$$\frac{P_i}{1-P_i} = exp(\beta_0 + \beta_i\, x_i) \tag{7}$$

The explanatory variables that are hypothesized to affect farmers' adoption of adaptation strategies are socio-demographic and economic characteristics. We have re-coded the explanatory variables into binary and continuous variables for analysis (Table 2). The selection of explanatory variables is based on the review of the literature, focus group discussions, and field experience (Table 1).

The model for farmers' adoption of adaptation strategies takes the form as follows:

$$Y_{i-v} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \varepsilon_i$$

Where, Y_{i-v} is the likelihood of adopting adaptation strategies *i* through *v*, β_0 = Constant, β_{1-8} = Coefficients to be estimated for explanatory variables, and ε_i = Error term.

Table 1
Description of model variables.

Sign	Explanatory Variables	Variable descriptions	Expected sign
X_1	Age of HH head (D)	Age of HH head (years)	+
X_2	Gender of HH (D)	1 if male headed HH and 0 if female headed HH	+
X_3	Literacy of HH head (D)	1 if HH head are literate and 0 if illiterate	+
X_4	Family size (D)	1 if HH have (1−4 members), 0 if (>4 members)	+/-
X_5	HH annual income (C)	Annual income of HH (USD)	+/-
X_6	Farm size (C)	Total cultivable farm land (acres)	+
X_7	Farm owned (D)	1 if farm land owned by HH, 0 otherwise	+
X_8	Farming experience of HH head (D)	Years of experience in farming	+

Note: HH: households; D: dummy variable; C: Continuous.

3. Results and discussion

The findings of the study are presented in three sections: the first section describes socio-demographic and economic characteristics of *char* dwellers, the second section describes the climate change risk perceptions of *char* dwellers, and the third section describes climate change adaptation strategies of *char* dwellers with respect to some key climatic events.

3.1. Socio-demographic and economic profile of char respondents

There are several variables which describe demographic characteristics of the respondents. The variables included in this analysis were household head's age, gender, education level, family size, primary occupation, annual family income, farm size, farm types as well as years of agricultural involvement. Total count frequency is used to interpret the results as some variable's data were collected from family members (Table 2).

Summary statistics for demographics and socio-economic data (Table 2) show that 37.76 % of the household head are within the middle age group (36−50) years, followed by 33.67 % in the old age group (36−50) and 28.57 % in the young age group (≤ 35) respectively. Out of all the responses, 90.82 % were male and only 9.18 % female. The ratio is not representative of the national ratio (Bangladesh Bureau of Statistics, 2012). This suggests that most of the *char* households are male-headed households, which aligns with social and cultural norms for the region.

From the table, we can see that majority of the respondents (78.57 %) have a low level (illiterate and can sign only) of education while only 21.43 % combined have completed primary (class 1−5) and secondary (6−10) level of education. In contrast, there was not a single household head found who had completed upper secondary (class > 10) or above. From this information, we can see that about 70 % (including, can sign only) of the *char* dwellers are literate. Many non-governmental organizations are now setting up mobile schools in *char* areas, so that the literacy rate may increase. From the focus group discussion, we found that, in our study *char*, there was a primary school for *char* dwellers, but the capacity for teaching is not sufficient to teach all *char* inhabitants.

Another important variable considered in this demographic analysis was family size. From the table, we can see that 65.31 % of *char* dwellers have a small family (up to 4) size, 33.67 % have a medium (5−6) family size and only a few (1.02 %) *char* dwellers have a large (> 6) family size. From the focus group discussions, we found that health workers from local NGOs are visiting the study *char* frequently and arranging small health camps. Both male and female members of the *char* participate in

Table 2
Demographic characteristics of the *char* respondents.

Characteristic	Scoring system	Categories	Respondents N	(%)	Mean	Standard Deviation
Age	Years	Young (≤ 35)	28	28.57 37.76 33.67	46.02	12.15
		Middle (36−50)	37			
		Old (> 51)	33			
Gender	Code	Male (1)	89	90.82	1.09	0.17
		Female (2)	9	9.18		
Education	Year of schooling	Illiterate (0)	31	31.63	2.14	0.86
		Can sign only (0.5)	46	46.94		
		Primary Level (1−5)	16	16.33		
		Secondary level (6−10)	5	5.10		
Family size	Number	Small (up to 4)	64	65.31	3.95	0.94
		Medium (5−6)	33	33.67		
		Large (> 6)	1	1.02		
Primary occupation	Code	Farming (1)	60	61.22	2.94	1.12
		Day Labor (2)	33	33.67		
		Housewife (3)	5	5.10		
Annual family income	USD	Low (up to USD 600)	70	71.43	513.35	465.67
		Medium (USD 601−1000)	18	18.37		
		High (> USD 1000)	10	10.20		
Farm size	Acres	Small (up to 2.4 acres)	91	92.86	0.65	0.84
		Medium (2.5−7.4 acres)	5	5.10		
		Large (> 7.5 acres)	2	2.04		
Farm types	Code	Owned (1)	38	38.78	2.18	0.93
		Shared (2)	4	4.08		
		Leased (3)	56	51.14		
Agricultural involvement	Years	Low (up to 5)	9	9.18	9.73	21.42
		Medium (6−15)	21	21.43		
		High (> 15)	68	69.39		

Source: Field survey, 2019

these health camps and receive information about family planning. As a result, they were using different methods of contraception and thus population per household may be deceasing.

The *char* dwellers have various occupations, but they are mostly agriculture based. The key jobs include farming service, day laboring and household work. 61.22 % respondents are involved with farming work, while 33.67 % and 5.10 % were involved with day laboring and household work, respectively. The majority (71.43 %) of the *char* dwellers belong to the low-income group (up to USD 600) while 18.37 % and 10.20 % fall under medium (USD 601−1000) and high (> USD 1000) income groups, respectively.

Additionally, 92.86 % *char* dwellers have small farm sizes (up to 2.4 acres or approximately 1 ha) while only 5.10 % and 2.04 % of *char* dwellers have medium (2.5−7.4 acres) and large farm sizes (> 7.5 acres). About 40 % of *char* dwellers have their own farm for cultivation while 51 % have leased farmland for cultivation. In contrast, only 4.08 % of *char* dwellers have shared farm types where they cultivate crops with other farmers. Nearly 70 % of *char* dwellers mentioned high levels (> 15 years) of agricultural involvement which indicates the potential for knowledge of past climatic events, while 21.43 % and 9.18 % had medium (6−15 years) and low (up to 5 years) levels of agricultural involvement.

3.2. Climate change risk perception of char dwellers

Climate change risk perception measurement is a complex procedure and depends on social, cultural, economic, and demographic factors (Cutter et al., 2012). Risk perception is a mental construct (Sjöberg, 2000) and farmers' climate change risk perceptions are unique in a sense that it allows for a differentiation between the actual real-world hazards, for instance, climate change, and intuitive evaluation of those dangers (Rosa, 2003; Cutter, 1996). As we know from the recent data and incidents that climate change is one of the greatest threats to life on earth, but when it comes to individual level evaluation, in our case the farm household level, then *char* dwellers' climate change risk perceptions vary greatly from one to another (Whitmarsh, 2011). Overall, personal experience plays an important role in determining farmers' climate change risk perceptions (Linden, 2017).

Many scholars have used similar techniques to measure climate change risk perception from personal experience using Likert scales (Sarker et al., 2020; Akanda and Howlader, 2015; Alam et al., 2017). In behavioral research, the Likert scale is widely used to help researchers in the construction of relative perception scales. In our study, we have used a similar type of Likert scale to measure *char* dwellers' risk perception regarding climate change. In this regard, the CCRPS and SCCRPI were calculated to elicit a better understanding of how *char* dwellers perceive risks associate with climate change.

From Eq. (1), we calculated the CCRPS on 16 climatic events which ranged from 25 to 277 (lowest value 0 to highest value 294). After analyzing the range of the CCRPS value, we simply cannot tell whether *char* dwellers are sensitive to the risk of climate change on average, rather we can say that *char* dwellers have low to medium levels of sensitivity for the last four climatic events (value 25 to value 87) and medium to high levels of sensitivity for the remaining the climatic events (value 140 to value 277). However, from the SCCRPI, we can see that the values varied substantially ranging from 8.50 to 94.22 which illustrates that *char* dwellers perception categories are heterogeneous. However, most of the *char* dwellers belong to medium to high perception index values (47.62–94.22) and less belong to low and medium perception index values (8.50–29.59). From the focus group discussion, we found that the index value we calculated for each climatic event matches with *char* dwellers cumulative responses.

Several studies have demonstrated that *char* dwellers are highly vulnerable to environmental threats and uncertainties (Lahiri-Dutt and Samanta, 2007; Roy et al., 2015). As a result of their high vulnerability to environmental risks, they are regularly affected by different types of climatic events mostly the 16 climatic events we have analyzed. The following table shows the climate change risk perception of *char* dwellers by some 16 predetermined climatic events along with their score and index value (Table 3).

After calculating the respective score and index value for each climatic event, we ranked them from 1 to 16 for better understanding and

Table 3
Climate change risk perception of *char* dwellers.

Sl No.	Climatic events	High Perception	Medium Perception	Low Perception	No Perception	CCRPS	SCCRPI	Rank
1	Drought	90	3	1	0	277	94.22	1
2	River erosion	90	2	1	0	275	93.54	2
3	Flood	84	2	10	0	266	90.48	3
4	Severe crop pest	71	8	3	0	232	78.91	4
5	Outbreak of diseases	52	34	7	1	231	78.57	5
6	Heavy fog	64	11	12	2	226	76.87	6
7	Extreme temperature (summer)	65	9	4	0	217	73.81	7
8	Extreme temperature (winter)	64	7	8	0	214	72.79	8
9	Outbreak of animal diseases	42	32	10	2	200	68.03	9
10	Insect infestation	58	10	4	0	198	67.35	10
11	Soil fertility loss	13	53	9	2	154	52.38	11
12	Extreme rainfall (summer)	20	25	30	3	140	47.62	12
13	Depletion of ground water	13	21	6	1	87	29.59	13
14	Safe drinking water scarcity	16	9	14	7	80	27.21	14
15	Arsenic contamination	16	6	7	16	67	22.79	15
16	Fire	3	3	10	20	25	8.50	16

Source: Author's calculation, 2020

interpretation. From the SCCRPI we found that drought, river erosion, flood, crop pests, outbreak of several diseases, heavy fog and extreme temperature during summer and winter are the major climatic risks perceived by the *char* dwellers. Similar results were found by other scholars (Lahiri-Dutt and Samanta, 2007; Alam et al., 2017; Sarker et al., 2020).

Household perceptions regarding vulnerability play an influential role in framing climate change risk perceptions and affect the three dimensions of vulnerability (exposure, sensitivity and adaptive capacity). To understand *char* dwellers' vulnerability to different climatic events and to test whether there is any relationship between underlying vulnerability and *char* dwellers climatic risk perceptions, we have used IPCC Climate Vulnerability Index (IPCC-CVI) analysis (Eq. (3)). The various dimensions of vulnerability are presented in (Table 4).

The IPCC-CVI index value of 0.153 indicated that *char* dwellers are moderately to extremely vulnerable (Table 4). The positive index value of 0.153 imply that *char* dwellers are more exposed to climatic events and hazards than their capacity to adapt to overcome adverse environmental impacts.

The vulnerability factors for exposure, sensitivity and adaptive capacity are shown in (Fig. 2). Based on the vulnerability triangle, we see that adaptive capacity (0.418), sensitivity (0.516) and exposure (0.882) clearly demonstrate the overall dimensional contributions toward *char* dwellers' overall vulnerability to climate change and environmental hazards. Exposure contributed the highest to overall vulnerability while adaptive capacity had the least value. From the results, we can say that *char* dwellers are frequently exposed to different natural disasters and climatic variability, and have a moderate level of sensitivity to those climatic events. In contrast, their adaptive capacity to fight against those climatic events was very low.

To better understand the climate change risk perceptions and associated vulnerability dimensions of the *char* dwellers of the study area, we have collected 30 years of historical weather data (temperature and rainfall) and analyzed those data to check trends and pattern. The observed historical data showed similar trends and patterns of climate change risks and vulnerability as perceived by *char* dwellers of the study area (Figs. 3 and 4). Specifically, temperatures in kharif are much higher and precipitation surges with the onset of the monsoons, which generates risks for agricultural production. Temperature boxplots suggest

Table 4
Indexed dimensions of climate vulnerability of *char* dwellers.

Vulnerability factors	*Char* dwellers Index Value
Exposure (Natural disaster and climate variability)	0.882
Sensitivity (Climate-related stimuli)	0.516
Adaptive capacity (Socio-economic characteristics)	0.418
IPCC-CVI	0.153

Source: Author's calculation, 2020

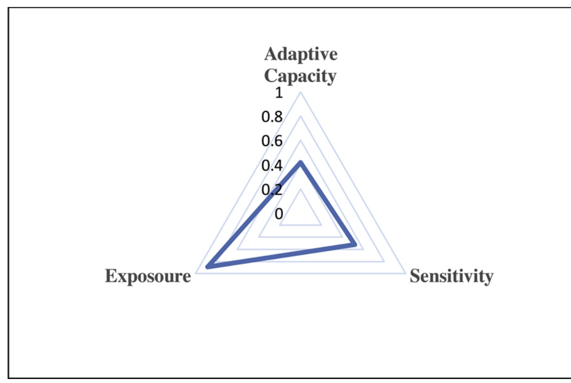

Fig. 2. Vulnerability triangle diagram of the climate vulnerability index. Source: Author's calculation, 2020.

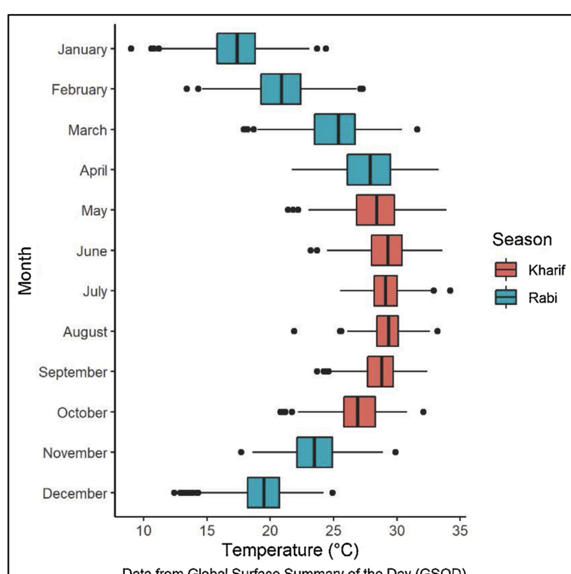

Fig. 3. Gaibandha historical temperature pattern (1990 to 2020). Source: Author's calculation using GSOD data.

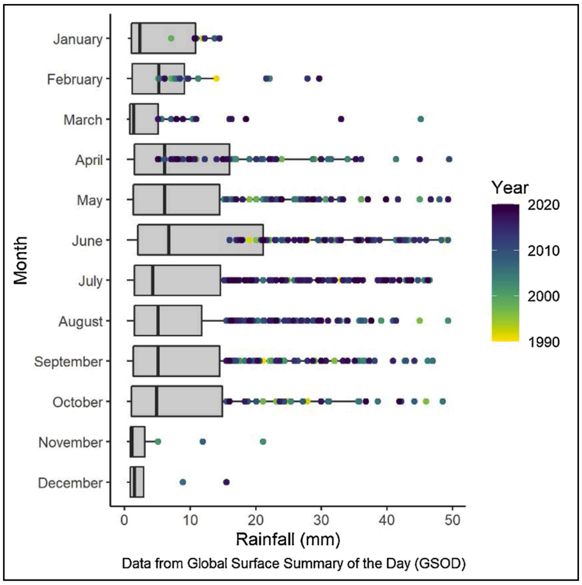

Fig. 4. Gaibandha historical rainfall pattern (1990 to 2020).
Source: Author's calculation using GSOD data.

relatively normal seasonal patterns with occasional outliers. However, pprecipitation plots illustrate that outlier events are occurring more frequently in recent years.

Bangladesh is a country considered to be extremely vulnerable to the adverse effects of climate change (Alam et al., 2019; Mahmood, 2012; Abdur et al., 2013; Ministry of Environment, Forest and Climate Change, 2009). The high predisposition of Bangladesh to climate change has been occasioned by its geographic proximity to the Himalayan mountains, source of its rivers and home to climate-threatened glaciers; its flat deltaic topography with very low elevation; its population density and poverty occurrence; and the reliance of the majority of its population on comprehensively climate- swayed crop agriculture (World-Bank, 2013).

In our study area, *char* people experience multiple types of climatic hazards such as drought, floods, river, erosion etc. And their perception about vulnerability varies from low adaptive capacity to high exposure. Kharif season (May to October) is the main cropping season in Bangladesh. In *char* areas, due to the difficulty of providing necessary irrigation to crop fields, sandy soil texture and high evaporation, most *char* farmers keep their land fallow during the Kharif season. Instead, *char* farmers mainly cultivate their land during the Rabi season (November to April) when temperatures are lower and soil-water retention capacity is more favorable for cultivation. Moreover, household's climate change perceptions and vulnerability were also supported by the observed climate data (Figs. 3 and 4).

In the case of the monthly mean temperature from 1990 to 2020, an upward trend (25–30 °C) was observed from the month of May to October in the study area (Fig. 3). In contrast, the mean monthly rainfall (> 0–5 mm) was recorded in that time period with outlier events (Fig. 4). Interesting temperature and rainfall patterns were observed for the month of November to March, the typical timeframe when *char* farmers cultivate primary production. Very little rainfall compared to higher temperature were recorded in that period of time. This strongly suggests that the study area as well as the nearby areas are experiencing a shift in climate to low rainfall coinciding with higher temperatures. This finding is consistent with previous studies (Dastagir, 2015; Rahman and Lateh, 2017; Hossain et al., 2019; Patwary, 2016).

3.3. Climate change adaptation strategies and drivers for adoption

There are several strategies used for adaptation to climate change in the context of agriculture, e.g. policies, improved access to climate information, new cropping patterns, and technology adoption. According to (Lein, 2009), *char* areas are mainly vulnerable to flooding, river erosion, and drought regardless of their geographic merit to the mainland and span from the growth centers. *Char* dwellers use their trial and error knowledge to adapt to these diverse effects of climate change in their situation. Studies have successfully shown that adaptation strategies rely on the knowledge and technical know-how of the locals (McNamara and Buggy, 2017). The adverse effects of climate change such as droughts, floods and riverbank erosion have considerably reduced agricultural productivity. According to (Hossain, 2014), small-scale farmers are the main victims of these impacts because they mainly rely on rain-fed agriculture for their existence.

In our study *char*, the dwellers have adopted more than one strategy for securing their livelihood, a process known as livelihood resilience. Besides, *char* dwellers mostly practice two types of adaptation, Individual Level Adaptation (ILA) and Planned Adaptation (PA) (Alam et al., 2017). ILA is not necessarily a response to climate change directly but is triggered by ecological, economic, and welfare changes in existing human systems, which is the result of private adaptation, initiated and implemented by individuals or households. Examples of ILA include changing planting time, cultivation of short duration varieties, crop rotation, mixed farming, etc. PA is usually directed by the collective needs of people but implemented mainly by the government or NGOs. Examples of PA include adoption of new varieties, tree plantation, rainwater harvesting technology, etc. After several rounds of sitting with the *char* community leader, nineteen local adaptation strategies were identified for our analysis which are practiced by the study *char* dwellers in response to climate change as highlighted by the three major climatic hazards (Table 5).

Among the nineteen adaptation strategies, *char* dwellers often replied with more than one strategy (multiple responses) among each of the three major climatic events. The major adaptation strategies are adoption of new crop varieties in farming practice, water intensive irrigation facilities, changing planting time, changing sizes of land under cultivation, cultivation of short duration varieties, crop rotation and livestock rearing (Yadav et al., 2020; Shew et al., 2019). In contrast, major climatic events in the analysis showed for which climatic hazards *char* dwellers are adopting different strategies. For instance, if we consider the first adaptation strategy, which is adoption of new varieties in farming practice, then we can see from the major climatic event results that more than 50 % of the *char* dwellers adopted this strategy in order to mitigate drought and flood impacts. The same types of interpretation will apply for the remaining adaptation strategies and major climatic events.

In the event of preventing floods, drought and erosion impact, various adjustments were made by *char* dwellers like change in cropping patterns, changing crop varieties, managing soil, and irrigation system, changing planting schedules, cultivation of short duration varieties and mixed farming. In agriculture operation, *char* farmers seem to change their cropping style and cultivate new crops such as maize, potato, jute, paddy, and pumpkin, cultivating drought-resistant crops or planting short duration crops, like potato, tomato, and peanuts. Some studies in Bangladesh have shown that farmers take part in technological innovations and systems innovation in water and drought management (Yadav et al., 2020). According to (Akinnagbe and Irohibe, 2015), some of the adaptation initiatives that can be adopted include planting crops that reduce impacts from extreme weather events such as drought, initiating crop diversification to push away the danger of erosion, adjusting the cropping patterns, initiating soil conservation measures, and agroforestry in regards to tree planting.

Riverbank erosion is one of the major problems in riverine *char* areas. Approximately 60,000 people are affected each year by riverbank erosion in Bangladesh. As a result, the government of Bangladesh is now implementing and emphasizing a country-wide river dredging program, and also recovering lands from braided rivers in the *char* areas of northern Bangladesh (Alam et al., 2017; Mutton and Haque, 2004).

Table 5
Major climatic hazards wise *char* dwellers climate change adaptation strategies.

Sl No	Adaptation strategies	Responses (%)	Major Climatic Events (%)			Comments
			Flood	Drought	Erosion	
1	Adoption of new varieties in farming practice	82.65 (n = 81)	54.08	67.35	26.53	ILA/PA
2	Water intensive irrigation facilities	75.51 (n = 74)	5.1	64.29	–	ILA/PA
3	Change planting time	74.49 (n = 73)	73.47	56.12	36.73	ILA
4	Changing sizes of land under cultivation	68.37 (n = 67)	41.84	48.98	54.08	ILA
5	Cultivation of short duration varieties	63.27 (n = 62)	60.2	50	38.78	ILA
6	Crop rotation	62.24 (n = 61)	52.04	54.08	15.31	ILA
7	Livestock rearing	50 (n = 49)	18.37	38.78	10.2	ILA/PA
8	Mixed farming	42.86 (n = 42)	30.61	33.67	16.33	ILA
9	Cultivation of maize	42.86 (42)	10.2	31.63	4.08	ILA
10	Cultivation of HYV varieties	39.8 (n = 39)	34.69	36.73	4.08	ILA/PA
11	Cultivation of vegetables	36.73 (n = 36)	16.33	26.53	7.14	ILA
12	Cover cropping	33.67 (n = 33)	3.06	25.51	2.04	ILA
13	Off-farm work	28.57 (n = 28)	24.49	18.37	12.24	ILA
14	Biological pest control	26.53 (n = 26)	2.04	–	–	ILA/PA
15	Inter-cropping	15.31 (n = 15)	5.1	8.16	2.04	ILA
16	Homestead gardening	12.24 (n = 12)	8.16	7.14	1.02	ILA
17	Rainwater harvesting technologies	9.18 (n = 9)	9.18	6.12	–	ILA/PA
18	Tree plantation	6.12 (n = 6)	2.04	2.04	2.04	ILA/PA
19	Poultry rearing	6.12 (n = 6)	2.04	5.1	2.04	ILA/PA

Note: Multiple responses were counted; Grouping adaptation categories: (i) Climate resilient crops variety (sl. no 1, 5, 10); (ii) Crop diversification (sl. no 8, 9, 11); (iii) Improved agronomic practices (sl. no 3, 4, 12, 14, 15); (iv) Income diversification (sl. no 7, 13, 16, 18, 19); (v) Improve irrigation (sl. no 2, 17).
Source: Field survey, 2019

Therefore, it is important to initiate and implement adaptation strategies that can cushion agricultural productivity from the harsh effects of climate change. With regards to climate change, an adaptation strategy comprises the execution of appropriate adjustments and measures that decrease the intensity of the adverse effects of climate change. It entails the actions taken by nations, communities, and individuals at their personal capacities to reduce climate change effects and make necessary adjustments where necessary (Akinnagbe and Irohibe, 2015).

Binary logistic regressions were carried out to determine the influence of *char* dwellers socio-demographic and economic characteristics on the farmers' adoption of adaptation strategies. The five major adaptation categories were used in independent models as response variables, i.e. Y_i = climate resilient crop varieties (model 1); Y_{ii} = crop diversification (model 2); Y_{iii} = improved agronomic practices (model 3); Y_{iv} = income diversification (model 4) and; Y_v = irrigation improvement (model 5). Besides, eight explanatory variables (X_1-X_8) were used to determine the potential drivers of farmers' adoption of different adaptation strategies (Y_{i-v}). The description of the model's variables is presented in (Table 1).

For model 1, model 2, model 3, model 4 and model 5, a Wald chi-square statistic was found to be significantly associated with *char* dwellers socio-demographic and economic characteristics. Logistic estimates of the *char* farmers' drivers of the adoption of climate adaptation strategies are presented in Table 6.

The results from model (1) show a statistically significant (coefficient= -1.286, $p < 0.05$) negative association between farm ownership and *char* farmers' adoption of climate resilient crop varieties. This indicates that farmers who owned farm land appear to have a lower probability to adopt climate resilient crop varieties as an adaptation strategy. In other words, as farm ownership increased, there was less likelihood of adopting new crop varieties as a climate adaptation strategy. The significant relationship between farm land and adaptation are consistent with previous studies (Alam et al., 2016; Alauddin and Sarker, 2014; Deressa et al., 2009).

Among the eight independent variables in model (2), three independent variables, i.e. age of household head (coefficient= -1.444, $p < 0.05$), household's annual income (coefficient= -0.002, $p < 0.01$) and farm size (coefficient= 1.097, $p < 0.05$) were significant, and those influences both positively and negatively the *char* farmers' adoption of crop diversification as an adaptation strategy. The coefficient of age was negative and significantly affects adaptation decisions. This indicates that a year increase in the age of the *char* farmer decreased the probability of adopting crop diversification as an adaptation strategy. The result is plausible since young farmers are more likely to be exposed to new technology, and less risk averse to adopt crop diversification strategies. This finding is consistent with previous adaptation studies (Hisali et al., 2011; Ali and Erenstein, 2017). Household annual income plays a part in the decision of a farmer to adopt adaptation strategies or not. Surprisingly, the coefficient for household annual income was negative and significantly affects adaptation decisions. This means that a unit (by 1 USD) increase in total annual household income does not increase farmers' probability to adopt crop diversification adaptation strategy by a factor of one. On the other hand, farm size had a positive relationship with *char* farmers' adoption of crop diversification adaptation strategy. This suggests that an increase in farm size increases the probability of farmers' adoption of crop diversification as an adaptation strategy. This indicates that farmers with larger farm size can easily diversify their crops. Similar findings were found in previous studies (Alauddin and Sarker, 2014; Ali and Erenstein, 2017; Abid et al., 2016).

The results from model (3) show a statistically significant (coefficient= -1.964, $p < 0.10$) negative association between family size and *char* farmers' adoption of improved agronomic practices. This indicates that households with less than 5 members have a lower probability to adopt improved agronomic practices in their farming system than those households with more than 5 members. The result is conceivable because many households have children who cannot work in the field. As a result, *char* farmers normally do not adopt improved agronomic practices which may require more labor to implement. Surprisingly, the results from model (4) suggest no significant association between the farmers' adoption of income diversification strategies and socio-economic characteristics. The income diversification strategies include homestead gardening, changing profession towards livestock, poultry rearing, and off-farm work.

Family size (coefficient= -1.609, $p < 0.05$) and the household head's years of farming experience (coefficient= -1.407, $p < 0.05$) both had a negative relationship with adoption of improved irrigation adaptation strategy in model (5). From our field experience we know that farming experience positively related to adaptation decision, but from our analysis, surprisingly, the coefficient of years of farming experience of household head was negative and significantly affects adaptation decision. This indicates that a year increase in farming experience of the *char* farmer decreased the probability of adopting improved irrigation as an adaptation strategy. The results are

Table 6
Logit regression of drivers influencing farmers' adoption of climate adaptation strategies.

Explanatory Variables	Response Variables (Adaptation Strategies)				
	Climate resilient crop varieties Model 1	Crop diversification Model 2	Improved agronomic practices Model 3	Income diversification Model 4	Improve irrigation Model 5
Age of HH head	−0.206 (0.755)	−1.444** (0.707)	−0.004 (0.963)	−0.133 (0.580)	0.579 (0.706)
Gender of HH	−0.419 (1.226)	0.298 (0.981)	−0.285 (1.343)	−0.108 (0.837)	−0.913 (0.989)
Literacy of HH head	−0.824 (0.693)	0.486 (0.557)	−0.471 (0.822)	0.773 (0.490)	−0.428 (0.613)
Family size	−0.670 (0.699)	−0.876 (0.614)	−1.964* (1.167)	−0.105 (0.512)	−1.609** (0.703)
HH annual income	−0.001 (0.001)	−0.002*** (0.001)	−0.001 (0.001)	−0.001 (0.0004)	−0.00003 (0.0005)
Farm size	0.888 (0.585)	1.097** (0.505)	0.692 (0.549)	0.508 (0.318)	0.048 (0.157)
Farm owned	−1.286** (0.597)	−0.083 (0.536)	−1.048 (0.695)	−0.238 (0.484)	−0.639 (0.544)
Farming experience of the HH head	−0.711 (0.711)	0.906 (0.647)	−1.336 (0.893)	0.548 (0.571)	−1.407** (0.649)
Constant	3.897*** (1.482)	1.838 (1.151)	5.324*** (1.827)	0.282 (0.965)	3.891*** (1.251)
Observations	98	98	98	98	98
Log Likelihood	−40.932	−49.369	−31.510	−58.448	−48.627
Akaike Inf. Crit. (AIC)	99.865	116.738	81.021	134.896	115.254
Pseudo R^2	0.25	0.27	0.33	0.14	0.26
Wald chi-square (8)	17.31	20.31	20.86	10.85	20.01
Probability (*p*)	0.03	0.01	0.01	0.21	0.01

Note: Standard errors are reported in the parentheses; *, **, and *** are significant at the $p < 0.10$, $p < 0.05$, and $p < 0.01$ level, respectively.

understandable as the newer farmers are more likely to venture out and try to implement the latest agricultural adaptation strategies into their farming practices. This finding is consistent with previous adaptation studies (Hisali et al., 2011; Ali and Erenstein, 2017).

4. Conclusions and policy implications

The livelihood of riverine *char* dwellers in Northern Bangladesh largely depends on agricultural production. In this study, we assess *char* dwellers' risk perceptions and agricultural adaptations to climatic changes. *Char* dwellers are highly vulnerable to natural disasters resulting from climate change. While this may serve as a disadvantage to most of the *char* dwellers, they may take this as a challenge to innovate their traditional methods into more practical and effective ones that can adjust to the demands of climatic and environmental changes. We found that droughts, river erosion, and floods are the major climatic risks perceived by *char* dwellers and have a serious effect on agriculture based on *char*dwellers' perceptions. The study also reveals that to reduce the climatic risk in agriculture, *char* dwellers have adopted several adaptation strategies such as implementing new or alternative farming practices, water intensive irrigation, changing planting times, and cultivating short duration varieties, among others. The results from this study are particularly important for policymakers as they seek to support adaptation strategies that improve the livelihood of *char* dwellers and their ability to face climate change. First, ensuring education in general, especially to middle and elder aged farmers, would likely improve the execution and adoption of different climate change adaptation strategies in their farming systems. Supporting these strategies could result in reducing agricultural vulnerability and increased food security for all *char* farmers. Second, both government and private extension service agents could provide early warning information in order to reduce agricultural and livestock losses by natural disasters. They could also provide information about flood and drought tolerant high yielding crop varieties, soil erosion control mechanisms and improved irrigation methods for long term agricultural sustainability. Third, programs should be developed to encourage adoption of multiple options for income diversification such as tree plantation, livestock and aquaculture farming. Finally, future policy initiatives both by government and non-governmental organizations should be location-specific and incorporate *char* people during policy design given the peculiar environmental conditions faced by these communities. Therefore, including these strategies in formal governmental programs and plans supported by the Ministry of Agriculture and others may be useful to farmers of the riverine *char* islands.

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CRediT authorship contribution statement

Zobaer Ahmed: Conceptualization, Methodology, Software, Writing - original draft, Data curation, Visualization, Investigation, Writing - review & editing. **Gauri S. Guha:** Supervision, Validation. **Aaron M. Shew:** Methodology, Software, Validation, Supervision, Writing - review & editing. **G.M. Monirul Alam:** Validation, Supervision, Resources, Writing - review & editing.

Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Supplementary data

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