Theoretical and Applied Climatology (2021) 148:441–454
https://doi.org/10.1007/s00704-021-03907-3

ORIGINAL PAPER

Exploring farmers' perception of climate-induced events and adaptation practices to protect crop production and livestock farming in the *Haor* area of north-eastern Bangladesh

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Received: 14 April 2021 / Accepted: 19 December 2021 / Published online: 31 January 2022

Abstract
Bangladesh is confronting terrible impacts of climate change on agriculture across the country, especially in low-lying area like *Haor*, coastal region, and islands. This socioeconomic study ($N=320$) examines the perception and knowledge of farmers on climate-induced events and experiences, and explores the adaptation practices they adopt to protect crop production and livestock farming from the impact of climate change in the north-eastern *Haor* area of the country. Using triangulation method, it is detected that farmers of the study area have an erroneous idea on climate change and the causes of frequent climate extremes. Study results show that respondents' perception and experiences on climate-induced events are verified positively with the historical trend and time-series analysis of climate indicators as well as with the findings of researchers using Knowledge, Attitudes, and Practices (KAP) and Participatory Rural Appraisal (PRA) tools and techniques. This study explores the traditional and systematic adaptation approaches of farmers which are practised at the individual or community level. The rationale of each of the approaches from the respondents' side is also analysed in the study. It is statistically tested using Chi-square that some of the scientific and systematic adaptation options for crop production are predominantly influenced by the educational qualifications of the respondents. The study reveals that lack of proper information prevents subsistence farmers to find the most effective adaptation pathways.

1 Introduction

Climate change has emerged as one of the most burning issues of our time triggering perilous effects on natural and human systems across the world (Intergovernmental Panel on Climate Change [IPCC], 2014). Increasing piles of empirical evidence identifying anthropogenic emissions is mostly responsible for global climate crises. According to the fifth IPCC report, anthropogenic GHG emissions, as well as other forcings, are responsible together for increasing more than half of the average surface temperature worldwide from 1951 to 2010 (Easterling et al., 2016; Bindoff et al., 2013; Knutson et al. 2017). Due to its topography, Bangladesh is regarded as one of the most climate-vulnerable deltas of the world holding 7th position in the "Long-Term Climate Risk Index (CRI)", calculated using 4 indicators for the twenty-year period (1999–2018). Climate change poses vital threats to food security, livelihood, agriculture, ecosystem services, etc., in Bangladesh (Eckstein, Kunzel, Schafer, & Winges, 2019; Coirolo et al., 2013; Alam, 2018; Becker et al., 2020; Anik & Khan, 2012). "Climate Crisis" is responsible for decreasing food production around the world, particularly in developing countries (International Fund for Agricultural Development [IFAD], 2010; The Guardian, 2019). Researchers recognized risk of climate extremes, changes in mean precipitation and temperature, increasing concentration of atmospheric CO_2, climate change-induced pest attack, etc., are affecting global crop production (Wreford, Moran, & Adger, 2010; IPCC, 2014; Deryng et al., 2014). Contrarily, some studies report that increased temperature-driven carbon fertilization will moderately increase production (Chen, Zhang, & Tao, 2018; Deryng et al., 2014). Map of global decrease in crop production by Cline (2007) recognizes a 30% decrease in production even with carbon fertilization in the Indian subcontinent due to changing climate.

There is not much scientific evidence to show the interaction between climate change and livestock farming

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(Thornton, van de Steeg, Notenbaert, & Herrero, 2009; Escarcha et al., 2018). However, contemporary studies suggest that climate change is expected to arrest livestock farming by affecting animal production as well as quantity and quality of food and forage; by worsening health, growth, and reproduction; by generating disease and pest attack; and by affecting livestock through climate extremes (Mader & Gaughan, 2011; Rotter & Van de Gejin, 1999; Food and Agriculture Organization of the United Nations [FAO], 2016).

Bangladesh is principally an agricultural country. According to the Bangladesh Bureau of Statistics, BBS (2020), agriculture sector adds 14.23% to the GDP of Bangladesh and more than 40.60% of people labour for this sector. Changing climate and climate extremes (e. g. flood, drought, salinity, cyclone, tidal surge, heavy rainfall, high temperature, excessive fog, etc.) are affecting the yielding of crops and livestock farming across Bangladesh where coastal region, islands, and *Haor* area are exceedingly affected (Monwar et al., 2014; Hossain, Nayeem, & Majumder, 2017). *Haor* is a low-lying large tectonic depression covering 8584.6 square km, situated in the north-eastern 7 districts of Bangladesh. Three hundred and seventy-three *Haor*s of Bangladesh receive surface runoff water from several rivers descending from the hills of India, where water remains either stagnant or in flash flooding condition during the months of June to November and *Haors* remain dry next of the year (Alam et al., 2010; Center for Environmental and Geographic Information Services [CEGIS], 2012; Kamruzzaman & Shaw, 2018). Most of the *Haor*s of Bangladesh are situated in Sunamganj, Netrokona, Kishoreganj, Sylhet, Habiganj, Moulvibazar, and Brahmanbaria Districts. *Haor* economy is principally based on agricultural activities as most of the inhabitants are farmers or fishermen. In the dry season, they cultivate *Rabi* crops (crops cultivated from mid-November to mid-March) in their land or work as sharecroppers and landless agricultural labourers, whereas in the wet season, they go for fishing in the *Haors* and rivers. 2017 flash flood severely affected the *Haor* area of Bangladesh, causing the suffering of 1 million people, damage of crops worth USD 450 million, and loss of thousands of livestock they used to rear (Kamal et al., 2018; CEGIS, 2012). Though according to Huq (2017), attributing climate change to the 2017 flash flood in *Haor* area is very difficult, some researchers accuse climate change responsible for that flood (Ferdushi et al., 2019; Mahtab, Ohara, & Rasmy, 2018).

Proper adaptation strategies can mitigate the impacts of climate change on crop production and livestock farming and help people cope with the extreme climatic conditions (Nelson et al., 2007; Alam et al., 2017). Farmers of either technologically advanced or developing countries are using modern as well as traditional techniques to adapt to the quickly changing global climate. Integration of modern technology and traditional or indigenous knowledge is bringing out the best pathway of adaptation (Ferdushi et al., 2019). According to IPCC (2014), climate change adaptation refers *to "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects"*. The effectiveness of adaptation strategies towards crop production and livestock rearing is widely dependent on farmers' perception and knowledge of climate and climate-induced events (Mertz et al., 2009). According to Maddison (2007), adaptation process includes two components— perception on climate change and adaptation approaches. Whereas adaptation process itself includes "people's perception" as the main component, inevitably this element is significant while choosing the best adaptation approach by the native farmers. Therefore, this study has been undertaken with the aims to i) find out farmers' perception of climate-induced events and ii) explore the adaptation strategies adopted by local people to strengthen their resilience.

2 Materials and methodology

2.1 Profile of the study area

Netrokona, a north-eastern district of Bangladesh, surrounded by *Garo Hills* of Meghalaya of India on the north, Kishoreganj District on the south, on the east by Sunamganj District, and Mymensingh District on the west. Netrokona District is situated in between 24°34´ and 25°12´ north latitudes and in between 90°00´ and 91°07´ east longitudes. The district has an area of 2794.28 square kilometres (1078.87 square miles). The annual average temperature of Netrokona is highest 33.3 °C and the lowest at 12 °C, while the annual average rainfall is 2174 mm (BBS, 2013; Banglapedia, 2015a).

This study was conducted in the *Haor* area of Netrokona District. Sixty-five *Haor*s are found in the district covering 6 Upazilas (sub-districts) [Netrokona District has 10 upazilas] with approximately 78,266 hectares of land. After examining the area and quantity of *Haor*, settlement, exposure, intensity, and sensitivity of people and assets to different climate extremes—3 Upazilas were purposively selected for the study: Khaliajuri, Madan, and Mohanganj (Fig. 1).

2.2 Methods of Data Collection

This study is a socioeconomic research. Mixed method was applied to conduct the study which facilitated to find out elaborated and in-depth information to better understand the problems. Quantitative data were collected by a survey using

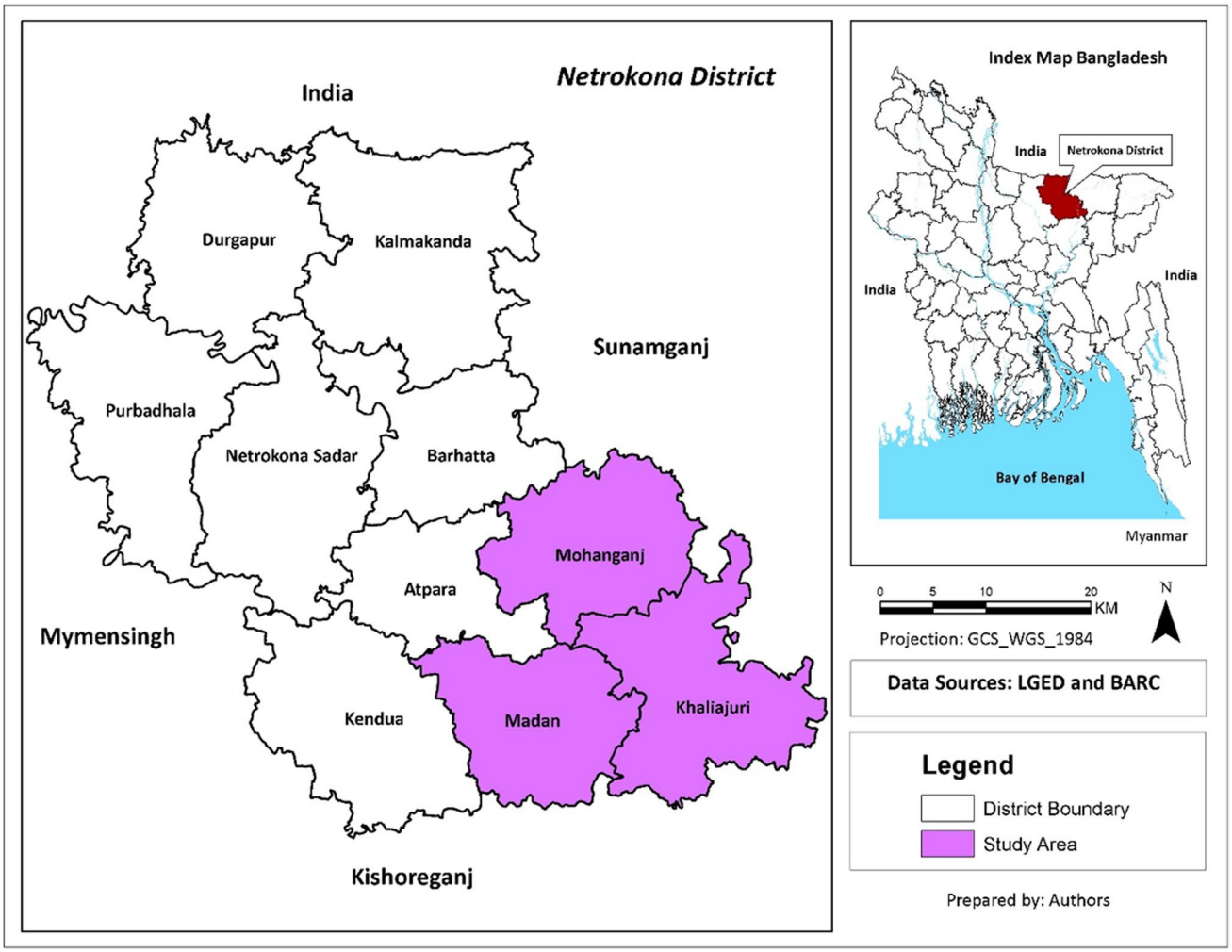

Fig. 1 Map of study area (Prepared by the Authors)

a structured questionnaire. After collecting quantitative data, it was cross-checked with qualitative (Key Informant Interview—KII and Focus Group Discussion—FGD) and secondary data which ensures proper data triangulation of the study. Primary and secondary both types of data were collected. To prepare the climatic hazard index, Participatory Rural Appraisal (PRA) tools and techniques—FGD, transect walk, mapping, and hazard calendar were used. Knowledge, Attitudes, and Practices (KAP) analysis tools have been exercised to know people's perceptions and behaviour.

2.3 Sampling Frame, Technique, Sample Selection, and Distribution

2.3.1 Sampling Frame

Farmers of all socioeconomic status, landowners, agricultural and non-agricultural labourers, housewives (who also work for processing crops and/or rear livestock), and people of diverse occupations who are associated with agricultural activities as secondary occupations were surveyed for the quantitative part of the study. For the qualitative part, local important persons, representatives of local government, government officers, NGO activists, academics, and experts were included.

2.3.2 Sampling Technique

The approach to the study involves two stages: i) field survey and ii) qualitative interview with the local people, key informants, and experts. Probability sampling was employed in the quantitative part of the study. Stratified random sampling has been applied to represent the population groups that are involved in crop cultivation and livestock rearing in the selected study area.

Table 1 Sample Size distribution for quantitative study (Source: Field Study)

Upazila (Sub-district)	Union	Village	Sample Size
Khaliajuri	Chakua	Bolli	51
	Mendipur	Nurpur Boali	49
Madan	Gobindasree	Gobindasree	59
		Padamsree	41
Mohanganj	Suair	Bhatia	31
	Gaglajur	Barantar	52
	Tethulia	Bara Paikura	37
Total			320

Table 2 Quantity of Qualitative Study Participants and FGDs (Source: Field Study)

Type of participants	Number of KIIs	Name of Upazila (Sub-district)	Number of FGDs
Local important persons	5	Khaliajuri	2
Representatives of local government	7		
NGO activists	2	Madan	2
Government officers	5	Mohanganj	2
Experts/Academicians	3		
Total	22	Total	6

2.3.3 Sample Selection and Distribution

320 respondents were surveyed while conducting the study. The number of respondents has been assigned considering the establishment of the area and number of population and degree of exposure and sensitivity of the people as well (Table 1). Besides, 22 KII and 6 FGD participants participated in the qualitative part of the study (Table 2).

2.4 Data Analysis

IBM SPSS Statistical Software (version 25) and Microsoft Excel were used to analyse collected data. Coding of questions helped quantify data where about 95% of the quantitative variables were categorical. Correlation, Chi-square, and likelihood ratio tests have identified if there is any association between the variables and measured the strength of association. Significance value $p < 0.05$ (confidence level 95%) was considered to verify the statistical significance. Using trendline in Microsoft Excel helped to find out the trend of climatic indicators. The map of the study area was prepared using ArcMap 10.8 (Table 3).

3 Results

3.1 Profile of the Respondents of Quantitative Part of the Study

Total 320 people were surveyed for the quantitative part during the field study. All the respondents are either directly or indirectly associated with agricultural activities. Most of the respondents are in the age group 31–40 (33.4%) where the age of 0.9% of respondents is below 20. Only 3.1% of people could pass higher secondary degrees, 33.8% have primary education, and 41.9% have no schooling. So, most of the agrarian people of *Haor* area are formally uneducated, though most of them fall in the age group 41–50 (42.54%) who were born in between the 1970s and 1980s when the literacy rate of Bangladesh was between 16.4% (1974) and 29.23% (1981) (Banglapedia, 2015b; The Global Economy, 2020). Among the respondents, 55.3% respondents have family members between 4 and 6. Data show that 98.8% of respondents do farming during the dry periods, 41.56% are fishermen, and 84.38% rear livestock. Among the respondents, people of other occupations are daily agricultural labourers (19.69%), daily non-agricultural labourers (14.69%), rickshaw/van pullers (12.5%), businessmen (14.7%), teachers (2.81%), housewives (10.9%), and students (0.9%), etc. The average monthly income of most of the households is within BDT 10,001–14,000 [USD 118–165] (33.8%).

3.2 Major Climatic Hazards affecting Crops and Livestock in the Study Area (Respondents' View)

According to the respondents, specifically, flash flood is the frequently happening (85.6%) climatic hazard in the study area. It is occurred here from the last of March to July. Sometimes flash floods wash away *Boro* rice as well as other *Rabi* crops and create economic and social disruption in this region. People identified hailstorms (61.6%), excessive fog (53.8%), storm/nor'wester (48.1%), drought (44.4%), and lightning (38.8%) as major climatic hazards which affect crop production and livestock farming. They also took cold wave (37.8%) and heat wave (32.8%) as two of the major hazards (Fig. 2).

3.3 People's Perception on Climate-induced Events

Understanding about Climate Change: 48.1% of people do not have an idea about climate change at all. Other people

Table 3 Community Perception and Experience of Climate Change (Source: Field Study)

Parameters	Respondents' Response	Khaliajuri (%) $N=100$	Madan (%) $N=100$	Mohanganj (%) $N=120$	Total (%) $N=320$
Change in temperature (last 10 years)	Increased	96	95	95.83	95.63
	Decreased	1	2	2.5	1.88
	No change	0	1	0.83	0.63
	Don't know	3	2	0.83	1.88
Change in the rainfall pattern during past 10 years	Increased	34	29	25.83	29.38
	Decreased	50	57	60.83	56.25
	No change	9	10	6.67	8.44
	Don't know	7	4	6.67	5.94
Length of summer season	Increased	78	75	74.17	75.63
	Decreased	10	6	13.33	10
	No change	7	6	6.67	6.56
	Don't know	5	13	5.83	7.81
Length of winter season	Increased	46	32	50.83	43.44
	Decreased	40	45	35.83	40
	No change	12	9	2.5	7.5
	Don't know	2	14	10.83	9.06
Length of rainy season	Increased	46	27	32.5	35
	Decreased	36	48	53.33	46.25
	No change	13	17	6.67	11.88
	Don't know	5	8	7.5	6.88
Change in the inundation time in the *Haor* area during the past 10 years	Late inundation	43	46	60	50.31
	Early inundation	41	35	28.33	34.38
	No change	13	15	10	12.5
	Don't know	3	4	1.67	2.81
Climatic hazards occur more frequently than before	Yes	92	95	96.67	94.69
	No	3	3	1.67	2.5
	Don't know	5	2	1.67	2.81
Types of flood, occurring in the area*	Flash flood	83	92	90.83	88.75
	Rain fed flood	76	84	70	76.25
	River flood	9	6	12.5	9.38

*Multiple Response

interpreted climate change as a form of different hazards and perturbations. 37.2% reported that they think of climate change as frequent flood, which is the characteristic of the study area, while 27.8% perceive climate change as extreme heat and 24.7% find irregularity of seasons as an instance of climate change. Others perceive climate change as frequent storms (20.3%), excessive cold (18.8%), irregular weather (13.4%), heavy precipitation (6.6%), and less precipitation (2.8%) (Fig. 3). From FGDs, it is revealed that most of the people know the term "Climate Change", but the meaning of the term is unknown to them.

3.4 Community Perception and Experience of Climate Change

3.5 Perception on the Reasons of Frequent Hazards/Disasters

The study (Fig. 4) finds that 45.9% of people still think "Act of God" is the reason for frequent hazards/disasters and 19.7% identified "Act of Nature" in this regard. Only 18% of respondents recognized "Climate Change" as responsible for

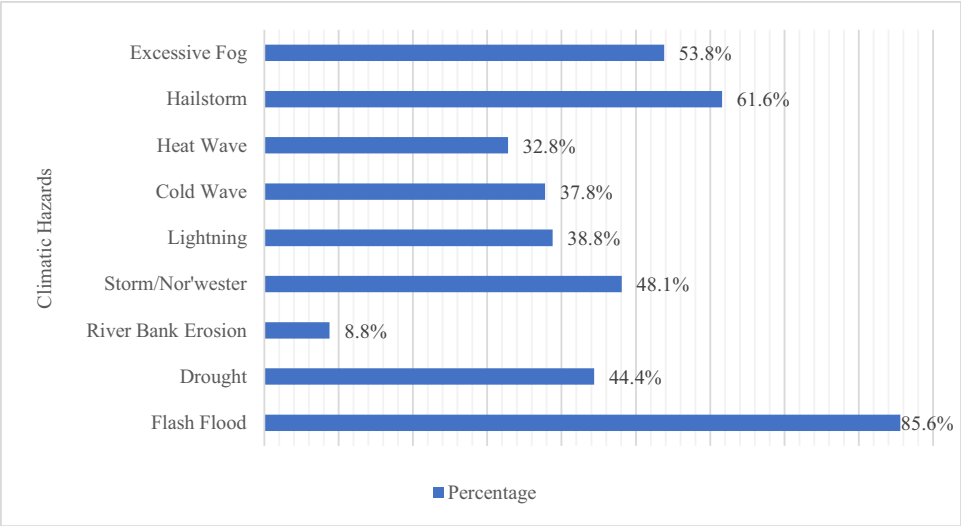

Fig. 2 Major Climatic Hazards in the Study Area according to Respondents' View (Source: Field Study)

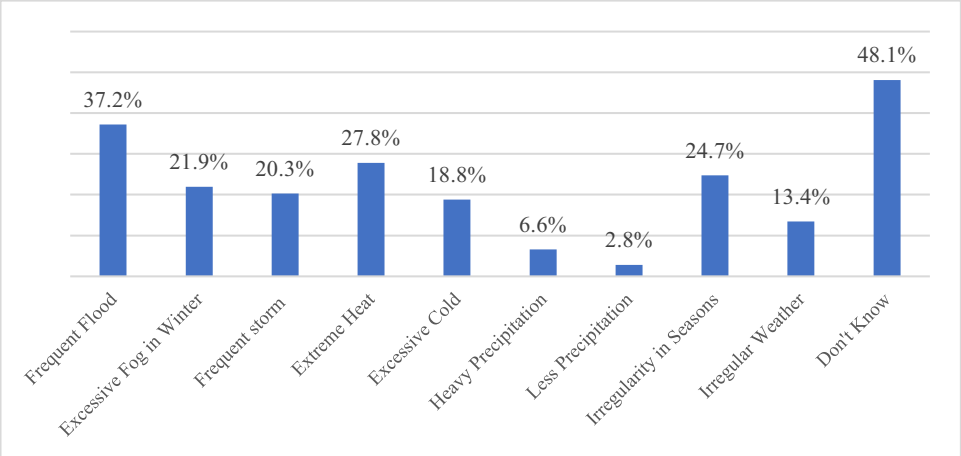

Fig. 3 Respondents' Understanding about Climate Change (Source: Field Study)

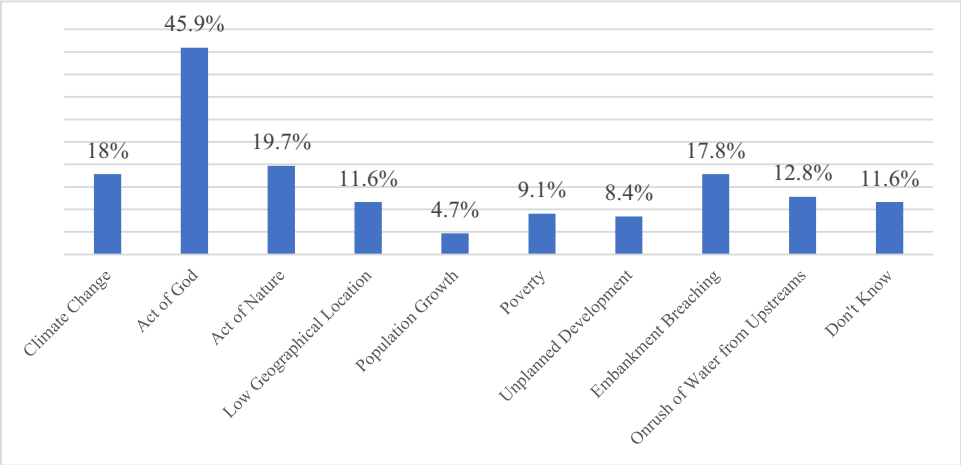

Fig. 4 Respondents' Perception on the Reasons of Hazards/Disasters (Source: Field Study)

frequent hazards and disasters. Other identified reasons are embankment breaching (17.8%), onrush of upstream water (12.8%), low geographical location (11.6%), poverty (9.1%), unplanned development (8.4%), and population growth (4.7%). 11.6% of respondents do not know any reason of frequent hazards/disasters.

3.6 Climatic Trends and Hazard Index to Validate People's Perception

To validate people's perception of climatic parameters (temperature and precipitation), Time-series (TS) Data of the Climatic Research Unit (CRU) of the University of East Anglia was collected which provides 0.5 × 0.5 degree high-resolution gridded data (Version 4.03) for 1901–2018 (Harris and Jones, 2020). Figures 5 and 6 show TS data on annual average temperature (˚C) and annual precipitation (mm) for 38 years (1981–2018). It is evident from the trendlines (Figs. 5 and 6) that during the 1981-2018 average temperature of Netrokona District increased where annual precipitation decreased which supports respondents' perception and experience. Figure 5 illustrates that after 2000 average annual temperature has been increased remarkably.

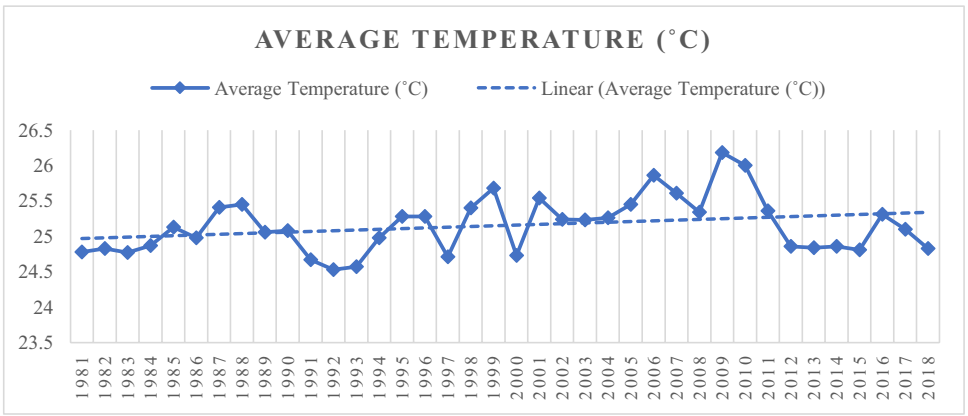

Fig. 5 *Average Annual Temperature (˚C) of Netrokona District with the Trendline (1981–2018)* (Harris & Jones, 2020)

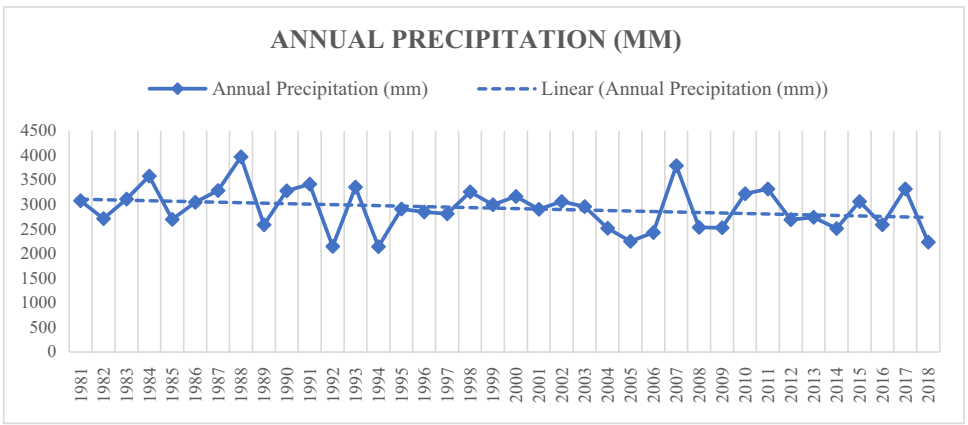

Fig. 6 *Annual Precipitation (mm) of Netrokona District with the Trendline (1981–2018)* (Harris & Jones, 2020)

Table 4 Climatic Hazard Index of the Study Area (Source: Field Study)

Hazard	Frequency (Value 1–5)*	Area Impact (Value 1–5)*	Magnitude (Value 1–5)*	Total Score [a]	Rank
Flash flood	4	4	4	32	1
Drought	2	3	4	20	4
River bank erosion	2	3	3	15	7**
Storm/Nor'wester	4	3	3	21	3
Lightning	4	2	3	18	5**
Heat wave	3	2	3	15	6**
Cold wave	3	2	2	10	8
Excessive fog	4	2	3	18	5**
Hailstorm	5	3	3	24	2

a = Total score = (Frequency + Area Impact) × Magnitude

* Values 1-5 denote the strength levels, with 1 representing the lowest and 5 the highest.

** If scores are tied, priority selection is based on the following criteria: 1. Magnitude, 2. Frequency, 3. Area Impact.

The parameters of the climatic hazards used to rank are frequency, area impact, and magnitude of hazards, where each of the parameters got a value from 1 to 5 indicating their levels of strength (Table 4). Ranking of the hazards was based on the total score obtained from the formula—Total Score = (Frequency + Area Impact) × Magnitude. Flash flood ranked top and hailstorm followed it, whereas cold wave scored the lowest. The hazard ranking partially endorses identified major hazards affecting crop production and livestock farming by the respondents.

3.7 Adaptation Strategies followed by the Local People

Researchers agreed that vulnerable communities can be resilient by following local-level adaptation strategies (Alam et al., 2017; Hiwasaki, Luna, Syamsidik, & Shaw, 2014) which can mitigate the impacts of climatic hazards and minimize the losses. The adaptation strategies of the study area (Table 5) are categorized into 3 categories below: (Table 6)

Table 5 Adaptation Strategies followed by the Local People of the Study Area (Source: Field Study)

Category	Adaptation Options	Percentage			
		Khaliajuri (%) N = 100	Madan (%) N = 100	Mohanganj (%) N = 120	Total (%) N = 320
Crop Production	Crop rotation	17	15	24.17	19.06
	Changing crop varieties (e.g. fast-growing crops)	30	46	37.5	37.81
	Using stressor-tolerant crops species	30	31	34.17	31.88
	Early harvesting of immature Boro rice	40	27	40.83	36.25
	Changing crop planting dates	55	64	61.67	60.31
	Using mechanical irrigation system	30	28	18.33	25
	Rainwater harvesting for irrigation	13	17	12.5	14.06
	Using pesticide to the crops	53	49	55.83	52.81
	Preservation of crop seeds	19	23	11.67	17.5
	Homestead gardening	33	41	40	38.13
	Planting *Hijol* and *Koroch* trees to protect crop lands from intense current of flood	15	20	23.33	19.69
	Using Kanda (high fallow land in *Haor*) for cultivating crops other than rice	41	52	42.5	45
	Planting palm trees to prevent lightning	27	33	43.33	35
Livestock and Poultry Farming	Preservation of feeds for livestock for the period of feed scarcity	30	33	35.83	33.13
	Purchasing feeds for the animals during the time of feed scarcity	33	32	27.5	30.63
	Putting cotton/jute made cover on the animals in winter	36	41	32.5	36.25
	Constructing permanent sheds/shelters for animals	20	19	20	19.69
	Take animals to the veterinary physician	46	37	40.83	41.25
	Grass cultivation for livestock	16	18	15.83	16.56
	Duck rearing	45	47	36.67	42.5
	Integrated livestock and poultry farming	12	9	14.17	11.88
Non-agricultural Activities	Migration of farming family	44	46	54.17	48.44
	Using different means of livelihood	54	50	49.17	50.94
	Cottage industries				
	Taking loans (with high interest) from lenders	47	39	42.5	42.81
	Selling/mortgaging property	48	37	52.5	46.25
	Selling of livestock in the emergency period	48	37	36.67	40.31
	Seeking early warning of different disasters from the authority	7	5	5	5.63

Table 6 Rationale (Respondents' View) for Available Adaptation Options (Source: Field Study)

Sl	Adaptation Options	Addressed Climatic Risks	Rationale (Respondent's View)
1	Crop rotation	Flash flood, drought	As cultivating only *Boro* rice creates financial risk, people are leaving their traditional practice to grow only rice during dry season in the *Haor* area. Hence, some people are cultivating wheat, spices, maize, pulses, potatoes, vegetables, etc., which is ensuring sustainable livelihood practices
2	Changing crop varieties (e.g. fast-growing crops)	Flash flood	Some people change crop varieties so that they can harvest the crops earlier. This adaptation approach saves their crops from the impacts of flash flood (e. g. lifetime of most common rice variety of *Haor* area BRRI-29 is 160 days. Contrastingly, lifetime is 140 days for BRRI-28. Though BRRI-29 variety provides more crops, some people are cultivating BRRI-28 for early harvesting)
3	Using stressor-tolerant crops species	Flash flood, excessive fog, drought, nor'wester, thunderstorm, heat wave/extreme temperature	Local farmers consult with the local officers of the Agricultural Extension Department and plant stressor-tolerant crop species which can withstand different climatic stressors; e.g. BRRI-28 Rice, BARI Mustard- 14, BARI Onion-1, etc
4	Early harvesting of immature *Boro* rice	Flash flood	Sometimes people harvest crops earlier when there is any probability of occurring early flash flood. Almost half amount of the rice is not ripe at that time, but this strategy can save up to 60% of rice. Unripe rice is used as fodder
5	Changing crop planting dates	Flash flood	Usually, farmers plant seedlings of *Boro* rice in Mid-*Poush* (Beginning of January). But as an adaptation strategy, to protect the rice from early flash flood, they occasionally plant seedlings in the beginning of *Poush* (Mid-December)
6	Using mechanical irrigation system	Drought, heat wave, extreme temperature	During dry season, if crop fields are affected by drought or lack of water for irrigation, people use mechanical irrigation system (e.g. shallow pump) to water the crops and moisturize soil
7	Rainwater harvesting for irrigation	Drought, heat wave, extreme temperature	The practice of rainwater harvesting to irrigate croplands is in small range in the *Haor* area. This strategy is used as Community Based Planned Adaptation (CBPA), executed by NGOs
8	Using pesticide to the crops	Climate change-induced pest attacks to the crops	Due to climate change-induced warming, insect pests are increasing in the *Haor* area which is destroying crops. To control pest attacks, people are using pesticides increasingly
9	Preservation of crop seeds	Extreme rainfall, flood (monsoon)	Preservation of crop seeds for the next cultivation time ensures the availability of good seeds even though there is any climatic hazard occurring. Based on indigenous knowledge, people are practicing this as Individual Level Adaptation (ILA)

Table 6 (continued)

Sl	Adaptation Options	Addressed Climatic Risks	Rationale (Respondent's View)
10	Homestead gardening	Flood (flash and monsoon)	Available land in the homestead is used for gardening which is a sustainable livelihood option for the *Haor* people as croplands are submerged under water most of the time of a year. Homestead gardening also ensures proper nutrition for the family members
11	Planting *Hijol* and *Koroch* trees	Flood (flash and monsoon)	As *Hijol* (*Barringtonia acutangula*) and *Koroch* (*Pongamia pinnata*) trees can live in the submerged or inundated area and can withstand the intense current of flood, some NGOs and government organizations are serving to plant these trees as part of Community Based Planned Adaptation (CBPA) strategy
12	Using *Kanda* (High fallow land in *Haor*) for cultivating crops other than rice	Flash flood	*Kanda* means high fallow land which isn't inundated by flood. Traditionally these lands remain fallow all the year-round. But now some people are using these lands for planting vegetables, pulses, spices, fruits, etc
13	Planting palm trees	Lightning	Government of Bangladesh (GoB) has taken an initiative to plant palm trees across the country to reduce fatalities due to lightning. In the study area this adaptation strategy is being executed by the government organizations
14	Preservation of feeds for livestock for the period of feed scarcity	Flood (flash and monsoon), extreme rainfall	People store grass, hay, corn in their houses to feed their animals in the rainy season. This adaptation strategy helps their livestock to be survived during any climatic disaster
15	Purchasing feeds for the animals during the time of feed scarcity	Flash flood, drought, nor'wester/storm	Due to heavy rainfall, flood, and storm, sometimes animal fodders are damaged. At that time subsistence farmers have no other option except purchasing fodders
16	Putting cotton/jute made cover on the animals in winter	Cold wave	To keep livestock safe from the effect of cold wave, local people use cotton and/or jute made cover in the winter season
17	Constructing permanent sheds/shelters for animals	Flood (monsoon), heavy rainfall, extreme temperature, heat wave, hailstorm, nor'wester/storm, lightning	Previously, it was seen that livestock are kept in the open places during day or night which posed the risks of being affected by climatic hazards. To cope with the situation, people are constructing permanent sheds/shelters at their houses for animals
18	Take animals to the veterinary physician	Climate change-induced pest-attack and diseases	Traditionally people of remote area are reluctant to bring their sick cattle to the veterinary physician. At present, the situation has been changed. People consult veterinary physician if their domestic animals are affected by climate-induced pest-attack and diseases/ other diseases
19	Grass cultivation for livestock	Climate change-induced fodder scarcity (flash flood, monsoon flood, heavy rainfall, drought etc.)	Climate change impacts are reducing pasture lands in the *Haor* area which is exaggerating scarcity of feeds for the livestock. To meet the demand, farmers are cultivating grass for feeding their animals

Table 6 (continued)

Sl	Adaptation Options	Addressed Climatic Risks	Rationale (Respondent's View)
20	Migration of farming family	Climatic hazards caused livelihood activities disruption	People migrate to urban and suburban areas for seeking new income source. Usually, this type of migration is seasonal which is happened when crops are damaged by flash floods, or in the rainy season. Seasonal migrants come back to their villages in crop cultivation time
21	Duck rearing	Flood (flash and monsoon)	As most of the lands are submerged under water in wet season, traditionally local people have been practicing duck rearing as an adaptation option
22	Integrated livestock and poultry farming	Climate change-induced livelihood activity disruption	With the help of Government of Bangladesh and NGOs, people are rearing goat, sheep, duck, and hen combinedly as these can cope with the climatic condition of *Haor* area. This livelihood initiative is increasing income of the subsistence farmers
23	Using different means of livelihood	Climatic hazards-induced livelihood activities disruption	As an adaptation option, diversified means of livelihood decrease the risk of financial crisis triggered by climate change. From the study we found that most of the respondents have more than one income sources
24	Cottage industries	Climatic hazards caused livelihood activities disruption	Cottage industry is an adaptive livelihood option for women of the *Haor* area. Women, associated with cottage industry have a sustainable income as there is institutional arrangement of marketing the products with the help of different NGOs
25	Taking loans (with high interest) from lenders	Climatic hazards caused livelihood activities disruption	In *Haor* area, lenders provide loan with high interest to the farmers. Usually small farmers take loan during crisis period, which in fact leads them towards another trouble
26	Selling/mortgaging property	Climatic hazards caused livelihood activities disruption	Farmers sell or mortgage their properties when there is lack of livelihood opportunities due to any stressor, and they are in need of cash to survive
27	Selling of livestock in the emergency period	Climatic hazards caused livelihood activities disruption	Some people have no other option except selling their livestock while they are in financial crisis. Selling livestock helps them to cope up with the terrible condition in the emergency
28	Seeking early warning of different disasters from the authority	Flash flood, monsoon flood, heavy rainfall etc	Seeking early warning of different disasters is very rare in the *Haor* area of Bangladesh. One of the reasons is- traditionally people can forecast disasters by observing sky and water of *Haor* and river. Nevertheless, nowadays people are seeking early warning from Union Councils and Department of Agricultural Extension (DAE) so that they can take precautions to save their crops

3.8 Rationale (Respondents' View) for Available Adaptation Options in the Study Area

3.9 Educational Level Influencing some Systematic Adaptation Options

Some scientific and systematic adaptation options for crop production are largely influenced by the educational qualifications of the respondents. From the quantitative and qualitative analysis, it has been observed in the *Haor* area of Netrokona District that farmers having no formal education or lower level of education are more reluctant to follow scientific recommendations of adaptation techniques like crop rotation, changing crop varieties, using stressor-tolerant crop species, etc., than the educated ones. Traditional farmers hardly can accept scientific and new strategies.

It is statistically tested that switching crop varieties (crop rotation), changing crop varieties, and using stressor-tolerant crops species have strong association with the level of education in the study area (Table 7).

3.10 Causes of not Taking Adaptation Measures

In total, 107 farmers responded on the reasons for not taking proper adaptation measures. Figure 7 shows that 63.4% of respondents identified lack of information as the main reason of not taking any adaptation measure. 33.9% of people said that lack of money prevents them to take adaptation measures, although money is not so required for adaptation. 30.6% of respondents do not know the reason; 26.2% are not aware of climate change which can motivate them to take adaptation measures. On the other hand, 9.8% of respondents are not interested in this matter.

4 Concluding Remarks

Climate change-induced reduced crop production and livestock is affecting food security, livelihood, health, and exaggerating the extent of poverty and social insecurity in the country (Chen, Zhang, & Tao, 2018; Barnett & Adger, 2007). This study examined the perception and knowledge of farmers on climate-induced events and experiences, and explored the adaptation practices they adopt to protect crop production and livestock farming from the impact of climate change in the *Haor*s of the north-eastern area in Bangladesh. Study result shows that respondents' perceptions and experiences on climate-induced events are verified empirically, but most of the respondents have a vague idea on climate change. The study extensively explored the adaptation approaches of the farmers which include some good practices like crop rotation, changing crop varieties, using stressor-tolerant crop species, integrated livestock and poultry farming, using different means of livelihood, etc. It is observed that farmers of *Haor* area are reluctant to follow crop diversification strategy; rather, they stick to traditional *Boro* rice cultivation.

Considering the above-mentioned scenarios, there is a necessity of urgent action to be taken by policy, academic,

Table 7 Educational qualifications have strong relationships with some scientific adaptation options

Variable	Adaptation Option	Statistical Test	Value	df	Significance*
Educational Qualifications	Switching crop varieties (Crop rotation)	χ^2	25.041[a]	7	0.001
	Changing crop varieties	χ^2	15.525[a]	7	0.030
	Using stressor tolerant crops species	χ^2	16.567[a]	7	0.020

*$P < 0.05$

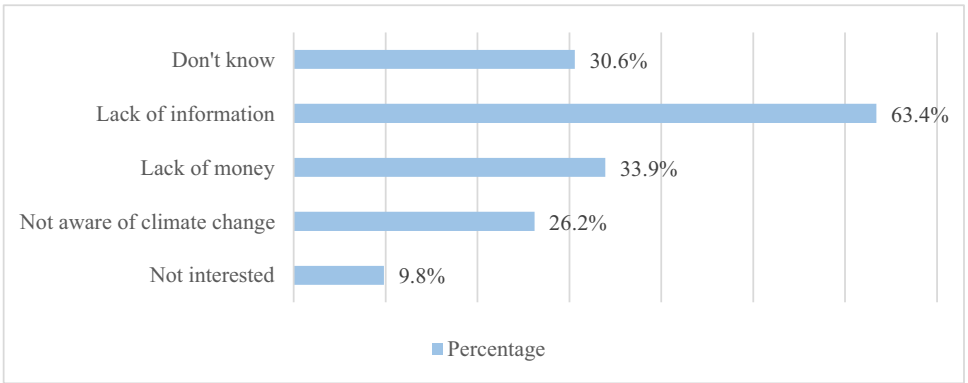

Fig. 7 Reasons of not Taking Adaptation Measures (Source: Field Study)

and execution authorities: (i) climate change adaptation and mitigation awareness campaigns should be popularized countrywide for the subsistence farmers and livestock rearers; (ii) evidence-based proper scientific and technological knowledge on "Crop Diversification" must be disseminated among farmers; (iii) introducing Nature-based Solution (NbS) and Ecosystem-based adaptation strategies among farmers of *Haor* area is necessary to ensure both adaptation and mitigation at the same time; (iv) local Livestock Department should be empowered more with additional manpower and resources to ensure prompt actions in the *Haor* area; (v) government and non-government bodies may work closely to promote more non-farm adaptation activities; (vi) as the global temperature trend is going upward, risk of climate extremes is also being accelerated. Therefore, to adapt to the changed climate, policy-level interventions are required for livelihood diversification and integrating indigenous and scientific knowledge which will efficiently increase the resilience of native people of the *Haor* area.

Further studies are highly suggested to explore the prospect and ways of Nature-based Solution (NbS) in the study area. To ensure proper crop diversification in *Haor* area, more advanced research can be undertaken. Apart from that, a socioeconomic study on the impact of climate change on the social structure of *Haor* area is also recommended.

Authors' Contribution Mr. Tasneem Chowdhury Fahim executed the research in field level with his own funding. He collected data with his team, analysed data, and wrote the research paper under the supervision of Mr. Bivuti Bhushan Sikder. Mr. Bivuti Bhushan Sikder also reviewed the article when needed.

Funding The research is part of master's thesis of Mr. Tasneem Chowdhury Fahim under the supervision of Mr. Bivuti Bhushan Sikder, Assistant Professor of Institute of Disaster Management and Vulnerability Studies, University of Dhaka. The research is totally self-funded.

Data Availability Data and materials are available. It can be shared upon editor's/reviewers' suggestions.

Code Availability No code availability.

Declarations

Ethical Approval This article is original and the manuscript has not been submitted to more than one journal for simultaneous consideration. The submitted work has not been published elsewhere before. The data are original, honest, and have not been fabricated.

Consent to Participate In this research, the respondents and participants are human and prior consent was ensured before conducting the study.

Consent for Publication The respondents and participants of this research have given their consent to publish their opinion in the research paper. All the authors are agreed to publish this research paper.

Human and animal rights No people or animals were harmed during executing the research in the field level.

Conflict of Interest/Competing Interest Mr. Tasneem Chowdhury Fahim and Mr. Bivuti Bhushan Sikder declare that they have no conflict of interest regarding this original research article. The authors have completed the research with their own funding. They have no affiliations with or involvement in any organization with any financial interest.

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