Bangladesh J. Agri. 2022, 47(1): 39-65 *DOI: https://doi.org/10.3329/bjagri.v47i1.60592*

ASSESSMENT OF CLIMATE CHANGE RISKS AND ADAPTATION OF IMPROVED FARMING PRACTICES IN DEKHAR HAOR OF SUNAMGANJ DISTRICT

M. A. Haque[1*], S. M. Moniruzzaman[2], M. F. Hossain[3] and M. A. Alam[2]

[1]Practical Action Bangladesh, Dhanmondi, Dhaka; [2]Bangladesh Jute Research Institute (BJRI), Dhaka; [3]Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Bangladesh

Abstract

Flash flood is the most commonly occurring water related disaster in the haor area of Bangladesh. It's occurs during the pre-monsoon season (March-April-May). The haor area is very susceptible to climatic risk and prone to early flash flood in consecutive year. In response, the government of Bangladesh has initiated a number of institutional interventions through development plans to better support sustainable adaptation. A study was carried out to assess the climate change risks and adaptation of indigenous farming practices of dekhar haor in Sunamganj district. Data were collected through direct interview from randomly selected 96 farmers, 4 Focus Group Discussion and 10 Key Informant Interviews during September 2019 to January 2020. It was found that the most potential climatic hazards of the study area were flash flood, thunderstorm, hailstorm and drought. The data related to agricultural adaptation strategies to climate change indicated that the majority (54.2%) farmers had medium adaptation and 45.8% low adaptation and no farmers were found with high adaptation. Climatic risks at different agricultural sectors such as crop protection, community protection, fisheries, livestock and risk of drought were assessed through comparative analysis of climatic hazards, vulnerability to climate change and adaptation capacity.

Keywords: Adaptation, Climatic risks, Dekhar haor, Flash flood, Indigenous farming practices

Introduction

Bangladesh is vulnerable to rapid onset disasters including floods, river erosion, cyclones, droughts, tornadoes, cold waves, earthquakes, drainage congestion/water logging, arsenic contamination, salinity intrusion and global climate change etc as so much of its economy relies on agriculture (DM and RD, 2010). Floods are annual phenomena, with the most severe flood occurring during the months of July and August. Regular river floods affect 20% of the country, increasing up to 68% in extreme years. The north-eastern part of Bangladesh is known as Haor region. It spread over seven districts Sylhet, Sunamganj, Habiganj, Maulovi Bazar, Kishoreganj, Bhramanbaria and Netrokona. The Haor area altogether covers 1.99 million ha which is around 13.5% of the country's total surface area (Khan, 2010). Dekhar haor is one of the most important, famous and large haor in Bangladesh. It is moderately deep, semi remote and core haor area located in east of the Tanguar system. The Haor covers four upazilas namely

* Corresponding author: enam4656@gmail.com

Sunamganj Sadar, Dakshin Sunamganj, Dowarabazar and Chhatak under the Sunamganj district. Total area of the Haor is about 11514.6 hectares. Dekhar Haor is made up of 36 small, medium and large interconnecting beels, canals, rivers and crop lands. There is a great importance of this haor in fish production and a big pocket of boro rice production. It is the source of livelihood for more than 1, 00,000 people. The haor goes under flooding (5-10 m) from late May to October while it looks like a sea (which is called haor corrupt word from Sagar). The haor area remains waterlogged for about six to seven months in a year. About 86% of the total cropped area of haor is highly potential for boro rice production and vital supplier of inland freshwater fisheries with a fishing area of 114793 hectares (Master Plan of Haor Areas, 2012). Swamp forest is dominated by Hijal (*Barringtonia acutangula*), Koroch (*Pongamia pinnata*) and other flood tolerant tree species are visible in the haor. Haor is predominantly a single cropped (boro rice) area. The scenario of existing cropping patterns practiced in Sunamgonj is Boro-Fallow-Fallow (80%), Fallow-Fallow-T.Aman (3%), Boro-Fallow-T.Aman (8%) and Fallow-Aus-T.Aman (6%) respectively (DAE and Field survey, 2008). Boro rice is the principle crop of this region. But pre-monsoon flash flood from the very steep uplands adjacent to the region in Asam and Meghalaya Hills range in India is a common phenomenon, causing immense damage to the standing Boro crops before harvesting. To protect the Boro crop damage due to pre-monsoon flash flood BWDB constructed 46 Submersible Embankments in the haor region. The positive impact of the submersible embankment on Boro production has also negated the notion that loss of Boro production from the unprotected areas of the region might outweigh any incremental production from the submersible embankment (Bangladesh Disaster Management Reference Handbook, 2015; Saleh and Mondal, 2007). Rural poor households have to depend upon fisheries and off-farm labour to supplement the meager farm income. The common property nature of the water bodies or Jalmohals and the uncertain lease arrangements inhibits the full growth potential of the fisheries sector. The haors are known as an area of severe poverty and limited livelihood options with many people seasonally migrating to find work. Vegetable production in the field using different vegetable based cropping patterns revealed that more than one crop can be harvested from comparatively high land of the haor area with higher net income as well as employment generation with higher rice equivalent yield thus creating opportunity for alternative livelihood option for the poor. Already today, there are high costs and consequences due to flooding in haor areas with land being eroded away, fatalities, construction, infrastructure failures and disease (IPCC, 2013; McBean, 2004). Higher sea level and changes in precipitation patterns will not only increase the risk of flooding but also of erosion and landslides (e.g. Andersson *et al.*, 2013, 2014). Therefore, the farmers will be more vulnerable to climate change in haor areas of Bangladesh and its impacts of climate variability and change cause additional risks for agriculture. In view of the above facts, the study was undertaken to climate change risks based on climatic hazards, extent of impact and agricultural adaptation status with the following objectives: (i) To identify the major climatic hazards and existing vulnerability for agricultural production in the selected haor area, (ii) To identify the adaptation levels of agricultural farming practices in the changing situation in the selected *haor* area, (iii) To analyze the climatic risks for different sectors of agricultural farming in the selected haor area and (iv) To explore the relationship between personal attribute of the farmers and their agricultural adaptations to climate change.

Materials and Methods

Description of the haor and selection of study area

Dekar haor is a resourceful wetland basin located in the North-East part of Bangladesh, lies between latitude 24°34'N to 25°12'N and longitude 90°56'E to 91049'E under Sunamganj district. The Dekar haor covers four upazilas namely Sunamganj Sadar, Dakshin Sunamganj, Dowarabazar and Chhatak having an area of 11514.6 ha. In monsoon, it is full of water look like an inland sea, but in the dry season maximum portion of the haor becomes dry except some deeper portions. The average water depth varies from 1.07 meters in winter and 3.1 meters in monsoon. The haor covers a total 36 small and large interconnecting beels, channels, rivers and crop lands (CNRS, 2004). The haor is a critical habitat for fishes and other aquatic species. A large number freshwater fishes, thousands of indigenous and migratory birds and non-fishes aquatic organisms have been found. The haor is also the home grounds for many organisms and provide suitable areas for feeding, breeding, nursing and so on. Boro is the main crop in the area.

The research instrument and its preparation

The study was conducted through peoples' consultation focused on farmers' response. Three tools were used to assess the climatic risks and adaptation measures around dekhar haor area under Sunamgonj district, such as (i) Farmers' Interview (ii) Focus Group Discussion (FGD) and (iii) Key Informant Interview (KII). The questionnaires were prepared for collection of data from the respondents keeping the objectives of the study in mind. The question and statements contained in the schedule were simple, direct and easily understandable by the farmers.

Population coverage and sampling

As per physical observation of the researcher, 86 villages listed on the bank of Dekhar Haor with a population of 87427 for 15150 households and their livelihood is very crucially depend on dekhar haor ecosystem.

Sampling village selection

As Dekhar Haor is surrounded by 8 unions under 4 upazilas of Sunamgonj district, for farmers' interview 2 villages has selected as sample village from each of 8 union considering the most adjacent to haor area and farmers' livelihood & vulnerability is more depended on haor context. For conducting FGD, 4 villages has selected on the East, West, North & South side of dekhar haor to accumulate the climatic risk in all sides of the haor.

Farmer's interview

Six sample farmers were selected from each of 16 sample villages in consultation with respective UP Member and community leader to include large, middle, small and landless farmers with diversification in livelihood intervention on crops cultivation, fishing, vegetable cultivation and livestock rearing etc. According to agricultural census of Bangladesh, a farm household was classified into three categories such as: small (up to 2.4 acres); medium (2.5 to 7.4 acres); and large (7.5 acres or more) (BBS, 2011). In a total 96 farmers' interview was conducted.

Focus group discussion (FGD)

4 FGDs were conducted at village level in 4 sides (East, West, North and South) of dekhar haor to accumulate different risk, vulnerability, experience and idea of all part of haor. 10-15 participants were took part in each FGD (Crop farmers, livestock farmers, fishermen's and community leaders) with representation of different categories farmer and community leader also. Age of the participants is not less than 30 years to capture the experience and idea in the changing climate during last 10 years.

Key informant interview (KII)

Ten categories of personnel had listed to conduct the KIIs for getting diversified experience and idea from different level and perspectives such as (i) Upazila level leader - Upazila Chairman, Sunamganj Sadar (ii) Union level leader-UP Chairman, Pandergaon UP, Dowarabazar (iii) Community level leader- UP Member, Mollapara UP, Sunamganj Sadar (iv) Women leader- Upazila Women Vice-Chairman, Dakshin Sunamganj (v) Planning level agricultural professional- Upazila Agriculture Officer, Sunamganj Sadar (vi) Implementation level agricultural professional- Sub Assistant Agriculture Officer, Dakshin Sunamganj (vii) Press media journalist- Editor, The Daily Sunamkantha (viii) Electronic media journalist- Staff Reporter, RTV (ix) Development worker- Upazila Manager, DASCOH and (x) Research worker- Research Associate, Sylhet Agricultural University (Dekhar haor project). The questionnaires for Farmers' Interview, FGD & KII has developed with same contents and in addition selected characteristics of the farmer included in Farmers' Interview. The following major issues, problem or statement had delivered in the questionnaires such as (a) Farmer characteristics: Age, Education level, Farm size, Annual income & Extension media contact of the farmer (b) Respondents' perception of climate change: believe in climate change, perception of climatic variability in changing situation and causes of climate change (c) Climatic risks analysis in agricultural farming: Climatic hazards ranking and Impact of climate change as experienced and observed by respondents and (d) Agricultural adaptation to climate change in Dekhar Haor as experienced and observed by respondents.

Questionnaires

The questionnaires for farmers' interview, FGD & KII has developed with same contents and in addition selected characteristics of the farmer included in farmers' interview. The following major issues, problem or statement had delivered in the questionnaires.

Farmer characteristics

Age, education level, farm size, annual income & extension media contact of the farmer.

Respondents' perception of climate change

Believe in climate change, perception of climatic variability in changing situation and causes of climate change.

Climatic risk analysis in agricultural farming

Climatic hazards ranking and Impact of climate change as experienced and observed by respondents. Agricultural adaptation to climate change in dekhar haor as experienced and observed by respondents.

Variables of the research and their measurement

The independent variables of the research were age, education level, farm size, annual income and extension media contact of the farmer, respondents' believe in climate change, perception of climatic variability in changing climate and causes of climate change. The dependent variables of the research were climatic hazards ranking as experienced by respondents, impact of climate change as observed by respondents and agricultural adaptation for climate change. Procedure for measuring independent and dependent variables has been presented below:

Measurement of independent variables

Age of the farmer was measured in terms of actual years from their birth to the time of interview. A score of one (1) was assigned for each year of one's age. Education of a farmer was measured on the basis of year of schooling in formal educational institution. Score 1 was given for each class have completed. Respondent who don't know how to read and write, education score was taken as zero (0). A score of 0.5 was given to that respondent who could sign his/her name only. The farm size of a farmer was measured in hectares. The data were first recorded in term of local unit i.e. 'care' and then converted to hectare.

Annual income of a farmer was measured in taka on the basis of his total yearly earning from different sources (e.g. agricultural and non-agricultural) in last year. A score of one (1) was assigned for each thousand taka. The extension media contact of the farmer was measured by the total scores of media contact on the basis of the frequency of visit and contact with 10 selected media contact. The extent of contact was determined against a four point scale and scores were arranged for all 10 categories of related media contact and frequency of communication such as Not at all, Rarely, Occasionally and Frequently 0,1,2,3 respectively. Thus the score of a farmer could range from 0 to 30, where 0 indicating no extension media contact and 30 highest extension media contact. Throughout the assessment: Farmers' Interview, FGD & KII, respondents were asked that they believe in climate change and find out response in terms of YES or NO. Number and percent of respondents in different interviews calculated. The perception of climatic variability (precipitation, temperature, wind speed & extreme events) during last 10 years and their comments were measured by Extent of perception were three categories Increased, Reduced and No change. Each category was divided into two parts (such as # is number and % is percentage). The respondents were asked about the causes of climate change and their comments were measured by counting number of citation.

Measurement of dependent variables

A-four point rating scale from “High” to “Not ever” was developed as High = 3, Medium = 2, Low = 1 and Not ever = 0 to measure the extent of damage for 10 listed climatic hazards in haor areas as experienced by the respondents. The range of climatic hazards score of the respondents could vary from 0 to 30, where, 0 indicate no climatic hazards and 30 indicated full climatic hazards. However, its having computed the “extent of climatic hazards” score for each of 110 respondents, the climatic hazards index (CHI) was calculated to compare the relative hazards with ranged from 0 to 330. A-four point rating scale from “High” to “Not ever” was developed as High = 3, Medium = 2, Low = 1 and Not ever=0 to measure the extent of impact for 15 listed problems as effect of climate change in hoar areas as experienced by the respondents. However, besides having computed the “extent of impact of climate change” score for each of 110 respondents, the climatic change impact index (CCII) was calculated to compare the relative impact. The CCII for each of the climate change problem/statement ranged from 0 to 330, where, 0 indicate no climate change impact and 330 indicated full or extreme impact of climate change. A-four point rating scale from “High” to “Not ever” was developed as High = 3, Medium = 2, Low = 1 and Not ever = 0 to measure the extent of adaptation for 15 listed adaptation aspects in haor areas as experienced by the respondents. The range of extent of adaptation score for climate change of the individual respondents could vary from 0 to 45, where, 0 indicate no adaptation for climate change and 45 indicated full adaptation for climate change. After having computed the “extent of adaptation” score for climate change for each of 110 respondents, the farmers was categories according to their overall agricultural adaptation to climate change. The climate change adaptation index (CCAI) for each of the adaptation aspects calculated to compare the relative adaptation. The CCAI ranged from 0 to 330, where, 0 indicate no adaptation and 330 indicated full adaptation for climate change.

Climatic risks assessment

Risk assessment is a process to determine the nature and extent of such risk, by analyzing hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend. According to the ISDR publication: Living with Risk, the stages of a risk assessment are the following (shown in the order in which they are normally conducted).

- Hazard identification to identify the nature, location, intensity and likelihood (probability or frequency) of a threat
- Vulnerability analysis to determine the existence and degree of vulnerabilities and exposure to a threat(s)
- Capacity analysis to identify the capacities and resources available to reduce the level of risk, or the effects of a disaster
- Risk analysis to determine levels of risk
- Risk evaluation to make risk priorities which need countermeasures

Adaptation policy framework (ADF)

The United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) have initiated a process to develop a so-called adaptation policy framework (APF). The APF project aims to strengthen adaptive capacity of human systems, in multiple sectors, to all climate-related threats. This is done by providing guidance to developing countries for conducting adaptation policy assessments that help them to integrate adaptation to climate change into sustainable development plans, and to link longer-term climate change to current problems caused by climate variability (UNDP, 2003). The APF builds on a framework published in Burton *et al.*, (2002). Key innovations of the APF, used in vulnerability and adaptation studies, are (i) It treats policy as the overarching purpose (and vulnerability as subordinate to it), (ii) It starts by assessing current vulnerabilities, including the effectiveness of adaptation to recent climate experiences, (iii) It links adaptation to climate change with adaptation to current climate variability and extremes, (iv) It integrates climate adaptation into sustainable development plans, (v) It emphasizes the importance of using a stakeholder-led approach

Data collection

Data were collected through interviewing 96 sampled farmers, facilitating 4 village level focus group discussions and conducting 10 key informant interviews to accumulate the climatic risk in all sides of the haor. So, total respondents of 110. The researcher himself collected data for this assessment. During data collection the researcher had taken assistance from local leaders and development worker of the research area to familiar himself with the sampled farmers and to arrange FGD. After physical observation of research area and sample selection the data were collected during September 2019 to January 2020.

Data processing and analysis

A database were developed with properly coded and transferred from all questionnaires to an excel sheet. The statistical measures, such as number, percentage, range, mean, standard deviation and rank order were used in describing the variables as applicable. The data analysis was performed by using Statistical Package for Social Sciences (SPSS). Pearson's Product Moment Co-efficient of Correlation-r (2-tailed) was used to determine the nature of relationship between the dependent and independent variables.

Results and Discussion

Characteristics profile of the respondents

Characteristics profile of the farmers were determined and presented in Table 1. It is revealed that most (about 81%) of the respondents were young to middle aged having varying level of education with the highest proportion 36.5% of the farmers had primary level and 13.5%of the farmers had secondary level of education. Majority (42.71%) of the farmers had medium farm size of the land and 50% of farmers had low income which is below the poverty line of WB-DRG (2016) and 40.63% medium income compared to 9.37% high income. Most of the households cannot maintain a monthly saving, since they are already facing income insecurity due to large household and changing climatic conditions and more than half of the respondents (59.37%) had low extension media contact, while 19.79% of them had medium extension media contact, 15.63% had no extension media contact and only 5.21% had high extension media contact. Thus, 75% of the farmers had zero to low extension media contact which is very below to up to the mark.

Table 1. Socio demographic characteristics profile (Diener and Don Rahtz, 2000)

Variables	Measurement	Categories	Respondents Number	Respondents %	Mean	Standard Deviation
Age	Years	Young (<35)	19	19.79		
		Middle (36-55)	59	61.46	46.63	10.19
		Old (>55)	18	18.75		
Education	Year of schooling	Illiterate (0)	31	32.3		
		Illiterate but can sign only(0.5)	17	17.7	3.26	3.49
		Primary (1-5)	35	36.5		
		Secondary (6-10)	13	13.5		
Farm Size	Hectare	Landless (0)	4	4.17		
		Small (0.01-1.00)	40	41.67	1.42	1.108
		Medium (1.01-3.00)	41	42.71		
		Large (>3.00)	11	11.45		
Annual income	Tk. in Thousand	Low income (<50)	48	50	58.104	
		Medium income (50-100)	39	40.63		32.14
		High income (>100)	9	9.37		
Extension media contact	Scoring Scale	No extension media contact (0)	15	15.63		
		Low extension media Contact (1-5)	57	59.37	4.06	3.63
		Medium extension media contact (6-10)	19	19.79		
		High extension media contact (>10)	5	5.21		

Respondents' perception of climate change

Respondents' believe in climate change: Throughout the assessment 100% of respondents of all interviews: Farmers' Interview, FGD and KII said that they believe in climate change. Number and percent of respondents in different interviews is shown in Table 2.

Respondents' perception on climatic variability in changing situation

To evaluate climate change parameters, respondents were asked to find out the features of major climatic variability: precipitation, temperature, wind speed and extreme events with some visual and measurable phenomenon in changing situation during last 10 years. The findings of respondents' perception are presented in Table 3.

Table 2. Number and percent of respondent based on believe in climate change

Respondent	Total Respondent	Yes		No	
		Number	%	Number	%
Farmers' interview	96	96	100	0	0
Focus Group Discussion (4#)	52	52	100	0	0
Key Informant Interview	10	10	100	0	0
Total	158	158	100	0	0

Table 3. Distribution of the respondents based on perception of climatic variability

S.N.	Climatic variability	Statement	Extent of perception (Total data=110) (# is number and % is percentage)					
			Increased		Reduced		No change	
			#	%	#	%	#	%
1	Precipitation	Annual	6	5.45%	94	85.45%	10	9.09%
		In rainy season	8	7.27%	59	53.64%	43	39.09%
		In dry season	7	6.36%	99	90.00%	4	3.64%
		Length of rainy season	6	5.45%	81	73.64%	23	20.91%
2	Temperature	Annual	108	98.18%	0	0.00%	2	1.82%
		In Winter season	93	84.55%	15	13.64%	2	1.82%
		In Summer season	108	98.18%	2	1.82%	0	0.00%
		Length of cold season	3	2.73%	104	94.55%	3	2.73%
		Length of hot season	106	96.36%	0	0.00%	4	3.64%
3	Wind speed	Intensity in Summer season	58	52.73%	38	34.55%	14	12.73%
		Intensity in Monsoon season	8	7.27%	61	55.45%	41	37.27%
		Intensity in Winter season	20	18.18%	50	45.45%	40	36.36%
		Intensity of hotness	110	100%	0	0.00%	0	0.00%
4	Extreme events	Intensity of coldness	88	80.00%	19	17.27%	3	2.73%
		Intensity of storm	10	9.09%	67	60.91%	33	30.00%
		Intensity & frequency of flash flood	109	99.09%	1	0.91%	0	0.00%

A promising approach to conveying the reality of climate change is to develop indicators– numbers and scales that track the state or level of some aspect of the climate. One widely used indicator in climate science is the change in the global average temperature of the lower atmosphere. This indicator is also one of the targets set out by the 2015 Paris Agreement on climate change, which calls for keeping a global temperature rise this century to well below 2°C above pre-industrial levels while pursuing efforts to limit the temperature increase even further, to 1.5°C. Indicators have a number of advantages. They are quantified, objective, based on data provided by virtually all countries, and they demonstrate change over time. In addition to indicators that capture progress on mitigation, indicators can measure changes in the climate change impacts that should be targeted by adaptation efforts.

Socio-economic indicators of how climate impacts sectors such as health and agriculture are also, of course, critically important. Developing these indicators is a major challenge because of the diversity of climate impacts and a lack of systematically collected data on climate impacts in affected sectors from authoritative sources. Most people are aware that the temperature or more specifically, the global average temperature of the atmosphere just above the earth's surface – is rising, but this is not sufficient as an indicator of climate change. People focus on the surface-level atmosphere because that is where we live, and its temperature, which has been reliably measured for over 150 years, shapes our daily lives. But more than 90% of the excess heat trapped by humanity's greenhouse gas emissions is stored in the ocean, with much smaller amounts absorbed by the atmosphere, the cryosphere and land. Therefore, the atmosphere's temperature does not provide a complete picture of the earth's climate or of the full dimensions of climate change, and at worst can contribute to a false sense of security.

Causes of climate change

There were many causes of climate change found in the interview with respondents; manufacturing and industry produce emissions, mostly from burning fossil fuels to produce energy for making things like cement, iron, steel, electronics, plastics, clothes and other goods. This leads to global warming and climate change. Out of these one was God and others were environment related. A large number of respondents (75.45%) believed that climate is changing by God. The causes of climate change had supported by the respondents is presented in Table 4. The causes of climate change supported by the respondents were 87.27% for deforestation, 75.45% by God, 53.64% for over population, 40.91% for agricultural practices, 24.55% for environmental pollution, 14.55% for use of motor vehicle, 13.64% for urbanization, 10.91% for industrial activities and 0.91% for natural and normal respectively. The impacts of climate change are devastating in developing countries due to lack of capacity in accordance with the changing climate. Forests are one the main natural factors that regulate and determine climate, weather patterns and amount of CO_2 of an area. With rapid industrialization and rapid urbanization there is a significant increase in deforestation and as a consequence rise in global mean surface temperatures. Strategies designed for mitigating climate change are focused on reducing the emissions of greenhouse gases (GHGs), particularly carbon dioxide (CO_2). One of the main causes of CO_2 emissions is deforestation. Forests act as natural filters for carbon dioxide absorption in the atmosphere.

Table 4. Distribution of the respondents based on causes of climate change

S.N.	Causes/Issues	Respondents' perception (N=110)		Ranking
		No of citation/ Assigned a number	% of Respondents	
1	Deforestation	96	87.27	1
2	Industrial activities	12	10.91	8
3	Agricultural practices	45	40.91	4
4	Over population	59	53.64	3
5	Urbanization	15	13.64	7
6	Use of motor vehicle	16	14.55	6
7	Environmental pollution	27	24.55	5
8	Natural and normal	1	0.91	9
9	God	83	75.45	2
	Total	354		

Identification of major climatic hazards in dekhar haor

Calculated the Climatic Hazards Index (CHI) to compare the relative hazards through computed the scores of extent of damage by each of 10 listed climatic hazards for each of 110 respondents. Distribution of the respondents according to the extent of damage for each climatic hazard was been shown in Table 5 along with climatic hazards index (CHI) and its rank.

Table 5. Distribution of the respondents based on extent of damage by climatic hazards index (CHI) and hazard ranking

S.N.	Name of the hazards	Extent of damage (Total data=110)				CHI	Ranking
		High	Medium	Low	Not ever		
1	Flash flood	110 (100%)	0	0	0	330	1
2	Flood	46 (42%)	47 (43%)	17 (15%)	0	249	6
3	Drought	84 (76%)	25 (23%)	1 (1%)	0	303	4
4	Cold	0	52 (47%)	57 (52%)	1 (1%)	161	7
5	Hailstorm	85 (77%)	25 (23%)	0	0	305	3
6	Haor wave	36 (33%)	67 (61%)	7 (6%)	0	249	5
7	Rainstorm	0	32 (29%)	78 (71%)	0	142	9
8	Thunderstorm	108 (98%)	2 (2%)	0	0	328	2
9	Tornado	0	13 (12%)	97 (88%)	0	123	10
10	Dew	0	44 (40%)	64 (58%)	2 (2%)	152	8

Climatic hazards index (CHI) of 110 respondents for each hazard was ranged from 0 to 330. Data presented in Table 5, indicated that the most potential climatic hazards in the research area faced by the respondents were flash flood (330), thunderstorm (328), hailstorm (305), drought (303) and haor wave (249) respectively, in accordance to probability of risks.

Identification of major impacts of climate change in dekhar haor

Computed the scores of extent of impact in each of 15 listed climate change impact statements for 110 respondents and calculated the climate change impact index (CCII) to compare the severity of impacts. Distribution of the respondents according to the extent of impact in 15 listed climate change impact statements have been shown in Table 6 along with climate change impact index (CCII) and ranking of impact statements.

Table 6. Distribution of the respondents based on extent of impact of climate change and impacts ranking

S.N.	Impact	Extent of impact (N=110)				CCII	Ranking
		High	Medium	Low	Not ever		
1	Temperature increased at Summer season	98 (89%)	11 (10%)	1 (1%)	0	317	4
2	Temperature decreased at Winter season	58 (53%)	25 (23%)	27 (24%)	0	251	9
3	Increased duration of flooding	4 (4%)	38 (34%)	45 (41%)	23 (21%)	133	13
4	Increased height of flooding	1 (1%)	13 (12%)	62 (56%)	34 (31%)	91	14
5	Changed seasonal diversity	4 (4%)	87 (79%)	19 (17%)	0	205	11
6	Changed cropping pattern	2 (2%)	36 (33%)	70(63%)	2 (2%)	148	12
7	Increased drought	95 (86%)	14 (13%)	1 (1%)	0	314	5
8	Decreased soil fertility	101 (92%)	9 (8%)	0	0	321	3
9	Decreased crop yield	1 (1%)	9 (8%)	6 (6%)	94 (85%)	27	15
10	Increased pest and diseases	86 (78%)	22 (20%)	2 (2%)	0	304	6
11	Decreased cultivable land	30 (27%)	46 (42%)	33 (30%)	1 (1%)	215	10
12	Decreased livestock production	49 (44%)	55 (50%)	6 (6%)	0	263	8
13	Decreased availability of fodder from natural source	84 (76%)	24 (22%)	2 (2%)	0	302	7
14	Decreased fish production	104 (94%)	6 (6%)	0	0	324	2
15	Increased frequency and intensity of extreme events	106 (96%)	3 (3%)	1 (1%)	0	325	1

The climate change impact index (CCII) of 110 respondents for each of 15 listed climate change impact statements could be ranged from 0 to 330 where 0 indicated no impact and 330 represented maximum impact of a single statement. Data presented in the table 6 indicated that most severe impacts of climate change (as top in ranking) faced by the respondents of the study area were increased frequency and intensity of extreme events (325), decreased fish production (324), decreased soil fertility (321), temperature increased at Summer season (317) and increased drought (314) respectively. The Table 6 also showed that the last three least severe impacts were decreased crop yield (27), increased height of flooding (91) and increased duration of flooding (133) respectively as observed by respondents of the study area.

Agricultural adaptations to climate change in Dekhar haor

Adapting to climate change entails taking the right measures to reduce the negative effects of climate change (or exploit the positive ones) by making the appropriate adjustments and changes. The intergovernmental panel on climate change defines adaptation as adjustments in natural or human systems in response to actual or expected climatic stimuli or effects, which moderates harm or exploits beneficial opportunities. It also refers to actions that people, countries, and societies take to adjust to climate change that has occurred. Adaptation has three possible objectives: to reduce exposure to the risk of damage; to develop the capacity to cope with unavoidable damages; and to take advantage of new opportunities. Based on their adaptation score, the farmers were classified into three categories: Low adaptation (0-20), Medium adaptation (21- 35) and High adaptation (>35). The distribution of the farmers according to their overall agricultural adaptation strategies to climate change is shown in Table 7. The majority 54.17% of the farmers had medium adaptation and 45.83% low adaptation and no farmer found with high adaptation (Table 7).

Table 7. Categories of farmer based on agricultural adaptation (calculated CCAI)

Observed range	Categories	Frequency	Percentage	Mean	SD
8-29 (possible range: 0-45)	Low adaptation (0-20)	44	45.83	21.97	3.93
	Medium adaptation (21-35)	52	54.17		
	High adaptation (>35)	0	0		
	Total	96	100.00		

Computed scores of extent of agricultural adaptation to climate change in each of 15 listed climate change adaptation options for 110 respondents, and calculated the climate change adaptation index (CCAI) to compare the extent of adaptations. Distribution of the respondents according to the extent of adaptation in each of 15 listed adaptation options was been shown in table 8 along with CCAI and ranking. The climate change adaptation index (CCAI) of the 110 respondents for each of 15 listed adaptation options could be ranged from 0 to 330 where 0 indicated no adaptation and 330 represented highest adaptation of a single measure. Data presented in the Table 8 indicated that most potential options (as top in ranking) adopted by the farmer of the study area were increased cultivation of short duration crops (289), developed seedbed in separate high land or homestead (272), construction and raising of crop protection

Table 8. Distribution of the respondents based on extent of agricultural adaptation to climate change and ranking of adaptation options

S.N.	Aspect of adaptation	Extent of adaptation (Total data=110)				CCAI	Ranking
		High	Medium	Low	Not ever		
1	Changing cropping pattern	3 (3%)	2 (2%)	101 (91%)	4(4%)	114	10
2	Crop diversification	0	17 (15%)	90 (82%)	3(3%)	124	8
3	Followed modern cultivation system	59 (53%)	44 (40%)	6 (6%)	1 (1%)	271	4
4	Introducing integrated farming system	1(1%)	6 (5%)	97 (88%)	6 (6%)	112	11
5	Followed the weather forecast	0	19 (17%)	82 (75%)	9 (8%)	120	9
6	Increased cultivation of short duration crops	75 (68%)	29 (26%)	6 (6%)	0	289	1
7	Changed sowing and planting time of crops	6 (5%)	45 (41%)	56 (51%)	3 (3%)	164	7
8	Increased livestock rearing (cow, goat, poultry, duck, etc.)	0	4 (4%)	104 (94%)	2 (2%)	112	12
9	Introduced and increased fodder cultivation for livestock	0	0	4 (4%)	106 (96%)	4	15
10	Increased vegetable cultivation	37 (34%)	55 (50%)	17 (15%)	1 (1%)	238	5
11	Increased tendency of conserving water in the ditch for irrigation	1 (1%)	17 (15%)	64 (58%)	28 (26%)	101	13
12	Developed seedbed in separate high land or homestead	55 (50%)	53 (48%)	1 (1%)	1 (1%)	272	2
13	Produced seedling in different slot in different time	14 (13%)	51 (46%)	43 (39%)	2 (2%)	187	6
14	Plantation of Hijol & Koros tree	0	7 (6%)	58 (53%)	45(41%)	72	14
15	Construction and raising of crop protection embankment	52 (47%)	57 (52%)	1 (1%)	0	271	3

embankment (271), followed modern cultivation system (271) and increased vegetable cultivation (238) respectively. The Table 8 also showed that the last three least adopted options were introduced and increased fodder cultivation for livestock (4), plantation of Hijol & Koros tree (72) and increased tendency of conserving water in the ditch for irrigation (101) respectively as observed by respondents of the study area.

Relationship between selected characteristics of the farmers and their agricultural adaptation to climate change

The findings of the relationships between the selected independent and dependent variables of the study explores in this section. The independent variables were age, education, farm size, annual income and extension media contact. The dependent variable was agricultural adaptation to climate change. Summary results of correlation co-efficient (r) between the selected characteristics of the farmers and their agricultural adaptation to climate change has been presented in Table 9. Pearson's Product Moment Co-efficient

Table 9. Correlation between dependent variable (agricultural adaptation to climate change) and independent variables (age, education level, farm size, annual income and extension media contact)

Variable	Age		Education level		Farm size (hector)		Annual income (BDT)		Extension media contact		Agricultural adaptation for climate change	
	R	Sig.	R	Sig.	R	Sig.	R	Sig.	R	Sig.	R	Sig.
Age	1											
Education level	0.039	0.708	1									
Farm size	0.044	0.670	0.495**	0.000	1							
Annual income (BDT)	0.138	0.179	0.273**	0.007	0.730**	0.000	1					
Extension media contact	- 0.096	0.353	0.322**	0.001	0.599**	0.000	0.642**	0.000	1			
Agricultural adaptation to climate change	0.116	0.259	0.383**	0.000	0.422**	0.000	0.309**	0.002	0.300**	0.003	1	

** Correlation is significant at the 0.01 level.

of Correlation (r) was used to test the null hypothesis concerning the relationships between two variables. One percent (0.01) and five percent (0.05) level of probability was used as the basis for rejecting null hypothesis. The result of correlation of co-efficient test between the selected characteristic of the farmers and their agricultural adaptation to climate change has shown in Table 9. The findings of Table 9 indicated that the age of the farmers had no significant and negative relationship with their agricultural adaptation to climate change. While the other selected characteristics of the farmer: education level, farm size, annual income and extension media contact had significant and positive relationship with their agricultural adaptation to climate change. Thus, it could be said that education level, farm size, annual income and extension media contact of the farmer played an important role on their agricultural adaptation to climate change. Therefore, it could be concluded as the higher the education level, farm size, annual income and extension media contact of the farmers, found the more capability in agricultural adaptation to climate change in the study area. The study conducted by Islam, (2013) also found similar findings in case of relationship between selected characteristics of the farmers and their agricultural adaptation to climate change in drought prone area of Rajshahi Division. The findings indicated that the age of the farmers had no significant and negative relationship with their agricultural adaptation to climate change while the education, firm size, annual income, credit received and cosmopoliteness of the farmers had significant and positive relationship with their agricultural adaptation to climate change. The study area occupies with semi braind soil and considered as semi drought prone area that the correlation analysis indicated that age, education, environmental hazards and impact of climatic change had no significant relationships with their agricultural adaptation to climate change. Credit received and agricultural adaptation to climate change had positively significant relationships. Farm size, annual income, knowledge about climate change and cosmopoliteness of the farmers had highly positive significant relationships with their agricultural adaptation to climate change.

Climatic risks assessment for different sectors of agricultural farming practices in dekhar haor

A number of sectoral policies and plans were developed by the Government of Bangladesh (GoB) since 1990s. Considering the fact that Bangladesh is highly susceptible to climate change, only one sectoral policy on the Haor areas, has considered climate change. The agricultural support services and institutions at the national and local levels need risk information for planning their activities and providing timely services to the ultimate beneficiaries. Better informed decision-support systems can be very efficient and capable of providing need-based information services to the farmers, livestock herders and fisheries. Users of climate information at institutional level need historical climate information, climate monitoring products and forecasting in different time scales for institutional decisions. The agriculture support institutions (extension and research) should offer and also make use of information about agriculturally relevant precipitation indices progress of the precipitation indices from the past to current, near real-time information about the crop state and early-warning systems for humanitarian response. Crop monitoring and yield forecasting allow timely interventions by the government to avoid crisis. The strategies include contingency plans, alternate livelihood options and response plans for food aid (Fig. 1). Large-scale monitoring of agriculture and crop-yield forecasting generally rely on: (i) regionalized analyses of cultivated areas, crop type distribution and crop condition based on near-real-time satellite imagery merged with available in-situ observations; (ii) meteorological monitoring and mid-term forecasts based on observation networks and model outputs; and (iii) regionalized knowledge of agricultural systems and their sensitivity to meteorological conditions.

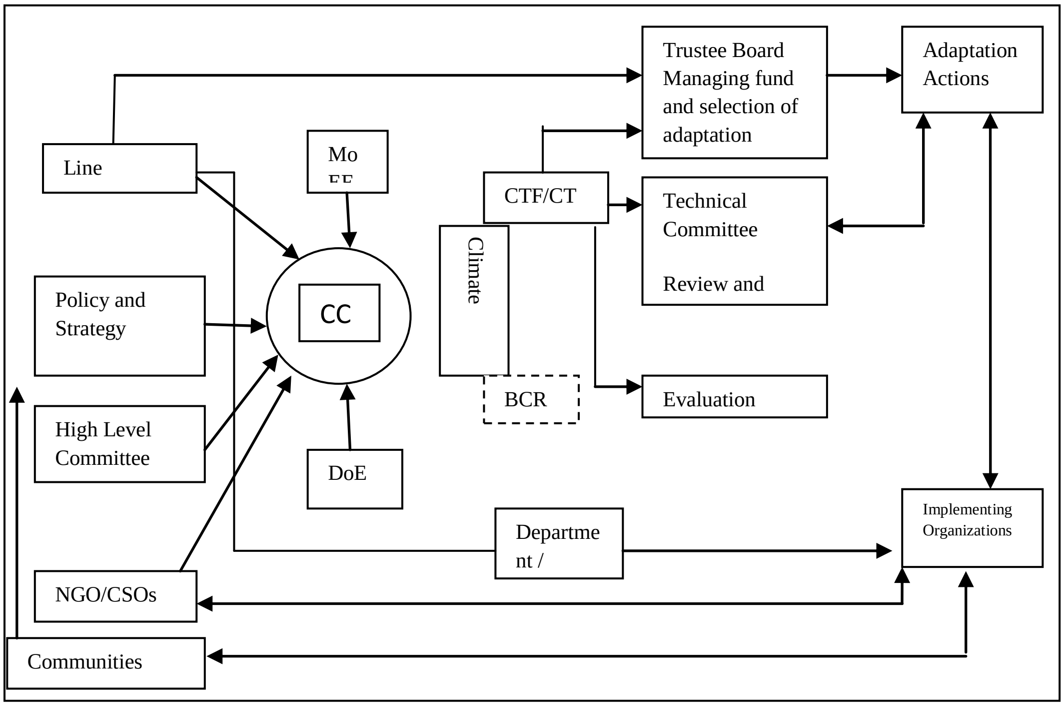

Fig. 1. Conceptual framework on climate change related policy and institutions in Bangladesh

The crop monitoring and yield forecasting capabilities in developing countries are weak and need strengthening at the national level with more emphasis on collection of data such as meteorological, agro-meteorological, soil, remote sensing and agricultural statistics. Climate information at all time scales is crucial to advance risk management and improve sustainable production. The climate information and likely decisions are: (i) climate change scenario to understand the trend and alter system-level decisions (cropping or grazing); (ii) seasonal climate information to make strategic decisions (crop type, marketing, forward selling, livestock herding rate, etc.); (iii) intra-seasonal forecasts to schedule tactical operations (e.g. fertilizer, water and other adjustable inputs); and (iv) weather forecasts for the day-to-day operations. .

Categorization of hazards, impacts and adaptations and interactive analysis

The listed climatic hazards, impacts of climate change (vulnerability) and agricultural adaptations to climate change (capacity) has categorized by different sectors of agricultural farming practices. The interactive analysis of hazards, impacts and adaptations by ranking and index score has expressed the risk situation of respective sector. The risk feature of different sectors has shown in Table 10.

Table 10. Categorization of hazards, impacts and adaptations and interactive analysis by ranking and index score

	Sectors	Hazards (rank)	Impacts (rank)	Adaptations (rank)	Index (score)
1.	Crop Protection	Flash flood (1)			330
		Flood (6)			249
			Increased frequency and intensity of extreme events (1)		325
				Increased cultivation of short duration crops (1)	289
				Construction and raising of crop protection embankment (3)	271
				Increased vegetable cultivation (5)	238
2.	Community Protection	Thunderstorm (2)			328
		Haor wave (5)			249
				Plantation of Hijol & Koros tree (14)	72
3.	Fisheries		Decreased fish production (2)		324
				No adaptation measure found	0
4.	Livestock		Decreased availability of fodder from natural source (7)		302
			Decreased livestock production (8)		263
				Increased livestock rearing (cow, goat, poultry, duck, etc.) (12)	112
				Introduced and increased fodder cultivation for livestock (15)	4

Table 10. Contd.

	Sectors	Hazards (rank)	Impacts (rank)	Adaptations (rank)	Index (score)
5.	Environmental Risk of drought	Drought (4)			303
			Increased drought (5)		314
				Changing cropping pattern (10)	114
				Increased tendency of conserving water in the ditch for irrigation (13)	101
6.	Crop Production	Hailstorm (3)			305
		Dew (8)			152
		Tornado (10)			123
			Decreased soil fertility (3)		321
			Increased pest and diseases (6)		304
			Decreased cultivable land (10)		215
			Decreased crop yield (15)		27
				Followed modern cultivation system (4)	271
				Followed the weather forecast (9)	120
				Introducing integrated farming system (11)	112
7.	Haor flooding	Rainstorm (9)			142
			Increased duration of flooding (13)		133
			Increased height of flooding (14)		91
				Produced seedling in different slot in different time (6)	187

Table 10. Contd.

	Sectors	Hazards (rank)	Impacts (rank)	Adaptations (rank)	Index (score)
8.	Changing seasonal feature	Cold (7)			161
			Temperature increased at Summer season (4)		317
			Temperature decreased at Winter season (9)		251
			Changed seasonal diversity (11)		205
			Changed cropping pattern (12)		148
				Changed sowing and planting time of crops (7)	164
				Crop diversification (8)	124
Total		10	15	15	

Identification of the sectors at risk

The following sectors were illustrated as at risk through interactive analysis of climatic hazards, impact of climate change and agricultural adaptation to climate change in Table 10. The graphical comparisons of climatic hazard index (CHI), climate change impact index (CCII) and climate change adaptation index (CCAI) are presented below to understand the risk feature of respective sector:

Crop protection

The interactive analysis in Fig. 2 indicated that the farmer has been adopting some measures to protect the crops from flash flood, flood and other extreme events. Hence the study considered only farmer and community level adaptation practices. But considering the time and scale of flash flood in changing situation, it would be beyond of farmers' copping capacity and it needs government and central level efforts to reduce the risk. So, still now crop protection is the top most burning issue for haor dwellers. Sunamganj District in the Haor region is a highly disaster prone area due to its geological location and geographic formation in particular to flashflood. Role of climate change on flash flood is yet to be established. A recent study by BUET (Islam, 2017), reveals that pre-monsoon rainfall and its intensity may increase in the future. The probability of the occurrence of flash flood will likely be higher in the future due to climate change. From 2000 flash flood hit haor region dated on 30 April 2000, 19 April 2002, 15 April 2004, 03 April 2010 and 17 April 2016. Changes of weather phenomenon and increase of extreme weather events has already been observed in all over the world. In 2016, new record of warming was set comparing to the modern temperate record dated since 1880 according to the NASA. The mean annual temperature of the planet was warmer above 0.99 ^{O}C than the mid-20th century. The average temperature of the planet has risen about 1.1 degrees Celsius since the late 19th century.

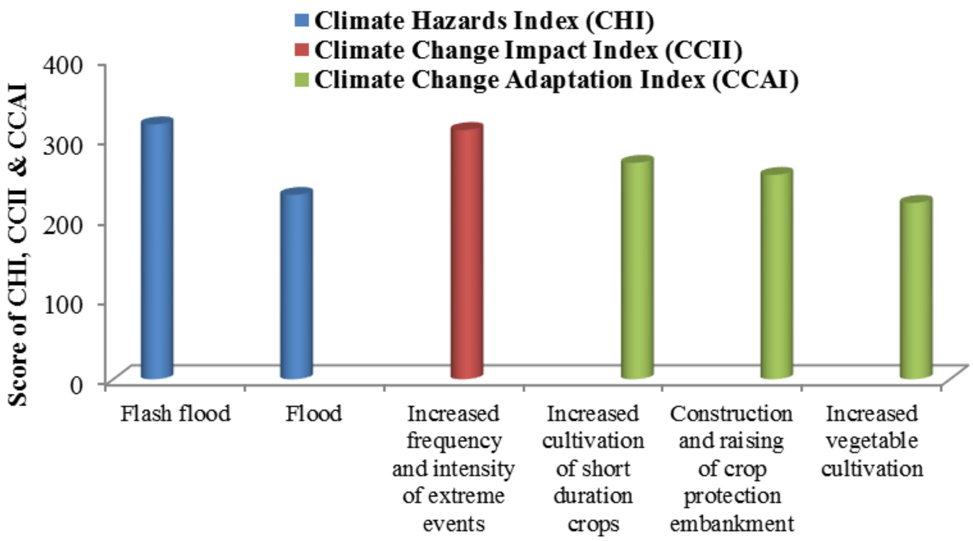

Fig. 2. Interactive analysis of hazard, impact and adaptation for crop protection

Community protection

Haor community is facing two climatic hazards, thunderstorm and haor wave which are potential threat to human life and homestead respectively. The interactive analysis in Fig. 3 indicated that plantation of Hijol & Koros tree was the least adopted option to protect homestead in dekhar haor and no adaptation measure found against thunderstorm. In Bangladesh, the number of thunderstorm and days when thunderstorm occurred has been increasing simultaneously for changing climate during recent years. People died by thunderstorm, about 67% when working in agricultural land, haor, pond, river, etc. The destruction feature of thunderstorm in Table 11 expresses the degree of risk. Through the satellite view analysis of last 10 years, NASA & Maryland University of USA reported that the highest number of thunderstorm occurred in Sunamganj around the world for the month of March-May. More than 25 nos. thunderstorm hit per sq.km in Sunamgonj during March-May. Naturally more thunderstorms occurred in North-East part of country due to its geographical location and topography. During March-May clouds cooled at Kashia Hill and Meghalaya area. Thunderstorm occurred by the friction between layers of clouds, so thunderstorm is more at the foot of this area in Sunamganj.

Fisheries

Fish and paddy are the two major resource of haor. The study found a vital climatic impact that fish production in dekhar haor has decreased crucially, but the interactive analysis in Fig. 4 indicated that no adaptation measure has taken in this contest. The issue was raised vitally in KIIs & FGDs that livelihood of a large number of

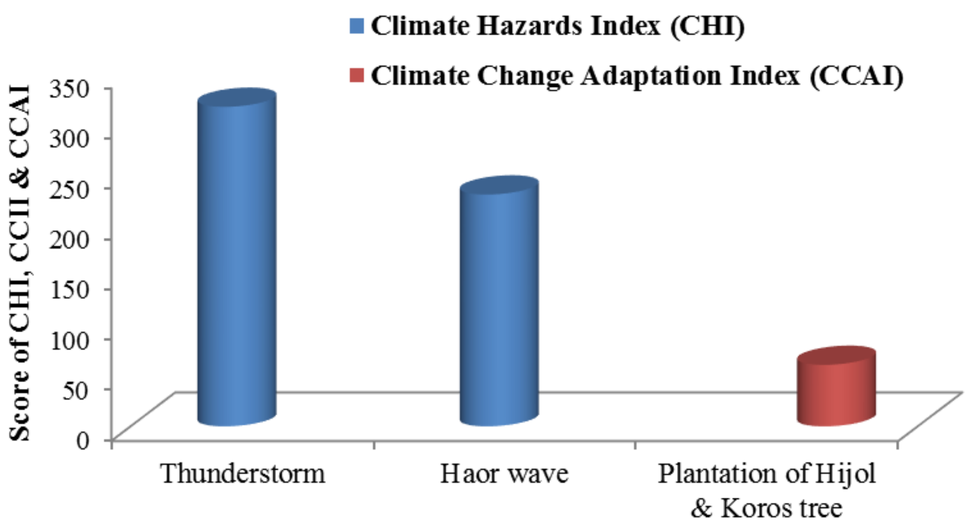

Fig. 3. Interactive analysis of hazard and adaptation for community protection

Table 11. Feature of thunderstorm in Bangladesh & Sunamganj context

Year	Average # of thunderstorm per year	# of person died by thunderstorm	# of person died by thunderstorm on the month of May	Destruction of thunderstorm in Sunamgonj
2011	978	179		
2012	1210	301		13 people died in a mosque of Dharmapasha Upazilla on 10th August 2012
2013	1415	285	128	
2014	951	210	79	
2015	1218	274	91	37 people died during last 3 years
2016	1500+	350	132	

(Data source: BMD & BDF, Data own analyses)

fishermen is going to insecure day by day due to mishandle of fish act and regulation. So, fisheries' is most vulnerable sector in research area and need to address to safe livelihood of haor dwellers. Mazumder *et al.*, (2015) observed in dekhar haor that total fish biodiversity was reducing drastically where about 19 available fish species became unavailable in the study area within 10-15 years. It was reported by the respondent fishers that the availability of fish has been declining due to various manmade and natural reasons. Main reasons for declining fish diversity were siltation, fishing by complete dewatering, indiscriminate fishing, use of illegal fishing gears, use of katha fishing method, use of chemical fertilizers, use of insecticides and pesticides in agriculture, drought in summer, making obstacle in natural movement of fishes through infrastructures etc. However, a total of 65 fish species have remained left in Dekhar Haor that need to be conserved.

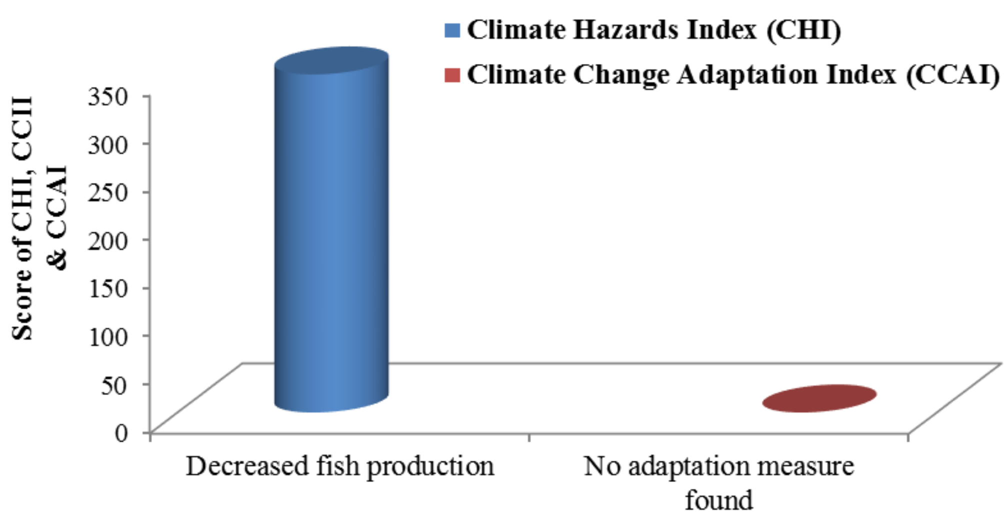

Fig. 4. Interactive analysis of climatic impact and adaptation for fisheries sector

Livestock

Livestock (cow, goat, sheep, check, duck, peacock, etc. rearing) sector could be an alternative livelihood intervention for haor dwellers to reduce climatic risk by minimizing dependency on only boro paddy. Livestock scenario in dekhar haor has discussed in KIIs & FGDs vitally that livestock rearing increased in small scale as commercial firm (chick & duck rearing) but decreased in widespread at household level, resulting livestock production has been decreasing day by day. To assess the livestock perspective in Dekhar Haor, the interactive analysis in Fig. 5 indicated that a very minimal scale of adaptation found in fodder cultivation and livestock rearing in contest to two climatic impacts in availability of fodder and livestock production with high scale. So, the study disclosed the livestock sector as at risk and need to be emphasized for the improvement of poor haor dwellers.

Risk of drought

Drought is one of the main problems which hamper the estimated agricultural production in Bangladesh over the last few decades. Causes of drought are related to non-availability of surface water resources and a shortage of rainfall. Now, haor agriculture is also

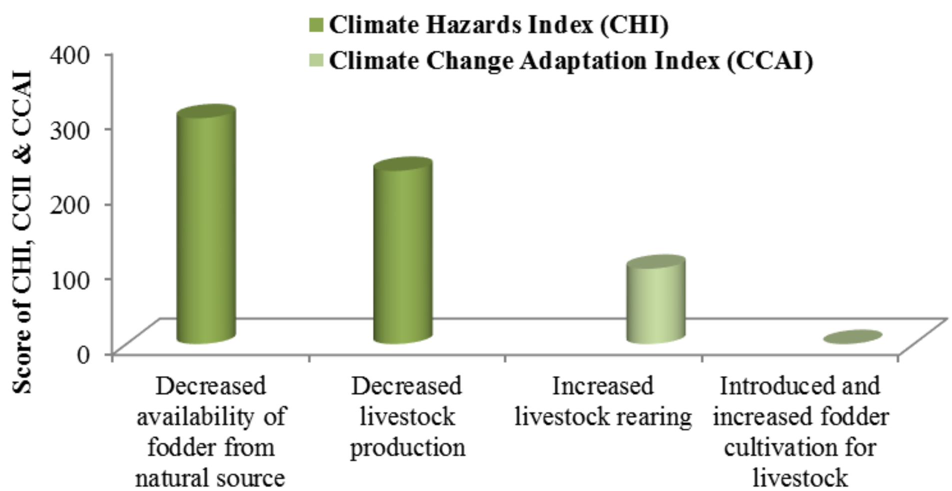

Fig. 5. Interactive analysis of climatic impact and adaptation for livestock sector

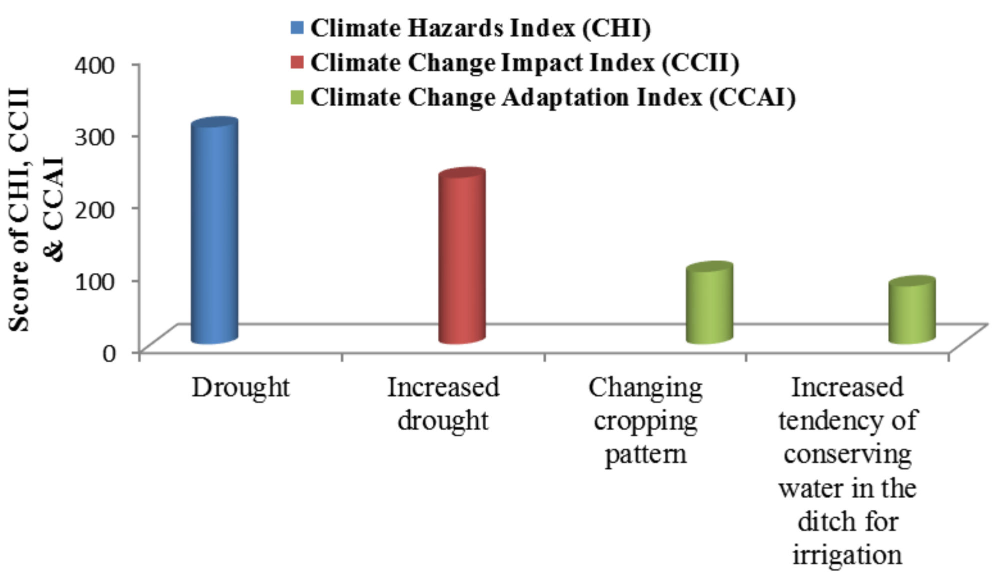

Fig. 6. Interactive analysis of hazard, impact and adaptation for risk of draught

susceptible to draught. The interactive analysis in Fig. 6 indicated that draught was one of the top most potential climatic hazards in the study area and it is increasing due to climatic impact in high scale, but very small scale of adaptation found in cropping pattern and conserving water which are not in satisfactory level. So, the risk of draught in dekhar haor needs to be addressed.

Conclusion and Recommendations

The study disclosed the agricultural sectors such as crop protection, community protection, fisheries, livestock and risk of draught are at climatic risk which needs to address by intensive research and risk reduction measures. During FGDs and KIIs, the respondents raised their opinions to take necessary initiative by government and nongovernment organization to mitigate the climatic risks in dekhar haor. Transible mitigation measures recommended in addressing the areas at risks: Introduction of short duration variety of boro rice to reduce risk of early flash flood and intensification of homestead vegetable cultivation and floating vegetable cultivation, crop diversification and increasing livestock rearing at household level to reduce dependency on mono crop (boro rice). Construction of the temporary earthen embankment duly and compartmental embankments cum submergible concrete road with adequate number of culvert and establishment of sluice gate or rubber dam on Mohasing River to protect dekhar haor from early flash flood. Enhance people’s awareness to stay in house during thunderstorm (particularly on the month of March-May), establishment of earthling system for high-rise building and massive plantation program (preferably date palm) could be undertaken in dekhar haor to safe human lives from thunderstorm. Digging the beels around dekhar haor, more restocking and caged-fish culture and establishment of sanctuary and community based fisheries management system to increase fish production in dekhar haor. Digging the beels around dekhar haor, more restocking and caged-fish culture and establishment of sanctuary and community based fisheries management system to increase fish production in Dekhar Haor. Establishment of weather station and flash flood forecasting and early warning systems for haor areas and enhance people’s knowledge on climate change perspectives: reasons, future scenario, impacts and adaptations, etc. in addressing the climatic risks Different climate change adaptation activists i.e. GoB, INGO, NGO, UN organization, local government, community and farmer etc. should have to be worked together with an integrated long term plan to protect livelihood of more than one lac dekhar haor dwellers. Some adaptations practices have been observed in dekhar haor are (i) Intensive homestead vegetable cultivation, a good practice at Nayagaon village in Dekhar Haor of Joykalas Union under Dakshin Sunamganj (ii) Floating vegetable cultivation,a demonstration of adaptation in dekhar haor at Lakshmansree UP under Sunamganj Sadar (iii) Livestock rearing and grazing in dekhar haor kanda, an opportunity for strengthening alternative livelihood for haor dwellers through introducing fodder cultivation (iv) Mustard cultivation as crop diversification, a crop diversification practice in dekhar haor at Nayagaon village of Joykalas union under Dakshin Sunamganj could be replicated and can help in finding out the strategy in future climate change adaptation.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

References

Andersson, S., Y.R. Bergman, M. Johansson, E. Persson and L. Nyberg. 2013. Efficiency of landslide prevention tools – evaluation of Scandinavian practices. *Int. J. Disaster Risk Reduction.* 3:44–61.

Andersson, S., Y. Falemo and S. Tremblay. 2014. Development of methodology for quantitative landslide risk assessment – example Göta river valley. *Nat. Sci*. 6 (3):130–143.

Bangladesh Disaster Management Reference Handbook, 2015. https://reliefweb.int/sites/reliefweb.int/files/resources/disaster-mgmt-ref-hdbk-bangladesh.pdf

BBS. 2011. Statistical Yearbook of Bangladesh, Bangladesh Bureau of Statistics. Dhaka, Bangladesh.

Burton, I., S. Huq, B. Lim, O. Pilifosova and E.L. Schipper. 2002. From impact assessment to adaptation priorities: the shaping of adaptation policy. *Climate Policy*. 2:145–149.

Climate Change – Scientists View – Do all scientists agree that climate change is occurring and is caused by human activity**.** https://warmheartworldwide.org/climate-change.

CNRS (Center for Natural Resource Studies). 2004. Management of aquatic ecosystems through community husbandry. Feasibility report on MACH (Management of Aquatic Ecosystems through Community Husbandry) outreach program. 10pp.

Department of Agricultural Extension (DAE), 2008. Field Crops wing, Khamar Bari, Farmgate, Dhaka-1215.

DM and RD. 2010. National Plan for Disaster Management 2010-2015, Disaster Management Bureau, Ministry of Food and Disaster Management, Bangladesh.

Intergovernmental Panel on Climate Change (IPCC). 2013. The physical Science Basis. Cambridge University Press, Cambridge.

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: Climate change impacts, adaptation and vulnerability - Summary for policymakers. Contribution of Working Group II to the Fourth Assessment Report of the IPCC.

Islam, A. 2017. Climate change and crops in haor areas. The Independent. Dhaka.

Khan, S.I. 2010. Wind analysis for wave prediction in haor areas. M. Engg. Thesis, Department of Water Resources Engineering, Bangladesh University of Engineering and Technology, Dhaka.

Master Plan of Haor Areas. 2012. Draft Final Report, Vol. II, Ministry of Water Resources, Bangladesh Haor and Wetland Development Board, Government of the People's Republic of Bangladesh, pp. 1-18

Mazumder, S., K.D. Pandit, M. Kunda, A.H.A. Rashid and M.A. Sufian. 2015. Present Status of Fish Biodiversity in Dekhar Haor, Bangladesh: a Case Study, Department of Aquatic Resource Management, Sylhet Agricultural University, Sylhet-3100, Bangladesh, *World J. of Fish and Marine Sci.* 7(4):278-287.

McBean, G. 2004. Climate change and extreme weather. A basis for action. *Nat. Hazards.* 31 (1):177–190.

Saleh, A., F.M. and M.S. Mondal. 2007. Impact of a Submersible Embankment Projects on Boro Production in Haor Areas, Final Report, IWFM, BUET, Dhaka. Socio demographic characteristics profile. 2000. Advances in quality of life theory and research 2000. Social indicators research series, Volume-4, Edited by Ed Diener and Don R. Rahtz @ Springer Science + Business Media Dordrecht.

UNDP. 2003. User's Guidebook for the Adaptation Policy Framework. Final Draft. United Nations Environmental Programme, New York City, NY.

WB-DRG (World Bank, Development Research Group) 2016. Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population). http://data.worldbank.org/indicator/SI.PO-V.DDAY.