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ORIGINAL ARTICLE

Climate change adaptation through local knowledge in the north eastern region of Bangladesh

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Abstract Climate change adaptation in the low laying developing countries is becoming crucial at the present time. However, the local knowledge regarding climate change adaptation is not well focused. This study evaluates climate related perception and identifying various adaptation strategies in the low lying areas of North-Eastern Bangladesh. Six focus group discussions and 120 households' survey were carried out to identify the major climate events in our study areas which were temperature change, drought, heavy rainfall and cyclone and storm surges. Furthermore, main livelihood problems arising from these events were lack of fish availability, scarcity of water in drought seasons and frequent flood in the rainy seasons. Results also revealed that a little portion (10%) of the respondents had well knowledge about the present climate change. However, seasonal livelihood and hazard calendar demonstrated that local people were increasingly changing their livelihood status with changing climatic hazards. At that situation local people tried to adapt themselves with the changing climate through changing their own behavior and introducing some adaptation strategies. We recognized total 16 adaptive measures in the study areas within which crop diversification, floating garden, duck rearing, cage aquaculture, wave protection walls, re-digging of canal and construction of embankments were popular. The present study revealed that local experiences in the face of climate change adaptation have merits which need special consideration. Continuous research and more incentives required for proper documentation and relegate the local adaptation knowledge in the tropic.

Keywords Adaptation · Developing countries · Drought · Extreme climate events · Flood · Hazard · Indigenous knowledge · Perception · Vulnerability

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1 Introduction

Bangladesh is frequently cited as one of the most vulnerable country to climate change (Rahman 1997; Ahmed et al. 1999; Venema and Cisse 2004), though the country contributes little to global greenhouse gas emissions which is the main reason of climate change. Due to the physiographical location Bangladesh is going to be the worst hit place on the planet from extreme climate events such as droughts, heavy rainfall, tropical cyclones and storm surges (Rawlani and Sovacool 2011). At the present time these climate events start harshly performing in this country (Ministry of Environment and Forest of Bangladesh 2008). Therefore, building responsiveness to climate change impacts through adaptation has been recognized as necessary for the survival of affected people (Ali 1999; Sajjaduzzaman et al. 2005). Several studies have been done on climate change impact assessment (Hossain et al. 2012; Ayers and Huq 2008; Ministry of Environment and Forest of Bangladesh 2008; Ali 1999) and adaptation policies (Hossain and Roy 2010; CCC 2009; Huq 2004) in this country, however, very few studies on local adaptation knowledge (Khan 2009; Ahmed et al. 1999) have been carried out yet.

Climate change already affecting the agriculture sector of Bangladesh by continuous flooding, drought and wind storm (Rahman et al. 2007). Mostly the farmers, fisher man, small businesses holders and other communities living in the *haor* areas (low laying waterlogged areas) are now experiencing a wide range of climate variability because the global warming and floods specially flash floods is found to be more pronounced in those areas (Government of Bangladesh 2005; Mirza 2002). This experience of climate change has not been a part of the literature or the folklore and some are new to the communities. People of the study areas are of no exception. They are facing excessive water in rainy season, occasional flash floods, crop damage due to flood, break down of road and embankments, continue decline of fish in water bodies and soil erosion in monsoon are common phenomena (CCC 2009). At that situation, they are trying to equipped themselves with various coping strategies. They are changing their behavior and adjust themselves with the changing climate through their own knowledge. Various non-government organizations (NGOs) and donor agencies such as Centre for Natural Resource Studies (CNRS), Institute of Development Affairs (IDEA) and CARE (Cooperative for Assistance and Relief Everywhere) are working with climate change adaptation for sustainable livelihood activities in the study areas. Perhaps we can't stop the process of climate change quickly but we can find some adaptation strategies for community resilience against the climate change impacts. Thus, the article asks: which impacts of climate change have merits in the study areas? In which ways are local communities changing their behavior to adapt these impacts? Results of this study might be helpful for the policymakers, researchers, NGOs and donor agencies concerned with climate change and it's adaptation in the tropics.

The inimitability of our exploration is threefold. Firstly, our study focuses intimately on the knowledge relating to climate change and climate change related hazards of the people living in the *haor* areas, which is of prime interest as they incessantly facing these hazards. Secondly, risk assessment is done on the basis of some tools such as; problem matrix, seasonal hazard calendar were made alongside with livelihood trend. Thirdly, the article investigates the adaptation measures and recognizes 16 adaptation measures which are practiced meaningfully and strengthen the community resilience. In this fact, we treat both institutional measures such as physical or infrastructural and individual measures taken at community level such as soft measures.

2 Climate change impacts and its adaptation: Bangladesh perspective

Climate change is the greatest environmental challenge facing the world today. According to the Intergovernmental Panel on Climate Change (IPCC 2007), over the past 150 years, global average surface temperature has increased 0.76°C. Under the most pessimistic emissions scenario developed in IPCC (2000), by the end of this century temperatures could rise to more than 4°C above 1980–1999 levels, ranging from 2.4 to 6.4°C. Least Developed Countries like Bangladesh facing most important challenge related to climate change and variability because of their strong economic reliance on natural resources and rain-fed agriculture (FAO 2007).

Global Circulation Model (GCM) predicted an average temperature increase in Bangladesh due to climate change which is 1.0°C by 2030 and 1.4°C by 2050 (FAO 2006). The monsoon precipitation is likely to be increased by 6.8% and the distribution patterns of precipitation during the growing season by the year 2050, high temperature and higher rates of evapotranspiration will create further water stress conditions and a decline in agricultural production (FAO 2006). Furthermore, climate change has posed a mortal threat to Bangladesh because of its low elevation from the sea, high level of population density and poverty and an overwhelming dependence on nature (Khan 2009). For these reasons the country might be affected most in near future. If the situation continues, it will cause significant impacts on the agricultural sector due to climate change and climate variability. In this purpose, proper adaptation policies and indigenous knowledge in relation to climate change and their coping ability should be highly prioritized.

The government has made significant progress in climate policy in Bangladesh which is in line with the global shift towards greater attention to adaptation. With the goal of establishing an integrated approach to climate change and disaster management, Bangladesh established a Comprehensive Disaster Management Programme (CDMP) with donor assistance in 2003. Bangladesh was the first of the LDCs to complete key national planning documents to inform and guide investments in the coming years namely National Adaptation Plan of Action (NAPA) in 2005. In 2007 the government announced an initiative to incorporate the impacts of climate change into development plans in its Poverty Reduction Strategy Paper (PRSP) revisions, proposing a draft policy and action plan by the end of 2008 (Ayers and Huq 2008).

Very few studies have been accomplished concerning climate change adaptation strategies in Bangladesh. National Adaptation Programme in Action (NAPA) recognized 15 priority adaptation activities for coping adverse impacts which in a summary were: coastal afforestation with community focus; provision of drinking water to coastal communities; flood shelter construction and related information and assistance center; adaptation in coastal crop agriculture and fisheries for combating salinization; adaptation to agricultural systems and fisheries to enhanced flooding; resilience enhancement of urban infrastructure and industries; capacity building for integrating climate change in planning, designing of infra-structure, conflict management and land – water zoning; information dissemination to vulnerable communities; insurance and other emergency preparedness measures; mainstreaming adaptation into policies and programs; promotion of research and educational curricula reform and development of eco-specific adaptive knowledge (Ministry of Environment and Forest of Bangladesh 2005).

Ahmed (2001) found that modifying the threat of crop loss and prevention of adverse effects on crop production are the most feasible adaptation options in Bangladesh. Another study done by Pender (2007) suggested various adaptive strategies such as; sharing losses, modifying threats, preventing effects, changing use, changing location and restoration. In

addition, Huq (2004) expressed the challenge of adapting climate change, such as awareness creation, identifying suitable adaptation options and resource allocation for adaptation. While, Ali (1999) suggested 3 adaptive options: retreat, accommodation and protection and discussed some adaptation strategies for the coastal area that may be pursued in Bangladesh such as afforestation, change in cropping practice and construction of embankments. Furthermore, IUCN (2005) pointed out some local adaptation strategies for different climatic zones, e.g. drought-prone, flood-prone and salinity-prone zones of Bangladesh. In Jamalganj upazila a study has also made during 2008 with the support of Climate Change Cell (CCC) and in collaboration with Bangladesh Rice Research Institute (BRRI) and Bangladesh Agriculture Research Institute (BARI). In that study adaptive cropping has been tested at the farmers' fields and showed that two varieties of winter rice (BRRI-29 and BRRI-45) with higher yields attained maturity by end of first week of April have high potential to avoid flashflood risks (CCC 2009).

Most of the above mentioned adaptation studies stated either some policies or recommend some strategies but few of these documented the local knowledge regarding climate change adaptation. Therefore, the present study was carried out focusing the climate change adaptation through local knowledge.

3 Methodology

3.1 Study area

Jamalganj upazila (Fig. 1) is situated in the Sunamganj district of Bangladesh. Ecologically it is located in the *Haor* basin and hydrologically in the northeast region of this country. Geographical location of Jamalganj is 24°59′ 48″ north latitude and 91°14′ 23″ east longitude. It consists of five unions namely, Beheli, Sachna, Jamalganj, Fenarbak and Bhimkhali. Communication system is typically remote of these areas. Major occupation of the communities agriculture (43.18%) and fishing (4.2%), agricultural laborer (28.27%), wage laborer (4.48%), transport (3%), commerce (7.43%), service (2.66%) and others (9.78%). Jamalganj upazila covers with an area of 338.74 sq km and main rivers are Naya *Gang*, Baulai and Dhanu; Pakna *Haor* and *Hail Haor* are also notable (Banglapedia 2011). The climate of this area is humid subtropical with a predominantly hot and humid summer and a relatively cool winter. Annual maximum temperature is 33.2°C and minimum is 13.6°C. Nearly 80% of the annual average rainfall of 3,334 mm occurs between May and September. The soil of this area is generally sandy loam to clayey loam. (http://www.banglapedia.org/httpdocs/HT/J_0045.HTM, Browsing date 10.11.2011)

3.2 Methods

Jamalganj upazila was selected purposively because the area is situated in the *"haor basin"*. Reconnaissance survey was carried out to ascertain the primary idea about the locality, farming system and people's perception about climate change of the study area. Three unions were selected purposively from the entire five unions of the study area. Then six (6) study villages, two (2) from each union were selected purposively as climate change adaptation strategies were mostly taken in those villages. Focus group discussions (FGDs) and Questionnaire survey were carried out along with some other tools like seasonal calendar, livelihoods mapping, problem matrix and problem scoring to identify and prioritize the climate related risks faced by the community.

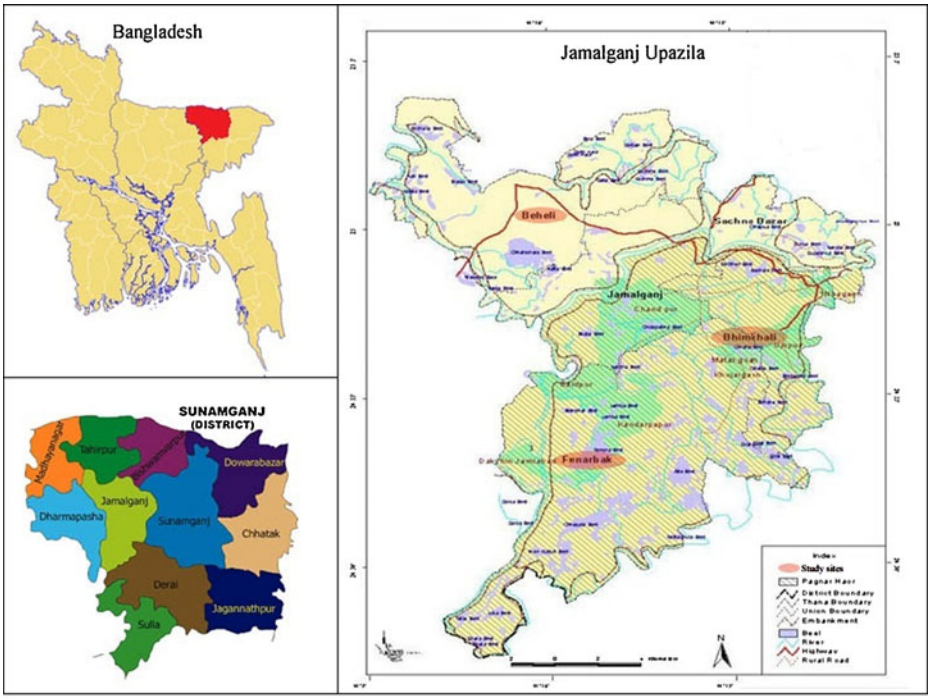

Fig. 1 Map of Jamalganj Upazila. Study areas have marked in the Jamalganj Upazila map. (Adapted from Banglapedia 2011 and IUCN 2005)

Based on the objectives of the study, six FGDs, one from each village, were conducted which covering variety of respondents within the study villages. A total of six participants (both male and female) were selected for each FGD. In addition, we also tried to include local chairman, government officials and development workers in each FGD for the validation of the study. In the FGD we gathered the knowledge about the study areas regarding climate change impacts. During the FGD seasonal calendar and livelihoods mapping were also done.

Household survey was carried out through a semi structured questionnaire survey and direct (face-to-face) interview was applied for information collection. A total number of 120 household, 20 from each village were surveyed randomly from the six study villages (Table 1). The survey result was checked against the reports of FGDs for validation analysis.

Problem matrix was based on the respondent's opinion. A list of problems regarding climate change impacts was prepared based on the lessons learned from the FGDs in the study areas. This list was provided to each respondent and asked to sort all problems separately into 5 categories namely, very high, high, moderate, low and very low or no risk. We fixed the values for different categories which were 5 for very high, 4 for high, 3 for moderate, 2 for low and 1 for very low or no risk. Problem frequency was also collected through questionnaire survey from the respondents. Then score was calculated by multiplying the problem values with problem frequency.

Table 1 Name of the study villages and number of respondents. We randomly selected 20 households from each village. Total 120 households for six villages were surveyed

	Study villages	Number of households surveyed	Total no. of households
Beheli UP[a]	Ahsanpur	20	120
	Haripur	20	
Sachna UP[a]	Palok	20	
	Kukrabashi	20	
Fenarbak UP[a]	Rajapur	20	
	Matargaon	20	

[a] *UP* Union Parishad

(Source: Analysis of field data 2009)

4 Results

The study revealed that climatic events mainly the hydro-meteorological phenomena affected the livelihood of the residents of low lying area. Many villagers of Jamalganj had their own experience with water logging, floodwater inundation and drought which affected their livelihoods, crop cultivation, employment opportunities, income, food, malnutrition and health related problems. Erratic behavior of weather and extreme climatic events affected agriculture, homestead vegetable cultivation, fish culture and human health adversely. Poor women and marginal sections of the community were affected the most.

4.1 Perception and risk assessment

In the study areas, majority of people (41.67%) stated that they had no clear idea about climate change. A little portion (10%) of the respondents had well knowledge about the phenomena (Table 2). The elderly people of the communities sometimes could predict disaster well in advance (like flood and drought) by monitoring the early or late rainfall status at the running year. But they could not predict occurrence of tornado and hailstorm.

During our field investigations, communities identified the major extreme climate events which were drought, heavy rainfall and temperature change. These climate events are

Table 2 Climate related knowledge among the respondents. We asked some climate change related question to the respondent for example- what is climate change? What are the consequences of climate change? Why climate is changing? What are the major climate events? Why drought and flood are frequently happening at the present time? What are the reasons behind it? etc. Based on their answer we prepared the categories in this table

Categories	Number of respondents (%)
Well-known	12 (10%)
Known	30 (25%)
Not clear	50 (41.67%)
Don't know	20 (16.66%)
No comments	8 (6.67%)
Total	120 (100%)

Source: Analysis of field data 2009

affecting the rural livelihoods in our study villages. Results revealed that unavailability of fish was the number one problem in the study areas. Other problems were lack of irrigation water, flash flood, long term flood, cold and worm seasons, pest and disease attack, riverbank erosion and lack of drinking water. All these problems were ranked based on the respondents' opinion in the problem matrix (Table 3). These problems affected their livelihood, crop production and employment opportunities.

Table 4 showed the trends of livelihood activities constructed by local communities in response of time. Enormous drought affected livelihood of the communities by creating various sorts of livelihood problems. The trend demonstrated that increase use of modern techniques in agricultural sector, cover areas which remains unproductive in particular seasons. The table also showed that dependence on fishery decreased with time due to lack of fish in the dry season. Duck raring was increasing as this livelihood activity provides income with small investment and less affected by climate change impacts. Agriculture and direct nature based sources of livelihoods were declining over time while new kind of jobs (of which most were absent in the past) like cottage industry and day labor were increasing. People were engaging with cottage industries, stationary shops, rickshaw puller and day labor as their alternative livelihood and the rate of these changes had gained pace in the recent years. This indicated that nature based livelihood activities were falling sharply responding to the environmental changes that were occurring in that area.

Communities were facing variable extreme climate events that were ultimately threatening their adaptive capacity with changing climate. Seasonal livelihood calendar (Fig. 2) showed that fishing was the primary livelihood activities for year round income of the community but presently the fishing profession was limiting 5 months during the dry season. People were migrating from their traditional occupation and went nearby town for employment such as day labor or rickshaw puller. The duration of paddy cultivation was also

Table 3 Problem matrix for climate related hazards in the study areas. Problem matrix was based on the respondent's opinion. See method section for details

Problem[a]	Category[a]	Frequency per year	Score[b]	Rank
Level 1 (Consequences of climate change)				
Drought or low rainfall	Very high (5)	2	10	1
Heavy rainfall	High (4)	2	8	3
Temperature change	Moderate (3)	3	9	2
Cyclone and storm surges	Low (2)	1	2	4
Fog	Very Low (1)	1	2	4
Level 2 (Results of consequences)				
Unavailability of fish	Very high (5)	3	15	1
Lack of irrigation water	High (4)	2	8	2
Flash flood	High (4)	2	8	2
Long term flood	Moderate (3)	2	6	3
Cold and very worm season	Moderate (3)	2	6	3
Pest and disease attack	Moderate (3)	1	3	5
Riverbank erosion	Low (2)	2	4	4
Scarcity of drinking water	Very low (1)	2	2	6

[a] Numbers in the parenthesis indicate the category value

[b] Score = Value of problem category × frequency

Table 4 Trends of livelihood activities in the study areas

Livelihood activity	In Past	Present	Future
Agriculture	Common	Increase	Increase
Fishery	Common	Decrease	Decrease
Day labor	Rare	Increase	Increase
House hold as maid	Rare	Increase	Decrease
Rickshaw puller	Rare	Common	Increase
Duck Raring & poultry	Common	Common	Increase
Cottage industry	Rare	Increase	Increase

decreased for water scarcity in the dry season and flash flood in the rainy season. Local rice varieties were likely to be rare for the introduction of improved and high productive rice variety. Horticultural crops were also cultivated widely during the *robi* season which was rare before 90s. Communities also reported that horticultural crops and homestead cultivation serves as reserve bank for the year when the traditional crops damaged by pest, drought, flash flood or other environmental influences.

Local community prepared seasonal hazard calendar which showed that unavailability of fish, lack of irrigation water, flash flood, pest and disease attack, riverbank erosion and lack of drinking water increased with time (Fig. 3). These problems affected the crop cultivation and household productivity. The study areas consisted of several rivers and *beels* and situated in the *haor* basin. Water availability in this area determines the agriculture and fishery activities i.e. the livelihood of the communities in the wetland. Temperature related hazard such as drought created problem to the farms because all the low lying areas are dried out. More riverbank erosion occurred in the winter seasons when water level became lower in the river. Though, frequent flash flood affected almost everywhere and damage crop production in the rainy seasons, community claimed that their livelihood is much easier in rainy season than drier months.

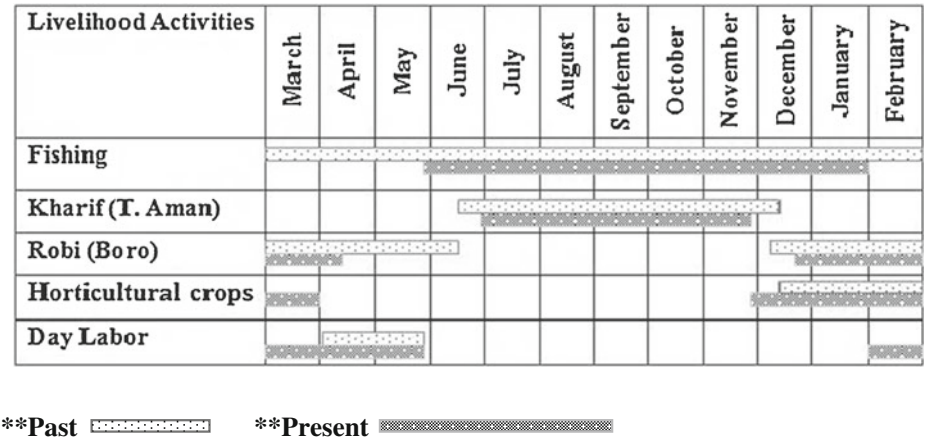

Fig. 2 Seasonal calendar for livelihood activities. In the figure black doted white bars denote climate related hazards before 90's and white doted black bars denote the present status. We arranged the months from March as the local people follow the Bengali year and its starts form mid-March

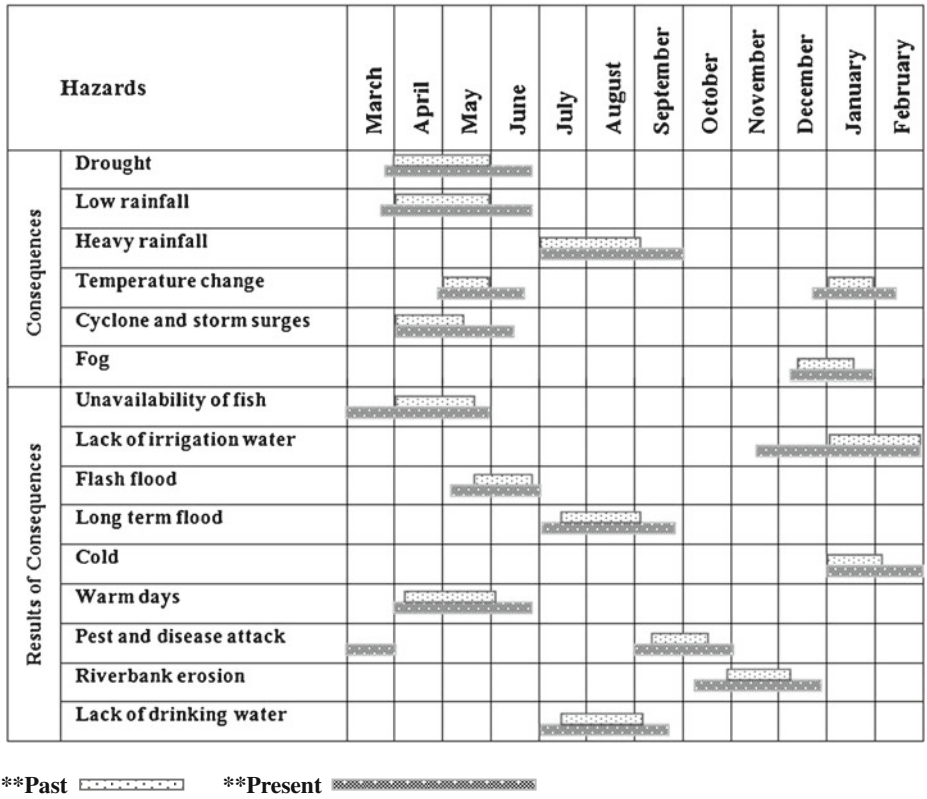

Fig. 3 Seasonal calendar for climate related hazards. In the figure black doted white bars denote climate related hazards before 90's and white doted black bars denote the present status. We arranged the months from March as the local people follow the Bengali year and its starts form mid-March

4.2 Adaptation

We identified total 16 adaptation strategies in the study areas which were practiced by the respondents in different seasons. All the adaptation strategies were based on indigenous knowledge except the planned adaptations which were supported by different NGOs and government organization. In case of all community level planned adaptation strategies respondents were beneficiaries only as all technical and financial supports were given by different organization. Local people were mostly depended on fishing in the recent past but due to environmental hazards and unsustainable harvesting like catching mother fishes in the egg hatch period there remains scarcity of fish in the *haor* areas. That's why people who were fisher in profession are now depending on alternate livelihood activities like duck raring, cage aquaculture and cottage industries. Percentage of respondents who were practicing different adaptation strategies to cope with the present climate change impacts have given in the Table 5.

4.2.1 Crop diversification

During the field visit it was found that in many areas of Jamalganj crop cultivation is being diversified. In past, people didn't cultivate any kind of horticultural and cereal

Table 5 Popular climate change adaptation strategies in the study areas

SL. No.	Adaptation strategies	Remarks[1]	Respondents[2]			
			12 months	6 months	3 months	Total (N=120)
1	Crop diversification	ILA	37(30.83)	52(43.33)	15(12.50)	104(86.67)
2	Homestead gardening	ILA	78(65.00)	25(20.83)	08(06.67)	111(92.50)
3	Change in planting and harvesting time	ILA	58(48.33)	24(20.00)	00(00.00)	82(68.33)
4	Application of Pesticides	ILA	26 (21.67)	19 (15.83)	05(04.17)	50(41.66)
5	Plantation in heap	ILA	12(10.00)	39(32.50)	13(10.83)	64(53.33)
6	Mulching	ILA	00(00.00)	65(54.17)	26(21.67)	91(75.83)
7	Conversion of agricultural land	ILA	11(09.17)	00(00.00)	00(00.00)	11(09.17)
8	Floating garden	ILPA	00(00.00)	16(13.33)	22(18.33)	38(31.67)
9	Duck rearing	ILA	20(16.67)	17(14.17)	00(00.00)	37(30.83)
10	Cage Aquaculture	CLA	15(12.50)	30(25.00)	00(00.00)	45(37.50)
11	Cottage industries	ILPA	08(06.67)	05(04.17)	06(05.00)	19(15.83)
12	Koroch plantation establishment	CLA	25(20.83)	28(23.33)	00(00.00)	53(44.17)
13	Wave protection walls	CLPA	00(00.00)	52(43.33)	00(00.00)	52(43.33)
14	Shelter house	CLPA	00(00.00)	00(00.00)	31(25.83)	31(25.83)
15	Digging & re-digging of canals & river	CLPA	00(00.00)	75(62.50)	00(00.00)	75(62.50)
16	Construction of embankments	CLPA	00(00.00)	69(57.50)	00(00.00)	69(57.50)

(Source: Analysis of field data, 2009)

[1] ILA = Individual level adaptation based on indigenous knowledge; ILPA = Individual level planned adaptation supported by different NGOs or Government organizations, CLA = Community level adaptation based on indigenous knowledge, CLPA = Community level planned adaptation supported by different NGOs or Government organizations.

[2] Number of respondents who are practicing different adaptation strategies for different period are given here. Numbers in the parenthesis indicate the percentage of respondents

crops in agri-fields and in the dry season a largest part of the agricultural lands remained uncultivated. Peoples of that area are now changing the cropping pattern in response to the changing climate and near about 86.67% respondents cultivated various horticultural crops such as mustard (*Brassica* spp.), yam (*Dioscorea spp.)*, linseed (*Linum usitatissimum*) and some pulses in dry season.

4.2.2 Homestead gardening

Homestead gardening ensures sustained use of available land in homestead and increase the family income and provide continuous supply of food materials. About 92.3% respondents of the study areas are practiced home gardening with improved techniques which helped them by providing continuous supply of nutrients in their food chain and subsequent income throughout the year. Along with tree species, respondents are now cultivating vegetable crops in their homestead as these lands are usually not affected by flash flood in rainy seasons.

4.2.3 Change in planting and harvesting time

During the study it was found that 68.33% respondents change their planting and harvesting time to cope with the adverse effect of climate change such as excessive rainfall, flood and storms. Usually they face flash flood in the late February in each year that's why they planted rice earlier in November to get early harvest. However, in recent past they started rice planting from December or January. They are now largely depends on short duration rice variety which are also flood tolerant. BRRI-45, BRRI-29 and BRRI-28 were cultivating widely among which BRRI-45 is found as top choice with farmers.

4.2.4 Application of pesticides

Due to the adverse effect of climate change and erratic weather pattern pest and disease attack to the crop is more frequent and increasing day by day. In that situation people largely depends on pesticides. Though pesticides are harmful to the environment, 41.66% respondents rely on it because of ensured protection against pest and disease.

4.2.5 Plantation in heap

Due to heavy rainfall and water logging condition for longer period, 53.33% respondents raised their plantation in heap for easy drainage and prevent root damage from decay. The heaps were found to prepare in rows above which the plantation were occurred. The sides of the heap provide a means of water runoff keeping safe the crops and plants.

4.2.6 Mulching

During the study it was observed that farmers give mulch to the crop and trees. Mulching protect crops from moisture stress and provide organic nutrient to the crop. Water hyacinth is found as widely used mulching material for its availability in the study areas. About 75.83% respondents practiced this adaptation as it serves a good barrier against moisture stress.

4.2.7 Conversion of agricultural land

Some low laying agricultural lands in the study areas are remains under water for 6 months in the rainy season. About 9.17% respondents convert their low laying agricultural lands in to pond for fish cultivation as these lands were unsuitable for crop cultivation. At the present time some of them were also found to manage their less productive water bodies as fish farming which provide high income than agriculture.

4.2.8 Floating garden

About 31.67% respondents adopting low cost vegetable cultivation technology locally called *baira* for waterlogged areas which improved their food and economic security. In past, they couldn't produce any crops in low lying areas for water stagnancy. In that situation, they often didn't find any other employment and sometimes they migrate to city areas to find jobs. Some non-government organizations introduced the technique of floating garden which involves the cultivation of traditional crops on beds floating on water rather than in soil (Fig. 4a). The floating beds used by the farmers are usually made of water hyacinth. The main crops cultivated in floating gardens include okra (*Abelmoschus esculentus)*, cucumber

Fig. 4 (**a**) A fermaer working in his floating vagetable garden (**b**) A traditional duck rearing farm in the study area (**c**) Floating fish cages in the water (**d**) Fishermen catching fish from their cage for selling in the market

(*Cucumis sativus*), bitter gourd (*Momordica charanteakohlrabi)*, tomato (*Lycopersicon esculentum*), turmeric (*Curcuma domestica*) and potato (*Solanum tuberosum*).

4.2.9 Duck rearing

Duck raring is a traditional practice of the study areas as most of the lands were submerged under water near about 6 months in a year. During the field survey it was found that women were highly involved in duck farming which provides subsequent incomes in the year round. About 30.83% households were involved in duck rearing and each farm having average 50–80 ducks (Fig. 4b). But duck farms were vulnerable to various diseases including '*Bird flu*'. In that situation they usually depend on *kobiraj* (local doctors) and mostly on local knowledge to prevent the diseases. Duck rearing also enhanced income to the households in the study areas.

4.2.10 Cage aquaculture

Cage aquaculture was another alternative income generation activities found in the study areas which was practiced by the respondents (37.5%) during flood and water logging period. Cages (Fig. 4c) were usually sized 3 m×2 m made of bamboo and iron pipe covered with net. Eight thousand taka required for the preparation of each cage. Because of high market demand '*Telapia*' fish was extensively cultivated in the cage (Fig. 4d). The cages were owned by a group of farmers consists of fifteen members. A farmer claimed that 27,000 taka could be earned from each cage in an interval of 5 month.

4.2.11 Cottage industry

Murta based cottage industries were common in our study areas. Murta or patipata (*Schumannianthus dichotoma*) is the main raw materials of those industries which are used for the preparation of mat (locally called *pati*). In our study areas Murta is grown naturally and about 15.83% households involved in this cottage industries. Mainly women were largely involved in the preparation of mat and men were responsible for selling in the market. One special product of this industries is called *Shitalpati* (one kind of traditional mat) is famous to all over the country. A variety of products such as bags, wall mats, prayer mat were also produced from Murta. Many NGOs helps them in marketing of patipata based products.

4.2.12 Koroch plantation establishment

Newly established Koroch (*Pongamia pinnata*) plantation was found for the protection of wave action in the study areas as this plantation can tolerate water stagnancy and flood. This appeared to be a viable and sustainable low-cost alternative technique compared to the other hard engineering approaches. In addition to protecting the village mound from erosion during the monsoon season, villagers were also able to collect fuel-wood from this plantation. While this plantation serve as a means of preventing erosion and reversing the degradation, the groves of trees also restored the ecology of the site by enhancing its biotic diversity (Fig. 5a).

Fig. 5 (**a**) An established koroch plantation in the study areas (**b**) Traditional wave protection wall (**c**) Digging of canals for easy water movement and rain water harvesting (**d**) Construction of an embankment for the protection of agricultural field and houses from flash flood

4.2.13 Wave protection walls

Houses of the local people situated on the earthen mound are common features in our study area. Scattered mounds look like an island during the rainy season. One of the main problems in our study areas is the erosion of the village mound by wave actions during the monsoon. Wave protection walls provide an effective protection, even though expensive solution, to the erosion of their village mounds (Fig. 5b). SHOUHARDO project constructed about 31 protection walls in the '*Haor*' areas funded by CARE and USAID in cooperation with Government of Bangladesh.

4.2.14 Shelter house

Flood is a common natural disaster in our study areas. Two or three storied building like community clinics and school grounds was found to provide safe shelter to a huge number of flood affected people including their livestock. Village mound with protection walls made by bamboo have saved houses and their belongings and livestock of vulnerable people in the study areas also.

4.2.15 Digging and re-digging of canals and rivers

Due to high siltation most of the *canals* and rivers became filled up as a result water logging condition is common in our study areas. Throughout the study we found that some government and non-governments organization were digging canals (Fig. 5c) and re-digging of small rivers with the help of local people which also helps the poor households by providing employment opportunities and easy water movement in the monsoon. Through this adaptation strategy local farmers also harvested the rain water for irrigation in the dry seasons.

4.2.16 Construction of embankments

Construction of new embankments was found to protect the wave action and facilitate communication in Jamalganj area (Fig. 5d). Embankment provides security to crops raised in the field and protects wash out of soil from mound through flash flood. Government and different NGOs built these embankments with the participation of local people which was found as satisfactory adaptation measure in response to water logging and flood protection.

5 Discussion

We identified the major climate events which are the consequences of climate change in our study areas. These events are drought, heavy rainfall, temperature change, cyclone and storm surges and fog. Verchot et al. (2007) also stated that the most possible consequences of climate change in developing countries are temperature increase, high or low rainfall, droughts, sea level rise etc. Moreover, we listed all the impacts from the changing climatic events in the study areas which were frequent flood, lack of irrigation water, pest and disease attack, lack of drinking water and river bank erosion. Hossain and Roy (2010) also found more or less similar results in his study conducted in a low lying area of southern Bangladesh. Several studies (Verchot et al. 2007; Coakley et al. 1999; Nagarajan and Loshi 1978) indicated that climate change increased pest and disease incidence, changed in the growing season

and decrease in yield of most crops as temperature increased. Besides, Rosenzweig et al. (2002), Chen and McCarl (2001) pointed out the necessity of increased use of agricultural pesticides with increased temperature. Climate change also has a direct effect on water storage, putting increased stress on water availability for irrigation (Verchot et al. 2007; Nagarajan and Loshi 1978; Hossain and Roy 2010).

We tried to explore the perception of climate change in the study areas but respondents hardly relate any of the observed changes to past and future climate. Only few of them had clear knowledge about the present climate but maximum had no idea about it. Similarly Rahman et al. (2007), Berger et al. (2009) and Mahmood et al. (2010) found that elderly inhabitant's memory is the only source of information for assessing perception but they were not able to share any knowledge about climate change. However, risk perception is largely reflected by the combinations of age, gender, education, occupation and place specific but there is marked difference in percentage among gender (Tanner et al. 2009 and Warrick 2009). In addition, Sherwood and Bentley (2009) found that 'case of observation' and 'perceived relevance' influence local knowledge on climate.

Seasonal livelihood calendar and seasonal hazard calendar have used in the present study for better visualization of information at different situations of a year. We found two seasonal calendars in our study areas, one is for livelihood activities and another is for hazards. Results revealed that seasonal calendar can represent the hidden constraints of livelihood opportunities of rural people to regulate household activities. Boudreau (2009) found the same result in his study. Furthermore, different calendars have found to be used in different studies. Such as rain calendar was used to compare weather conditions (rainfall and temperature) in Ethiopia (Awuor and Hammill 2009), hazard risk calendars were used for the pilot study locations with special emphasis on the agriculture sector in drought prone areas of Bangladesh (Selvaraju et al. 2006) and climate time lines were used to record extreme weather events and temperature trends over the past 30 years in Sudan (Christian Aid 2009). Seasonal calendar is found to be highly beneficial to the researchers (Warrick 2009) but it has limited scope in learning for the participants.

Adaptation refers to the strategies that enable people to cope with adverse climatic events (Nyong et al. 2007). Various adaptation measures like floating garden, crop diversification, change in planting and harvesting time, mulching and plantation in heap were found throughout the study which is in line with some other studies e.g. Rahman et al. 2007; Khan 2009 and Akhter 2010. Though some of these practices are traditional in some parts of Bangladesh, recently these activities are being popular as climate change adaption (Rahman et al. 2007; Ali 1999). Another recent studies (CCC 2009) suggested to cultivate some vegetables instead of rice which can be harvested at least a month before the current timing of flashfloods in the low laying areas. However, in our study we found that respondents were planting rice 1 month before the traditional time so that they can harvest it before the flood attack. However, in other developing countries for example in Nigeria some indigenous people also shorten their growing season when rainfall reduced or drought occurred due to increased temperature (Ishaya and Abaje 2008). In addition, people also use mulching and sheltering techniques to conserve soil moisture for crops like yam and zinger. However, Narain (2003) identified a range of strategies to adapt with water scarcity such as improving access to available water, coping periodic drought through use of stored seeds and food grains, sale of livestock and diversifying livelihood activities through alternative employment opportunities. Furthermore, floating vegetable cultivation, home gardening and case aquaculture were found to improve economic and food security during the water logging period in our study areas which is also supported by study findings of Rahman et al. (2007). Increase income through alternative livelihoods activities like duck rearing and cottage

industries are common in our study areas. Poor vulnerable people of the waterlogged areas have been found to improve their livelihoods securities adopting these alternative livelihood activities (Rahman et al. 2007). On the other hand, plantation establishment, wave protection walls, shelter house, construction of embankment and re-digging of pond and canal locally called *khal* are found as popular adaptation measures in some studies (for example- Ali 1999; Rahman et al. 2007; Ahmed and Chowdhury 2006).

6 Conclusion

The study finding shows that climate change has some effects on livelihood of local people living in the water logged areas. Especially the fishermen and farmers are in more vulnerable condition due to climate change. They are trying to cope with the adverse impacts of climate change with their own knowledge but their situation is as like as a soldier without sword. Training related to alternative income generation activities should be introduced by the local government and non-government organization to save them from this critical situation. However, the present study revealed that local knowledge regarding the climate change adaptation is important to cope with the present climate change impacts. We strongly recommended the application of participatory approach to relegate the adverse impacts of climate change and introduction of new cultivars which can withstand the current climatic situation. Continuous research and long term investment in agricultural sector might be promoted for the betterment of the affected people also. Further studies in other waterlogged and drought prone areas are highly recommended to explore the climate change adaptation related local knowledge which might helpful for the policy makers, researcher and more importantly for the climate affected communities in the tropics.

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