Socio-Economic and Physical Perspectives of Water related Vulnerability to Climate Change: Results of Field Study in Bangladesh

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Abstract:

The present paper deals with the socio-economic perspectives of the water related vulnerability to climate change based upon the data collected from the Selected Hydrological Unit (SHU) through questionnaire survey supported by PRA/FGD and interview with key Informants. The SHU which is situated in the northern part of Bangladesh to the left Bank of the river Brahmaputra (locally named as Jamuna) is highly vulnerable to floods. The analysis of the past climate of Bangladesh shows that the average temperature increases at the rate of 0.16^{o}C/decade. The pre-monsoon and monsoon rainfall has increased by about 20 % during the past 30 years. The hydrological observations show that the frequency of severe floods and the intensity have been found to increase during the last 3 decades. The scenarios of climate change as obtained through the analysis of the outputs of HadRM2 regional climate model shows that the annual mean temperature over the region of the SHU is expected to rise by 1.5 and 2.8^{o}C by 2020 and 2050respectively relative to 1990 and the annual precipitation by 9.1 and 22.7% for the above two time levels. The pre-monsoon precipitation would increase by 27 and 70%. The monsoon precipitation is expected to increase by 4.2% and 9.7% for the above two time levels.

The SHU is highly vulnerable to severe floods. The lives of the people are seriously affected by the severe floods, dwelling houses are inundated and damaged and the resources such as agriculture, livestock and fisheries also suffer severe damages. People suffer from the lack of shelter, food, medicine and potable water. The increased rainfall is expected to further increase the flood intensity and enhance the vulnerability in the future. The riverbank erosion has been identified as another water related hazard which is more active during the floods.

The people are coping to some extent in the agriculture sector. They wait until the peak flood is over for planting of the aman rice which is grown in the monsoon and post-monsoon season. In case, the crops were damaged due to severe floods, the farmers replant the aman rice in the fields as soon as the flood water recedes. It came out from the field information that the farmers do not depend on the aman rice anymore as they have shifted towards the irrigated cultivation in the dry season to recover the crop damages due to floods in the monsoon season. However, they have not abandoned the aman rice cultivation, because if there is no flood they can get a very good harvest.

As regards the adaptation in other sectors such as housing, livestock, etc. Strong houses need to be built by raising the lands above flood level so that neither the dwelling houses nor the lawn of the houses are affected. In that case the livestock will not be affected anymore. This will solve the problems permanently and reduce the sufferings. However, a huge majority of the people lives below the poverty line and can not afford these

expensive coping options. Thus poverty alleviation is identified as a crucial means of increasing the adaptive capacity of the people.

1. Introduction

1.1 Background

According to IPCC-WG-I Third Assessment Report (IPCC, 2001), the global average surface air temperature has increased by 0.6^{o}C during the 20 century. The cause of such warming has been attributed mainly to the increase of atmospheric emission of GHGs. The warming trend has accelerated in the recent decades and has been observed to be 0.15^{o}C/decade during the last two decades. The 1990s were the warmest decade and 1998 was the warmest year in the instrumental record since 1861 (IPCC, 2001). According to IPCC projection, the global temperature is likely to rise by 1.4-5.8^{o}C over the period from 1991-2100. The changes are expected to have spatial variations, which is likely to modify the overall pressure fields and the circulation patterns.

The South Asia's water resources are predominantly influenced by monsoon variability and also by the glacial cycle in the Himalayas. In this context, the arid to semi-arid parts of the region comprising large area of Pakistan and northwestern states of India experiences frequent droughts, and the eastern Himalayan sub-region, on the other hand, experience frequent floods. These two sub-regions represent two extreme conditions in terms of their water resources vulnerabilities. In the backdrop of the looming disastrous climate-induced events in South Asia, a study has been launched to understand the observed and future climate change and analyze the potential vulnerability of water resources and evaluate the various adaptation strategies and coping mechanisms that reduce the vulnerability of human population of the region.

The country study of Bangladesh aims at meeting the objectives of the regional study. The present paper deals with the findings of the investigation performed through the field survey on the socio-economic perspectives of the water-related vulnerability to climate change for Selected Hydrological Unit (SHU) of Bangladesh.

1.2 Physical Description of the SHU

The location of the SHU has been shown in Figure 1. The SHU is the Sherpur Upazila ('Upazila' is the administrative unit, a number of which makes a 'district') and is situated in the left bank of the river Brahmaputra (locally named as Jamuna after entering Bangladesh). The old Brahmaputra which was the original course of the Brahmaputra until 1787 has bounded the SHU from its north-side and passed across the upazila through its eastern side. The SHU is roughly located within 24^{o}39′ and 25^{o}10′N latitudes and 89^o 39′and 89^{o}56′E longitudes.

Figure 2(a) shows the river networks in and around the SHU and Figure 2(b) shows the map of SHU showing its physical characteristics. The left bank of the river Jamuna is highly vulnerable to erosion. The map in Figure 2 (c) shows that a vast area has been eroded during the last 2 decades.

1.3 Socio-Economic Description

The upazila has an area of about 370 sq km and estimated population for 2001 was 337,000. The population density is 911.8 per square kilometer. The eastern part of the upazila comprising older and higher flood plain demonstrates higher population density compared to the erosion and flood vulnerable western part of the upazila. The overall literacy rate is about 45% well below the national average which is 63%. The crop cultivation is the major economic activity in the SHU. 50% of the household heads are engaged in farming or farm-based labour, though two third of them have a secondary income source like business or fisheries. Flood plain fisheries is an important component of the livelihood of the SHU. Livestock is the integral part of the household assets. The rural households raise cattle, goat and poultry. Health conditions are related to the socio-economic status of the SHU's population. The access to healthcare services in the SHU is extremely poor. The most common diseases in flood season are diarrhea, dysentery, jaundice, typhoid and skin ailments. The sanitary conditions are poor in the SHU. The SHU has a number of haats (local weekly markets) which provide opportunities for trading of local agricultural commodities as well as items of daily needs.

1.4 Past and Current Climate Variability

The SHU has cool and dry winter with average minimum and maximum temperature of 11.8 and 25^{o}C in the month of January. The warmest month is April with average maximum temperature of 32.6 ^{o}C. The area gets an average rainfall of 2383 mm per year. About 66.7 % of the annual rainfall occurs in the monsoon season and 21.9% occurs in the season.

The analysis of the past and present climate change of Bangladesh has been performed using the temperature and rainfall data of past 40 years (1961-2000). The results show that the average temperature over Bangladesh has an increasing trends of 0.16/decade which is very close to the the rate of warming of the global surface temperature as observed in the recent decades (IPCC, 2001). The central and southern parts of Bangladesh have shown stronger warming compared to the northern part (Choudhury et al., 2003). The precipitation has been found to increase in all the seasons, but substantial increase has been found to occur in the pre-monsoon and monsoon seasons. The monsoon rainfall trends are high over the northern part of the country over the catchments of the Ganges, Brahmaputra and Meghna (GBM) catchments. The analysis of the monsoon rainfall over Bangladesh shows that rainfall has increased all over the country except the southeastern part where the monsoon precipitation has been found to have some decreasing trends. Over the northern Bangladesh which includes the SHU the pre-monsoon and monsoon rainfall has been found to increase by about 20 during the past 30 years period (1961-2000). The sea level in the Bangladesh part of the Bay of Bengal has been found to rise at the rate of 4-7.8 mm/year (Khan et al., 1999).

1.5 Observed Hydrological Changes and Extreme water events

The analysis of the monsoon rainfall data indicates that monsoon rainfall undergoes strong variability in Bangladesh which results droughts and floods. The years 1962, 1972, 1979, 1989, 1994 and 1997 were the years with strong rainfall deficit. On the other hand, the years 1965, 1968, 1974, 1987, 1988 and 1998 had high rainfall in the GBM basin 92% of which lies outside Bangladesh. Thus, the runoff over 92% of the catchments due to heavy rainfall passed though rest 8% of the catchments lying over Bangladesh and caused severe floods. From the flood records of Bangladesh, it can be seen that severe floods of extreme nature had occurred in 1974, 1987, 1988 and 1998, each of these floods were the largest until the time of the occurrence of the respective floods in terms of depth, area of inundation and duration. The peak discharge of the rivers Ganges at Hardinge Bridge, Brahmaputra (Jamuna) at Bahadurabad and Meghna at Bhairab Bazar were 80,230, 98,600 and 19,900 m^3 /sec respectively against the mean discharge of 54,000, 67,000 and 14,000 m^3 /sec respectively. As reported by Flood Forecasting and Warning Centre (FFWC, 1998), the river Brahmaputra crossed the ever highest record in 1998 in terms of discharge, but not in water level. The water level crossed the highest peak in 1988. The Ganges recorded the highest water level in 1998. Analyzing the area of inundation due to the floods from 1952-2001, it was found that the area of inundation of the extreme floods have been increasing since 1974 and the return period of the 25 years floods have been shrinking rapidly. The duration and depth of flooding have been found to increase during the last few decades.

1.6 GCM and Regional Climate Model results of Future climate variability and extreme events (2020 and 2050)

The future climate change scenarios of Bangladesh were developed for two time frames 2030 and 2050 based on GCMs superimposed on long-term climatic patterns (WB, 2000 and Ahmed and Alam 1998). The above GCM results have been interpolated to generate the scenarios for 2020 using linear interpolation (table 1).

Table 1: Future Climate Change scenario for temperature and precipitation relative to 1990 based on GCM results (after WB, 2000)

Year	Temperature		Precipitation (%)	
	Winter	Monsoon	Winter	Monsoon
2020	1.0	0.5	-2	7.0
2050	1.8	1.1	-37	11.0

The climate change scenarios were developed for the SHU and its surrounding areas based on the Hadley Cetre Regional Climate Model (HadRM2). The model outputs were provided by Rupa Kumar Kolli (IITM) for control run (without GHG) and for 2020 and 2050 with GHG. The HadRM2 output has the spatial resolution of about 50 km. The results of the control run were validated against the observed data. It has been found that the temperature matches well in terms of magnitudes and in its annual patterns. The monthly distribution of the precipitation shows that the annual profile shows a good matching in its distribution patterns with the observations while the magnitude of the precipitation for the pre-monsoon, monsoon and post-monsoon shows much lower values with respect to the observed precipitation. An adjustment factor is obtained by taking the ratio of the observed precipitation and output of the control run which is multiplied with the results of the GHG runs. This operation effectively adjusts the model precipitation with the observed precipitation. The scenarios have been developed on the seasonal basis and presented in table 2.

Table 2: Future Climate Change Scenarios for temperature (^{o} C) and precipitation (%) relative to 1990 based on HadRM2 results

Years	TEMPERATURE (^{o} C)				
	Winter	Pre-monsoon	Monsoon	Post-monsoon	Annual
2020	1.7	0.8	1.4	1.8	1.4
2050	3.4	1.5	2.9	3.6	2.8
	PRECIPITATION (%)				
2020	30.4	26.6	4.2	5.3	9.1
2050	70.4	70.3	9.7	11.3	22.7

The above HadRM2 generated results show that the stronger warming trends for all the seasons compared to the GCM results generated in the earlier studies. The results show that the winter precipitation is increasing which is contrasting to the GCM results. The HadRM2 results indicate that the winter and pre-monsoon precipitation will increase at faster rates compared to the monsoon and post-monsoon precipitation. The increase of the monsoon precipitation has been found to be lower in the HadRM2 results compared to the GCM results.

2.0 Physical Perspectives of Water Related Vulnerability to Climate Change in SHU

2.1 Water balance and distribution

Table 3 shows the distribution of the precipitation (P), potential evapo-transpiration (E_p), and minimum and maximum temperature for the SHU (BARC, 2004). The table shows that the months May-October have precipitation higher than evapo-transpiration. Thus these months have positive water balance. The months November-April have low precipitation and show negative water balance. These months are extremely dry. The annual profile of the water balance ($P-E_p$) has also been shown in table 3. The months March-May have high evaporation with maximum in April (168mm/month). These months are highly vulnerable to droughts.

Besides the rainfall within the country, huge flux of water is carried to Bangladesh through the major rivers and their tributaries during the monsoon season. Excess rainfall in the GBM river basin causes severe floods which inundates large area of the country. The SHU is a high flood vulnerable area. The agriculture in the monsoon season is dependent on the monsoon rainfall. The winter rice is grown under artificial irrigation using surface and ground water. The water produced by the monsoon activity is the main source for recharging the ground water. Besides, the ground water is the main source of potable water.

Table 3: Monthly average Precipitation (P), Potential Evapotranspiration (E_P), Minimum and Maximum temperature (Tmax and Tmin respectively) and Water Balance (P- E_P)

Climatic Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	9	20	32	86	254	380	349	354	309	141	16	3
E_P (mm)	81	95	138	168	152	128	125	118	115	111	93	83
Tmax	25.9	28.6	33.3	35.8	34.1	32,5	32.0	32.0	32.3	31.6	29.3	26.7
Tmin	12.2	14.2	18.6	22.8	24.4	25.4	26.1	26.1	25.7	23.4	18.0	13.8
Water Balance	-72	-75	-106	-82	102	252	224	236	194	30	-77	-80

2.2 Water Related Vulnerability

2.2.1 Floods

The analysis of the past flood data suggests that about 19-25% of the country is inundated in normal year. About 68% of the country is vulnerable to high floods of different intensity. The floods of 1974, 1997, 1988 and 1998 were of extremely divastating nature. It has been found that there is tendency of the increase of the severity of the extreme floods in terms of area inundation, depth of flooding and duration due to increasing trends of precipitation in the catchment areas. It is found that monsoon precipitation has increased by 18% in the northern part of Bangladesh covering the SHU resulting in 3 times increase of the flood inundation area reference to 1961 level. The analysis of Qureshi and Hobbie (1994) shows that an increase of monsoon rainfall of Bangladesh by10% would cause an increase of the runoff depth by 18-22%.

From the model results (GCM and HadRM2) the monsoon rainfall is expected to increase within the range 4-7% by 2020 and (10-11%) by 2050; this suggests that the surface runoff will increase in the order of 10 and 20% respectively. According to the World Bank study (WB, 2000) with the future increase of precipitation the total area of inundation would approach the observed area of inundation under the current 20 year flood events. However there will be increase of the depth of flooding.

Floods are expected to be more severe and durable by the climate change induced sea level rise. Moreover, stronger discharge during high floods carry larger amount of sediment loads compared to that during normal flow condition. The prolonged discharge of flood water causes the settling of higher amount of sediments in the riverbeds, river mouth and floodplains. Thus the riverbed and the adjacent floodplains will rise leading to further drainage congestion. This drainage congestion is expected to aggravate the flood further.

The observation during the period from 1961-2000 also indicates strong increase of the rainfall of Bangladesh (Choudhury et al., 2003). Currently, the northeastern and southeastern part of Bangladesh experiences severe flash floods during late April and May due to heavy rainfall over the region and in the adjacent hilly areas of India which affects the Boro rice production. There was a heavy rainfall in April 2004 which caused severe flooding in the central-northern and northeastern part of the country. This pre-monsoon flood was the cause of the damage of Boro rice and other agricultural crops over vast area. This flood caused immense sufferings lives. According to the HadRM2 scenario of the SHU, the pre-monsoon precipitation is expected to increase by 26.6 and 70.3% by 2020 and 2050 respectively. Such increase in the future rainfall will enhance the pre-monsoon flood vulnerability in the northern and eastern part of the country including the SHU. The stronger flash floods will cause more damage to the agricultural crops especially the Boro and AUS rice.

Bangladesh withdraws 22,500 million m^3 of water (WRI, 1988) annually. According to the MPO (1991) the total requirement of water consumption in 2020 will be 24,370 million m^3. The HadRM2 model shows an increase of annual rainfall by 9.1% in 1020 and 22.7% in 1050. Moreover the winter rainfall has been found to increase at the high rate (Table 2). Thus it is expected that the surface water situation including the natural flow of the rivers will improve in the dry period. As a result, there will be enough supply of water to meet up the future water requirement considering that there are no such inventions in the surface water flow which may generate adverse impacts on the augmentations of the drainage systems.

2.2.2 Droughts

The deficit water balance during the period November-May causes drought like situations. The droughts would be severe if there is prolonged absence of rain in these seasons. Much lower than normal rainfall (lower than the one standard deviation) for a long period (a few weeks or months) within the seasons will cause drought. Use of the ground water for mainly irrigation has solved the drought problems in agriculture during the winter and pre-monsoon seasons when the surface water is scarce. Drought during the monsoon is hazardous to crops as they grow only through natural irrigation available from rainfall. On the other hand the ground water recharge is also affected if there are droughts in the monsoon season. This affects both the surface and ground water situation vis-à-vis the irrigation in the following dry seasons. According to HadRM2 model projections the annual temperature is expected to rise by 1.4 and 2.8^o C by 2020 and 2050 respectively. The increase is stronger during winter and post-monsoon seasons which will enhance the evapo-transpirations. Though the overall water balance situation is expected to improve in the future due to the projected strong increase of precipitation during the relatively dry parts of the annual cycle, it is anticipated that the droughts would also be severe due to high evapo-transpiration.

2.3 Water quality

Severe flood causes the dwelling houses go under water. During this period the surface and river water becomes highly polluted and carries diseases. Thus using the floodwater for any sort of domestic use is fatal for health. The commonly used water is extracted from the hand tube wells in the rural areas. However, when tube wells are submerged due to high floods, their water becomes unsuitable for use.

In the rural areas, it has been found that the groundwater extracted by hand tube wells is contaminated with arsenic in many places. Drinking this Arsenic contaminated water is hazardous for health. The increased atmospheric temperature would exacerbate droughts, which would enhance the dependence on groundwater for various uses including drinking and other domestic uses and especially irrigation for agriculture. This condition would increase the risk of arsenic contamination through agricultural food products.

2.4. Water use efficiency for agriculture

Rice is the major crop in Bangladesh. The rice crop which is grown during the monsoon and post-monsoon seasons is called 'Aman' rice. The Aman rice is grown in the natural irrigation due to monsoon rainfall. The 'Aus' rice grows in the pre-monsoon season without irrigation using only rain water of and early part of monsoon. The winter rice which is known as 'Boro' rice is cultivated using the irrigation obtained from mainly ground water sources.

The distribution of the area and production of Aus, Aman and Boro rice for the Jamalpur district (which encloses the SHU) shows the temporal characteristics of the crop area and production since 1991 (Figure.3). The figure shows that Aman rice area has slight increasing trend. It can clearly be seen that the area and production of Boro rice has been increasing rapidly. The expansion of Boro cultivation has been possible due to extensive use of ground water for irrigating the rice plants. The irrigated area is expected to be doubled by the year 2020 (WB 2000). The irrigation efficiency may be increased by introducing and extending the cultivation of those crops which require relatively less water.

3.0 Socio-Economic Impacts, Agriculture and Livelihood, Coping Practices and Adaptation Measures of Extreme Water Events

The extreme water events – droughts and floods cause sufferings of the livelihood of the people and their economy. Since the surface water is scarce during the dry period, the increasing use of the ground water irrigation has solved the problems of drought in the agriculture sector to a great extent. On the other hand the excess water in the monsoon season causes severe floods affecting the livelihood and economy of the people. The agriculture and livestock sectors suffer the most.

A questionnaire survey supported by PRA/FGD and interview with key Informants was conducted in the SHU to reveal people's perception regarding recent severe flood events, changes in climatic parameters which may have linkages with present as well as future flood events, impacts of past flood events, coping mechanisms applied by the local people and the needs of the flood vulnerable people to enhance future coping etc.

The SHU is believed to be highly flood-prone in recent years. A number of causes have been identified for this. However, the general perception of an increase in frequency of flood is mainly the result of recurrent bank erosion and the relative location of the study area from the riverbank, which is largely unprotected. About 96 per cent of the respondents reported that floods occur every year, while rest of the respondents reported that flood occurs once in two years. According to the questionnaire survey about 80% of the respondents, intensity of present-day floods has actually increased compared to those occurring 20 years ago. Only 13% of the respondents believe that flood intensity has been on the decline over the past 20 years.

The SHU is believed to be highly prone to floods. About 96% of the respondents reported that floods occur every year. About 80% of the respondent reported that the intensity of the present day floods has increased compared to those occurring 20 years ago. The general perception of the cause of increase in frequency of flood is mainly the result of the recurrent bank erosion and the relative location of the study area to the river banks. The rise in water level in the rivers, breach of embankment, excessive rainfall in the upstream areas and reduction in drainage capacity and flow were identified as the major causes of floods. The results are in agreement with the observations testifying that the local people are quite aware of the causes of floods. The vast majority of the respondents believe that the duration of the floods have increased and floods in recent times have been occurring 10-20 days early.

3.1 Flood vulnerability, coping mechanism and adaptation

3.1.1 Agriculture sector

Vulnerability

The study revealed that the crop is totally lost in low lands and about 50-100% in the medium low lands to medium high lands due to high intensity floods. In case of a flood, the transplantation of Aman rice is done after the flood water was receded. If the flood water receded by mid-August, the potential crop loss would be minimum. If the transplantation of Aman rice was delayed further due to late recession of flood water, a reduction of potential yield would occur. The more is the delay in transplantation, the higher is the loss of potential yield. It was reported that the potential risk of pest attack was high in the post-flood season.

Besides the rice crop, the other crops like jute, sugarcane, vegetables, fruits or fruit trees were damaged. About 23% of the respondents suffered losses due to destruction of vegetable gardens and about 90% of them reported that they lost fruit-bearing trees.

It was reported that the normal flood increases fertility of soil as it deposits fine silts enriched with minerals and nutrients. 75% of the respondents think that high floods also increase the fertility and 24.5% reported that high floods reduced the fertility of the soil. Further investigation through PRA/FGD it was found that high flood brings course sands in some areas as in the case of 1988 and 1998, which degraded fertility of the top soil and hampered the cultivation of winter (Boro) rice in the upcoming season. The farmers removed the sands to bring these lands to bring these degraded lands back to cultivation.

Coping and adaptation Practices
About 25.8% of the respondents refrained sowing crops in anticipation of flood, while 21.9% of the respondents still go for crops, the usual variety suited for the Aman season, without worrying about the consequences. As a adaptive action, 17.6% transplanted late to avoid peak flood season, while in anticipation of late flooding 13.2% transplanted earlier than usual.

Flood response in cropping reportedly is completely changed when anticipated floods do occur in the locality. Once the land has been affected by flood, over 45% of the respondents reported that they waited for water to recede and then purchased seedlings from the local market and transplanted the seedlings. About 38.5% of the respondents reported that they prepared their seedbeds in relatively high lands, which were flood free, while 14.9% informed that they waited for water to recede and then transplanted the seedlings. During the PRA it was revealed that, only the well-to-do families could prepare seedbed on highlands and avoid flood vulnerability. It was informed that, flood free lands were highly priced and poor farmers could not afford to own such lands. Therefore, the option of preparing seedbeds on flood-free high lands was limited to relatively wealthier farmers.

The people did not hear about the crop insurance. However, after being briefed about the benefit of the crop insurance people expressed their willingness to pay premiums. However, they have very limited ability to pay in order to generate an effective demand for such insurance.

From the group discussions with local residents it came out that the people has remarkably coped with the loss in agriculture sector by changing the cropping pattern. They have started to depend on the winter crops which is cultivated through extensive irrigation and least depend on the Aman rice. However, they did not abandon the aman rice cultivation as they can get a good production if there is a normal flood or the flood recedes early i.e. by mid August.

3.1.2 Livestock and fisheries

Vulnerability
The survey results indicate that the livestock are highly vulnerable to the severe flood situations. In such a condition almost all the land areas including the houses are inundated. As a result the livestock had to stay in the water due to which the cattle and goat heads are lost or also fall sick. The animal feeds and the fodders are damaged by the floods which causes the animals to starve. People generally find it difficult to safeguard the animals and the animal feeds during such high intensity floods when their own life and properties are at stake.

Apparently, from the survey it was found that vulnerability of poultry was the highest among the livestock types. About 100% of the respondents reported that their poultry died during the floods due to various reasons related to flood.

The fish stocks are lost from the cultured ponds as the ponds are washed by the high floods.

Adaptation and Coping

When the respondents were asked what did they do to safeguard their livestock and other sources of income, the majority of them (54.4%) replied that they relocated their livestock to safer places in the neighbourhood. Figure-4 describes their other responses graphically. The graph shows that 22% changed feed and 14% sold their animals. Only 9% responded that they sold the vegetables and 1% caught the fishes.

The safeguarding of the livestock depends on the overall coping of the floods which largely depends on the economic condition of the inhabitants.

3.1.1 Impacts on livelihood and coping mechanism

The high floods cause extreme sufferings to the lives of the people and domestic animals and poultry. For them survival becomes a question. Some are stuck in the ocean of water for a number of days waiting for some one to come for rescue and give shelter and relief. In the island areas and in the areas where erosion is dominant, the houses and lands are eroded away seldom causing casualties of lives of human and animals. During severe floods, the houses are inundated and many of them are damaged. The food reserves and other belonging of the dwellers are also damaged. They suffer from the lack of food, potable water and various diseases. The poor section of the dwellers is more vulnerable to the severe floods. These are the general picture of flood impacts on livelihood.

The severe floods like those of 1987, 1988 and 1998 inundated almost whole area of SHU including the dwelling houses. The strong floods have damaged lot of houses. People have lost houses including the land due to river erosion, a process that is very active during and after the flood. 84% respondents reported that they suffered due to destruction of their land. The economic activities have almost stopped and they had to take shelters on safe places. Those who did not suffer major losses reported that they had increased the plinth-height or built their houses on stilts. Some people dismantled their houses and shifted to safer places (Figure 5) and rebuilt after the flood had receded. Some people did not leave their houses and had prepared temporary shelter on the raised platforms or lived on boat, but the female and child members were shifted to the relatives who were not affected.

The dwellers have reconstructed or repaired their houses after the recession of the flood water. Of those who suffered losses due to destruction of dwellings only 26.6% (59 households) could use their own resources to rebuild the damaged dwellings. Figure shows the means how they arrange their own resources. About 19% (i.e. 42 households) could arrange half the amount needed to rebuild their houses from their own income.

When asked whether the respondents needed to rebuild their dwelling(s) following the past high intensity flood, to over 80% of the respondents the answer was affirmative. Of those who suffered losses due to destruction of dwellings, only 26.6% (i.e., 59 households) could use their own income to rebuild damaged dwellings. Figure 6 shows the means how they arrange their own resources. About 19% (i.e., 42 households) could arrange half the amount needed to rebuild their dwellings from their own income. About 73% of the respondents (i.e., 219 households interviewed) reported that they borrowed money from various sources to rebuild their dwellings. This reflects high vulnerability of the people in the area due to damaged dwellings. This also reveals that, they usually find institutions and neighbours to borrow money from. About 24.3% of the respondents totally depended on borrowed money to rebuild their dwellings. About 13.5% of the respondents borrowed money with a promise to pay interests. Only 4 households (1.8%) reported that they received micro-credit, a proportion of which was used to rebuild their damaged dwellings.

In addition to arrange credit, a host of other measures were taken by the respondents for reconstruction of damaged dwellings. Figure-6 shows relative shares of the various responses. Among the well-defined responses, the most preferred response was to sell extra labour, while the second most important category was to sell out livestock and other valuables. About 10.1% of the respondents leased out their croplands in order to rebuild their damaged households.

The flood affected people suffered acute scarcity of food, potable water, fuel and medicine. They receive some relief, which is not adequate for survival.

The flood water is highly contaminated with diseases. In normal time, people use the ground water obtained through tube wells. In the severe flood situation most of the tube wells are sunk under water and the tube wells become contaminated. The availability of potable water becomes a major difficulty to most of the respondents. Figure 7 shows how a flood victim is swimming across the flood water to fetch potable water.

Inadequacy of potable water causes health hazards in the form of diarrhea, skin diseases, typhoid and many other infective diseases. Though most the households collects the drinking water from the tube wells which had not been affected but keeping in contact with the flood waters around them ultimately might affect their health.

The transportation system is seriously affected as the roads, railways and bridges are inundated and damaged. People mainly use boats for their short distance transportation.

Permanent out-migration
In response to a question regarding permanent out-migration as a response to avoid floods, 53.7% of the respondents (n = 299) reported that their neighbours out-migrated from the

area. However, 46.3% of the respondents could not recall such incidents. In the PRA, people opined that permanent out-migration was regarded as the least preferred option. It was also revealed that usually the poorest use to opt for such an extreme response and local people find it derogatory. Mr. Abdul Matin (27) said "…if someone fails to find any way to survive and loses everything in order to pay off loans and interests, what choice does he have other than relocation? If that comes to me, I do not see any better choice. I can still use my physical labour to earn a living in big cities". The elderlies, however, did not prefer to leave their ancestral villages.

Mr. Shahidullah, a well to do farmer said that he has shifted his house thrice because of erosion. He prefers to live in the locality in spite of the risks of floods and erosion as he has landed properties in and around. Some of his lands once eroded long time back has been accreted as islands, which are now being used for agriculture. So he has no alternative but to reside in that locality.

The erosion causes irreversible damages on the economy and livelihood of the people. The relatively poor people after losing their cultivable lands and dwelling houses through erosion can not withstand the losses. They are gripped by severe poverty and move mainly towards the cities in search of the fortune. From the above it is revealed that river erosion has severe impacts and long term adverse consequences on the society.

Flood forecasting and warning

Flood forecasting and warning is an important part of the adaptation and coping mechanism against the flood disaster. It came out from the questionnaire survey that people are not aware of the flood warning. This is contradictory of the reality as BWDB is operating a very strong and well equipped Flood Forecasting and Warning Center. To further clarify the people's perception the question asked during our visit to the local people whether they are aware of the flood warning served by the government, their answer was affirmative. When asked whether this warning is useful and how they are useful, they replied that the flood warning is useful because they come true most of the time. The warning generates the mental realization of a probable flood, which gives opportunity of preparedness to the extent possible. The warning is useful at different stages of the flood. Most people have access to radio and TV and listen to the flood warning bulletin.

4.0 A synthesis of present adaptation capacity and future potential

The vulnerability to droughts has been adapted to a great extent in the agriculture sector through ground water irrigation. There are some irrigation projects which are using the river water for irrigation. The surface water irrigation is expected to intensify through constructions of damns and storing monsoon rain water. Presently, the agriculture sector uses the largest amount of the water. It is recommended that crops requiring low irrigation may be introduced in the future for conservation of both surface and ground water. The crop insurance would be another coping mechanism, however, the limited financial capacity would restrict the poor people to adopt the insurance protection to the crop damages.

The adaptive capacity of the people to the severe floods depends on the economic condition of the people. The experience of the field survey depicts that quality of the dwelling houses of most of the inhabitants are poor which implies the extreme poverty situation of the area. The other flood prone areas of Bangladesh have similar economic pattern. The adverse impact of the recurrent floods is one of the most vital causes of such poverty. Thus people of the flood prone areas as also in the SHU have in general poor adaptive capacity.

In spite of the above, the people have successfully adapted in the flood time agriculture to some extent by adjusting the planting of Aman rice with the recession of the flood water. In anticipation of the flood, they wait until the flood is over for planting. In anticipation of late flooding, some farmers plant the rice at an earlier time. As the seed beds are damages due to the floods, as an adaptive measure the seed beds are done on a relatively higher lands which are not affected by flood. They also buy the seedlings from the market. Thus adequate supply of seedling is required. In case of severe floods, the seeds to be used for agriculture in the next season are damaged. So, the farmers with the help of the local administration will have to make some adaptive measures to save these seeds. It is known that the government provides assistance for recovering the losses through agricultural rehabilitation programs. The crop insurance would be another coping mechanism; however, the limited financial capacity would restrict the poor people to adopt the insurance protection against the crop damages.

The people have coped with the floods also by producing more crops in the following dry period which is not affected by flood. Since the winter and the following post-monsoon season do not have adequate rainfall for producing rice, the surface and ground water irrigations are extensively used for producing the Boro rice. The expected rise of the rainfall in the winter and pre-monsoon seasons will help crop cultivation during this period, but the risk of inundation of the rice crop in the month of May due to pre-monsoon flooding may increase. The Boro rice may escape such vulnerability by planting the crops in January and harvest by April. It is seldom found that the Boro rice being matured in April and May stands on the field up to the end of June due lack of manpower for harvesting. Thus there is a crop loss and degradation of the crop quality for late harvesting. As a result, suitable mechanized harvesting technology is to be introduced so that timely harvesting may be performed to save the crops from pre-monsoon flooding.

The Aus rice which is grown during the period from April-July are seldom found to be damaged by the pre-monsoon or early monsoon floods. The analysis of temporal data of Aus rice shows that the area of Aus rice cultivation has been rapidly decreasing. Thus the cropping pattern is being changed as adaptive measures against floods.

The dwellers suffer most due to the inundation and destruction of their houses and damage of the food and other essential household goods.

The construction of the dwelling houses on strong structures and over the high plinth-height would reduce the sufferings to some extent. Raising the land levels of the yards above the flood level and then build the house would be a sort of permanent solution when not only the dwellers but also the livestock would be safe. But at present very few people have that capacity.

The floods visit more frequently in the lower floodplains which are relatively close to the river banks or in the islands inside the rivers. The erosion is an additional feature along with the floods which affect the people. The loss they suffer from the riverbank erosion is not recoverable because all physical properties including the land are lost. The process makes the poor even poorer. The effective poverty alleviation programs may help these people to enhance the adaptive capacity to the natural calamities including the floods. Here, the lesson learned from the farmer, Mr. Asadullah of the SHU may be mentioned. Mr. Asadullah lost his house thrice due to erosion and lot of agricultural lands has been eroded. But because, he is a rich farmer, he has the adaptive capacity because of which he was able to tolerate the losses and is still doing quite well.

5.0 Present and Future Policies

Severe floods of increasing intensity are supposed to be the major water related climate change vulnerability in Bangladesh which causes immense sufferings of the people and economy. The overall poverty situation of the country limits the individual's adaptation capacity. On the other hand, destructions and damages caused by the floods and associated riverbank erosions causes the poor to become poorer. Since, the poor section of the society is more vulnerable and has low adaptive capacity, the first and foremost policy of the government and the development partners should be to improve the socio-economic condition of the people. The government in fact has given priority on the population control, development of manpower, education and health care facilities including rural sanitation and socio-economic development aiming at poverty alleviation.

The government has enhanced the weather and flood warning and dissemination system which is being continuously upgraded with the advancement of technology. The flood prediction system provides 72 hours advance prediction, which is a good enough lead time for short term disaster preparedness for the flood vulnerable people. The existing flood models are run using the DEM generated from the low resolution elevation data captured in the early sixties. As we know that Bangladesh is an active delta of the GBM river systems which (rivers) carry enormous suspended sediments while flowing to the Bay of Bengal. The sediments are deposited at various places of the flood planes and in the estuaries. There are accretions, erosions and changing of the morphological patterns and topographic heights. Thus it is high time to capture most up-to-date elevation and morphological data. Such data would improve the performance of the flood prediction model and will support the development plans especially the flood mitigation measures through engineering structures. The up-to-date knowledge of elevations are essential for undertaking the flood adaptation measures. The plans are being formulated to prepare up-to-date DEM. It is envisaged that the models are to be made capable to capture the sedimentation and morphological change patterns for a longer time to generate the future scenarios of the respective parameters along with the mapping of the flood vulnerability.

The long-term preparedness and adaptation policies should be developed based upon the vulnerability study using the carefully generated climate change scenarios.

The government has taken adequate response to the possible climate change impacts, vulnerability and adaptation. A number of studies have already been completed on climate change issues and the government has already submitted its Initial National Communication on Climate Change to United Nations Framework Conventions on Climate Change (UNFCCC).

Government has developed several plans, policies and legislations to environmental conservation and resource management, however, these plans, policies and legislation should include climate change components. Bangladesh Government has worked out the National Action Plan for Adaptation (NAPA) of the Climate Change and a project is presently being undertaken in the country. At the same time, another project is going on with the title of Comprehensive Disaster Management Project (CDMP) which has a climate change component. The government has implemented a number of programmers to assess the GHG emissions and reduction of the emissions. The banning of the vehicles with two stroke engine, introduction of CNG run vehicles, banning the transports older than 20 years, extensive aforestation programs and awareness generation activities are the major success of Bangladesh in the climate change mitigation plans.

The government along with NGOs undertakes the required measures to assist the flood victims with food, medical care and emergency shelters. The Vulnerable Group Feeding Program undertaken by the government helped the people to survive during the past severe floods; as a result, the casualties were very low.

The floods have been mitigated at various basins using the flood embankments. However, breaching of the embankments due to lack of their maintenance creates more hazardous flood. The dredging of the riverbeds and the canals are very important to maintain the natural flow patterns of the drainage system and for quick drainage of the floodwater. This will effectively reduce the flood vulnerability.

6.0 Conclusions

The results of the study indicate that strong warming at the rate of $0.16^{o}C$ / decade has occurred over Bangladesh during the recent decades. The rainfall was found to increase over most parts of the country except the southeastern side where a decrease of rainfall has occurred during the period 1961-2000. The pre-monsoon and monsoon rainfall has increased by about 20 over the northern Bangladesh during the last 30 years.

The increased frequency and intensity of the severe floods of Bangladesh since 1974 is perhaps related with this increase of rainfall over the catchments of GBM river systems. The vulnerability of the events of severe floods and the coping mechanism have been studied with respect to the SHU situated in the northern part of Bangladesh to the left bank of the river Barahmaputra (locally known as Jamuna). Most of the areas of the SHU is highly vulnerable to severe floods. The outputs of the regional climate model HadRM2 show that the SHU and the surrounding areas would be warmed by 1.4 and 1.8^{o}C by 2020 and 2050 respectively relative to 1990. The annual rainfall is expected to increase by 9.1% and 27.7% for the above two time levels. The rainfall is supposed to increase by 26.6 and 70.4 % for 2020 and 2050 in the pre-monsoon season and by 4.2 and 9.7% in the monsoon season. The SHU and the country as a whole would be vulnerable to more severe flooding in the future due to anticipated increase of rainfall.

The results of the socio-economic study over the SHU indicate that the economy of the SHU is mostly agriculture based. The people have wonderfully coped with the flood in the agriculture sector. They cope with the flood by adjusting the planting or replanting of the crops with the recession of the flood water. The seedbeds are produced in the high lands which are not affected by floods. Besides, the farmers have given more attention towards dry season cropping through mass-scale irrigation using mostly the ground water. This has relieved the farmers from the dependency on aman rice which is vulnerable to severe floods.

People suffer most due to inundation of their dwelling houses. The houses, which have week structure, are damaged due to the onrush of floodwater. The stored food, seeds, animal feeds and other belongings are also damaged. The livestock and poultry which are integral part of the house-hold economy also suffer. The affected people take shelters to safe places under the supervision and guidance of the local administration and community workers. The poor people are most vulnerable to the impact of floods. They suffer from lack of food, health care and security. The government feeds these people through VGF program for their survival. The doctors and health workers are sent to the affected areas for health care. People rebuild their houses partly or fully using their own resources or taking loans.

To build houses on high plinth height or on stilts is an important coping mechanism. The most appropriate coping mechanism would be to build houses with strong structure on the lands whose levels are raised above the highest flood levels so that the flood water does not inundate the lawn areas of the house. Such coping requires lot of resources, which are not available with the poor people. The coping capacity of the people thus depends on the socio-economic conditions. Since majority of the population of the country live below the poverty level, it is necessary to take the appropriate steps for alleviation of the poverty which will enhance the coping capacity of the people to the disasters such as flood.

Bangladesh has an efficient flood forecasting and warning system. The forecasting and warning of the floods was found to be highly useful to the people for coping the flood impacts. It is recommended that the flood forecasting and warning system be further improved.

The paper has given a compressive description of the present adaptation policies for adaptation to the climate change induces impacts.

The attached figures show the project area and the coping mechanism adopted by flood-affected people in Bangladesh.

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