Chapter 15
Climate Change and its Impacts on the Livelihoods of the Vulnerable People in the Southwestern Coastal Zone in Bangladesh

Md. Afjal Hossain, Md. Imran Reza, Sania Rahman and Imrul Kayes

Abstract Bangladesh is globally considered one of the most vulnerable and exposed countries to climate change (Climate change and Bangladesh Department of Environment, Government of People' Republic of Bangladesh. Climate Change Cell, Dhaka, 2007). There is evidence of prominent increases in the intensity or frequency of many extreme events such as flood, land erosion, heat waves, tropical cyclones, intense rainfall, tornadoes, drought, storm surges, salinity intrusion, etc. which cause loss of livestock, damage to pasturelands, increase fodder scarcity, destroyed shelters, decreased production, increased management costs to incidence of diseases, etc. in Bangladesh. This paper therefore intends to do three things: (1) it shall identify the extreme climatic hazards, vulnerabilities and risks; (2) it shall find out the impacts of climatic hazards on the livelihood of the vulnerable people; and (3) it shall propose some possible strategies for reducing the vulnerability to the climatic hazards. The present paper is intended as a concept paper to deal with the impact level assessment on livelihoods due to climate change. The method has followed both qualitative and quantitative approaches in the southwestern coastal zone in Bangladesh and used secondary data and information. The livelihood and income of a large population depends on the natural resource base and most of the poor people often live in marginalized lands and areas more prone to natural disasters. Climate change means that many natural disaster-prone areas will become more prone due to increased frequency and intensity of disasters. Drought-prone areas will become hotter and drier, with less predictable rainfall; flood frequency and intensity along onset and recession will be changed in future; the nature of cyclone and storm surges will be different from the historical trend. All of these together will change crop yields and affect many poor people's livelihoods. Agriculture yields have been decreased and cropping pattern has been changed in recent years. Adverse

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impacts of climate change are likely to reduce availability and deteriorate quality of water for domestic use. Moreover, climate change is likely to increase the prevalence and infection of vector- and water-borne diseases such as malaria and dengue fever, cholera and dysentery, etc. Degradation of biodiversity will reduce the availability of many traditional medicines which may affect poor and rural people who depend more on natural resources for medicine as well as income and food. Sea level rise (SLR) will drastically affect the poor people who are in coastal area and flood plain zone in Bangladesh. However, many actions undertaken to address the baseline or contextual risks in Bangladesh are also synergistic with the so-called adaptations that might be required as climate change impacts manifest themselves.

Keywords Climate change · Livelihood · Vulnerability

Introduction

Bangladesh is globally considered one of the most vulnerable and exposed countries to climate change (Climate Change Cell 2007). Bangladesh is geographically exposed to a multitude of adverse impacts of climate change, because of its location in the tropics, in the delta of three of the world's biggest rivers and its flat low-lying deltaic topography. The country has low adaptive capacity due to its extreme poverty (World Bank 2000). The Stern Review and IPCC 4th Assessment Report both state that climate change will have adverse impacts on people's health, safety and livelihoods, with the "poorest people in the poorest countries expected to suffer first and foremost". Predicted climate change will create barriers to future poverty reduction and reverse many of the important socioeconomic gains made by developing countries.

Sea level rise will affect the vast coastal area and low-lying river estuary zones of Bangladesh. The livelihoods of coastal communities and the natural environment of the coastal zones will be submerged by the anticipated sea level rise. The Mangrove forest locally called Sundarbans is the most important ecosystem of the country on which 10 million people's subsistence depends. People will be forced to move out from their homes, will have to take refuge on dry lands and change their way of earning (Sarwar 2008); this will result in a total change of their way of life.

There is evidence of prominent increases in the intensity or frequency of many extreme events such as flood, land erosion, heat waves, tropical cyclones, intense rainfall, tornadoes, drought, storm surges, salinity intrusion, etc. in Bangladesh. Such impacts pose additional risks for already vulnerable communities striving to combat poverty and achieve sustainable development. Therefore, climate change poses a serious and additional threat to the region's poor farmers and rural communities who live in remote, marginal areas. Impacts of such disasters range from hunger and susceptibility to disease, to loss of income and human livelihoods. Climate change is in fact emerging as the pre-eminent development issue in Bangladesh.

The present paper is intended as a concept paper to deal with the impact level assessment on livelihoods due to climate change, with both qualitative and quantitative approaches in the southwestern coastal zone in Bangladesh and the use of secondary data and information. This paper therefore shall do three things: (1) it shall identify the extreme climatic hazards, vulnerabilities and risks; (2) it shall find out the impacts of climatic hazards on the livelihood of the vulnerable people; and (3) it shall propose some possible strategies for reducing vulnerability to the climatic hazards.

Key Hazards, Vulnerabilities and Risks Due to Climate Change

Bangladesh is one of the poorest countries in the world and is a member of the least developed countries group. It has a population of 139.2 million (UNDP 2006), making it one of the most densely populated countries, and the present population growth rate is 1.7% in 2004. Though growth rate has decreased significantly, the high base population makes the need for development efforts that much more challenging. Climate change comes as an additional and huge burden on an already stressed economy and ecosystem. Bangladesh's geological and spatial location makes its highly populous and extended coastal lands and islands extremely flat, dynamic and vulnerable.

Current Climate

Bangladesh has a humid, warm, tropical climate. Its climate is influenced primarily by monsoon and partly by pre-monsoon and post-monsoon circulations. The southwest monsoon originates over the Indian Ocean and carries warm, moist and unstable air. Besides monsoon, the easterly trade winds are also active, providing warm and relatively drier circulation.

In Bangladesh there are four prominent seasons, namely, winter (December to February), Pre-monsoon (March to May), Monsoon (June to early October), Post-monsoon (late October to November). The general characteristics of the seasons are as follows:

- Winter is relatively cooler and drier, with the average temperature ranging from a minimum of 7.2–12.8°C to a maximum of 23.9–31.1°C. The minimum occasionally falls below 50°C in the north, although frost is extremely rare.
- Pre-monsoon is hot with an average maximum of 36.7°C, predominantly in the west for up to 10 days, very high rate of evaporation, and erratic but occasional heavy rainfall from March to June. In some places the temperature occasionally rises up to 40.6°C or more.
- Monsoon is both hot and humid, brings heavy torrential rainfall throughout the season. About four-fifths of the mean annual rainfall occurs during monsoon.

The mean monsoon temperatures are higher in the western districts compared to those for the eastern districts.
- Post-monsoon is a short-living season characterized by withdrawal of rainfall and gradual lowering of night-time minimum temperature.

Sea Level Rise

The SAARC Meteorological Research Council (SMRC) carried out a study on the recent relative sea level rise on the Bangladesh coast. The study used 22 years of historical tidal data from the three coastal stations. It is predicted that around 10% of the Bangladesh area will be inundated by 45 cm and over 21% of the country areas confined in the coast Bangladesh will be inundated by 1 m sea level rise (IPCC 2001). This will reduce agricultural productivity, alter livelihoods and risk food security and climate-induced marine migration. Put simply, 30 years of development investment will be wiped out by a 30 cm sea level rise.

Saltwater Intrusion

Changes in surface water salinity due to a 30 cm and 1 m rise in sea level were investigated by considering the topography and contours of the area and present streamflow patterns. Changes in the surface water salinity pattern due to a 30 cm rise in sea level revealed that the present dry season saline front (2 dS/m) is expected to move 30 km to 50 km north, affecting most of Khulna, Jessore, Barisal, Patuakhali and Noakhali (greater) districts and parts of Faridpur and Comilla districts. With a 1 m rise in sea level, the saline water front will move far north on the northeastern side of Bangladesh. Most of Jessore, Faridpur, Comilla and part of Dhaka (greater) districts will be affected by saline surface water intrusion. Most of Barisal, Patuakhali, Sundarbans, Bhola, Hatia and Sandwip will be directly inundated by saline/brackish water or will have a serious saline waterlogging problem. The drinking water supply of major cities such as Dhaka, Chittagong and Khulna will be affected by salinity. On the western side of Bangladesh, the saline water front will move close to Kushtia and Pabna districts. With a 1 m rise in sea level, it may be expected that cyclonic surges will penetrate further north into the country.

Increased Intensity of Extreme Events

The geographical setting of Bangladesh makes the country vulnerable to natural disasters. Every year, one or more natural calamities upset people's lives in some parts of the country. The major natural hazards include flood, cyclone and storm

Table 1 Historical record of cyclones formed in the Bay of Bengal

Year	Maximum wind (km/h)	Surge height (m)	Casualties	Year	Maximum wind (km/h)	Surge height (m)	Casualties
Nov 1904	62–88			Nov 1970	224	4.55	500,000
Oct 1905	62–88			Dec 1973	111	5.1	1,000
Sep 1919	120		3,500	Dec 1981	167	4.55	72
May 1923	89–117		6	Nov 1983	135	1.5	300
May 1926	89–117		2,700	May 1985	154	4.55	10,000
May 1941	89–117	3.03–3.64	5,000	Nov 1986	110	0.61	60
Oct 1947	89–117		500	Nov 1988	161	4.4	5,683
Oct 1960	129	6	9,450	Apr 1991	225	7.6	138,882
Oct 1960	193	6.6	5,149	Jun 1991	110	2.5	300
May 1961	161	5	11,468	Nov 1992	50		
May 1961	161	6.5		Apr 1994	210	4.85	184
Oct 1962	93			Nov 1995	210		650
May 1963	193	6	22,000	May 1997	230	4.55	155
Oct 1963	81			Sep 1997	150	3.05	67
May 1965	161	3.7	19,279	May 1998	150	2.44	
Dec 1965	184	3.6	3,000	Nov 1998	90	2.44	
Oct 1966	139	6.67	850	Nov 2007	220	4.5	3,000

Source: SMRC 2003 and Wikipedia

surge, flash flood, drought, tornado, earthquake, riverbank erosion and landslide. Floods and cyclonic storm surges are major killers, as well as being a cause of most direct and indirect impediment to economic development. Agriculture probably suffered more than non-agricultural sectors.

Increasing Cyclones and Storm Surges

One of the predictions of climate change is the intensification of extreme weather events such as cyclones and associated storm surges. The Bangladesh coast is vulnerable to recurrent cyclones. The increase in the intensity of wind velocity is expected to incur greater losses to vulnerable communities and ecosystems. The Bay of Bengal is an ideal breeding ground for tropical cyclones and depressions. The funnel-shaped configuration of the coastline of Bangladesh produces the catastrophic ravages of cyclones and storm surges. During pre-monsoon and post-monsoon periods, disastrous tropical cyclones form in the Bay of Bengal. In Bangladesh alone, about 40% of the total number of global storm surges are recorded. Over the last 30 years, different scales of cyclones have been affecting the country with loss of valuable lives and property. Table 1 shows that cyclones usually struck this country in the months of April, May and October, November and December (Fig. 1).

In the 1991 ‘‘super cyclone” (which was a storm of exceptional intensity with wind velocities up to 225 km/h), a large number of deaths occurred mainly in three

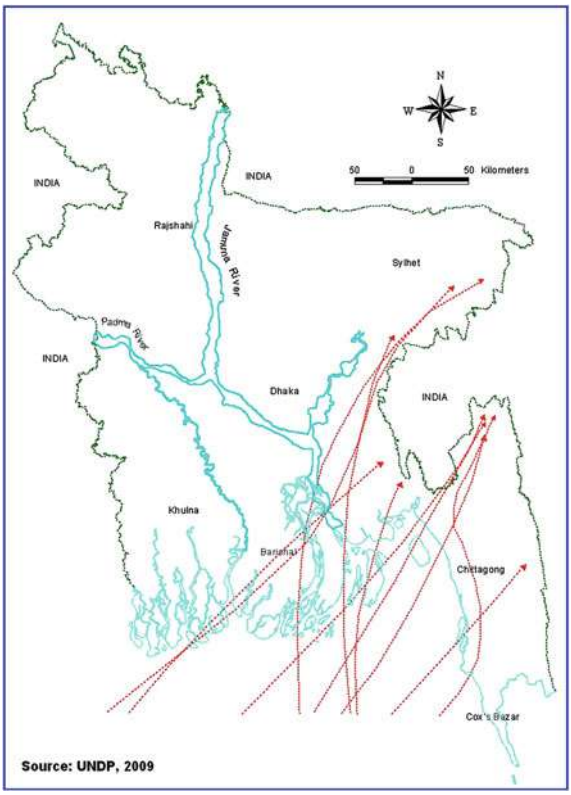

Fig. 1 Cyclone pathways in Bangladesh

coastal districts in Bangladesh: Chittagong (79,697 dead and 2,600 injured) Cox's Bazar (51,147 dead and 133,000 injured) and Noakhali (8,878 dead and 995 injured). The economic losses alone from the cyclone were estimated at US$2.4 billion. The loss of life was, however, substantially less than the 1.2 million people killed by the 1970 cyclone. The loss of human life further declined due to large investment and awareness-raising activities after the 1991 cyclone.

Climate Change Impacts on Coastal Flooding

The low-lying costal zone in Bangladesh is located between the extensive drainage network of the Ganges–Brahmaputra–Meghna river system on one side, and tidal and cyclonic activity from the Bay of Bengal on the other. The coastal embankments paradoxically also tend to block efficient drainage of freshwater on the other (land) side at times of excess rainfall and riparian flooding.

The increased snowmelt from the Himalayan permafrost, due to increases in temperature, will force more water to flow through the Ganges, Meghna, Brahmaputra river systems and their river networks. This will create additional

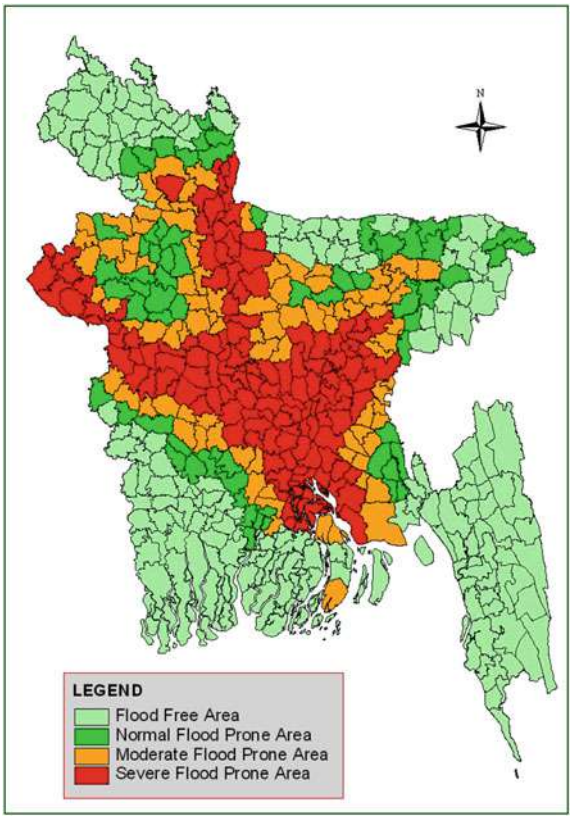

Fig. 2 Flood prone area in Bangladesh

flooding extending over the central floodplain of Bangladesh. Furthermore, the additional flow will bring with it sediments which will make the shallow riverbed even shallower. This will result in a lower capacity of the riverbed to flow out water rapidly, thus increasing the probability of enhanced flooding and erosion of riverbanks (Fig. 2).

Flood is a regular natural disaster occurring in Bangladesh, entailing huge damage to the economy. Four main types of natural floods occur in Bangladesh: (Table 2)

The devastating floods of 1987, 1988 and 1998 inundated more than 60% of the country. The 1998 flood alone caused 1,100 deaths, inundated nearly 100,000 km^2, rendered 30 million people homeless, damaged 500,000 homes and caused heavy losses to infrastructure. In 2004, floods inundated 38% of the country (MoEF (Ministry of Environment, Forest) (2005)).

But over the last ten years, the country has been experiencing early, late or prolonged floods. NAPA-Bangladesh has also identified the erratic behaviour of major disasters, including flood. About 1.32 m ha of cropland is highly flood-prone. Besides this, crops, perennial trees and livestock are damaged by flood every year. In two severe flood years of 1974 and 1987, the shortfall in production

Table 2 Different types of flood occurring in Bangladesh

Type of flood	Causes of occurrence	Time/duration	Tentative affected area
Flash flood	Runoff during exceptionally heavy rainfall occurring in neighbouring upland areas	Pre-monsoon months of April and May	The foot of the northern and eastern hills of Bangladesh
Rainwater flood/ Monsoon flood	Heavy rainfall occurring over floodplain and terrace areas within Bangladesh	April–May, June–August	In the southwestern part of the country
River flood	Snowmelt in high Himalayans, heavy monsoon rainfalls over the Himalayans, the Asam Hills, Ganges floodplains	April–May and June–September	Catchments areas of three major rivers
Coastal flood	In case of major cyclones the entire coastal belt is flooded. Coastal areas are also subjected to flooding	Tidal flood occurs from June to September	Southwestern coastal areas

Source: Ahmed 2006

Table 3 Broad adverse impacts of major floods during the last 50 years

Year	Impact
1954 floods	Affected 55% of country
1974 flood	Moderately severe, over 2,000 deaths, affected 58% of country, followed by famine with over 30,000 deaths
1984 flood	Inundated 52,520 km^2, cost estimated at US$378 million
1987 floods	Inundated over 50,000 km^2, estimated damage US$1.0 billion, 2,055 deaths
1988 floods	Inundated 61% of country, estimated damage US$1.2 billion, more than 45 million homeless, between 2,000 and 6,500 deaths
1998 floods	1,100 deaths, inundated nearly 100,000 km^2, rendered 30 million people homeless, damaged 500,000 homes, heavy loss to infrastructure, estimated damage US$2.8 billion
2004 floods	Inundation 38%, damage US$6.6 billion, deaths 700, affected people nearly 3.8 million

Source: MoEF (Ministry of Environment, Forest) (2005)

from the trend was about 0.8 and 1.0 million Mt of rice, respectively. During 1984, flood affected both Aus and Aman rice crops and the shortfall was about 0.4 million Mt. The following table shows major floods and its impacts: (Table 3)

Increased Drought

Drought is primarily an agricultural phenomenon that refers to conditions where plants are responsive to a certain level of moisture stress that affects both the vegetative growth and yield of crops. The farmers' concern on drought is when

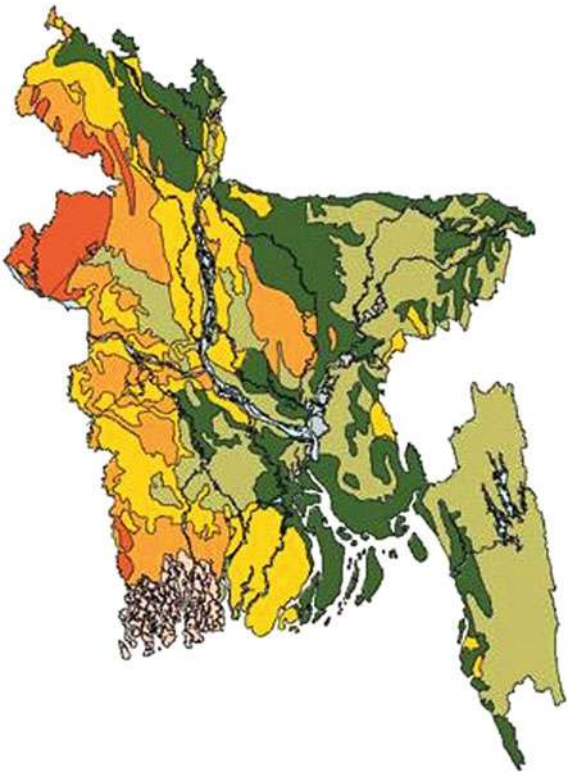

Fig. 3 Kharif drought (T. Aman) in Bangladesh

crop production gets hampered due to lack of rain and soil moisture. According to the local people of the drought-affected areas, the intensity and longevity of drought are increasing over time. The western part of the country is receiving less rainfall, averaging some 1400 mm as against the national average of about 2150 mm. As a consequence, susceptibility to and severity of drought in the western districts are much higher than elsewhere. Drought of different intensities in Kharif, Rabi and pre-Kharif seasons cause damage to 2.32 million ha of T. Aman and 1.20 million ha of Rabi crops annually. Yield reductions due to drought vary from 45 to 60% in T. Aman and 50 to 70% in Rabi crops in very severe drought situations. (Fig. 3)

Key Impacts and Vulnerabilities

The geographical location and socio-demographic features of Bangladesh make it one of the most vulnerable countries to climate change, variability and extreme events. Its long coastline, vast low-lying landmass, high population density and nature-dependant traditional agricultural practices would be impacted upon due to

climate change. It is likely that vulnerability of the disadvantaged and poor community would be worse than the non-poor and better-off strata of the society. The issue of climate change in relation to vulnerability and adaptation for Bangladesh has been assessed through several studies.

Crop Agriculture and Food Security

Various studies indicate that a temperature rise of 1 to 20°C in combination with lower solar radiation causes sterility in rice spike lets. High temperature was found to reduce yields of HYVs of Aus, Aman and Boro rice in all study locations and in all seasons. The effect was particularly evident at a rise of temperature by 40°C. Climate changes, especially in temperature, humidity and radiation, have great effects on the incidence of insect pests, diseases and microorganisms. A change of 10°C changes the virulence of some races of rust infecting wheat (DAE 2007).

The production of crops in Bangladesh is constrained by too much water during the wet season and too little during the dry season. Presently, the total irrigated area is 4.4 million ha which is more than 50% of the potentially irrigable area of 7.12 million ha cultivated area (DAE 2007). This area is being irrigated through surface and groundwater resources. As a result, the groundwater table in Bangladesh is declining at a rapid rate, causing STWs to become non-operational in many parts of the country during the dry period.

It was noticed that a temperature increase of 40°C would have a severe impact on food-grain production, especially for wheat production. On the other hand, carbon dioxide fertilization would facilitate food-grain production. A rise in temperature would cause a significant decrease in production of 28 and 68% for rice and wheat respectively (DAE 2007). Moreover, doubling of atmospheric concentration of CO_2 in combination with a similar rise in temperature would result in an overall 20% rise in rice production and 31% decline in wheat production (Karim et al. 1999).

The apparent increase in yield of Boro (dry season rice crop generally grown under irrigated conditions and including high-yielding varieties) and other crops might be constrained by moisture stress. It is feared that moisture stress would be more intense during the dry season, which might force the Bangladeshi farmers to reduce the area for Boro cultivation. A shortfall in food-grain production would severely threaten food security of the poverty-ridden country (Karim et al. 1999).

Under a severe (40°C temperature rise) climate change scenario, the potential shortfall in rice production could exceed 30% from the trend, while that for wheat and potato could be as high as 50 and 70% respectively (Karim 1996). Under a moderate climate change scenario, the crop loss due to salinity intrusion could be about 0.2 Mt (Habibullah et al. 1998). The loss of production due to such effects may be relatively higher compared to that under floods. The effect of low-flow on

agricultural vulnerability is considered to be much less intense compared to other effects. The ultimate impacts of loss of food-grain production would increase import of food which would require spending hard currency.

Livestock

In addition to affecting human beings, natural disasters cause tremendous sufferings for the livestock population of Bangladesh. Livestock suffer large-scale death in cyclonic storm surges (Haider et al. 1991). Prolonged flood can also cause death of livestock through a number of direct and indirect mechanisms (Ahmad et al. 2000). During droughts, livestock in Bangladesh do not suffer death, but lack of water increases their vulnerability to diseases. Since climate change would increase susceptibility to natural disasters, as mentioned in earlier sections, the anticipated toll on the livestock sector would be quite high (Ahmed 2005; GoB 2005).

The sufferings of livestock in the coastal zone are much higher than in other parts of the country. Field observations clearly suggest that livestock density is relatively low in the coastal areas, particularly in the southwestern parts of the country. The local elderly informed that gradual increase in salinity also increased competition for freshwater resources, and the livestock suffered the brunt of such a calamity (RVCC 2003). Animals used to have the least access to freshwater sources during the dry season. Due to drinking of poor-quality water, these animals fall victim to diseases, which reduce their economic efficiency (draught power, milk production, etc.). Lack of grazing land and the proliferation of shrimp areas are also identified as potential reasons for decreasing population of livestock in coastal areas. It may therefore be concluded that the livestock sector would also be vulnerable to the adverse impacts of climate change.

Coastal Zone

Several studies indicate that coastal zone vulnerability would be acute, due to the combined effects of climate change, sea level rise, subsidence, changes of upstream river discharge, cyclone and coastal embankments (World Bank 2000). Four key types of primary physical effects, i.e. saline water intrusion, drainage congestion, extreme events and changes in coastal morphology, have been identified as key vulnerabilities in the coastal area of Bangladesh (World Bank 2000).

The effect of saline water intrusion in the estuaries and into the groundwater would be enhanced by low river flow, sea level rise and subsidence. Pressure of the growing population and rising demand due to economic development will further reduce the relative availability of freshwater supply in future. The adverse effects of saline water intrusion will be significant on coastal agriculture and the availability of freshwater for public and industrial sectors will fall.

The combined effect of higher seawater levels, subsidence, siltation of estuary branches, higher riverbed levels and reduced sedimentation in flood-protected areas will impede drainage and gradually increase waterlogging problems. This effect will be particularly strong in the coastal zone. The problem will be aggravated by the continuous development of infrastructure (e.g. roads) further reducing the limited natural drainage capacity in the delta. Increased periods of inundation may hamper agricultural productivity, and will also threaten human health by increasing the potential for waterborne disease.

Impact on Mangrove Ecosystem

Sundarbans in coastal southern Bangladesh will be exposed to several of the above risks, particularly sea level rise, saline intrusion and intensive extreme weather events. Given enough time, the mangrove under threat and rapid change is expected to readjust and recolonize if space and time permit. But the demographic pressures in areas north of the Sundarbans would not permit the requisite space. The rate at which climate change-related sea level rise and saline intrusion is likely to take place is going to be much faster than the rate at which the mangrove ecosystem will be able to readjust. This will result in the reduction of species and biodiversity, as well as a decrease in the areas of the mangrove forest with all the concomitant consequences.

Settlements and Infrastructure

About half the population of Bangladesh falls below poverty line. Under the prevailing socioeconomic circumstances, it is easily understandable that the poor do not have good-quality houses. Moreover, natural disasters often take a huge toll on poorly built houses and sanitation infrastructure (Ahmad et al. 2000). Human settlements are, therefore, highly vulnerable to climate change-induced floods and cyclonic storm surges. Floods, especially the high-intensity floods, often devastate physical infrastructure such as road networks, educational centres, market places, administrative buildings, etc. (Nizamuddin et al. 2001; Siddiqi 1997; Siddique and Chowdhury 2000). The telecommunications network was torn off during the cyclone of 1991 and the entire coastal belt was disconnected for weeks.

Climate change-induced high-intensity events pose huge threats to existing physical infrastructure. Damage to national motorways due to flood alone is estimated at 1,011 and 3,315 km by 2030 and 2050, respectively. The corresponding damage to embankments is estimated at 4,271 and 13,996 km by 2030 and 2050, respectively. The aggregated damage figures for health centres and hospitals due to floods, cyclones, sea level rise and salinity intrusion is estimated at 1,682 and 5,212 km, respectively, for the above two time horizons (BRTC-BUET 2005).

Table 4 Relation between disaster and livelihood vulnerability

Type of disaster	Livelihood vulnerability
Flood	Reduce livelihood options due to loss of agriculture, illness, restriction of movement
Drought	Lack of job opportunity due to lack of agricultural activities, illness due to extreme heat, etc.
Cyclone and storm surges	Limited fishing time in the Bay, loss of life, and illness

Source: UNDP Human Development Report, 2007

Impact on Livelihoods

Whatever happens to the climate, and subsequently to various other sectors, is important, for the main reason that it affects the lives and livelihoods of the people. Climate change is expected to have major physical impacts on agriculture, industry, infrastructure, disaster, health and energy and consequently on people's livelihoods in terms of employment, income and consumption (including food security). Various groups in society will experience the impacts in various degrees depending upon their initial economic conditions (poor or non-poor), location (coastal or non-coastal, rural or urban) and gender.

The impacts on livelihood due to climate change depend on the nature and severity of the physical impacts relating to agriculture, water availability and quality, disaster-proneness, hospitability of the physical environment due to rising temperature and changing water regimes to pathogenic activity and coastal inundation. Climate change impacts on livelihood thus become a challenge of development under the most adversarial changes in dynamics of nature.

Part of the vulnerability will be due to water shortages for agriculture. But there are other areas where water-related vulnerability may increase. Some of this would be related to health and disaster. On the other hand, extensive waterlogging that is being experienced now may exacerbate, creating major problems for the livelihood of a poor person, all of whose land may be submerged permanently.

Both flooding and drought may increase in frequency. Particularly floods may be more devastating, creating major problems of livelihood and macroeconomic dislocations, slowing growth and pushing people down to the poverty line. Also, if cyclones and storm surges increase in frequency and intensity, the potential losses to life and livelihood would be most severe. The following table illustrates the relationships between different types of disaster and livelihoods (Table 4).

The health problems due to climatic factors, such as temperature rise and degrading water quality and shortage, will increase the likelihood of cholera, diarrhoea, dysentery, malaria and typhoid, and also involuntary foetus abortion, in the coastal areas due to rising salinity leading to hypertension. Increased food insecurity will exacerbate the problems further by causing more widespread malnutrition. Unfortunately, these are little calibrated or not enough to be superimposed on to socioeconomic trends to refine the livelihood impacts.

Taking a livelihood analysis approach to potential impacts of climate change, it is clear that the most vulnerable groups within each community are the poorest among them and even within the poor groups the most vulnerable are the women, children, elderly and the sick. It is therefore quite likely that the adverse impacts from climate change will fall disproportionately on these most vulnerable groups within the country as a whole, as well as within each vulnerable region of the country.

Vulnerability of Small Farmers in the Coastal Zone

A recent study on coastal area vulnerability and livelihood relationship revealed that physical or natural vulnerabilities are strong in regard to small farmer's livelihoods all over the coastal zone. Particularly cyclone/tidal bore, waterlogging/drainage congestion, various types of flooding, sand deposition and soil salinity became the major physical hindrances to farming and production. These are also found as the major causes of sudden crop damage to small farmers. Seasonal attack by rats and insects was another important vulnerability which led to massive crop damage in many districts.

Physical vulnerability varies across the coastal region. For example, in Khulna region, waterlogging, soil salinity, lack of cultivable land are significant; in Barisal, region tidal flooding, cyclone/tidal bore, salinity, siltation, rats/insects are found to be the most adverse physical or natural vulnerabilities; and in Chittagong region, cyclone/tidal bore, different types of flood, deterioration of soil fertility due to salinity are found to be the major physical vulnerabilities.

Wage Labour in the Coastal Zone

Rural wage labourers are more vulnerable to economic and social factors. Lack of employment opportunities and low wage rate seem to be the major vulnerability factors among the rural wage labourers. Physical vulnerabilities such as lack of cultivable land, climate change stress, etc. that has an effect on agriculture ultimately converts into lack of employment opportunities for the wage labourers (Fig. 4).

Changing Lives

Changes have already been visible in the fact that saltwater from the Bay of Bengal has penetrated inland along tributary channels. The impacts of these observed changes have been significant on agriculture, particularly on food production and security. Climate change here is a day-to-day reality, as it would entail an additional 17 million Bangladeshis being displaced from their homes and farms

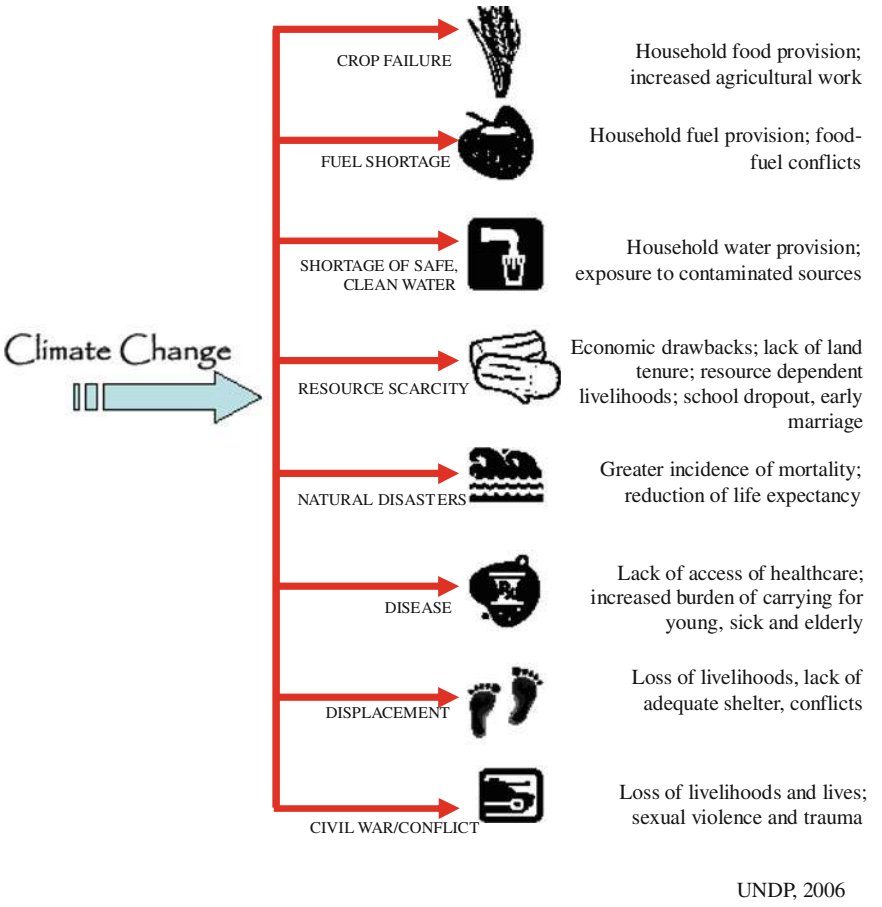

Fig. 4 Impacts of climate change on human security

by 2030 (UNEP 1989 in Sarwar 2008). Their lives would be plunged into darkness. These "climate refugees" would have to leave the region to find work in the cities in Bangladesh or neighbouring India.

Losing Livelihood: Gradually

The problem has been compounded because the flow of the rivers during the dry season has fallen, offering less resistance to the increasing power of the sea. With saltwater penetrating further inland and deeper into the groundwater, climate change is the root cause of the problems for gradually destroying from traditional cultivation and all available livelihoods. The mangrove forest is a breeding ground for fish, shrimp and crab, thus providing livelihoods for hundreds of thousands of people

living in the area. Among the other economic activities, collecting seed shrimps or fry shrimps is the main livelihood of many landless men and women. Collection of seed shrimps (*Panaeus monodon*) is one of the main sources of earning for the small and landless fishermen and women of this area. These shrimp larva are highly sensitive to the pH condition of water, which mainly depends on the salinity of water and temperature. Shrimps are destroyed by invaded saline water and also because they are losing their natural habitats as mangrove forest is being destroyed. Due to the reduced abundance of fry over the past several years and a shortening of the fry season, many fry collectors are moving towards alternative employment. This is the common story of thousands, as when one man found himself unable to feed his two children, he moved to Dhaka, the capital of Bangladesh, where he pedals a rickshaw tricycle through the heavy traffic and takes in a swelling slum.

Lost Livelihood: Sudden

A category four storm SIDR hit the Sunderbans and southwestern coast of the country on 15 November 2007. According to the Disaster Management Centre in Bangladesh, the cyclone resulted in severe damage and 3,363 deaths, 8.9 million affected people, 2,472,944 acres of crop damage and an estimated US$3.1 billion economical loss (GoB 2008). Spiral winds of 220 km/h with 5-m water surges devastated much of the country's coastal belt, leaving almost 1.5 million homes damaged or destroyed. The total value of damage to housing is BDT 57.9 billion (US$839 million), representing more than half of the total damage and losses of all sectors (GoB 2008: 17). Dwelling houses blew away, trees were uprooted, standing crops demolished, roads and livestock washed away. Almost one-third of the Sunderbans has been totally demolished. A large number of people who earn their livelihood by engaging in fishing or fish-related business have literally been made paupers. The landless men and women and fishermen have lost their boats and nets, the shrimp cultivators their stock of shrimp, and the fish traders their business. As many of the households had complex livelihoods before the cyclone, combining several overlapping activities, some were simultaneously affected by losses in crops, livestock, fisheries, commerce, industry or wage employment. The most vulnerable groups were landless labourers, and marginal farmers with very little land and no other sustainable source of income (GoB 2008).

The concomitant losses to livelihood, trade and industry in these costal communities have not yet recovered, as the BBC documented 100 days after the cyclone hit. The BBC interviewed one Union chairman (Union is the lowest administration in Bangladesh) in the southern community of the Sundarbans, who described their main problem is the homeless, as they lost homes and were forced to live in the open. Although the international community promised to build their houses, by that time they had not yet done it. There were no shops to buy foods, all having been destroyed. They had no food. They were forced to live on handouts. They had to wait until the next crop harvesting sessions.

Table 5 Causes of impacts, vulnerable areas and impacted sectors

Climate and related elements	Critical vulnerable areas	Most impacted sectors
Temperature rise and drought	Northwest	Agriculture (crop, livestock, fisheries)
		Water
		Energy
		Health
Sea level rise and salinity intrusion	Coastal area Island	Agriculture (crop, livestock, fisheries)
		Water (waterlogging, drinking water)
		Human settlement
		Energy
		Health
Floods	Central region Northeast region Char land	Agriculture (crop, livestock, fisheries)
		Water (urban, industry)
		Infrastructure
		Human settlement
		Health
		Energy
Cyclone and storm surge	Coastal and Marine zone	Marine fishing
		Infrastructure
		Human settlement
		Life and property
Drainage congestion	Coastal area Urban Southwest	Water (navigation)
		Agriculture (crop)

Source: UNDP Human Development Report, 2007

After one year following the cyclone, the BBC revisited the same area and were told by development workers in the area that around 80% of people were still living in tents or temporary dwellings. As the government decreed a ban on entering the forest, hoping for natural regeneration of the forest, people have not found their livelihoods. As fishermen lost their boat and nets, people were forced to change their occupation to one in which they had no competence, resulting in less income than before. Many have left for nearby cities and the capital to find work.

The point is the Sundarbans' great value was evident once again as it protected local communities from huge damage. In this case, the importance of the Sundarbans as a natural barrier to reduce wind velocities (protecting embankments and settlements) was evidenced (GoB 2008). The Sundarbans is Bangladesh's guardian angel as far as storms and tidal waves are concerned. If there was no Sundarbans, the cyclone would have caused more havoc in the southern districts.

Table 6 Intensity of impacts on different sectors due to climate change

Sectoral vulnerability context	Physical vulnerability context							
	Extreme temperature	Sea level rise		Drought	Flood		Cyclone and storm surges	Erosion and accretion
		Coastal inundation	Salinity intrusion		River flood	Flash flood		
Crop agriculture	+++	++	+++	+++	+	++	+++	–
Fisheries	++	++	+	++	++	+	+	–
Livestock	++	++	+++	–	–	+	+++	–
Infrastructure	+	++	–	–	++	+	+	+++
Industries	++	+++	++	–	++	+	+	–
Biodiversity	++	+++	+++	–	++	–	+	–
Health	+++	+	+++	–	++	–	++	–
Human settlement	–	–	–	–	–	–	+++	+++
Energy	++	+	_	–	+	–	+	–

Source: MoEF (Ministry of Environment, Forest) (2005)

Summary of the Key Impacts

From the above findings, the impacts of climate change and variability on biophysical systems and consequences are evident. It is also found that the coastal zone, northwestern zone, central region and piedmont plain are most susceptible to existing climate variability and anticipated future climate change. A summary of causes of impacts, vulnerable areas and impacted sectors are given (Table 5). Intensity of impacts on different sectors due to changes of vulnerability context is given in Table 6.

Adaptation Strategies for Reducing Vulnerabilities Due to Climate Change

A careful analysis of the above definitions suggests that all these refer to adjustments in a system in response to climatic perturbation, but they also indicate differences in scope, application and interpretation of the term adaptation. Adaptation can refer to climate change, to change and variability, or just to climate. Adaptation can be in response to adverse effects of climate variability and change, which refer to past, actual or anticipated conditions, changes or opportunities.

The implications of high-intensity floods cannot be overemphasized in Bangladesh. Management of floods in future will remain a major challenge, especially in view of further densification in increasingly flood-vulnerable lands (Ahmed et al. 1998). Community efforts to cope with floods can benefit tremendously from the issuance of early warnings. Improvement of the current flood

warning system and dissemination in a people-friendly manner are thought to be highly potential adaptation options for the future (Ahmed 2005).

Removal of impediments of drainage (dredging/re-excavation of choked rivers/khals, drainage canals), construction of drainage structures (culverts, bridges and regulators), rehabilitation of structures such as roads, embankments, etc. should be considered as adaptation measures towards facilitating drainage and reduce flood-related vulnerability (Ahmed et al. 1998). Pumping out water to remove water-logging, especially in polder areas, has already been practised, and is likely to be considered an adaptation option for the future. Multi-purpose cyclone shelters and flood shelters should be built in FVAs (Choudhury et al. 2003; GoB 2005). In recent years, community-based flood management practices had shown high potential, which could also be considered as an important modality to adapt to climate change-induced floods (Ahmed 2004).

For drought management, making water available to offset moisture deficit appears to be the major adaptation modality (Karim 1996). However, the creation and recreation of water storage systems (ponds, khals, reservoirs, etc.)—operated and maintained by vulnerable communities—needs to be given due emphasis (World Bank 2000). Capacity building for advanced irrigation techniques could also be considered as an important adaptation option in order to conserve available water resources. Resuscitation of surface water bodies including silted-up rivers and rivulets should be given due priority in order to maintain water bodies even during the dry season for irrigation purposes (Ahmed et al. 1998).

Deaths arising from cyclones and associated tidal bores (both human and livestock) could be minimized by maintaining the Cyclone Preparedness Programme, and further strengthening the programme by means of building new MCSs, killas and other facilities along the coastal zone (Mahtab 1989; Ali 1999). The polders which might be at risk of inundation due to rising sea levels and/or by invigorated tidal waves should be identified and rationalized, in order to enhance their efficiency towards safeguarding lives, crops and properties (Ahmed 2005). NAPA for Bangladesh proposed community-focused coastal afforestation as a priority adaptation measure to reduce climate hazards (GoB 2005).

In addition to adaptation in the water resources sector, one must consider adaptation in the agricultural sector. The gravity of the issue and its importance on people's livelihoods deserve special treatment, which is why the potential adaptation options in agriculture are discussed separately in the following section.

According to WB, the risk associated to human health in tropical developing countries is one of the salient risks of climate change (World Bank 2000). Bangladesh's current vulnerability to outbreaks of cholera and other waterborne and diarrhoea diseases such as dengue or dysentery needs to be given due importance in view of increasing risk potentials caused by climate change-induced drainage congestion and standing water. Treating pathogen-laden water with a mixture of lime, bleaching powder and alum, as provided in Ahmad et al. (2004), should be given due importance to avoid a large-scale outbreak of waterborne diseases. Inadequate provisions for drinking water in saline-affected regions add to people's vulnerability, which needs to be given high priority towards designing a

national adaptation programme (Ahmed 2005). Providing saline-free drinking water should be considered as an immediate adaptation in view of current as well as future health risks (Ahmed 2004). The pressure on the availability and access to safe water, in particular during the dry period, and the increasing reliance on groundwater are an additional threat.

Awareness needs to be increased among illiterate and poor people, especially along the drier western parts of the country, to combat heat stress-related health disorders. Improved cyclone and flood shelters, with increasing capacity and coverage, are likely to reduce overall death tolls in the case of climate change-induced high-intensity disastrous events. Similarly, building relatively stronger houses by low-cost retrofitting along the cyclone-affected coastal regions could save lives as well as assets (RVCC 2003). Safe use of carbolic acid would reduce susceptibility to snake bites in flooded regions. Use of oral rehydration saline for treating diarrhoea patients will continue to save lives. Another major adaptation proposed for human health involves improving the healthcare system, which is needed anyway to address the current human health situation. These improvements could significantly reduce the risks to human health from climate change (World Bank 2000). Thus, the benefits of improving healthcare are likely to be even greater when avoided health impacts of climate change are accounted for.

Conclusion

The livelihood and income of a large population depends on the natural resource base and most of the poor people often live in marginalized lands and areas more prone to natural disasters. Climate change means that many natural disaster-prone areas will become more prone due to increased frequency and intensity of disasters. Drought-prone areas will become hotter and drier, with less predictable rainfall; flood frequency and intensity along onset and recession will be changed in future; the nature of cyclone and storm surges will be different from the historical trend. All of these together will change crop yields and affect many poor people's livelihoods. For example, the 2007 floods inundated 32,000 km^2 in area, destroying over 85,000 houses and destroying or partially damaging approximately 1.2 million acres of crops. Total estimated loss was over US$1 billion.

It is likely that natural disasters will damage more houses and will cause temporary migration. It may also require children to help more with household tasks, leaving less time for schooling. Malnourishment and diseases also impair learning. Extreme climate change-related disasters threaten school buildings and educational materials. For example, cyclone Sidr caused huge damage to school buildings and wiped out teaching materials.

Adverse impacts of climate change are likely to reduce availability and deteriorate quality of water for domestic use. Direct climate change effects include increases in mortality and illness associated with heat waves, particularly among

the elderly and the urban poor. Women and children are particularly vulnerable to extreme weather events. For example, when the 1991 cyclone hit Bangladesh, 90% of victims were women and children.

Climate change is likely to increase the prevalence and infection of vector- and waterborne diseases such as malaria and dengue fever, cholera and dysentery, etc. Children and pregnant women are particularly susceptible to such diseases. Climate change will probably cause a decline in the quantity and quality of drinking water, which is a prerequisite for good health. Malnutrition, the main cause of ill health among children, could also be exacerbated due to declining natural resource productivity and inadequate supply of food.

Changes in temperature and rainfall distribution, and sea level rise and salinity intrusion are likely to change ecosystem characteristics and shift ecosystem boundaries. Climate change also poses a greater survival threat than the destruction of many natural habitats including coral reefs. Degradation of biodiversity will reduce the availability of many traditional medicines which may affect poor and rural people who depend more on natural resources for medicine as well as income and food.

Sea level rise (SLR) will drastically affect the poor people who are in coastal areas and floodplain zones in Bangladesh. The disasters of climate change are somewhat obvious. It is already visible in the costal area in this delta. Climate change is not some "distant fury"; its widespread consequences are already being felt in costal areas especially among local communities around the Sundarbans with livelihood losses caused by gradual and sudden climatic changes. It is not a matter of the distant future. Climate change has effects on living conditions in ways that violate human rights. The lives of millions have changed due to global warming. Especially in these local communities, climate change has had multiple consequences on the mangrove forest. The mangrove forest in the Sundarbans is linked with millions of people's livelihoods. Their livelihoods have been destroyed by climate change-induced natural hazards. Climate change is not only destroying the mangrove forest, it affects the Sundarbans ''ecological services".

Many projected climate change impacts, including sea level rise, higher temperatures and evapotranspiration losses, enhanced monsoon precipitation and runoff, potentially reduced dry season precipitation, and an increase in cyclone intensity, would in fact reinforce many of these baseline stresses that already pose a serious impediment to the economic development of Bangladesh. By the same token, many actions undertaken to address the baseline or contextual risks in Bangladesh are also synergistic with the so-called adaptations that might be required as climate change impacts manifest themselves. With regard to structural adaptations, such as coastal embankments and salinity reduction, even though it is true that many of these measures have already been integrated in development projects and policies in Bangladesh, there remains an ongoing challenge with regard to their durability and sustainability. Structural adaptations therefore need to be matched by efforts to facilitate financial and institutional adaptation—sustained interest on the part of the government and donors, and the participation of local populations to help monitor and maintain infrastructural projects.

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