Global Warming Induced Extreme Weather Conditions and the Threats to Livelihoods in the Bay of Bengal Delta

Moazzem Hossain and Anthony Selvanathan

Abstract

While the nations of the Bay of Bengal delta have been making progress in the early part of the 21st century, there have emerged new challenges. The most important among these is global warming and its impacts on the livelihoods of millions in the delta. It is now widely recognised that the South Asia region, in general, and the coastal belt of the Bay of Bengal (southern parts of Bangladesh, West Bengal and Orissa), in particular, would suffer heavily in socio-economic terms from global warming. The Copenhagen summit (COP15) in 2009 has identified Bangladesh as one of the most vulnerable countries (MVCs) in the region. Thus, the paper examines three major areas of weather and weather related extreme conditions: rainfall, temperature, and sea water surge due to cyclonic storm and sea-level rise. With this bleak picture in hand, the paper attempts to investigate extreme weather conditions in the Bangladesh part of the Bay of Bengal delta over 1960 and 2009. Using historical evidence, these conditions will be analysed and their impacts on agriculture and fisheries will be examined.

Keywords: Global warming, threats, livelihood, Bay of Bengal delta

I. INTRODUCTION

According to the World Bank, South Asia’s poorest of the poor are most at risk due to global warming. In particular, almost 30-40 million people of the coastal belt of the Bay of Bengal will suffer from inundation by 2030 [25]. Stern [24], is of the view that even a moderate rise in temperature could cause serious changes to the environment in South Asia. Stern led the ‘Stern Report on the Economics of Climate Change’ commissioned by the UK Treasury and released in October 2006. Moreover, according to Oxford University climatologist Mark New, over the past 30 years snow cover and ice cover may have been reduced by 30 per cent in the eastern Himalayas. There is now a real risk that these glaciers might disappear altogether in the coming decades. If this happens, Bangladesh’s mighty rivers originating in the eastern parts of the Himalayas would be affected severely.

The onslaught of global warming induced extreme weather conditions on the Bay of Bengal delta have been studied by various authors in the past. However, major studies had been conducted in this area with international participation based on Bangladesh-wide data. Among these, the following observations are of importance: Bangladesh will receive heavier rainfall during the monsoon because the rate of evaporation is expected to increase by up to 12 per cent. Mean monthly rainfall may significantly change over current variability. Monsoon rainfall may increase by 11 per cent by 2030 and 27 per cent by 2070. Due to global warming, over the past 100 years temperature has increased by 0.50 degree Celsius but in the next 50 years, that is, by 2050, the temperature in Bangladesh is projected to rise by 1.5 to 2.00 degree Celsius [1, 11].

A number of studies have found that high temperature would reduce the yields of high-yielding varieties (HYVs) of rice over all seasons throughout Bangladesh. A recent study revealed that a 60 per cent moisture stress on top
of other effects might cause as much as 32 per cent decline in Boro (winter) rice yield. A quarter of the country’s landmass is currently flood prone in a normal hydrological year, which may increase to 39 per cent, and prolonged flooding can effectively reduce overall potential for HYV Aman (summer) rice production. Global warming will make tropical cyclones and tornadoes in Bangladesh stronger and more frequent. The frequency of recent cyclones, Sidr in November 2007, Aila in 2009 and Nargis in southern Myanmar in 2008 have drawn world-wide attention to the destruction they caused for lives and properties in recent years [22, 6].

It has been thus recognised by the international donors of Bangladesh that out of its 150 million people more than 30 million are likely to be affected directly by global warming in the next 30 years [25]. In this paper, therefore, our major aim is to investigate the extreme weather conditions experienced in recent years and their socio-economic impacts in the Bay of Bengal delta. Before attempting this, let us review a few global and regional studies that have been carried out in recent years.

II. EARLIER STUDIES

It is now widely recognised that the coastal regions of both developed and developing world would suffer heavily, both in economic and social terms, from frequent natural hazards due to the direct impact of extreme weather conditions and rising sea-level. It has been noticed that in recent years sea-level rise, frequent storms and cyclones and erosion have taken a serious turn in coastal regions all over the world. The threats from rising sea level and other climatic hazards are now genuine whether the people live in the small island nations of the South Pacific, African coasts or Bay of Bengal delta [10]. It is important to investigate the impact of recent climatic hazards on the livelihoods of coastal people. Presently, there are three major methods available to measure socioeconomic vulnerability from climate change and from other catastrophes: these are economic, environmental and institutional methods see [12] for economic method; [3] for environmental approach; and [19] for institutional method.

The Bay of Bengal delta is known to be one of the vulnerable regions of South Asia. This region is also identified as the most vulnerable region on earth due to climate change by the Copenhagen Accord, 2009. Bangladesh and West Bengal (India) are located at the confluence of the Ganges, Brahmaputra and Meghna (GBM) river systems which collect water from the Himalayas and north-eastern hills of India. The Ganges runs in a catchment area of 1,087,000 sq. km, Brahmaputra has 552,000 sq. km and the Meghna 82,000 sq. km [11]. Metcalfe [14] states that, the Bangladesh landscape is a flat to gently undulating delta flood plain with a network of river systems. More than half of the delta plains is at elevation of less than 10 m’ (p. 301). The southern coastal region forms part of the largest mangrove forest complex called Shundarban (listed as a World Heritage Area). This mangrove forest is bordered by West Bengal in the west and Bangladesh in the east. Natural resources of this region include abundant summer freshwater, alluvial land, sweet water and sea fisheries, forests and wild-life. The huge and rapidly expanding population of this region places an immense pressure on the natural resources and on the environment.

The sea-level along the Bay of Bengal coast-line is currently rising by 3 mm per year. Catastrophic rainy monsoons, which previously occurred in only every half a century, on average are now occurring every 10 years or even more frequently [16]. Increasing devastation from cyclones has also increased with rising sea-level which has impacted on the availability of coastal resources [26]. Most recently back-to-back category 5 cyclones (Aila 2009 and Sidr 2007) brought a huge loss of lives and properties to this region [17].

The Dhaka based South Asian Association of Regional Cooperation (SAARC) Meteorological Research Centre (SMRC) has been working on extreme weather issues over the last few decades and investigates rainfall, temperature and sea-level rise along the Bay of Bengal coast. The rainfall data over 1961 and 1989 show, among the three threshold of precipitation days per year (heavy precipitation days, 10 mm, very heavy precipitation days, 20 mm and extremely heavy precipitation days, 50 mm), there is an increasing trend with the advancement of years for all three thresholds [21]. Another SMRC study covering rainfall data until 1999 shows that in Bangladesh, monthly maximum 1-day precipitation has been declining, whereas 5-day precipitation has been increasing, which suggests there were more
frequent wetter days in recent decades [20]. Investigations on temperature suggest that the maximum daily maximum temperature did not increase between 1961 and 1989. However, a study found that there is a sign of warming in Bangladesh: the minimum temperature had been rising at a faster rate, even though the maximum temperature remained in almost unchanged [21]. Rising sea level in and around the coastal belt of the Bay of Bengal also remains a major threat to the livelihoods of millions of people of this delta. A study on Bangladesh suggests that the sea-level rise at the Bay of Bengal delta is likely to be in the range of 30 to 100 cm by 2100 [17].

III. EXTREME WEATHER CONDITIONS AND THE BAY OF BENGAL DELTA

While the SMRC and other studies in the past have made clear that the Bay of Bengal delta is certainly experiencing frequent extreme weather conditions, there was hardly any attempt made in the past to analyse the socio economic consequences. In the remaining parts of this paper, these will be investigated by taking three major aspects of extreme climatic conditions: rainfall, temperature and cyclonic storms, including sea-level rise.

A. Rainfall

As mentioned earlier, the Bay of Bengal delta is not a stranger to extreme weather conditions, in terms of high precipitation, variable temperature and frequent sea water surges together with sea-level rise. The GBM combined rainfall catchment area is over 12 times larger than the size of Bangladesh and all the rain water flushes through the Bay of Bengal delta [11]. Table 1 presents rainfall data for various coastal districts over 2003 and 2008.

Four coastal weather stations have been chosen to investigate the climate variations. Cox’s Bazar located on the south eastern point of the Bay. Hatiya is one of the island stations in the Bay. Bhola is also an island station located almost 50 km north (close to mainland) of the coast. Khepupara is located right on the coast. Over the last 5 years (until 2008), the annual rainfall data show that, while two centres captured increased precipitation, this has declined in the rest. The summer season carries the bulk of the precipitation. The rainfall in the summer (June, July and August) was one quarter of the total at Cox’s Bazar and Hatiya. This was only one-fifth at Bhola and Khepupara in 2008. The summer rain increased at all weather stations between 2006 and 2008.

Table 1. Rainfall in selected coastal regions in millimetre, 2003-2008.

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</thead>
<tbody>
<tr>
<td>Cox’s Bazar</td>
<td>4113</td>
<td>3430</td>
<td>0</td>
<td>616</td>
<td>3534</td>
<td>7</td>
<td>775</td>
</tr>
<tr>
<td>Hatiya</td>
<td>3664</td>
<td>2519</td>
<td>25</td>
<td>703</td>
<td>3546</td>
<td>28</td>
<td>816</td>
</tr>
<tr>
<td>Bhola</td>
<td>1819</td>
<td>2142</td>
<td>0</td>
<td>345</td>
<td>1993</td>
<td>13</td>
<td>425</td>
</tr>
<tr>
<td>Khepupara</td>
<td>1758</td>
<td>3400</td>
<td>0</td>
<td>440</td>
<td>3010</td>
<td>25</td>
<td>603</td>
</tr>
</tbody>
</table>

Note: Winter months: December, January and February; Summer months: June, July and August. Source: [11].

These variations in rainfall in the coastal belt of the Bay of Bengal were not isolated cases, if one considers average annual rainfall all over Bangladesh. Historically, it is well established that since the nation is located north of the Bay of Bengal/Indian Ocean and in the south of the great Himalayan Mountains, geographically the nation is vulnerable to rainfall variations. According to Mirza [15] about 80 per cent of the total rainfall occurs during the monsoon period, in the months of June, July, August and September. It has been estimated by the above author that the average annual rainfall of the country varies from 1200 mm in the west to 5000 mm in the east.

B. Temperature

Recently, Islam and Neelim [11] comprehensively studied the temperature issues in Bangladesh and examined their economy wide consequences. While this study was comprehensive and covers the entire nation, the coastal temperature variations over time were also investigated with care. The study maintains that, over the last 60 years, the annual average temperature was increased by almost 1 degree Celsius (Table 2). However, it is not the annual averages which matter most, it is the seasonal variation of temperature that is most important. In this respect, Islam and Neelim [11] suggest that in the winter the minimum reading has been increasing at an alarming rate. There was a big jump in the minimum temperature over the last few decades compared to the maximum readings, which was experienced in almost all weather
stations of Bangladesh in the winter.

Table 2. Nationwide annual mean temperature in Celsius, 1950-2008.

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</thead>
<tbody>
<tr>
<td>Annual</td>
<td>25.1</td>
<td>25.3</td>
<td>25.1</td>
<td>25.3</td>
<td>25.7</td>
<td>26.4</td>
<td>26.3</td>
<td>26.4</td>
<td>25.9</td>
</tr>
<tr>
<td>Winter</td>
<td>20.0</td>
<td>21.0</td>
<td>21.0</td>
<td>21.5</td>
<td>21.8</td>
<td>22.6</td>
<td>21.6</td>
<td>22.3</td>
<td>21.3</td>
</tr>
<tr>
<td>Summer</td>
<td>27.5</td>
<td>28.4</td>
<td>26.3</td>
<td>27.5</td>
<td>26.5</td>
<td>28.5</td>
<td>27.5</td>
<td>28.0</td>
<td>27.5</td>
</tr>
<tr>
<td>Monsoon</td>
<td>28.1</td>
<td>28.3</td>
<td>28.0</td>
<td>27.9</td>
<td>28.3</td>
<td>28.4</td>
<td>28.3</td>
<td>28.9</td>
<td>28.5</td>
</tr>
</tbody>
</table>

Note: Annual: January to December; Winter: November to February; Summer: March to May; Monsoon: June to October. Source: [11].

While the nationwide readings showed that minimum temperature has been increasing and the gap between minimum and maximum has been shrinking over the last decade, it is clear that the number of hotter days over time will become more frequent. Let us look at this phenomenon from the data taken from the four weather stations on the Bay of Bengal delta. Among these stations, summer maximum has been recorded in Cox’s Bazar at 34.5 degree Celsius. Minimum high summer temperature was also recorded in Cox’s Bazar (Table 3). A similar pattern has emerged for the winter for all other stations.

Table 3. Average maximum and minimum temperature in Celsius, new readings, 2008.

<table>
<thead>
<tr>
<th>Bay of Bengal Delta</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Summer</td>
<td>Winter</td>
</tr>
<tr>
<td>Cox’s Bazar</td>
<td>34.50</td>
<td>31.30</td>
</tr>
<tr>
<td></td>
<td>(31.15)</td>
<td>(27.60)</td>
</tr>
<tr>
<td>Hatiya</td>
<td>33.40</td>
<td>27.50</td>
</tr>
<tr>
<td></td>
<td>(28.15)</td>
<td>(26.00)</td>
</tr>
<tr>
<td>Bholha</td>
<td>34.30</td>
<td>27.00</td>
</tr>
<tr>
<td></td>
<td>(32.06)</td>
<td>(24.00)</td>
</tr>
<tr>
<td>Khepupara</td>
<td>33.30</td>
<td>27.20</td>
</tr>
<tr>
<td></td>
<td>(31.14)</td>
<td>(25.00)</td>
</tr>
</tbody>
</table>

Note: Figures in parentheses show base readings taken from the range of last 30-60 year averages. Source: [11].

It appears that the variations between the maximum and the minimum summer temperature, taking the base year’s temperature into consideration, has been increasing in the coastal region as well. This is also the case in the winter months. Thus, one can conclude, without reservation, that in the coastal region not only were there more and more warmer days in recent years, both in summer and winter, the days are becoming even hotter. These outcomes have major implications for agriculture, fisheries and tropical diseases.

In summary, in seasonal and annual mean temperature terms, a trend of 1 degree Celsius rise between 1948 and 2007 has been established.

C. Cyclonic storms and sea-level rise

The Bay of Bengal is known as the world’s largest delta both in length and population size. The delta is more than 700 km long and more than 40 million people live within 100 km of the coast. The livelihood in this vast wet region has been based for centuries on agriculture, fisheries and small scale tourism particularly in the south east corner (Cox’s Bazar) and near Sundorbon in the south west. Although the environment and the climatic conditions have been very hostile in the region, the population density has been growing, compared to any other deltaic regions. Cyclonic storms, hurricanes and formation of depressions are regular occurrences in this region.

Table 4 presents a picture of the occurrence of natural disasters between 1960 and 2009. On average, over the last 50 year at least one cyclonic storm or a storm with hurricane intensity hit the coast of the Bay of Bengal in every 1.5 years. Over the last five decades, the frequency of cyclonic storms has been very high, except between 1971 and 1980. The highest frequency was observed between 1960 and 1970 and the second highest was between 1991 and 2000. Due to the frequency and strength of storms and sea water surges more than half a million lives were lost between 1960 and 1970. In the 1980s, about 100,000 people perished due to the cyclonic storms. The damage was unprecedented both in terms of loss of lives and property in the 1960s and 1970s, since the disaster management capacity and the early warning devices then were almost absent. In the post-1990s, the nation has been establishing with international assistance cyclone shelters on the coast and early warning systems have been put in place making use of radio and TV networks and local volunteer corps. These have kept the loss of lives within tolerable limits, however, the damage to properties, businesses and crops have been greater in recent times, since the population has grown at an alarming rate, more than doubling over the last 30 years.

Most recently rare back-to-back cyclones hit the coastal belt in 2007 and 2009. Both were rated as category 5 cyclones namely, Sidr and Aila, respectively. Sidr claimed more than 3000
lives, 9 million people were affected in 25 districts out of Bangladesh’s 64. More than 750,000 acres of crop land were destroyed and 175,000 acres were partly damaged. On top of these, livestock, fisheries and wild-life were the major casualties of simultaneous tidal surges [4].

Table 4. Frequency of major cyclonic storms from 1960 to 2009.

<table>
<thead>
<tr>
<th>Years</th>
<th>Frequency</th>
<th>Range of wind speed (kph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-1970</td>
<td>11</td>
<td>160-224</td>
</tr>
<tr>
<td>1971-1980</td>
<td>1</td>
<td>163</td>
</tr>
<tr>
<td>1981-1990</td>
<td>6</td>
<td>93-160</td>
</tr>
<tr>
<td>1991-2000</td>
<td>9</td>
<td>60-278</td>
</tr>
<tr>
<td>2001-2009</td>
<td>7</td>
<td>65-223</td>
</tr>
</tbody>
</table>

Source: [4].

The debate on sea-level rise in recent years has been directed towards long-term prediction to 2100. The Intergovernmental Panel on Climate Change (IPCC) and Bangladesh-sponsored studies, in recent years, have found that the Bay of Bengal delta is too vulnerable to the sea-level rise due to ice melt in the Arctic and Antarctic, and melting of glaciers in Greenland and the Himalayas. For South Asia, SAARC Meteorological Research Centre (SMRC) began looking at this phenomenon in 2002 and the IPCC’s Fourth Assessment Paper examined this issue in 2007 [23, 10]. The SMRC [23], concluded that the sea-level rise along the Indian coast in and around Visakhapatnam (south-west coast of Bay of Bengal), has been increasing by 0.9 mm per year between 1937 and 1991. The variations in sea-level rise between seasons appear to be higher in the Bay of Bengal coast than any other coasts of South Asia. It appears that this region has been experiencing minimal rise in sea level in the post-monsoon period. According to the IPCC [10], however, a 10 cm rise is expected by 2030. This would be sufficient to inundate 2500 sq. km which is about 2 per cent of the total land of Bangladesh along the 700 km long coastal belt. The IPCC’s long term prediction on the sea-level rise along the Bay of Bengal coast suggests three scenarios: rising up to 1 m, up to 2 m and up to 5 m by 2100. With a minimum 1 m rise in mind, it is expected that all the districts located within 50-60 km of the coastal belt and most of the offshore islands on the Bay would be submerged making 30-40 million people homeless by 2100.

The IPCC’s prediction has been countered by a Bangladesh-based study and claims that the IPCC failed to consider the role of sedimentation in its prediction for sea-level rise [5]. This study concludes that even if sea levels rise by a maximum 1 m in line with the IPCC’s 2007 predictions, most of Bangladesh’s coastline will remain intact. This is due to the fact that the coast line of Bangladesh would rise with sediments originating and carried all the way from the Himalayas in the monsoon which would ultimately raise the sea level bed at least at a same rate of sea level rise [5]. The sediment rise would mean that the relative sea level would be unchanged, particularly in the Bay of Bengal delta, the study claims. While the IPCC welcomes this observation it, however, warns that this body of scientific evidence was formed out of only a single study. Further studies are needed to make such a claim credible. In the future, the IPCC is expected to carry out further studies on the rate of sedimentation on the bed of the Bay of Bengal delta [2].

IV. LIVELIHOODS UNDER EXTREME WEATHER CONDITIONS

The global warming induced climatic impact discussed above will have major consequences for the livelihoods of the millions in the Bay of Bengal delta. While livelihood in the literature generally covers the economic issues, coastal populations endure adverse social and environmental conditions, which are also important. Thus, the rest of this paper is concerned with the socioeconomic consequences of the extreme weather conditions along the Bangladesh part of the Bay of Bengal delta. Since the income of the inhabitants is predominantly based on agriculture and fisheries, let us investigate the food grain and fish production issues first.

A. Food grain production

Cropping contributes more than 80 per cent of value added in agriculture in Bangladesh. Moreover, rice and wheat account for more than three-quarters of value adding in cropping. Therefore, the increase in food grains production is the major source of agricultural growth in Bangladesh (see trends for last three decades in Fig. 1). The southern parts of Bangladesh located on the mouth of the Bay of Bengal have contributed almost a quarter of this growth over the last three decades [9].
Fig. 1 shows the food grain production in Bangladesh during the period 1980/81 to 2006/07. As can be seen, the production increases at a steady rate throughout the sample period, except for some variation during the mid-1990s. This indicates that the food grain production can be modelled using a linear trend model. The estimated linear model for the given data is:

\[
\text{Food crop production} = 0.8907 \times \text{Time} + 14.419 \\
R^2 = 0.8438
\]

The high $R^2$ value indicates a good fit. This model can be used for forecasting food grain production.

The food grain production trends presented in Fig. 1 certainly suggest that Bangladesh, as a whole, was successful in doubling production over the last quarter of a century keeping growth rate at or even exceeding, the rate of growth in population. This achievement was possible for at least three main reasons: adding additional land under irrigation, bringing additional land under cereal production and by increasing the rate of fertiliser use. For example, estimates of these factors of production between 1992 and 2003 suggest that irrigated land had increased by 20.5 per cent, land under cereal cultivation increased by 5 per cent and fertiliser uses increased by 53 per cent [9].

All these achievements are likely to be threatened by the extreme weather conditions in the years and decades to come. For example, a study by the SMRC [22] examined the impact on rain-fed rice yield, locally known as Aman (summer) rice, due to the variation of temperature and rainfall in recent years. This study used Bangladesh-wide data for the period 1971-1999. The study found that there was a significant negative correlation between monthly maximum temperature and rice yield during the months of September, October and November. The month of October was found to have the highest negative correlation with the correlation coefficient of –0.65. This means that the yield declined substantially with an increase in temperature. The rainfall data showed a negative (–0.48) correlation in August. This suggests that the excess rainfall in August caused yield reduction through physical crop damage due to flood and inundation over a prolonged period of time.

There were several studies conducted nationally and internationally over the last decade on the issue of sea-level rise along the Bay of Bengal delta [17, 10]. A local study [18] with more than 10 years tidal data (1977-1998) from three collection points (Hiron point, Char Changa and Cox’s Bazar) found that the mean tidal level had been increasing in all three points. The mean tidal level at Hiron point has showed an increasing trend of about 0.4 cm/year, Char Changa (0.6 cm) and Cox’s Bazar (0.78 cm). An estimate suggests that salinity, water logging and acidification affect 3.05 million, 0.7 million and 0.6 million hectares of crop land of the coastal belt, respectively. Most importantly, the consequences of all these, about 15-20 per cent of arable land is expected to be inundated by saline water and this would drop food grain production substantially by 2030. Salinity and inundation of farm land would result in millions of farmers displaced from their land and depriving them of their main sources of livelihood.

B. Fish grain production

The fisheries sector contributes more than 5 per cent of the total exports of Bangladesh. While this sector’s growth has been extraordinarily high over the last two decades, the sector has been facing major challenges due to the climatic hazards that have frequently hit the nation, particularly in the southern part, the Bay of Bengal delta. Bangladesh, as we know is a land of rivers, historically having abundant sweet water fish (inland) together with vast marine fishery resource. Both of these fisheries sub-sectors combined have been progressing well over the last two decades (Fig. 2). The southern parts of Bangladesh, particularly located those on the coast of the Bay of Bengal cater for huge value adding to marine fisheries and have been the main source of exports.
Fig. 2 shows fisheries production in Bangladesh between 1984/85 to 2006/07. As can be seen, fish production increased at a slower rate in the earlier period and continued to increase at a faster rate in the later period of the sample years. This indicates that fisheries production can be modelled using a polynomial model rather than a linear model. When a linear model and polynomial model of order 2 were fitted for the data, it was found that a polynomial of order 2 fitted in terms of the model diagnostics. The estimated quadratic model for the given data is:

\[ \text{Fish production} = 0.0058 \times \text{Time}^2 - 0.0331 \times \text{Time} + 0.8426 \]

\[ R^2 = 0.9874 \]

The high \( R^2 \) value indicates a good fit. This model can be used to forecast fisheries production.

The fish production trend presented in Fig. 2 certainly suggests that Bangladesh, as a whole, was successful in more than doubling production between 1984 and 2006. This high growth in the country was possible for at least three main reasons: strengthening the government’s extension program on natural fish cultivation in rural areas, encouraging more and more private investment in shrimp cultivation along the Bay of Bengal delta and increased export opportunities. Hossain, Kathuria, and Islam [9] found that there has been considerable success in developing a sizeable export trade in frozen and otherwise processed fish products, of which shrimps have been the dominant export items. Exports hit more than US$500 million in 2007 [4].

The achievements in the fisheries sector illustrated above are now under major threat from sea-level rise. Finan [7] painted a very alarming picture for the development of shrimp aquaculture in the coastal belt of the Bay of Bengal due to sea-level rise. In recent decades, commercial shrimp production alone has been earning more than US$350 million each year from exports. According to Finan, sea-level rise will likely result in a much larger volume of saline water moving into the canals that feed the beels (shallow water lakes), contaminating water resources and eroding gher (commercial shrimp cultivation in earthen mini-polders) embankments, which are the major sources of commercial shrimp cultivation. Another likely result of sea-level rise is saltwater intrusion through groundwater flows. This would have major adverse consequences for the groundwater irrigation system of the delta.

C. Population displacement

Sea-level rise and its consequences for the displacement of coastal populations all over the world have been predicted by the IPCC [10] under various scenarios to 2100. As mentioned earlier, for the Bay of Bengal coast, the IPCC estimates the sea-level rise under three scenarios: low (up to 1 m), medium (up to 2 m), and high (up to 5 m). Taking the low scenario into consideration, it is expected that most of the Low Elevation Coastal Zone (LECZ) will be inundated. The LECZ is considered as those areas which are located below 10 m average sea level. The inundation of low lying lands would create an environment which would displace millions of coastal people and push them to higher grounds. It is estimated that almost a million people would be rendered homeless by 2030 under the medium scenario [13].

There are also other effects both social and economic. Due to space limit we are unable to analyse them here. However, these will be addressed in a paper currently under preparation for another outlet.

V. CONCLUSIONS

The Bay of Bengal delta is one of the most vulnerable regions on earth due to the reality of global warming. Millions are under a genuine threat, not only from lost livelihoods, they are likely to face natural eviction from their land due to sea-level rise in the not too distant future. The coast of the Bay of Bengal is more than 700 km long and is the largest delta on earth. Historically,
this region has been subject to climatic hazards, particularly from cyclonic storms and sea-water surges at least twice or three times in every 10 years. In recent decades, it has been established that the strength of the cyclones and storms have been increasing. In the literature, it has been recognised that due to geographical location, the Himalayas in the north and the Bay of Bengal/Indian Ocean in the south, make this delta even more vulnerable to the climatic hazards. According to a recent study, the funnel shape of the Bay of Bengal and the low elevation of the coastal region induce cyclones to hit intensely and frequently [8]. Due to the geographic position of the Bay of Bengal delta the extreme weather conditions faced in the past, however, were not isolated cases. It appears that these have regular event due to climate change hazards. The investigation of climatic hazards in this study over the recent decades reinforces this argument, once again.

Due to the extreme weather conditions in terms of variations in rainfall, temperature and sea-level rise, this study reached the conclusion that for the people of the Bay of Bengal delta the outlook remains bleak for the years and decades to come. The extreme weather conditions will make life on the coast intolerable with the imminent threat of homelessness due to sea-level rise and inundation. It is now certain that within the next two to three decades, Bangladesh will face a major catastrophe in both economic and social terms, as it witnesses millions of people would be moving north to search for higher grounds as climate refugees, whether the world likes it or not. In few decades, climate refugees will become a reality, hitting the millions of the Bay of Bengal delta in the first instance.

REFERENCES


