Loss &
Damage

Loss and Damage from the Local Perspective in the Context of a Slow Onset Process:

The Case of Sea Level Rise in Bangladesh

Ainun Nishat, Nandan Mukherjee, Anna Hasemann and Erin Roberts

June 2013

CDKN
ICCCAD International Centre for Climate Change and Development
GERMANWATCH
MCII
UNITED NATIONS UNIVERSITY
UNU-EHS

Foreword

The impacts of sea level rise (SLR) are already being felt – and inflicting loss and damage – throughout the coastal areas of Bangladesh. However, there is still little understanding of how that loss and damage manifests and more importantly, how it can be addressed. At the eighteenth Conference of the Parties (COP), Parties acknowledged the need to enhance understanding of loss and damage from slow onset processes. However, while these discussions are taking place at the international level, loss and damage is being felt at the local level. Therefore it is important to understand how loss and damage can be addressed at the local level. This paper seeks to address this gap in the national context of Bangladesh.

We are very grateful to the experts from all around the globe who participated in the expert workshops and global climate negotiations and thereby contributed to furthering the understanding of loss and damage. We also acknowledge the contribution of the team at the Centre for Climate Change and Environment at BRAC University and thank them for their dedicated input. Last, but not the least, we are grateful to Dr. Saleemul Huq for his leadership in building an understanding of loss and damage in Bangladesh over the past year.

We are grateful to Koko Warner of United Nations University (Bonn), Sven Harmeling and Sönke Kreft of Germanwatch for their valued comments and suggestions.

BRAC UNIVERSITY

Centre for Climate Change
and Environmental Research (C3ER)

Authors/contributors:
Ainun Nishat*, Nandan Mukherjee**, Anna Hasemann, and Erin Roberts

* Vice-Chancellor, BRAC University
** Assistant Professor of BRAC University and Program Manager of Centre for Climate Change and Environmental Research (C3ER)

Table of Contents

List of Tables

List of Acronyms

AR4	IPCC Fourth Assessment Report
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BWDB	Bangladesh Water Development Board
CCC	Climate Change Cell
CDMP	Comprehensive Disaster Management Programme
DoE	Department of Environment
GCM	General Circulation Models
GoB	Government of Bangladesh
GWT	Ganges Water Sharing Treaty
IPCC	Intergovernmental Panel on Climate Change
MoEF	Ministry of Environment and Forests
MoF	Ministry of Finance
RSL	Relative Sea level
SLR	Sea Level Rise
TAR	IPCC Third Assessment Report
TRM	Tidal River Management

Executive summary

Sea level rise (SLR), a slow onset process and an impact of climate change, has two major causes: thermal expansion of the oceans, and the loss of land-based ice due to increased melting. A rise in the local, relative sea level can occur due to sedimentation, especially prominent near river deltas. Bangladesh is at risk of SLR due to its flat terrain in the coastal region, the impacts of which are already manifesting in a variety of ways. While estimates vary, the average estimate of SLR for the year 2100 is 0.62 m.

Estimates have shown that as much as 20 percent of the total country and 62 percent of the coastal region may be lost to SLR by the end of the century. This phenomenon may also increase cyclonic storm surge depth. Moreover, SLR reduces the availability of freshwater through salinity intrusion in both water and soil. Projected SLR may increase the extent of salinisation as saline water travels further inland. The reduction of the fresh water zone will have far-reaching effects on the ecology of Bangladesh and may threaten species already endangered. SLR is not the only cause of salinisation, however; the salt concentration of water in southern Bangladesh can also be attributed to a decrease in upstream freshwater flow following the construction of the Farakka Dam in India.

Rising sea levels also pose a significant threat to infrastructure. In addition, agriculture will be severely affected due to the salinisation of both land and water further north from the coastal region, which will negatively impact those who rely on agriculture for their livelihoods. Aquaculture is also threatened, as SLR will likely cause loss and damage to fisheries, especially shrimp and white fish cultures. Flooding associated with rising tides and storm surges causes the overflowing of shrimp ponds, pushing shrimp into open water. The industry might be harmed in other ways as well, as SLR could affect processing systems. Thus, those whose livelihoods depend on fisheries and fish cultivation will also incur losses from SLR.

South-west Bangladesh is home to the Sundarbans, the world's largest mangrove forest, which has a delicate ecosystem and supports over 1500 species of flora and fauna; this ecosystem's salinity balance is threatened by SLR. By the year 2050, SLR could inundate 75 percent of the Sundarbans, a process that would lead to significant biodiversity loss and negatively impact the livelihoods of those who are dependent on the forest.

Food security and health will both decrease, especially for the poor, with food grain and protein availability per person decreasing, and pathogen and water borne diseases increasing. As many as 52 million Bangladeshis may be affected by SLR by the year 2020, rising to as many as 97 million people by the year 2080. Even using a low emissions scenario (with the base line year 2005), about 44 percent of Bangladeshis will be affected by additional flooding – exacerbated by SLR - by the year 2080.

The risk of SLR can be addressed through a broad range of approaches, which include a variety of structural and non-structural measures such as building embankments, tidal river management, and upstream flow augmentation. Regional cooperation for freshwater distribution, such as the Ganges Water Sharing Treaty of 1996, is another method to address the impacts of salinisation. Another method is the development of saline tolerant seed varieties and new cropping patterns and methods, in which there has been some success with jute and tomatoes. However, many will still lose their livelihoods in the coastal region, and as such, alternative income generation will become an increasingly important risk reduction practice. In the worst-case scenario, relocation may be necessary, though permanently relocating vulnerable groups will be difficult for political reasons.

At the policy level, the National Adaptation Programme of Action, Bangladesh's Integrated Coastal Zone Management Plan, and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) all deal in part with SLR and how to address its impacts. At the institutional level, a dedicated Climate Change Unit has been developed, which works in conjunction with climate change focal points that are being established in each ministry. However, gaps in current policies, institutions, and approaches exist and this paper proposes a set of recommendations to address them. These recommendations are related to establishing a monitoring mechanism as well as capacity building for impact assessment, research on salinity resilient crop development, regional cooperation, and alternative livelihood development. Furthermore, the availability of a global fund and technology transfers are key foundational requirements, both for understanding and addressing the range of approaches related to SLR.

1. Introduction

The main objective of this paper is to improve the understanding of climate change induced loss and damage due to sea level rise (SLR) and suggest how it might be better addressed in Bangladesh, particularly at the local level where loss and damage is incurred.

The coastal zone of Bangladesh is one of the most exposed and vulnerable to loss and damage from sea level rise.

The coastal zone of Bangladesh is one of the most exposed (for example, in terms of asset and population density) and vulnerable (for example, in terms of poverty) areas in the world to loss and damage from SLR (World Bank, 2010; IPCC, 2001). As a result, SLR and resulting salinity intrusion are the most pressing slow onset events in Bangladesh.

Slow onset processes such as SLR are defined as such because they do not emerge from a single, distinct event, but gradually over time (OCHA, 2011). Two major causes of SLR exist: the thermal expansion of the oceans (water expands as it warms) and the loss of land based ice due to increased melting (Islam, 2001). Global sea level variation is determined by the change in volume of seawater in the global hydrologic cycle. However, at the local level, or more specifically along the coastline and estuary, SLR is estimated at a relative scale – termed as relative sea level (RSL) – which differs from the global estimate due to local geological differences. As this paper focuses on the local experience of SLR in Bangladesh, it will analyse approaches to address local SLR.

Climate change-related SLR is a source of potentially devastating loss and damage in coastal regions

Understanding the process of SLR and assessing the range of possible approaches is a complex task considering the uncertainty of future climate change impacts and projections, but one of significant importance. Climate change-related SLR is a source of potentially devastating loss and damage in coastal regions, for example, through the loss of productive land, income, livelihoods and biodiversity, among other losses and damages.

In order to advance the understanding of loss and damage from the local perspective in the context of a slow onset process, this paper addresses the following research questions:

1. What is the potential loss and damage from sea level rise?
2. What policies need to be in place in order to address loss and damage from sea level rise in Bangladesh?

First, the paper will give an overview of currently observed and projected SLR. Second, the paper will discuss the impacts caused by SLR and the subsequent chapter will outline loss and damage caused by climate change induced SLR. This will be followed by a discussion on the range of approaches to address loss and damage caused by SLR as well as the existing policy and institutional environment. Finally, the paper will conclude with a set of recommendations for addressing SLR at the local level in Bangladesh.

2. Sea Level Rise in Bangladesh

2.1. Observed SLR in Bangladesh

The largely flat topography of Bangladesh's coastal region and the sensitivity of its ecosystem make it highly vulnerable to SLR-associated risks. For example, the world's largest mangrove forest, the Sundarbans, is home to more than 1500 species of flora and fauna not found in other bio-ecological regions of the country (Gopal and Chauhan, 2006). Moreover, adaptive capacity of coastal dwellers is very poor. In most coastal districts, the percentage of people living below the lower poverty line is below national average (World Bank et al., 2009).

There is some disagreement amongst researchers on the extent of SLR in Bangladesh (e.g. Alam, 2003; Rahman et al., 2011). In the last decade, a study by the South Asian Association for Regional Cooperation (SAARC) Meteorology Research Centre (SMRC) found that tidal levels (which is a proxy indicator for SLR) along the Bangladesh coastline are increasing (Alam, 2003). Through the observance of tidal gauge records over the period 1977 to 1998, an annual rise was noted in the south-west, south-central, and parts of the eastern-hill region at the rate of 4.0 mm/year, 6.0

Period of analysis	Observed Water Level[1] (in metres)			
	Hiron Point (West)	Moheshkhali (East)	Cox's Bazar (East)	Sandwip (Central)
1968-1977		207.10		
1977-1986	177.35	214.35	199.87	279.31
1987-1996	182.76	214.97	213.68	337.75
1997-2002	186.20		206.54	291.29
Change in the mean sea level (from trend line)	0.55 cm/yr	0.749 cm/yr	0.5055 cm/yr	0.7044 cm/yr

Table 1: Observed mean annual RSL at different tidal water level stations (Rahman et al., 2011)

mm/year and 7.8 mm/year, respectively. This study also finds that the rate of the tidal trend on the east coast is almost double that of the west coast (Ibid). This difference might be due to subsidence and uplifting of land[1] (Ibid).

In recent years, a new study by Rahman et al. (2011) also found an increasing trend. The updated study found mean annual change in sea level of 5.5mm/year in the south-west region, 7.04 mm/year in the south-central region, and 5.0 and 7.5 mm/year in the eastern-hill region (see Table 1)[2].

… net SLR rise might be around half a meter by the end of this century if the current trends persist over the next 100 years …

Thus, it can be concluded that mean sea level is rising and sea level variance can be considered to be within the range of 5 mm/year to 5.5 mm/year.

2.2. Projected SLR for Bangladesh

Drawing on past and current trends of SLR discussed above, it can be concluded that net SLR rise might be around half a meter by the end of this century if the current trends persist over the next 100 years. However, due to the uncertainty of future climate change, past trends might not be a valid indicator of future estimates (Hayhoe et al., 2007). Therefore, climate change scenarios of future events offer insight only to a certain extent. Nevertheless, they provide useful understanding that can guide urgently needed strategies and programmes with adjustments made as new data and knowledge becomes available.

Over the past two decades, a number of research initiatives were undertaken to estimate possible future SLR in Bangladesh. A pioneer research initiative on developing climate change scenarios for Bangladesh has estimated that net SLR could be between 30 and 50 cm by 2050 (DoE, 1993). Ahmed and Alam (1998) used general circulation models (GCM) to generate climate change scenarios for ten locations in Bangladesh and estimated a one-meter change of sea level by the middle of the 21st century. This prediction combines a 90 cm rise in global SLR and about 10 cm local SLR due to subsidence.[3] The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) estimates that local SLR in the Bay of Bengal could be up to 50 cm by the

[1] Subsidence occurs when land sinks to a lower level in elevation, with uplifting being its opposite.
[2] Expert opinion supports these findings; Dr. Maminul Huq Sarker, who is an eminent morphologist working for the Centre for Environmental and Geographic Information Services (CEGIS), was consulted.

[3] The IPCC's Third Assessment Report (TAR) (2001) states that global SLR was 9 cm in 1999 and may reach 88 cm by 2100. According to the IPCC's Fourth Assessment Report (AR4) (2007), global average SLR might be in the range of 0.26 m to 0.59 m by the end of the 21st century.

year 2100 (IPCC, 2007). There exists a wide range of predictions in the literature concerning the extent of such changes (Rahmstorf, 2007; Mote et al., 2008; Dasgupta et al., 2009). For instance, a study criticised the AR4 for discounting recent observations of substantial ice losses from the Greenland and Antarctic ice sheets in its projections of future SLR, giving an estimate of an upper limit for ice sheet loss contributions to global SLR of 34 cm by 2100 (Mote et al., 2008). Thus, a more realistic range of future SLR for Bangladesh falls within the range of 26 cm to 98cm by 2100[4].

2.3. Sea Level Rise: Three Scenarios

As discussed in the first chapter, assessing the risk of SLR on Bangladesh's coast is difficult. Considering this fact, we explore three different cases: (a) SLR as an isolated slow onset process; (b) SLR combined with storm surge; and (c) SLR combined with salinity intrusion.

2.3.1. Permanent Inundation due to SLR (as an Isolated Slow Onset Process)

As an isolated slow onset process, SLR will likely lead to gradually accumulating loss and damage (Coumou and Schaeffer, 2012). This will not only result in direct loss and damage (e.g. gradual loss of agricultural production due to salinity increase from SLR) but also in indirect and intangible – or non-economic- losses and damages (e.g. loss of traditional livelihood, loss of culture and heritage and so on).

Currently, there is significant variance among SLR estimates. For instance, Ali (2000) predicts that about 2,500 sq. km, 8,000 sq. km and 14,000 sq. km might be lost due to SLR of 0.1m, 0.3m and 1m, respectively. The potential land loss estimated by the IPCC's Third Assessment Report (2001) is even worse: 29,846 sq. km of land might be lost and 14.8 million people made landless in the case of a 1m SLR. A joint study by the Centre for Environmental and Geographic Information Services (CEGIS) and the Institute of Water Modelling (IWM) (2007) showed that under the IPCC's A2 emissions scenario[5], high tide in the south-central region may increase by 30 cm and 80 cm for a 32 cm and 88 cm SLR, respectively (Ibid). Seawater will continue to move further inland and freshwater river systems will be converted to brackish water systems – water with higher saline concentration – resulting in higher soil salinity (Ibid). Overall, the south-west and south-central regions of Bangladesh will be exposed most to SLR (MoEF, 2009).

the range of approaches to address SLR will need to include continuous learning and feedback

SLR may lead to the loss of agricultural land, homes, roads, and other infrastructure as well as biodiversity, culture, and heritage (IPCC, 2001). Loss and damage caused by SLR will occur gradually over time and, given our current scientific understanding of this process, we do not yet know its full extent. Therefore, the range of approaches to address SLR will need to include continuous learning and feedback. Ultimately, policies and programs will have to aim at building the resilience of vulnerable people through adaptive measures such as livelihood diversification, improving education, and health care.

2.3.2. Exposure to SLR-induced Storm Surges: The Combination of Extreme Events and Slow Onset Processes

The IPCC's AR4 (2007) projects that due to climate change, globally, cyclones will increase in intensity (due to increased wind speeds of 5-10 percent). Closely related to cyclones are storm surges, rapid onset events that cause immense loss and damage, which can reach 1.5-9 meters during severe cyclones (World Bank, 2010). Projected SLR increase may have an exponential impact on increasing the height of storm surges (Mukherjee et al., 2011). Dasgupta et al. (2010) demonstrated that, assuming a 10 percent increase in tropical cyclone intensity, the storm surge caused by a severe cyclone could potentially inundate around half the coastal zone (3000 square kilometres) with water at least 1 metre in depth (Ibid). In addition, it is projected that by 2050, storm surges exceeding 3 metres will increase by 69 percent, potentially inundating an additional 10,163 to 17,193

[4] The pragmatic mid-range estimate is 62 cm; close to the top end of the range for global SLR of 59 cm under the AR4 projected scenario and the observed mean sea level at 55 cm.

[5] The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines (IPCC, 2000: 5).

square kilometres (compared to 2005 baseline data) (Ibid).

Given the above SLR is an important variable in influencing the magnitude and extent of loss and damage caused by storm surges. However, storm surges are also influenced by other geological variables, such as coastal morphology, wind speed, and direction (Bunya et al., 2010). Traditional mathematical modelling approaches for assessing loss and damage due to storm surges and SLR often fail to adequately incorporate the above-mentioned factors because they use simplified data, largely because the various natural processes involved in causing SLR and storm surges are not well understood (Dietrich et al., 2011). Nevertheless, it can be concluded that the intensity of extreme events such as storm surges might increase proportionately in combination with SLR, heightening the exposure of already vulnerable people, environments, and infrastructure.

Unlike the slow onset impacts of SLR, which accumulate gradually, loss and damage caused by SLR in combination with storm surges will be more rapid in nature. Therefore, the range of approaches to address this scenario will consequently need to focus on reducing exposure to storm surges as well as offering relief immediately after a possible disaster impact. Recommended measures include infrastructural approaches (such as retro-fitting the height of coastal embankments) as well as using social safety net programmes in the wake of a disaster.

2.3.3. SLR Combined with Salinity Intrusion

Rising sea levels have a significant impact on water resources by reducing fresh water availability through salinity intrusion (MoEF, 2009). In Bangladesh, two types of salinity exist: water and soil salinity. Increased water salinity occurs when SLR causes sea water to move upstream, in some cases leading to the disappearance of the freshwater zone (which turns into brackish water) (Ibid). Consequently, soil salinity occurs, decreasing agricultural productivity and negatively impacting livelihoods (Chowdhury, 2000). The likely disappearance of much of the country's fresh water zone (CEGIS 2006) will have a far reaching effect on its ecological systems, including the extinction of many endangered species (IUCN, 2012).

Projected SLR may increase the extent of salinisation by pushing the saline waterfront – where freshwater and seawater mix – even further inland. Research by IWM and CEGIS (2007) has shown that a 27 cm and 62 cm increase in SLR may cause the salinity line to move upstream by 10 or 20 km, respectively. Moreover, during the dry season, a 62 cm increase in SLR by 2080 will increase brackish water areas by nine percent and during monsoon season by six percent (Ibid).

However, it needs to be pointed out that, although the rise in tidal water level contributes to increased water salinity in the estuarine zone of Bangladesh, the salinisation of water in Bangladesh's southern region is largely caused by a decrease in upstream fresh water flow (Mirza and Sarker, 2005). The construction of the Farakka Dam in India drastically affected the Ganges and Gorai rivers in Bangladesh and is a major reason for fresh water reduction (Mirza, 1998). This problem was to some extent remedied with the 1996 Ganges Water Sharing Treaty (GWT), but freshwater flow is still significantly reduced. As a result, in recent years, extremely low flows in the Gorai River in the dry months have appeared to exacerbate the intrusion of saline water into Bangladesh's south-west region (Wirsing et al., 2013).

In the case of loss and damage from salinisation, traditional structural and non-structural approaches will not be sufficient as the scale of impacts will intensify significantly and be much higher than currently experienced (Warner et al., 2012). Thus, transformational approaches as proposed by the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) (IPCC, 2012) are needed, such as land use zoning, sustainable farming as well as focusing policies and institutions on addressing climate change induced loss and damage.

3. Loss and Damage due to Sea Level Rise

The previous section established that the increase in vulnerability due to SLR is going to pose a serious threat to Bangladesh's population, the environment, and infrastructure systems. In the following section, potential loss and damage that SLR will give rise to in different sectors will be outlined.

3.1. Crop Agriculture

The agricultural sector will be significantly affected by salinisation (Rashid et al., 2004; Ashraf et al., 2002). Using hydro-dynamic models[6] to assess the impact of

[6] Using three scenarios: 27 cm SLR by the year 2050, 62 cm SLR by the year 2080, and 88 cm by the year 2100.

SLR on agriculture, IWM and CEGIS (2007) found that the viability of cultivating rice may decrease from 84 percent (in the base year 2005) to 12 percent, while the viability of lentil cultivation could drop from 17 percent (in the base year 2005) to nine percent due to a SLR of 88 cm by 2100.

Mukherjee et al. (2011a) showed that 32 percent of land not affected by flooding (25,169 sq. km) and 9 percent of the land suitable for rice cultivation (950 sq. km) might be inundated due to a SLR of 62 cm by the year 2080. This study also found that net incremental annual crop damage was as high as USD 133.4 million. Ali (2006) found that 77 percent of the loss of rice production was caused by the conversion of rice fields into shrimp ponds and 23 percent was due to yield loss.

3.2. Fisheries

SLR will likely change the geography of the river estuary by pushing the freshwater zone further inland, changing fish habitats and breeding grounds, especially of shrimp and white fish cultures (IWM and CEGIS, 2007). If coastal land mass will be, as predicted, permanently flooded, present shrimp farming ponds will be lost and destroyed (Sarwar, 2005). Moreover, increased tidal flooding, which will most likely occur during the monsoon season, might cause additional harm to the sector by prompting the overflow of shrimp ponds and pushing shrimp into open water (Ibid). This will have a negative impact on one of Bangladesh's main foreign exchange earning sectors (Ibid). Storm surge flooding intensified by SLR may destroy the fishing and processing industries of the coastal region, which will alter diets and severely impact livelihoods (Ibid).

3.3. The Mangrove Ecosystem: The Sundarbans

The south-west region of Bangladesh is host to the world's largest single track of mangrove forest, the Sundarbans, sheltering more than 1500 species of flora and fauna (Gopal and Chauhan, 2006). The mangrove forest extends 80 km inland and constitutes 24 percent of the total forest area of Bangladesh, covering 5771 sq. km (Sarwar, 2005). Approximately seventy percent of the land is inundated by tidal flooding twice a day (CEGIS, 2006). During the monsoon season almost 85 percent of the land is inundated twice daily (Ibid).

During the monsoon season almost 85 percent of the land is inundated twice daily

Consequently, SLR poses a severe threat to the Sundarbans. Research by CEGIS (2006) has shown that 84 percent of the Sundarbans might be severely flooded by 2050 due to a 32 cm SLR. Under a SLR scenario of 88 cm by 2100, the whole of the Sundarbans might be lost (Ibid). Moreover, climate change induces higher evapotranspiration[7], which, combined with the low flow of rivers in winter, is projected to increase salinity (Mirza and Ahmad, 2005). As a result, the growth of fresh water flora and fauna will likely be impaired. Eventually, species offering dense canopy cover will be gradually replaced by non-woody shrubs and bushes (World Bank, 2000). Correspondingly, those depending on forest services will suffer significantly (IWM and CEGIS, 2007).

3.4. Society and Livelihoods

Since climate change will have significant impacts on water-related slow onset processes, peoples' livelihoods will also be severely affected (RVCC, 2003; Ahmed and Schaerer, 2004; Asaduzzaman et al., 2005).

Low-income households will also face adverse health effects

Adverse impacts on subsistence agriculture will have a correspondingly negative effect on the food security of those living below the poverty line (Lobell and Burke 2010). Low-income households will also face adverse health effects, as they are most exposed to outbreaks of pathogen-driven and water borne diseases, and are often unable to relocate due to a lack of financial capacity (Beddington et al., 2012).

many will be forced to search for alternative income and livelihood options

[7] Evapotranspiration is defined as the sum of both evaporation and vegetative transpiration.

CEGIS and IWM (2007) estimated that under the IPCC's moderate emissions scenario A2, the population affected by SLR might be 52, 79, and 97 million by the years 2020, 2050 and 2080, respectively. When SLR penetrates further inland, farmers and fishermen will lose their traditional livelihood opportunities, significantly reducing per capita food grain availability and protein consumption as well as economic output. As a result many will be forced to search for alternative income and livelihood options (C3ER, 2013). However, as the coastal regions are already very poor, viable livelihoods in this region are limited and thus many may ultimately be forced to migrate to other parts of the country (Beddington et al., 2012).

4. A Range of Approaches to Address Loss and Damage Caused by SLR

In the following chapter, a range of approaches to address loss and damage caused by SLR in Bangladesh are analysed.

4.1. Coastal Protection

Land mass in the coastal region can be saved by building embankments along the coast. Under the planning of the Bangladesh Water Development Board (BWDB), wards[8] have already built 5,376 km of coastal embankments, which provide a good foundation to further mitigate current and future inundation risks (Mukherjee et al., 2011). Nevertheless, a total of 2,095 km of land boundaries are still directly exposed to the sea and 1,410 km of the estuary might be exposed to SLR due to the backwater effect[9] in internal rivers (Mukherjee et al., 2011a). Thus there is a need for the construction of new embankments and the retrofitting of existing ones. The total cost of adapting to a 27 cm SLR was estimated at USD 17.1 billion and for a 62 cm SLR at USD 25.5 billion (Mukherjee et al., 2011).

Timely repair of infrastructure can reduce loss and damage

The timely repair of coastal protection infrastructure immediately after the occurrence of disasters can significantly reduce the extent of ensuing loss and damage (Masud-All-Kamal, 2013). Experience after the occurrence of cyclone Aila suggests that a delay may lead to irrecoverable losses. For instance, due to long delays in repairing embankments, several thousand square kilometres of land could became permanently saline and thus can no longer productive (Nishat et al., 2013).

However, there are also drawbacks to structural approaches such as embankment construction. For example, drainage will be slower through sluice gates[10] as waterways are narrowed (CCC, 2009). This will cause water logging (flooding inside the embankment) and transform agricultural land into wetland (Adri and Islam, 2012). Consequently, appropriate structural measures will have to take these drawbacks into account.

4.2. Land Development and Land Reclamation

Two very common practices in Bangladesh for land development and reclamation are building cross-dams (i.e. barriers between two islands or land masses) in the estuary for land reclamation and tidal river management (TRM) (IWM, 2009; Kibria, 2011). The two main land reclamation projects are Meghna Cross Dam I and II, constructed in 1957 and 1963-64 respectively (CEGIS, 2010). As a result of the construction of these cross dams, it is estimated that up to 1995 about 1,001 sq. km of land had been reclaimed (Ibid). Since then no further land reclamation projects have been undertaken due to funding problems, as this type of infrastructural measure is very costly (IWM, 2009). Currently, the BWDB is planning to build a series of cross dams to establish offshore island connectivity and facilitate the land reclamation process in the coastal region (Ibid). It should be noted that this kind of infrastructural development can have negative impacts on fish migration routes, in turn affecting fisheries and the local economy as well as people's livelihoods (Larinier, 2001).

Another option for land development is Tidal River Management (TRM). Estuarine rivers in the region

[8] Bangladesh is comprised of 7 divisions, 64 districts, which are further divided into 493 sub-districts or Upazillas. Upazillas are further divided into Union Parishad's (4,451 in total), each of which has nine wards. Wards are the smallest administrative unit in Bangladesh.

[9] Rise of water level at the upstream due to some external influence on the downstream.

[10] Sluice gates are drainage infrastructures that prevent excess water to enter the area of interest. Existing opening of drainage sluices will be inadequate for meeting the future projected increase in runoff due to an increase in monsoon rainfall (World Bank, 2010).

experience two tidal cycles a day, which leave sediment deposits on the riverbed resulting in huge drainage congestion. Local people use indigenous knowledge to cut riverside embankments in certain locations, allowing the sediment to enter and raise flood plains (Kibria, 2011). Thus, TRM is an effective option for managing the residual impacts of drainage congestion on coastal protection systems as well as by promoting climate change adaptation by raising floodplains. The BWDB has been trying to institutionalise the TRM process in some of the selected wetlands of the southern region (CEGIS, 2008). This project has been very successful in terms of implementation (Ibid). However, TRM requires barren land to allow sediment to enter, which cannot be used for agricultural purposes for several years (Ibid). Consequently, TRM requires the reallocation of land or monetary compensation to affected individuals. If compensation is not adequate, many will be left destitute (New Age, 2012).

4.3. Upstream Flow Augmentation and Regional Cooperation

Constructing barrages can increase freshwater flow and reduce salinity (WARPO, 2001). The BWDB is planning to construct a barrage in the south-west region and is currently undertaking a feasibility study (New Age, 2013). The augmented and diverted flow would allow water to flow into the tributaries of the Ganges between the Farakka Dam in India and the Gorai River in Bangladesh (WARPO, 2001). The barrage would minimise the gap between demand and availability of water while decreasing saline intrusion, sustaining navigation depths, and protecting fish (Ibid). Five more barrages have been proposed, however, due to the costs involved it is not clear whether their construction will be possible.

... fostering regional cooperation to ensure the equitable distribution of river water among co-riparians

Another option for augmenting upstream flow is fostering regional cooperation to ensure the equitable distribution of river water among co-riparians. The signing of the GWT in 1996 mentioned above, led to increase water flow in the Ganges River, improving agricultural access to water and ecosystem conservation as the influx of freshwater reduced salinity levels (Bhaduri and Anand, 2012). Currently, Bangladesh is pursuing treaties with India for other trans-boundary rivers (Ahmed, 2008). As most of Bangladesh's rivers originate in neighbouring countries, regional cooperation is an important factor impacting SLR at the local level.

4.4. The Agricultural Sector: Development of Saline Tolerant Seed Varieties

Using salt tolerant seed varieties is an important solution to help overcome the negative impacts of soil salinity (MoEF, 2009). Field experiments found that the introduction of high yielding salt tolerant rice varieties could produce sustainable grain yields in coastal regions, despite salinisation (Sarwar, 2005). In addition, tomatoes and okra were grown successfully under improved management practices with raised beds and mulch in medium saline soils (Ibid). However, the impact of introducing genetically modified seeds into agriculture is not yet fully understood (Snell et al., 2012) and, as such, long-term trials should ideally be undertaken to test the seeds before scaling this practice up. However, for scaling up to happen, capacity building in the research sector is required. Nonetheless, the rapid advancement of salinisation in the coastal regions may require the employment of genetically modified seeds before adequate testing has been performed in order to sustain agricultural output and reduce the threat to food security. Consequently, solutions to address the anticipated risk for the agricultural sector should not only focus on economic impacts (loss of production), but also on protecting the food security of those most vulnerable to SLR.

4.5. Awareness Raising and Training

The complexity of information on climate change and inadequate integration of climate change issues into formal education curricula have contributed to low public awareness of climate change (MoEF, 2012). The GoB's Climate Change Cell (CCC), which undertakes basic research on climate science and impact assessment, has initiated several strategies for increasing awareness among stakeholders and NGOs (Ibid). However, there still exists a significant lack of understanding on climate change among the wider population.

4.6. Alternative Income Generation and Livelihood Diversification

People living in the coastal regions of Bangladesh will likely have fewer livelihood options in the coming years due to SLR because many in this area are traditionally involved in resource dependent livelihoods like fishing, agriculture, salt production, shrimp farming, and extracting forest resources, which are sectors extremely vulnerable to SLR (C3ER, 2013). Alternative income generation programmes therefore aim at creating non-climate sensitive sustainable livelihood options (Ibid). For example, BRAC's alternative income generation programme for women living in extreme poverty in five coastal regions offers training in sewing as well as making handicraft and clothing (Nishat et al., 2013). The project has already helped many women diversify their livelihoods (Ibid).

Sustainable long-term measures need to be in place

However, livelihood diversification programmes are often designed as short-term fixes rather than long-term strategies (Ibid). For instance, in one project, traditional crop farmers received training in fishing, even though the fish stock is already diminishing and further fish breeding grounds will likely be lost due to SLR (Ibid). To provide livelihood options to address loss and damage from slow onset processes like SLR - which occurs gradually - sustainable long-term measures need to be in place. Thus, livelihood diversification requires field research and pilot programmes, for example, through the exploration of alternative cropping in the coastal region and training in non-climate sensitive sectors such as sewing and transportation.

4.7. Migration

While different drivers of migration exist – including social, political, economic, environmental, and demographic (Beddington, 2011) – it is anticipated that a one metre rise in sea level will lead to the displacement of millions of people in Bangladesh, with the estimates ranging from between 13 million to 40 million by 2100 (IOM, 2010).

A one metre rise in sea level will lead to the displacement of between 13 million and 40 million people

At the moment, migration tends to be mainly from rural to urban areas (Raleigh et al., 2008), though international migration to nearby countries like India is also seen (Alam, 2003). In addition, seasonal migration by agricultural workers within Bangladesh and contract labourers to the Middle East is common (Deshingkar and Akter, 2009). Temporary migration also occurs following disasters induced by extreme events such as cyclones (Oliver-Smith, 2006). These migrants tend to return to their homes once the initial danger has passed (Bardsley and Hugo, 2010). However, as SLR will lead to long-lasting impacts such as the loss of livelihoods and ecosystem services – as well as a loss of territory – many temporary migrants may eventually be forced to migrate permanently. Consequently, it is likely that loss and damage will lead to increasing instances of forced migration for many, while the most vulnerable who lack the social and financial capital to move, may be trapped (Foresight, 2011).

To an extent, the impacts of SLR are already visible in the salinisation of drinking water, which has had negative maternal health impacts on many women that have led to social marginalisation and, in extreme cases, forced families to migrate in order to find mates for their daughters (Shamsuddoha et al., 2012).

Given that migration has a number of drivers and unfolds in a variety of ways, a number of different policies will need to be implemented. For those for whom migration is forced, provisions and social safety nets should be provided by the government and humanitarian agencies to help these individuals settle in their new homes, which are often urban slums (Ibid). In addition, programmes and policies which facilitate anticipated migration as a result of SLR and salinisation should be put in place (Ibid).

4.8. Policy

In Bangladesh, no local level policies for addressing loss and damage due to climate change exist. Even though national policies should reflect local needs, the culture of policy preparation in Bangladesh is very centralised and top-down. The annual budget, for instance, does not include much input from the local level, where priorities are often not in accordance with the central government's long-term policies and strategies.

In Bangladesh, no local level policies for addressing loss and damage due to climate change exist.

Bangladesh's National Adaptation Programme of Action (NAPA) (MoEF, 2005) lists the sectors on which SLR and salinisation will have the greatest impact including: agriculture, water, energy, health, and human settlements. The projects proposed under the NAPA for the reduction of coastal climate change hazards include afforestation with community participation, aiming to build the capacity of individuals and institutions (Ibid). However, due to difficulties accessing money from the Global Environmental Facility (GEF) only one project (under the guidance of the United Nations Development Programme (UNDP)) has been implemented so far (MoEF, 2012).

The 2005 Coastal Zone Policy and 2006 Coastal Zone Strategy are part of the Integrated Coastal Zone Management Plan, which proposes sea dykes as a first line of defence against SLR as well as a framework to monitor SLR (WARPO, 2005). As not enough financial resources are available for constructing this kind of costly infrastructure, only a few of the proposed projects have entered the implementation phase (MoEF, 2012).

Bangladesh's long-term strategic planning document, Vision 2021, acknowledges that a substantial part of the coastal zone may become inundated by SLR (General Economic Division, 2010). In response to this, Vision 2021 proposed the implementation of adaptation strategies such as promoting saline tolerant crops, facilitating land reclamation, and strengthening coastal afforestation programmes. Vision 2021 also states that the Coastal Zone Policy and Coastal Zone Strategy will be used as guidance for action and may be revised as necessary, with emphasis placed on desalinisation (Ibid). However, most of the proposed programmes have not been implemented yet and only a few are in the design phase, again, due to a lack of funding (MoEF 2012).

The Bangladesh Climate Change Strategy and Action Plan (BCCSAP) (MoEF, 2009) recognised that SLR would result in problems such as coastal embankments being overtopped and saline intrusion into rivers and groundwater. The BCCSAP noted that necessary investments included the upgrading of embankments and polders in the coastal zone, improvement of crops and cropping systems and the provision of potable water (MoEF, 2009). The Strategy proposed a programme to monitor SLR and use climate models to predict future SLR and its impacts (Ibid). The Climate Change Unit under the Ministry of Environment and Forests (MoEF) has started implementing more than fifty projects listed in the BCCSAP (MoEF, 2012) out of which around 22 projects are related to SLR and salinisation (Climate Change Unit, n.d.).

4.9. Institutional Framework

To date, no dedicated institutional mechanism to address SLR exists in Bangladesh. Issues related to SLR mostly fall under the agenda of the Ministry of Water Resources (MWR), but general climate change issues are predominantly dealt with by the MoEF. Due to a lack of harmonisation among ministries, the Ministry of Water Resources has not mainstreamed climate change into their policies. Consequently, more coordination and synergy between the two ministries is required in order to establish the institutional framework required to adequately address loss and damage due to SLR.

To date, no dedicated institutional mechanism to address SLR exists in Bangladesh

To facilitate the implementation of the BCCSAP, a National Steering Committee on Climate Change has been established and is chaired by the Head of the MoEF (MoEF, 2009). A Climate Change Unit under the MoEF has also been created (Ibid). This Unit will be working in conjunction with climate change focal points, which will be established in each of the ministries. So far, sixteen climate change focal points have been established under different ministries[11].

5. Policies and Institutional Environment to Address Loss and Damage from Local SLR

While the national policy level for addressing SLR and associated impacts is well developed – 35 policies exist, covering most ministries and departments (MoEF, 2012) – local viewpoints and needs are rarely incorporated. For instance, the BCCSAP did not

[11] Ministry of Environment and Forests, Ministry of Water Resources, Ministry of Agriculture, Ministry of Land, Ministry of Fisheries, Local Government Engineering Department, Ministry of Local Government and Rural Development, Ministry of Education, Ministry of Women Affairs, Ministry of Disaster Management, Ministry of Food and Relief, Ministry of Foreign Affairs, Ministry of Finance, Economic Relations Division, Ministry of Health, Power Department, Ministry of Mineral Resources (Personal Interview with Key Informant, 27th February 2013)

acknowledge the need to include community-based activities on adaptation (MoEF, 2009). There should be a mix of policies, ensuring that many follow a bottom-up approach, rather than a top-down approach, as local knowledge is imperative for designing comprehensive and effective solutions to SLR. However, due to centralised governance in Bangladesh, local governments are not empowered to inform even local policy let alone include the voice of its constituents (Ayers, 2011). In addition, the timely and effective implementation of the plans and programmes that do exist does not always occur (Ibid). To address these shortcomings, a set of recommendations is proposed below.

... local viewpoints and needs are rarely incorporated

The government needs to develop and implement national policies that meet the concerns and needs at the local level, where loss and damage is incurred. Local government institutions that could design such policies already exist; however, human capacity at the local level (of local government officials and constituents) needs to be improved significantly. To do so, additional resources are needed.

The National Water Policy needs to be revised to include recommendations for establishing a monitoring protocol for assessing the rate of SLR and salinisation. In addition, the policy should be harmonised with the coastal zone strategy as both policies will be primarily implemented under the MWR.

... the institutional framework needs to be strengthened

In order to implement the above policy changes, Bangladesh's institutional framework needs to be strengthened. For example, the Ministry of Agriculture, the Ministry of Fisheries and Livestock, and the Ministry of Rural Development and Cooperatives need support in terms of capacity building, technology transfer, and financial resources. Most importantly, the Ministry of Finance and the Planning Commission should be more proactive in terms of integrating climate change issues such as SLR into their plans and policies, as their decisions influence all other ministries and departments.

Understanding local level RSL is mandatory for planning effective options for addressing local SLR induced loss and damage. Bangladesh receives global SLR projections from the IPCC, which should be augmented by data and information at the national and local levels. Additional parameters necessary for measuring local SLR need to be clarified, which will require the capacity to simulate different SLR scenarios and impacts.

To improve data collection and management to enhance understanding of SLR and other slow onset processes will require financial, technological and capacity building support. Access to and disbursement of existing funding should be made possible and the establishment of national, regional, and international mechanisms for the management of funds and technology transfer should explored.

6. Conclusion

Bangladesh is at risk from a variety of climate change impacts, from extreme events like cyclones to slow onset processes like SLR and salinisation. In the future, climate change will bring impacts that human societies have not yet experienced, many of which will be beyond adaptation and will inflict losses and damages in a number of ways. Addressing loss and damage to climate change impacts is going to require new ways of thinking and doing. There is no one-size fits all approach, nor can one approach address loss and damage on its own. Instead, addressing loss and damage will require a combination of approaches, aimed at different sectors. Given the range of climate change impacts experienced in Bangladesh, approaches to address slow onset processes will need to be combined with those to address extreme events.

Addressing loss and damage to climate change impacts is going to require new ways of thinking and doing.

The GoB will also need to start thinking about how to address non-economic losses resulting from slow onset processes. Rising sea levels will eventually render parts of Bangladesh uninhabitable, which will induce permanent migration and alter the social fabric of communities, inflicting social and cultural losses as well as psychological and mental damage. SLR will likely increase cyclonic storm surge depth and severity, reduce the availability of freshwater, food security, and biodiversity as well as increasing soil and water salinity. Salinisation will affect the health of communities, which will inflict losses and damages on future generations. In an increasingly warmer world, non-economic losses will become more prevalent. Though difficulties exist with assessing the extent and impact of future SLR and thus loss and damage at the local level, approaches to address non-economic losses must be developed, which could be enhanced through collaboration and knowledge sharing at the regional and international levels.

For Bangladesh SLR is the slow onset process that poses the greatest threat to its population and thus has been used as the case study for this paper. However, other slow onset processes such as drought and changes in weather and temperature patterns must also be explored in future research on long term climate change impacts to understand what the future will bring and develop approaches to address future losses and damages before they are incurred.

References

Adri, N., and I. Islam. (2012). Vulnerability and Coping Strategies in Waterlogged Area: A Case Study from Keshabpu, Bangladesh. *International Journal of Environment* 2(1): 48–56.

Ahmed, A. U. and M. Alam. (1998). Development of Climate Change Scenarios with General Circulation Models. In S. Huq, Z. Karim, M. Asaduzzaman, and F. Mahtab, eds. *Vulnerability and Adaptation to Climate Chane for Bangladesh*. Dordrecht, the Netherlands: Kluwer Academic Publishers.

Ahmed, A. U. and C. Schaerer. (2004). Sustaining Livelihoods Opportunities for the Coastal Poor Under Climate Change: A Case Study from Bangladesh. In Anonymous (ed). *Conference on Coastal Zone Asia Pacific: Proceedings of Coastal Zone Asia Pacific*. Brisbane, 7-9 September 2004.

Ahmed, S. (2008). The Status and Challenges of Water Infrastructure Development in Bangladesh. In: Anonymous (ed). *The First Regional Workshop on Co-efficient Water Infrastructure in Asia.* Seoul: United Nations Economic and Social Commission for Asia.

Alam, M. (2003). Bangladesh Country Case Study. *Asian Regional Workshop for the Preparation of National Adaptation Programme of Action.* Thimphu, Bhutan. [Online] Available at: http://www.napapana.org/files/workshops/buthan/11_Bangladesh_Case_Study.pdf [Accessed 31 January 2013].

Ali, A. M. S. (2006). Rice to Shrimp: Land Use/ Land Cover Changes and Soil Degradation in Southwestern Bangladesh. *Land Use Policy* 17(1 & 2): 421 - 435.

Asaduzzaman, M., Ahmed, A. U., Haq, E., and S. M. Chowdhury. (2005). *Climate Change and Bangladesh: Livelihoods Issues for Adaptation.* Dhaka, Bangladesh: Bangladesh Institute of Development Studies (BIDS).

Ashraf, M. Y., Sarwar, G., Ashraf, M., Afaf, R., and A. Sattar (2002). Salinity Induced Changes in α-Amylase Activity During Germination and Early Cotton Seedling Growth. *Biologia Plantarum*, 45(4):589-591.

Ayers, J. (2011). Resolving the adaptation paradox: exploring the potential for deliberative adaptation policymaking in Bangladesh. *Global Environmental Politics*, 11(1), pp. 62 - 88.

Bardsley, D.K. and G.J. Hugo. (2010). Migration and climate change: examining the thresholds of change to guide effective adaptation decision-making. *Population and Environment*, 32(2-3), pp.238-62.

Beddington, J., Asaduzzaman, M., Clark, M., Fernandez, A., Guillou, M., Jahn, M , Erda, L., Tekalig, M., Nguyen, V. B., Nobre, C., Scholes, R., Shama, R. and J. Wakhungu. (2012). *Achieving Food Security in the Face of Climate Change: Final Report from the Commission on Sustainable Agriculture and Climate Change.* Copenhagen: Commission on Sustainable Agriculture and Climate Change.

Bhaduri, A., and B. K. Anand. (2012). *Linking Rivers in the Ganges-Brahmaputra Basin: Exploring the Transboundary Effects and Possibility of a Win-Win Situation.* New Delhi: National Agriculture Science Centre.

Bunya, S. et al. (2010). A High-Resolution Coupled Riverine Flow, Tide, Wind, Wind Wave, and Storm Surge Model for Southern Louisiana and Mississippi. Part I: Model Development and Validation. *American Meteorological Society*, 138, pp.345-77.

Bhuiyan, M. and D. Dutta. (2012). Assessing impacts of sea level rise on river salinity in the Gorai river network, Bangladesh. *Estuarine, Coastal and Shelf Science* 96: 219-227.

Climate Change Cell. (CCC). (2009). *Economic Modeling of Climate Change Adaptation Needs for Physical Infrastructures in Bangladesh. Component 4b.* Dhaka: Comprehensive Disaster Management Programme and Ministry of Food and Disaster Management.

Climate Change Unit. (n.d.). *Climate Change Unit.* [Online] Available at: http://www.moef.gov.bd/Climate%20Change%20Unit/Bangladesh%20Climate%20Change%20Trust%20Fund%20Approved%2082%20Project%20List%20Ministry%20wise%20Fund%20allocation.pdf [Accessed 31 January 2013].

Centre for Environmental and Geographic Information Services (CEGIS). (2006). *Impacts of Sea Level Rise on Land-use Suitability and Adaptation Options.* Dhaka: Ministry of Environment and Forests.

Centre for Environmental and Geographic Information Services (CEGIS). (2008). Prediction for Bank Erosion and Morphological Changes of the Jamuna River. Dhaka: Centre for Environmental and Geographic Information Services.

Centre for Environmental and Geographic Information Services (CEGIS). (2010). *Feasibility study of integrated development of Urir Char.* Dhaka: Char Development and Settlement Project (CDSP) and Bangladesh Water Development Board (BWDB).

Chowdhury, S. (2000). *Bangladesh - Climate Change and Sustainable Development.* Washington, DC: The World Bank Group.

Coumou, D. and M. Schaeffer. (2012). Science Update: Loss and Damage – Climate Change Today and under Future Scenarios. A report prepared by Climate Analytics. [Online] Available at: http://www.loss-and-damage.net/download/6817.pdf [Accessed 17 January 2013].

Center for Climate Change and Environmental Research (C3ER). (2013). Meeting on Loss and Damage, Bangkok 2013 [online] Available at: http://dspace.bracu.ac.bd/bitstream/handle/10361/2042/Sept%202012.pdf?sequence=1 [Accessed 11 February 2013].

Dasgupta, S., Huq, M., Khan, Z. H., Ahmed, M. M., Mukherjee, N., and M.F. Khan. (2010). *Vulnerability of Bangladesh to Cyclones in a Changing Climate: Potential Damages and Adaptation Cost.* Washington DC: The World Bank Group.

Dasgupta S., B. Laplante, C. Meisner, D. Wheeler and J. Yan. (2009). The impact of sea level rise on developing countries: A comparative analysis. *Climatic Change,* 93, pp. 379–388.

Deshingkar, P. and S. Akter. (2009). *Migration and Human Development in India*. Research Paper 2009/13, Human Development Reports. UNDP.

Department of Environment (DoE). (1993). *Assessment of the Vulnerability of Coastal Areas to Climate Change and SLR. A Pilot Study of Bangladesh.* Dhaka: Ministry of Environment and Forest (MoEF).

Dietrich, J. C. et al. (2011). Hurricane Gustav (2008) Waves and Storm Surge: Hindcast, Synoptic Analysis, and Validation in Southern Louisiana. *Monthly Weather Rev*iew 139: 2488–2522.

Foresight. (2011). Migration and Global Environmental Change: Final Project Report. London: The Government Office for Science.

General Economic Division. (2010). *Outline of the perspective plan: Vision 2021.* Dhaka, Bangladesh: Planning Commission.

Gopal, B., and M. Chauhan (2006). Biodiversity and its conservation in the Sundarban Mangrove Ecosystem. *Aquatic Sciences*, 68(3): 338-354.

Hayhoe, K., Wake, C. P., Huntington, T. G., Luo, L., Schwartz, M. D, Sheffield, J. Wood, E., Anderson, B., Bradbury, J., De Gaetano, A., Troy, T. J., and D. Wolfe. (2007). Past and future changes in climate and hydrological indicators in the US Northeast. *Climate Dynamics* 28(4): 381–407.

IPCC. (2012). Summary for Policymakers. In V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.): Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*.* Cambridge: Cambridge University Press.

Islam, M. S. (2001). *Sea Level Changes in Bangladesh: The Last Ten Thousand Years.* Dhaka: Asiatic Society of Bangladesh.

Institute of Water Modelling (IWM). (2009). Survey and Modeling Study of Sandwip-Urir Char-Noakhali Cross Dam for Land Reclamation. Dhaka: Bangladesh Water Development Board.

Institute of Water Modelling (IWM) and Centre for Climate Change and Environmental Research (CEGIS). (2007) *Investigating the Impact of Relative Sea Level Rise on Coastal Communities and their Livelihoods in Bangladesh.* Dhaka: Institute of Water Modelling and Centre for Climate Change and Environmental Research.

International Organization for Migration (IOM). (2010), World Migration Report. Geneva: International Organization for Migration

International Union for Conservation of Nature (IUCN). (2012). *IUCN Red List of Threatened Species. Version 2012.2*. [Online] Available at: http://www.iucnredlist.org/ [Accessed 25 February 2013].

Key Informant from the Ministry of Environment and Forests. Interviewed by: Mukherjee, N. 27th February 2013.

Kibria, Z. (2011). Tidal River Management: Community based river basin management and climate change adaptation in Southwest Coastal Region of Bangladesh. [Online] Available at: http://www.uttaran.net/publications/tidalrivermanagement(TRM).pdf [Accessed 20 January 2013].

Larinier, M. (2001). *Environmental issues, dams and fish migration.* In G. Marmulla (ed.) FAO Fisheries Technical Paper 419. Rome: Food and Agriculture Organization.

Lobell, D. B., and M. Burke (eds.) (2010). Climate Change and Food Security: Adapting to a Warmer World. London: Springer.

Masud-All-Kamal, Md. (2013). Livelihood Coping and Recovery from Disaster: The Case of Bangladesh. *Current Research Journal of Social Sciences* 5(1): 35-44.

McCarthy, J. J., Canziani, O. S., Leary, N. A., Dokken, D. J., and K.S. White. (2001). *Climate Change 2001: Working Group II: Impacts, Adaptation, and Vulnerability (Chapter 11).* Cambridge: Cambridge University Press.

Mirza, M. M. (1998). Diversion of the Ganges Water at Farakka and Its Effects on Salinity in Bangladesh. *Environmental Management* 22(5): 711-722.

Mirza, M. M., and Q. K. Ahmad. (2005). Climate Change and Water Resources in South Asia: An Introduction. In M. M. Mirza, and Q. K. Ahmad (eds.), *Climate Change and Water Resources in South Asia.* London: Taylor & Francis.

Mirza, M. M. and M. H. Sarker. (2004). The Ganges Water Diversion: Environmental Effects and Implications. In M. M. Mirza and M. H. Sarker (eds.), *Effects of Water Salinity in Bangladesh*. Dordrecht, the Netherlands: Kluwer Academic Publishers.

Ministry of Environment and Forests (MoEF). (2005). *National Adaptation Programme of Action.* Dhaka: Ministry of Environment and Forests (MoEF).

Ministry of Environment and Forests (MoEF). (2009). *Bangladesh Climate Change Strategy and Action Plan 2009.* Dhaka: Ministy of Environment and Forests.

Ministry of Environment and Forests (MoEF). (2012). *Second National Communication.* Dhaka: Ministry of Environment and Forests.

Mote, P.W., A.F. Hamlet, and E.P. Salathé. (2008). Has Spring Snowpack Declined in the Washington Cascades? *Hydrology and Earth System Sciences*, 12:193–206.

Mukherjee, N., Choudhury, G. A., Khan, M. F., and A. K. Islam (2011a). Implication of changing consumption patterns on food security and water resources in Bangladesh. In Anonymous, ed. *3rd International Conference on Water and Flood Management*. Dhaka, January 8-10, 2011.

Mukherjee, N., Khan, M. F., Chakravorty, N., Rahman, R., Chowdhury, G. A., and A. Hassan. (2011b). Economics of adaptation to climate change for water management development in the coastal region of Bangladesh. In: Anonymous, ed. *3rd International Conference on Water and Flood Management*. Dhaka, January 8-10, 2011.

Nakicenovic, N. et al. (2000). *Special Report: Emissions Scenarios Summary for the Policy Makers.* Geneva: Intergovernmental Panel on Climate Change.

New Age. (2012). *Govt needs to correct its course about tidal river management.* [online] Available at: http://www.newagebd.com/detail.php?date=2012-06-19&nid=14193#.UVW8XldGj5c [Accessed 10 July 2012].

New Age. (2013). *Ganges Barrage Project: Water board submits feasibility report*. [Online] Available at: http://newagebd.com/detail.php?date=2013-01-08&nid=36036#.UVfJlxlhN-U [Accessed 31 January 2013].

Nishat, A., Mukherjee, N., Rahman, S., Khanum, R., Nipa, S. N., and T. Huq Easher. (2013). *Reducing vulnerability of women affected by climate change through viable livelihood options.* Dhaka: BRAC University Environment and Climate Change programme and Centre for Climate Change and Environmental Research.

Nishat, A., Mukherjee, N., Rahman, S., Khanum, R., Hasan, A., and T. Huq Easher (forthcoming). The *Role of governance against climate change induced Migration*: *Assessment and Policy*. Dhaka: BRAC University Centre for Climate Change and Environmental Research.

Oliver-Smith, A. (2006). *Disasters and Forced Migration in the 21st Century.* [online] Available at: http://understandingkatrina.ssrc.org/Oliver-Smith/ [Accessed 10 July 2012].

UN Office for the Coordination of Humanitarian Affairs (OCHA). (2011). *OCHA Occasional Policy Briefing Series, Brief No. 6: OCHA and slow-onset emergencies.* New York: UN Office for the Coordination of Humanitarian Affairs.

Rahman, R., Khan, M. F., Nishat, B., Mukherjee, N., and S. Ahmed. (2011). *Indicators to Assess Impacts on Hydro-Meteorology.* Dhaka: International Union for Conservation of Nature.

Rahmstorf, S. (2007). A Semi-Empirical Approach to Projecting Future Sea-Level Rise, *Science* 315(5810): 368-370.

Raleigh, C., Jordan, L., and I. Salehyan. (2008). *Assessing the Impact of Climate Change on Migration and Conflict.* Washington DC: The World Bank Group.

Rashid, M. M., Hoque, A. K., and M. S. Iftekhar. (2004). Salt Tolerances of Some Multipurpose Tree Species as Determined by Seed Germination. *Journal of Biological Sciences* 4 (3):288-292.

Reducing Vulnerability to Climate Change (RVCC). (2003). *A Community Level Vulnerability Assessment Conducted in Southwest Bangladesh.* Dhaka: CARE Bangladesh.

Sarwar, M. G. (2005). *Impacts of sea level rise on the coastal zone of Bangladesh.* Lund: Lund University (Masters Thesis).

SAARC Meteorological Research Center (SMRC) (2000). *Cyclones in a changing climate: The case of Bangladesh.* Kathmandu: SAARC Meteorological Research Center.

Shamsuddoha, Md., Khan, S. M. M. H., Raihan, S. and T. Hossain. (2012). *Displacement and Migration from Climate Hot-spots: Causes and Consequences*. Dhaka: Center for Participatory Research and Development and ActionAid.

Solomon , S., Qin, D., Manning, M., Chen, Z., Marquis, M., K. B. Averyt et al. (eds.) (2007). *Summary for Policymakers. In:Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

Snell, C., Bernheim, A., Bergè, J-B., Kuntz, M., Pascale, G., Paris, A., and A.E. Ricroch. (2012). Assessment of the health impact of GM plant diets in long-term and multigenerational animal feeding trials: a literature review. *Food and Chemical Toxicology* 50(3):1134-48.

Warner, K., van der Geest, K., Kreft, S., Huq, S., Harmeling, S., Kusters, K., and A. de Sherbinin. (2012). *Evidence from the frontlines of climate change: Loss and damage to communities despite coping and adaptation.* Bonn, Germany: United Nations University.

Water Resources Planning Organisation (WARPO). (2001). *National Water Management Plan (NWMP)-Volume 2.* Dhaka: Ministry of Water Resources .

Water Resources Planning Organisation (WARPO). (2005). *Impact Assessment of Climate Change on the Coastal zone of Bangladesh.* Dhaka: Ministry of Water Resources.

Wirsing, R., Stoll, D. and C. Jasparro. (2013). International conflict over water resources in Himalayan Asia. London: Palgrave Macmillan.

World Bank, Bangladesh Bureau of Statistics (BBS) and World Food Programme (WFP). (2009). *Updating poverty maps of Bangladesh.* Dhaka: The World Bank, Bangladesh Bureau of Statistics (BBS), and World Food Programme (WFP).

World Bank. (2010). Economics of Adaptation to Climate Change: Bangladesh. Washington DC: The World Bank Group.

The Loss and Damage in Vulnerable Countries Initiative

Accepting the reality of unmitigated climate change, the UNFCCC negotiations have raised the profile of the issue of loss & damage to adverse climate impacts. At COP-16, Parties created a Work Programme on Loss and Damage under the Subsidiary Body on Implementation (SBI). The goal of this work programme is to increase awareness among delegates, assess the exposure of countries to loss and damage, explore a range of activities that may be appropriate to address loss and damage in vulnerable countries, and identify ways that the UNFCCC process might play in helping countries avoid and reduce loss and damage associated with climate change. COP-18, in December 2012, will mark the next milestone in furthering the international response to this issue.

The "Loss and Damage in Vulnerable Countries Initiative" supports the Government of Bangladesh and the Least Developed Countries to call for action of the international community.

The Initiative is supplied by a consortium of organisations including:

Germanwatch

Munich Climate Insurance Initiative

United Nations University – Institute for Human and Environment Security

International Centre for Climate Change and Development

Kindly supported by the Climate Development and Knowledge Network (CDKN)

For further information: **www.loss-and-damage.net**

International Centre for Climate Change and Development (ICCCAD)

Based in the Independent University, Bangladesh (IUB), the International Centre for Climate Change and Development's aim is to develop a world-class institution that is closely related to local experience, knowledge and research in one of the countries that is most affected by climate change. ICCCAD supports growing capacity of Bangladesh stakeholders, as well as enabling people and organizations from outside the country to benefit from training in the field, where they are exposed to the adaptation "experiments" and increasing knowledge. Through the expertise and research outputs of ICCCAD and its local partners, international organizations will be able to continue to share and transmit knowledge of climate change and development challenges around the world for the benefit of other LDCs, and their governments, donors and international NGOs. ICCCAD has begun running regular short courses for NGOs, donors, the media, government staff, private sector, etc. As well as initiating courses for local participants and Bangladeshi stakeholders, it provides tailor-made courses for organizations and departments that are seeking to enhance their capacity in regard to climate change.

For further information:

International Centre for Climate Change and Development (ICCCAD)
Independent University, Bangladesh (IUB)
Plot-16, Block-B, Aftabuddin Ahmed Road
Bashundhara R/A, Dhaka- 1229
Tel- 88-02-840-1645-53 (extn-226,391)
Fax-88-02-840-1991
Website: www.iub.edu, www.icccad.org