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Monographic issue

Effect of Climate Change and Rise of Sea Level: A Risk Profile of Bangladesh

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Letter from the editors

The Emergency and Disaster Reports is a journal edited by the Unit for Research in Emergency and Disaster of the Department of Medicine of the University of Oviedo aimed to introduce research papers, monographic reviews and technical reports related to the fields of Medicine and Public Health in the contexts of emergency and disaster. Both situations are events that can deeply affect the health, the economy, the environment and the development of the affected populations.

The topics covered by the journal include a wide range of issues related to the different dimensions of the phenomena of emergency and disaster, ranging from the study of the risk factors, patterns of frequency and distribution, characteristics, impacts, prevention, preparedness, mitigation, response, humanitarian aid, standards of intervention, operative research, recovery, rehabilitation, resilience and policies, strategies and actions to address these phenomena from a risk reduction approach. In the last thirty years has been substantial progress in the above mentioned areas in part thanks to a better scientific knowledge of the subject. The aim of the journal is to contribute to this progress facilitating the dissemination of the results of research in this field.

This monographic issue is about disaster risk profile of climate change and rise of sea level in Bangladesh.

Bangladesh is among the top 10 countries having coastal areas less than 30 feet the sea level and with a large proportion of their population living in the coastal areas, the risk profile of Bangladesh is of great interest. It is one of the world's poorest nations and also the country most vulnerable to sea-level rise. Its population is already severely affected by storm surges. Catastrophic events in the past have caused damage up to 100 km inland. It is hard to imagine to what extent these catastrophes would be with accelerated sea-level rise.

The risk profile described and analyzed here and the impact of climate change on the sea level and the subjacent vulnerabilities in Bangladesh.

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ABSTRACT

Impacts of sea level rise on Bangladesh were examined through literature review using secondary data from various research papers and reports prepared by national and international organizations working in this field. The study revealed that a one meter sea level rise will affect the vast coastal area and flood plain zone of Bangladesh. Height of sea level and population in the coastal area are the two factors which increases the risks of a country from rise of sea level, since Bangladesh meets the both criteria. Both livelihood options of coastal communities and the natural environment of the coastal zone will be affected by the anticipated sea level rise. It will also affect national and food security of the country. The Sundarbans, the most important ecosystem of the country will be totally lost with one meter rise in sea level. To minimize the impacts of rise of sea level Government of Bangladesh along with all stakeholders such as community, NGOs and other national and International organizations need to put in their concerted efforts.

Key words: *Rise of Sea level, Bangladesh, coastal zone, impacts, effects, mitigation, adaptation*

Background: The term disaster has been defined in different way by different agencies. Oxford dictionary defines Disasters as "a sudden accident or a natural catastrophe that causes great damage or loss of life". Out of different types of disasters, total loss of live were maximum due to climatological events. Climate changes effect ecosystems, hydrology and water resources, food and fiber production, coastal systems, human settlements, human health, and other sectors or systems (including the climate system) and Earth's land surface. One of the important impact of change in climate is rise of sea level.

Rise in sea level directly effects the coastal areas which are the interface between the land and water. Effect of sea level in costal areas are important to monitor because a majority of the world's population lives in such areas. Rise of sea level increases salinity of earth and water and hence affects agriculture, reduction of earth and last but not the least the health of human beings.

Looking into the vast effect of rise of sea level on human being this study was designed.

General objective: The aim of this study was to synthesize the available knowledge about effect of climate change on sea level and to develop risk profile of Bangladesh, which is among most affected country by rise of sea level.

Study design: Since goal of the study was to find out different types of causes and to identify different effect of climate change on sea level in Bangladesh a exploratory study design was used.

Data Type: This study was based on secondary data. Data from various open sources such as IPCC, CDC, WHO, Medline, google scholar etc. were used to find both qualitative and quantitate evidences.

Framework of analysis: Risk is defined as chances of occurrence of non desirable events. For risk of disasters, it is generally linked to availability of hazards and vulnerability of the people. Risk =Hazards x Vulnerability. Hazards are the factors which will cause the disasters whereas, vulnerability are the characteristics, which will multiply the effect of the disasters. Similarly strategies which are adopted to reduce the impact of risk in a given populations were also studied to find its effect and relevance in the current scenario.

Methods: The study was based on the literature review. Prisma framework, which is a minimum set of items for reporting in systematic reviews and meta-analyses, was used as model (1). All literature reviewed in the study were indexed in the report using *Endnote* software.

Findings: Rise of sea level poses greatest threat to coastal areas with low sea level and the places which has maximum number of people living near the sea level. Low sea level which is recognised with higher risk to human life are the places less than 30 feet above sea level. Census figures from 224 countries showed that low-elevation areas are home to 634 million people. "Roughly one in 10 persons in the world lives in this low-elevation coastal zone. Some of the countries have very large populations:

The 10 countries with the most people in the low coastal areas are:

1. China,

2. India,
3. Bangladesh,
4. Vietnam,
5. Indonesia,
6. Japan,
7. Egypt,
8. United States,
9. Thailand, and
10. the Philippines.

The countries with the largest share of their populations living in low-elevation areas are:

1. Bahamas,
2. Suriname,
3. the Netherlands,
4. Vietnam,
5. Guyana,
6. Bangladesh,
7. Djibouti,
8. Belize,
9. Egypt, and
10. Gambia.

Two-thirds of world's largest cities which have more than five million people are partially in these low areas. "Over the next 100 years, when there will be sea level rise, people living in those areas will also increase. Bangladesh and Egypt are in top ten countries which are most affected by rise of sea level by both the criteria.

Characteristics of Bangladesh: Bangladesh formally known as People's Republic of Bangladesh is located in South Asia, is surrounded almost entirely by India,. Geographically, the country is situated in the fertile soil of the delta of the river Ganga, which is subject to annual flooding caused by monsoons and cyclones. Along with the Indian province of West Bengal, it is the ethno-linguistic region of Bengal. In fact, in Bengali, the name "Bangladesh" means "Country of

Bengal". After independence, country had gone through many political turmoil and natural disasters.

Since Bangladesh is among the top 10 countries having coastal areas less than 30 feet the sea level and with a large proportion of their population living in the coastal areas, the risk profile of Bangladesh is of great interest. It is one of the world's poorest nations and also the country most vulnerable to sea-level rise. Its population is already severely affected by storm surges. Catastrophic events in the past have caused damage up to 100 km inland. It is hard to imagine to what extent these catastrophes would be with accelerated sea-level rise.

Institutional Framework in Bangladesh: For long time it had adopted traditional system of reactive mode of disaster management. In 1990 it adopted proper system and established National Disaster Management Program under the ministry of Agriculture and Disaster Management. However, still there is no policy on disaster management all the work of the department is governed by a office order on disaster management. Despite the fact that rise of sea level is main cause of disaster in Bangladesh there is separate cell about it.

Effect of Rise off Sea Level on Salinity Intrusion : One of the main effect of sea level rise are intrusion of salinity and hence deduction in fresh water availability in the coastal areas. Increase in water salinity along the coastal areas causes increase in soil salinity. A one meter sea level rise will expand the soil and water salinity area at a faster rate.

Impacts on Fisheries and Aquaculture : Rise of sea level greatly affect the fisheries and aquaculture, which is the main source of food and economy of the people living in this zone. All the districts that are located in the coastal zone vulnerable to sea level rise, shrimp hatcheries and shrimp fields are also vulnerable to the phenomena. However, sea level rise is helping shrimp farming by introducing salinity in the coastal area, but it is also harmful. If we consider another sea level rise phenomena, for instance flooding; it is doing massive harm to the sector by overflowing shrimp pond and let the shrimps to set free in open water.

Effect on Agriculture: The effect of rise of sea level on agriculture is linked to increase in soil salinity and increase in water salinity. Salinity intrusion due to sea level rise will decrease agricultural production by unavailability of fresh water and soil degradation. Salinity also decreases the terminative energy and germination rate of some plants. Sea level rise affects coastal agriculture, especially rice production in two ways. Salinity intrusion degrades soil quality that decrease or inhibit rice production. Secondly people start converting rice fields into shrimp ponds, total rice production decreases because of degraded soil quality. Increased salinity from a 0.3 meter sea level rise will cause a net reduction of 0.5 million metric tons of rice production.

Impact on Landmass and Settlement: The SLR will inflict its impacts on Bangladesh in the coastal area and through the coastal area, on the whole of Bangladesh. About 2,500, 8,000 and 14,000 $km^2$of land (with a corresponding percentage of 2%, 5% and 10% with respect to the total land area of the country) will be lost due to SLR of 0.1m, 0.3m and 1.0m respectively. The potential land loss estimated by GRID suggest that 16% of total areas and nearly 15% of the population will be affected due to rise of sea level. Increase in affected land areas will lead to loss of agricultural land, loss of road and other communication infrastructure and above of loss of wide range of biodiversity.

Sea level rise will play important role in erosion processes in the coastal zone. Raised water level wash out the loose top soil of the coast, making the coastal region steeper. Backwater effect is accelerated by sea level rise that also cause erosion. Silt or other particles eroded from the surrounding areas are deposited when the lowlands of the coastal areas are filled with water.

Effect of Rise of Sea Level on Health People in Bangladesh: Rise of sea level increases salinity of water and most of the salt present in the form of sodium chloride (NaCl) breaks up into Na+ and Cl- ion when dissolved in water. Therefore, coastal area is breeding and nursery ground of cholera disease. Sea level rise may increase the risk of health hazards like diarrhea, cholera, etc. in the coastal area of Bangladesh.

Effect of Rise of Sea Level on Ecosystem of Bangladesh: Rise of sea level will have huge impact on ecosystem of the Bangladesh. Species like Sundari, main economic species in the Sundarbans, would be replaced by less valuable Goran and Gewa.

Loss of the Sundarbans and other coastal wetlands would reduce breeding ground for many estuarine fish, which could reduce their population. Sea level rise would result in saline water moving further into the delta. This would reduce the habitat for fresh water fish, although it could increase the habitat for estuarine fish.

Effect on Food, Education and Cloths Availability in Bangladesh; Rise in sea level will cause massive reduction in land mass in the coastal areas, which will damage educational institutions, beside affected population will have to keep on changing their houses and hence it will increase poverty and therefore reduce access to education and availability of house, cloths and education. Country may have to hugely depend on foreign aid.

Effect of Rise of Sea Level on Economy and Life of Bangladesh; Rise in sea level due to climate affects and gets affected by the ecosystem of a country along with their hydrology and water resources, food and fiber production, coastal systems, human settlements, human health, and other sectors or systems (including the climate system) important to 10 regions that encompass the Earth's land surface.

Ecosystems are of fundamental importance to environmental function and to sustainability, and they provide many goods and services critical to individuals and societies.

Measures Taken by Bangladesh: Bangladesh is paying its attention to minimize the impacts of sea level rise by either mitigation strategies (In relation to rise of sea level mitigation is defined as a response to the broad issue of climate change and it involves reducing or stabilizing greenhouse gas emissions or levels, in order to mitigate changes in climate) or adaptation strategies (which is referred to adjustments in ecological-social-economic systems in response to actual or expected climatic stimuli, their effects or impacts). During first four decades after its independence (that 1971-2011), Government of Bangladesh and its Development partners have invested over USD 10 billion in projects aimed at decreasing the country's vulnerability to natural hazards. Some key interventions taken by Bangladesh are:

Embankments: Low-lying southern coastal regions are the most vulnerable and therefore 5,107km-long network of flood embankments have been created to protected these areas.

Early Warning System: The Government of Bangladesh has installed warning systems; built shelters to protect people from extreme weather events, and planted saltwater-tolerant crops to protect food supplies. But more work will be required to further reduce climate risks.

WASH Strategy: Since coastal areas faces increased salinity which causes cholera outbreak. Working with the Government of Bangladesh, WHO Bangladesh has developed a Health National Adaptation Plan and a water, sanitation and hygiene (WASH) strategy; and launched a surveillance system to track and combat climate-sensitive diseases, like diarrhoea, dengue and malaria. WASH aims to ensure water remains safe during extreme weather events and reduce water borne epidemic.

Recommendations: First and foremost, there is a need that Bangladesh's government makes a comprehensive policy on reducing impact of rise of sea level. Other recommendations may be classified into three categories. 1) reducing impact of environment on rise of sea level 2) Measures for improving the resilience power of the people living in the Low Sea Level and 3) Adaptation to rise of sea level. The brief recommendations under the three above mentioned categories are given below.

Reducing Speed of Rise of Sea Level: The first priority while fighting impact of rise of sea level may be to reduce the speed of rise of sea level by reducing global warming and reducing changes in environment. Since Bangladesh's contribution to emission is very less, more on this has to be done by developed countries themselves.

Suggestions for Improving Resilience of People Living in Low Sea Level: The measures may includes i) Protect Natural Barriers, ii) Create/Harden Artificial Barriers, Afforestation of the coastal areas, iii) Educate People about the threat, assist the most vulnerable, iv) Proper Monitoring of Sea level v) Establishing Early Warning System, vi) Establishing mechanism of data sharing mechanism among affected population, vii) Low Cost Rapid Public Transportation System, viii) Low cost community based Crop Insurance and General Insurance

Suggestions Adaptation to Rise of Sea Level are: Better communication and public awareness program in coastal areas, Promoting alternative mode of cultivation, Promoting floating agriculture in lowlands, submerged by water. In the method, dried hyacinth is piled on a floating structure and seedlings are grown on it. This soil less agriculture may be promoted in coastal areas to reduce the impact on agriculture even if farmers' lands are submerged. Promoting different varies of sea food which are more adoptable to saline water, promoting cage and pen culture in submerged and coastal areas with relatively weak water current and promoting Pearl culture may be another option to be introduced in the zone.

Conclusions**:** Rise of sea level is global challenges. It is more challenging for people living in the low sea level and particularly in costal areas with high population density. Therefore a conscious efforts must be taken to reduce the impact of environment on ecstatic sea level rise, tidal range amplification and a decrease in fresh water input and also improve the resilience of people living in the low sea level so that in case of any disaster like situation people the loss to life and properties both may be minimised. Need for global and united fight for this change in environment can thus never be overemphasised.

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Acronyms

CRED : Centre for Research on the Epidemiology of Disasters

CDC : Center for disease control

EM-DAT :Emergency Events Database

CM DAT : Complex Emergency Database

GIA : Glacioisostatic adjustment

GIC : Glaciers and ice caps

GDP : Gross domestic product

IPCC : Intergovernmental Panel on Climate Change

MOC : Meridional Overturning Circulation

SLR : Sea level rise

UN : United Nations

UNFCCC : United Nations Framework Convention on Climate Change

WHO : World Health Organization

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1. Background:

1.1 Disaster and Its Type:

The term disaster has been defined in different way by different agencies. Oxford dictionary defines Disasters as "a sudden accident or a natural catastrophe that causes great damage or loss of life" (2). It is also defined as "a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources"(3) or "a situation or event, which overwhelms local capacity, necessitating a request to national or international level for external assistance"(4).

Disasters are primarily categorized in to two types i) manmade disasters or the events that are caused by human being including terrorism ii) Natural disasters. Natural disasters have further been classified into four types. a) Climate change related (extreme temperature, drought, and wildfires) b) Meteorological Disaster (cyclone and storms/waves surges), c) or Geophysical (earthquakes, landslides and volcanic activities) or d) biological (such as disease epidemics and insect/animal plagues etc.).

As given in Table 1, during 1900 to 2016 the disasters due to technological reasons were more frequent followed by Hydrological and Meteorological but total loss of lives were maximum due to climatological events.

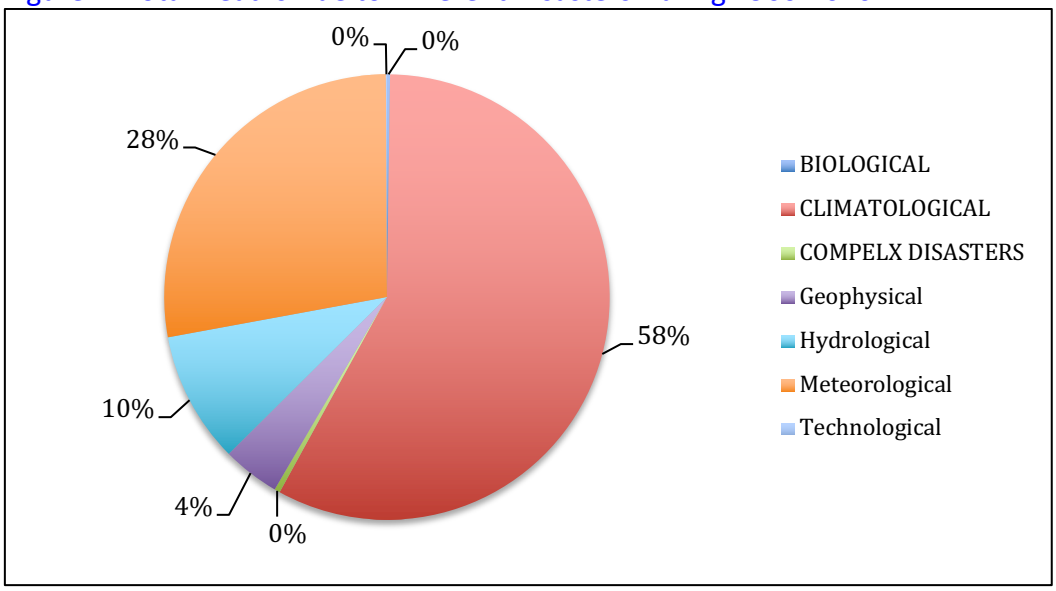
Table 1.Frequency of Events and Losses For Different Disasters During 1900-2016

Disaster subgroup	Occurrence	Total deaths	Injured	Total Affected	Total Damage
Biological	353	65,29,462	1,27,090	81,89,785	925
Climatological	248	96,64,175	858	2,09,83,49,225	5,40,21,764
Complex Disaster	6	6,10,000	0	1,46,75,614	
Geophysical	850	18,56,739	18,04,135	15,11,48,663	55,78,30,698
Hydrological	2,285	68,32,396	12,53,530	34,62,02,628	43,24,58,389
Meteorological	1,800	13,01,371	14,04,371	1,01,03,23,779	26,37,04,981
Technological	3,673	1,76,505	2,41,742	27,95,858	31,58,145
Total	**9,215**	**269,70,648**	**48,31,726**	**6,74,96,85,552**	**1,31,11,74,902**

Source: EMDAT

As per EMDAT data the deaths due to Climate change related events was nearly 58% of all deaths in last 116 years and therefore events due to climate change requires constant scrutiny of all those working in the humanitarian programs.

Figure 1. Total Deaths Due to Different Disasters During 1900-2016



Source: EMDAT

1.2 Climate Changes and Its Consequences:

"Climate change" refers to any change in climate over time, whether due to natural variability or as a result of human activity. United Nations Framework Convention on Climate Change (UNFCCC), defines "climate change" as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (5).

Events caused by Climate change is associated with a range of serious consequences, some of which will have immediate effects such as intense rain and flooding while some will have impact over the longer term, such as spread of disease and sea level rise (6).

Climate changes effect ecosystems, hydrology and water resources, food and fiber production, coastal systems, human settlements, human health, and other sectors or systems (including the climate system) and Earth's land surface. Notably, the effect of climate on above mentioned areas are found to be of different magnitude in different region of earth. These differences could be due to regional differences in local environmental conditions, pre-existing stresses to ecosystems, current resource-use patterns, and the framework of factors affecting decision-making—including government policies, prices, preferences and values (4, Summary of policy makers).

1.2.1. Climate Changes and Its Effect on Ecosystem:

Ecosystems are of fundamental importance to environmental function and to sustainability, and they provide many goods and services critical to individuals and societies. These goods and services include:

(i) providing food, fiber, fodder, shelter, medicines and energy;
(ii) processing and storing carbon and nutrients;
(iii) assimilating wastes;
(iv) purifying water, regulating water runoff and moderating floods;
(v) building soils and reducing soil degradation;
(vi) providing opportunities for recreation and tourism; and
(vii) housing the Earth's entire reservoir of genetic and species diversity.
(viii) In addition, natural ecosystems have cultural, religious, aesthetic and intrinsic existence values.

Changes in climate have the potential to affect the geographic location of ecological systems, the mix of species that they contain, and their ability to provide the wide range of benefits on which societies rely for their continued existence. Ecological systems are intrinsically dynamic and are constantly influenced by climate variability. The primary influence of anthropogenic climate change on ecosystems is expected to be through the rate and magnitude of change in climate means and extremes—climate change is expected to occur at a rapid rate relative to the speed at which ecosystems can adapt and re-establish themselves—and through the direct effects of increased atmospheric CO2

concentrations, which may increase the productivity and efficiency of water use in some plant species. Secondary effects of climate change involve changes in soil characteristics and disturbance regimes (e.g., fires, pests and diseases), which would favour some species over others and thus change the species composition of ecosystems. Based on model simulations of vegetation distribution, which use GCM-based climate scenarios, large shifts of vegetation boundaries into higher latitudes and elevations can be expected. The mix of species within a given vegetation class likely will change. Under equilibrium GCM climate scenarios, large regions show drought-induced declines in vegetation, even when the direct effects of CO2 fertilization are included.

By comparison, under transient climate scenarios—in which trace gases increase slowly over a period of years—the full effects of changes in temperature and precipitation lag the effects of a change in atmospheric composition by a number of decades; hence, the positive effects of CO2 precede the full effects of changes in climate. Climate change is projected to occur at a rapid rate relative to the speed at which forest species grow, reproduce and re-establish themselves (past tree species' migration rates are believed to be on the order of 4–200 km per century). For mid-latitude regions, an average warming of 1–3.5°C over the next 100 years would be equivalent to a poleward shift of the present geographic bands of similar temperatures (or "isotherms") approximately 150–550 km, or an altitude shift of about 150–550 m.

Therefore, the species composition of forests is likely to change; in some regions, entire forest types may disappear, while new assemblages of species and hence new ecosystems may be established. As a consequence of possible changes in temperature and water availability under doubled equivalent-CO2 equilibrium conditions, a substantial fraction (a global average of one-third, varying by region from one seventh to two-thirds) of the existing forested area of the world likely would undergo major changes in broad vegetation types—with the greatest changes occurring in high latitudes and the least in the tropics. In tropical rangelands, major alterations in productivity and species composition would occur due to altered rainfall amount and seasonality and increased evapotranspiration, although a mean temperature increase alone would not lead to

such changes. Inland aquatic ecosystems will be influenced by climate change through altered water temperatures, flow regimes, water levels and thawing of permafrost at high latitudes. In lakes and streams, warming would have the greatest biological effects at high latitudes—where biological productivity would increase and lead to expansion of cool-water species' ranges—and at the low-latitude boundaries of cold- and cool-water species ranges, where extinctions would be greatest. Increases in flow variability, particularly the frequency and duration of large floods and droughts, would tend to reduce water quality, biological productivity and habitat in streams.

The geographical distribution of wetlands is likely to shift with changes in temperature and precipitation, with uncertain implications for net greenhouse gas emissions from non-tidal wetlands. Some coastal ecosystems (saltwater marshes, mangrove ecosystems, coastal wetlands, coral reefs, coral atolls and river deltas) are particularly at risk from climate change and other stresses. Changes in these ecosystems would have major negative effects on freshwater supplies, fisheries, biodiversity and tourism. Adaptation options for ecosystems are limited, and their effectiveness is uncertain.

Options include establishment of corridors to assist the "migration" of ecosystems, land-use management, plantings and restoration of degraded areas. Because of the projected rapid rate of change relative to the rate at which species can re-establish themselves, the isolation and fragmentation of many ecosystems, the existence of multiple stresses (e.g., land-use change, pollution) and limited adaptation options, ecosystems (especially forested systems, montane systems and coral reefs) are vulnerable to climate change.

1.2.2. Climate Changes and Its Effect on Hydrology and Water Resources:

Water availability is an essential component of welfare and productivity. Currently, 1.3 billion people do not have access to adequate supplies of safe water, and 2 billion people do not have access to adequate sanitation. Although these people are dispersed throughout the globe—reflecting sub-national variations in water availability and quality—some 19 countries (primarily in the Middle East and north and southern Africa) face such severe shortfalls that they

are classified as either water-scarce or water-stressed; this number is expected to roughly double by 2025, in large part because of increases in demand resulting from economic and population growth. For example, most policy makers now recognize drought as a recurrent feature of Africa's climate. However, climate change will further exacerbate the frequency and magnitude of droughts in some places.

Developing countries are highly vulnerable to climate change because many are located in arid and semi-arid regions, and most derive their water resources from single-point systems such as bore holes or isolated reservoirs. These systems, by their nature, are vulnerable because there is no redundancy in the system to provide resources, should the primary supply fail. Also, given the limited technical, financial and management resources possessed by developing countries, adjusting to shortages and/or implementing adaptation measures will impose a heavy burden on their national economies.

Various approaches are available to reduce the potential vulnerability of water systems to climate change. Options include pricing systems, water efficiency initiatives, engineering and structural improvements to water supply infrastructure, agriculture policies and urban planning/management. At the national/regional level, priorities include placing greater emphasis on integrated, cross-sectoral water resources management, using river basins as resource management units, and encouraging sound pricing and management practices.

Given increasing demands, the prevalence and sensitivity of many simple water management systems to fluctuations in precipitation and runoff, and the considerable time and expense required to implement many adaptation measures, the water resources sector in many regions and countries is vulnerable to potential changes in climate.

1.2.3. Climate Changes and Its Effect on Food and Fiber Production:

The main direct effects of change in climate will be through changes in factors such as temperature, precipitation, length of growing season, and timing of

extreme or critical threshold events relative to crop development, as well as through changes in atmospheric CO2 concentration (which may have a beneficial effect on the growth of many crop types).

Indirect effects will include potentially detrimental changes in diseases, pests and weeds, the effects of which have not yet been quantified in most available studies. Evidence continues to support the findings of the IPCC SAR that "global agricultural production could be maintained relative to baseline production" for a growing population under 2×CO2 equilibrium climate conditions.

Generally, middle to high latitudes may experience increases in productivity, depending on crop type, growing season, changes in temperature regimes and the seasonality of precipitation.

In the tropics and subtropics—where some crops are near their maximum temperature tolerance and where dryland, non irrigated agriculture predominates—yields are likely to decrease. The livelihoods of subsistence farmers and pastoral peoples, who make up a large portion of rural populations in some regions, also could be negatively affected. In regions where there is a likelihood of decreased rainfall, agriculture could be significantly affected.

Fisheries and fish production are sensitive to changes in climate and currently are at risk from overfishing, diminishing nursery areas, and extensive inshore and coastal pollution. Globally, marine fisheries production is expected to remain about the same in response to changes in climate; high-latitude freshwater and aquaculture production is likely to increase, assuming that natural climate variability and the structure and strength of ocean currents remain about the same. The principal impacts will be felt at the national and local levels, as centers of production shift.

The positive effects of climate change—such as longer growing seasons, lower natural winter mortality and faster growth rates in higher latitudes—may be offset by negative factors such as changes in established reproductive patterns, migration routes and ecosystem relationships. Given the many forces bringing

profound changes to the agricultural sector, adaptation options that enhance resilience to current natural climate variability and potential changes in means and extremes and address other concerns (e.g., soil erosion, salinization) offer no- or low-regret options. For example, linking agricultural management to seasonal climate predictions can assist in incremental adaptation, particularly in regions where climate is strongly affected by ENSO conditions. The suitability of these options for different regions varies, in part because of differences in the financial and institutional ability of the private sector and governments in different regions to implement them.

In regions where agriculture is well adapted to current climate variability and/or where market and institutional factors are in place to redistribute agricultural surpluses to make up for shortfalls, vulnerability to changes in climate means and extremes generally is low. However, in regions where agriculture is unable to cope with existing extremes, where markets and institutions to facilitate redistribution of deficits and surpluses are not in place, and/or where adaptation resources are limited, the vulnerability of the agricultural sector to climate change should be considered high.

1.2.4. Climate Changes and Its Effect on Human Health:

Climate change could affect human health through increases in heat-stress mortality, tropical vector-borne diseases, urban air pollution problems, and decreases in cold-related illnesses. Compared with the total burden of ill health, these problems are not likely to be large. In the aggregate, however, the direct and indirect impacts of climate change on human health do constitute a hazard to human population health, especially in developing countries in the tropics and subtropics; these impacts have considerable potential to cause significant loss of life, affect communities, and increase health-care costs and lost work days.

Model projections (which entail necessary simplifying assumptions) indicate that the geographical zone of potential malaria transmission would expand in response to global mean temperature increases at the upper part of the IPCC-

projected range (3–5°C by 2100), increasing the affected proportion of the world's population from approximately 45 per cent to approximately 60 per cent by the latter half of the next century. Areas where malaria is currently endemic could experience intensified transmission (on the order of 50–80 million additional annual cases, relative to an estimated global background total of 500 million cases).

Some increases in non-vector-borne infectious diseases—such as salmonellosis, cholera and giardiasis—also could occur as a result of elevated temperatures and increased flooding. However, quantifying the projected health impacts is difficult because the extent of climate-induced health disorders depends on other factors—such as migration, provision of clean urban environments, improved nutrition, increased availability of potable water, improvements in sanitation, the extent of disease vector-control measures, changes in resistance of vector organisms to insecticides, and more widespread availability of health care. Human health is vulnerable to changes in climate— particularly in urban areas, where access to space conditioning may be limited, as well as in areas where exposure to vectorborne and communicable diseases may increase and healthcare delivery and basic services, such as sanitation, are poor.

1.2.5. Climate Changes and Its Effect on Coastal Systems:

Coastal zones are characterized by a rich diversity of ecosystems and a great number of socioeconomic activities. Coastal human populations in many countries have been growing at double the national rate of population growth. It is estimated that about half of the global population lives in coastal zones, although there is large variation among countries.

Changes in climate will affect coastal systems through sea-level rise and an increase in storm-surge hazards and possible changes in the frequency and/or intensity of extreme events. Coasts in many countries currently face severe sea-level rise problems as a consequence of tectonically and anthropogentically induced subsidence. An estimated 46 million people per year currently are at risk

of flooding from storm surges. Climate change will exacerbate these problems, leading to potential impacts on ecosystems and human coastal infrastructure.

Large numbers of people also are potentially affected by sea-level rise—for example, tens of millions of people in Bangladesh would be displaced by a 1-m increase (the top of the range of IPCC Working Group I estimates for 2100) in the absence of adaptation measures. A growing number of extremely large cities are located in coastal areas, which means that large amounts of infrastructure may be affected. Although annual protection costs for many nations are relatively modest—about 0.1 per cent of gross domestic product (GDP)—the average annual costs to many small island states total several per cent of GDP. For some island nations, the high cost of providing storm surge protection would make it essentially infeasible, especially given the limited availability of capital for investment.

Beaches, dunes, estuaries and coastal wetlands adapt naturally and dynamically to changes in prevailing winds and seas, as well as sea-level changes; in areas where infrastructure development is not extensive, planned retreat and accommodation to changes may be possible. It also may be possible to rebuild or relocate capital assets at the end of their design life. In other areas, however, accommodation and planned retreat are not viable options, and protection using hard structures (e.g., dikes, levees, floodwalls and barriers) and soft structures (e.g., beach nourishment, dune restoration and wetland creation) will be necessary. Factors that limit the implementation of these options include inadequate financial resources, limited institutional and technological capability, and shortages of trained personnel.

In most regions, current coastal management and planning frameworks do not take account of the vulnerability of key systems to changes in climate and sea level or long lead times for implementation of many adaptation measures. Inappropriate policies encourage development in impact-prone areas. Given increasing population density in coastal zones, long lead times for implementation of many adaptation measures, and institutional, financial and

technological limitations (particularly in many developing countries), coastal systems should be considered vulnerable to changes in climate

1.2.6. Climate Change and Its Effect on Volume of Water Resources:

One of the major effect on climate change has been increase in the sea level. Rise in sea level directly effects the coastal areas which are the interface between the land and water. Effect of sea level in costal areas are important to monitor because a majority of the world's population lives in such areas. The index used for measuring sea level is known as Global sea level rise (SLR). Coastal areas are continually changing because of the dynamic interaction between the oceans and the land. Several global and regional factors contribute to observed sea-level change along any particular coast (7).

Waves and winds along the coast are both eroding rock and depositing sediment on a continuous basis, and rates of erosion and deposition vary considerably from day to day along such zones. The energy reaching the coast can become high during storms, and such high energies make coastal zones areas of high vulnerability to natural hazards. Thus, an understanding of the interactions of the oceans and the land is essential in understanding the hazards associated with coastal zones. Tides, currents, and waves bring energy to the coast, and thus we start with these three factors.

Tides, which creates maximum effect on sea level during fool moon or new moon days. These high tides become important to coastal areas during hurricane season and we always hear dire predications of what might happen if the storm surge created by the tropical cyclone arrives at the same time as the highest high tides.

While sea level fluctuates on a daily basis because of the tides, long term changes in sea level also occur. Such sea level changes can be the result of local effects such as uplift or subsidence along a coast line. But, global changes in sea level can also occur which is called ecstatic changes. Ecstatic sea level changes are the result of either changing the volume of water in the oceans or changing the shape of the oceans (8).

Global warming, for example could reduce the amount of ice stored on the continents, thus cause sea level to rise. Since water also expands (increases its volume) when it is heated, global warming could also cause thermal expansion of sea water resulting in a rise in ecstatic sea level. Changing the shape of the oceans occurs if volcanic output on the sea floor or at oceanic ridges increases substantially, thus raising the floor of the oceans.

One of the most dire impacts of anthropogenic climate change is a rise in the global sea level caused by the melting of glaciers and land-based ice caps, as well as a smaller increase from expansion due to the higher temperature of the water itself. Unlike some other predicted effects of climate change, this impact has already been observed for some time. Indeed, not only is there evidence that sea levels are rising; there is also evidence both that the rate of sea level rise has been increasing in recent years and that it will continue to increase.

Global processes include changes in ocean mass (glacio-eustasy from ice melt), ocean volume (steric effects), viscoelastic land movements (glacioisostatic adjustment GIA), and changes in terrestrial water storage. Regional processes, often connected to steric and glacial changes, include changes in ocean circulation (Meridional Overturning Circulation [MOC]), glacial melting, local GIA, regional subsidence and others. Glaciers and ice caps (GICs) are important contributors to present-day global mean sea level rise (9, 10, 11, 12). Paleoclimate, instrumental and modeling studies show that combinations of these factors can cause relatively rapid rates of sea-level rise exceeding 3 mm yr -1 over various timescales along particular coasts.

1.2.7. Climate Changes and Its Effect on the Earth's land surface:

Climate has always been changing due to natural influences; however, there is now strong evidence that human actions, mainly the burning of fossil fuels, are the main causes of the increase in global temperatures and also affect precipitation patterns and extreme weather events. Changes in Climate makes a

great impact on the environment and they carry long term effects and therefore it has drawn attention of the scientist all over the world.

What have bothered the scientist greatly is the fact that the current global average temperature is likely higher now than in at least the last 2000 years (13). Researchers opine that climate changes would be highly unlikely without human influence. Which essentially means that if there were climate change but no human influence, we may not be able to avert the change through our actions, but would still be wise to adapt to it. However, since it is a well established fact that there is anthropogenic influence on climate, we can both try to avoid and prevent climate related disasters and adapt to the climate change.

A change in climate changes frequency, intensity, spatial extent, duration, and timing of weather and climate extremes therefore they cause unwanted events and disaster like situations such as droughts, floods and cyclone. Many weather and climate extremes are the result of natural climate variability (including phenomena such as El Niño), and natural decadal or multi-decadal variations in the climate provide the backdrop for anthropogenic climate changes. Even if there were no anthropogenic changes in climate, a wide variety of natural weather and climate extremes would still occur. Climate scientists have warned that more frequent hurricanes may be related to climate change (14).

According to the Intergovernmental Panel on Climate Change, an increase of greenhouse gases in the atmosphere will probably boost temperatures over most land surfaces, though the exact change will vary regionally. More uncertain—but possible—outcomes of an increase in global temperatures include increased risk of drought and increased intensity of storms, including tropical cyclones with higher wind speeds, a wetter Asian monsoon, and, possibly, more intense mid-latitude storms (15).

Climate change may not be responsible for the recent skyrocketing cost of natural disasters, but it is very likely that it will impact future catastrophes. Climate models provide a glimpse of the future, and while they do not agree on all of the details, most models predict a few general trends.

Sea level is presently rising and the rate of sea level rise may increase due to melting of continental ice sheets like now cover Greenland and Antarctica. The IPCC AR5 cites emissions-scenario dependent projections for global sea level rise circa 2081-2100 to be in the range 0.26-0.82m. Human habitation of low-lying coastlines may be in jeopardy in the near future. Higher sea level will make these coastal areas more susceptible to other hazards, like storms and tsunami.

1.4 Rational of the study:

As discussed above it is evident that change in climate increases water volume and thermal expansion of water which together cause rise in sea level. Rise of sea level increases salinity of earth and water and hence affects agriculture, reduction of earth and last but not the least the health of human beings. In view of vast effect of rise of sea level on human being it is important to develop the strategies to mitigate the effect of rise of the sea level and increase the resilience power of the affected communities. In view of the above, this study was designed.

1.5 General objective

The aim of this study was to synthesize the available knowledge about effect of climate change on sea level and to develop risk profile of Bangladesh, which is among most affected country by rise of sea level.

1.6 Specific Objectives:

The specific objectives were:

- To prepare the risk profile of areas affected by rise in sea level in general and one of most affected country Bangladesh in particular.
- To identify the strategies adopted in Bangladesh to mitigate risk related to rise in sea
- To develop strategies for reducing impact rise of sea level in Bangladesh.

2. Methodology

2.1 Study design:

Since goal of the study was to find out different types of causes and to identify different effect of climate change on sea level in Bangladesh a exploratory study design was used.

2.2 Data Type:

This study was based on secondary data. Data from various open sources such as IPCC, CDC, WHO, Medline, google scholar etc. were used to find both qualitative and quantitate evidences.

2.3 Framework of analysis:

Risk is defined as chances of occurrence of non desirable events. For risk of disasters, it is generally linked to availability of hazards and vulnerability of the people. Risk =Hazards x Vulnerability. Hazards are the factors (such as areas with risen sea level, use of technology and fuel which are responsible for emission of materials causing global warming), which will cause the disasters whereas, vulnerability are the characteristics, which will multiply the effect of the disasters.

Similarly strategies are the structure, programs, policies, interventions etc. which are adopted to reduce the impact of risk in a given populations. To study and develop the risk profile of Bangladesh hazards, vulnerability and strategies specific to rise of sea level in Bangladesh were studied and analyzed.

2.4 Methods

The study was based on the literature review. Prisma framework, which is a minimum set of items for reporting in systematic reviews and meta-analyses, was used as model (16). All literature reviewed in the study were indexed in the report using *Endnote* software.

References were selected using key words such as Impact of Climate on Sea Level, Effect of Climate on Sea Level, Issues related to rise in Sea level, assessment and Measurement of sea level etc.

The sources of literature includes google scholar, journals, international electronic resources available on the websites of national and international organizations including non governmental organizations (NGOs) providing policies and guidelines on disasters management.

Electronic resources of different research and academic bodies and government agencies involved in climate changes and monitoring of sea level were also searched. Data were also searched on popline, and medline databases. Since climates changes are a long-term process both published and unpublished articles featuring during 2000-2016 were included in the study.

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3. Findings:

This section describes the measurement of vulnerability due to rise of sea level, areas affected by rise in sea level, impact of rise of sea level, current strategies and future plan to mitigate impact of rise of sea level.

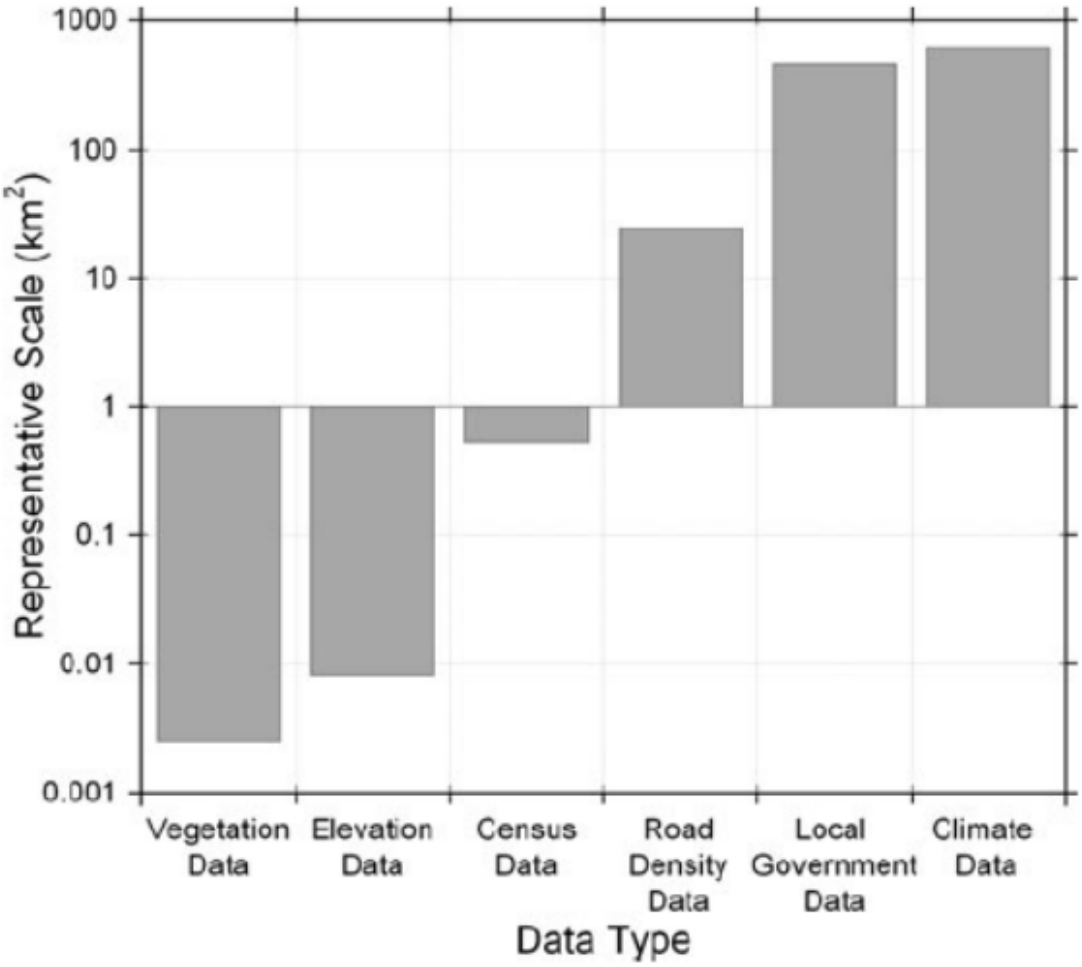
3.1 Measurement of Vulnerability Due to Rise of Sea Level

Measuring rise of sea level is a complex phenomenon and it is based on many data sources. Common resolutions of data sets used in vulnerability mapping is shown in Figure 2. On the one end are biophysical data, often derived from remote sensing, that are at high spatial resolutions. On the other end are climate data, which are generally coarse. Sandwiched between are the socio-economic data from censuses and surveys. This is a generalized view, as there are obvious exceptions, such as remote sensing derived vegetation data that are only available at 1 km pixel sizes, or climate data from individual meteorological stations that represent highly localized areas. Yet it is a useful representation since it highlights the fact that spatial VAs need to draw on data at different spatial scales, and hence the choice of output resolution in spatial VA needs to be considered carefully. Often this is determined by the highest resolution data sets available, but it is important to remember that even if coarser data are resampled at a high resolution, their nominal resolution is much lower. For local VAs, a resolution of 1 km is probably too coarse for available data, nor would it adequately resolve local features, so a higher resolution of 30-250m may be desirable. Developers of spatial VAs should seek to map at a resolution appropriate for the end users (decision-makers), and should avoid using coarse resolution data when higher resolution alternatives are available (17).

Integrating data at different spatial scales can result in artefacts in the maps that unintentionally draw attention to differences between areas that are not necessarily present on the ground. For example, abrupt discontinuities across borders may be an artefact of using national level adaptive capacity indicators, or it may reflect actual changes owing to different governance regimes. Apart from rigorous ground-level data collection it would be difficult to determine if these discontinuities actually reflect “real” changes in on-the ground vulnerability.

Maps that include continuous variables derived, for example, from remote sensing data (e.g., forest or crop land cover) may result in maps with pixelated results that may appear noisy; in these cases the use of a low-pass filter may help to reduce the noise and increase the communication value.

Figure 2. Spatial Scale Differences Among Different Data Sources

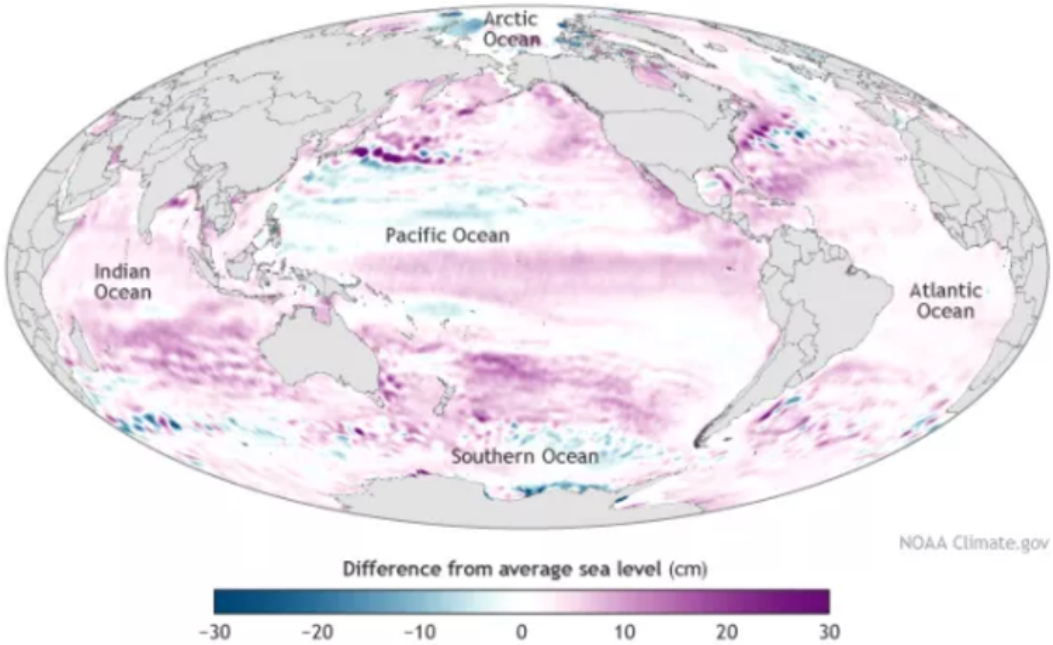


Source: Preston et al., 2011, p. 189.

3.2 Areas Most Affected by Change in Volume of Water Resources:

The impact of sea level rise is not felt equally around the globe. As shown in figure 3 some locations experience greater rise than others because of local terrain, local hydrological factors, and oceanic currents, among other regional factors.

Figure 3. 2014 Sea Level Compared to the Mean Sea Level From 1993-2013*



Source: Adopted from NOAA Climate.gov

Rise of sea level poses greatest threat to coastal areas with low sea level and the places which has maximum number of people living near the sea level. Low sea level which is recognised with higher risk to human life are the places less than 30 feet above sea level. Census figures from 224 countries showed that low-elevation areas are home to 634 million people. "Roughly one in 10 persons in the world lives in this low-elevation coastal zone. Some of the countries have very large populations:

The 10 countries with the most people in the low coastal areas are:

11. China,
12. India,
13. Bangladesh,
14. Vietnam,
15. Indonesia,
16. Japan,
17. Egypt,

* Adopted from National Oceanic and Atmospheric Administration (NOAA)

18. United States,
19. Thailand, and
20. the Philippines.

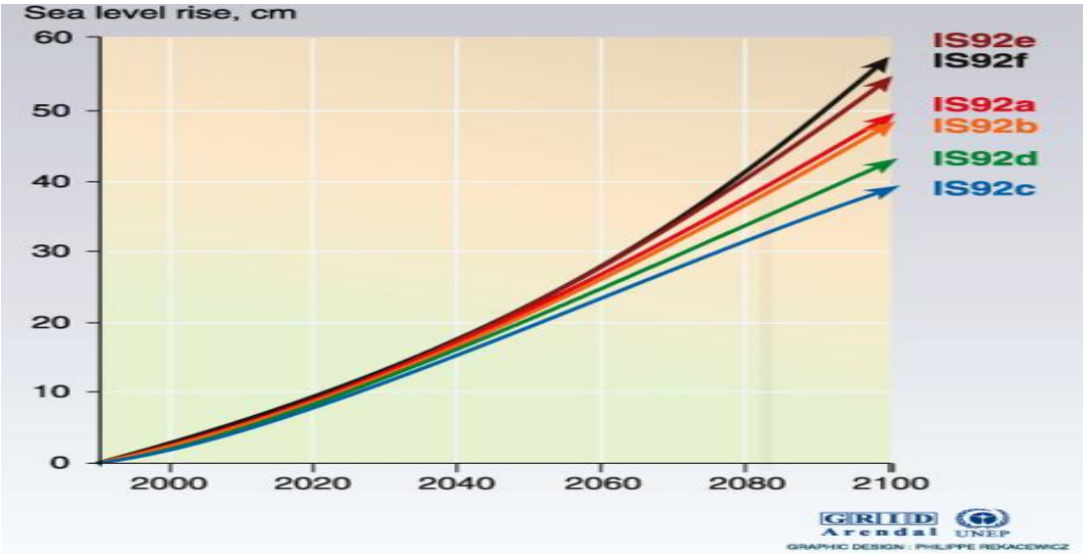
The countries with the largest share of their populations living in low-elevation areas are:

11. Bahamas,
12. Suriname,
13. the Netherlands,
14. Vietnam,
15. Guyana,
16. Bangladesh,
17. Djibouti,
18. Belize,
19. Egypt, and
20. Gambia.

Two-thirds of world's largest cities which have more than five million people are partially in these low areas. "Over the next 100 years, when there will be sea level rise, people living in those areas will also increase. Bangladesh and Egypt are in top ten countries which are most affected by rise of sea level by both the criteria.

During the first half of the next century, the choice of emission scenario has relatively little effect on the projected sea level rise due to the large thermal inertia of the ocean-ice-atmosphere climate system, but has increasingly larger effects in the later part of the next century. In addition, because of the thermal inertia of the oceans, sea level would continue to rise for many centuries beyond 2100 even if concentrations of greenhouse gases were stabilized at that time (Figure 4)[18].

Figure 4. Scenarios of Sea Level Rise



Source: Climate Change 1995, Impacts, Adaptation and Mitigation of Climate Change: Scientific-Technical Analysis, Contribution of working group 2 to the Second assessment report of the intergovernmental on the Climate Change UNEP, and WMO, Cambridge Press University, 1996, IPCC, Climate Change 1994, Radiative forces of Climate Change and an evaluation of the IPCC IS92 emission scenarios, 1995

Unfortunately, many large cities are located on coastlines that are particularly vulnerable to sea level rises. Improvements in high-resolution modelling have made it possible for the expected sea level rises in specific locations to be mapped, both in worst-case and expected-case scenarios. This very detailed awareness of the hazard has, in many locations, led to positive planning and actions to mitigate the impact (19).

Recently, a team of scientists published a study that found that the rate of sea level rise in the 20th century was greater than it had been in 2,800 years. Sea levels have risen almost 3 inches globally in the most recent 20 years and rise on an average of 1/8 inch each year. Melting land ice is responsible for a larger—and ever-increasing—amount of the global sea level rise in recent decades, as opposed to thermal expansion of seawater. A compounding problem with ice melt is that it can accelerate through positive feedback. Snow-covered ice has a high reflectivity or albedo, which means that radiation is reflected back from it and not as much is absorbed as heat. Water, however, has a very low albedo and does absorb high amounts of solar radiation and heat held in the earth's lower atmosphere.

Once ice has started melting, the process accelerates without an external influence to cause refreezing. Short-term climatic patterns that temporarily raise global temperature averages, such as a strong El Niño event, can therefore exacerbate the long-term trend unless a strong cooling event occurs quickly thereafter.

The current best estimates predict that sea level will rise up to 6.6 feet, or 2 meters, by the year 2100. Until recent years, this figure was viewed as pessimistic, with a rise of 3 feet considered more likely.

Recent studies raise the concern that the 6.6-foot estimate is actually the more probable one with "business as usual" carbon emissions. Earlier work accounted for glacial and Arctic melt, but had greater uncertainty about the West Antarctic Ice Sheet. The new research, developed in the last three years, modelled that the West Antarctic sheet would be undermined by warmed seawater, accelerating its decline.

The study also found that adhering to the agreements in the Paris climate summit of 2015, and thereby keeping the mean global temperature increase under 2°C, would lessen the melting of the West Antarctic Ice Sheet. Nonetheless, even in this optimistic case, some sea level rise will continue to occur due to current greenhouse gas levels in the atmosphere and the attendant warming.

3.3 Characteristics of Bangladesh Facing Rise of Sea Level

Bangladesh formally known as People's Republic of Bangladesh is located in South Asia. It is surrounded almost entirely by India, except for a small strip southeast boundary with Burma. Geographically, the country is situated in the fertile soil of the delta of the river Ganga, which is subject to annual flooding caused by monsoons and cyclones. Along with the Indian province of West Bengal, it is the ethno-linguistic region of Bengal. In fact, in Bengali, the name "Bangladesh" means "Country of Bengal".

Its current borders were established with the second partition of Bengal in 1947, when the region became the eastern Pakistan part of the newly formed

Pakistan. It got independence in 1971. After independence, country had gone through many political turmoil and natural disasters.

As shown in table 2, in year 2014 it has approximately 156,594,962 of populaiton which is ranked among eight most populous country in the world noted for its high population density, which is comparable only with small islands or microstates and not common for big countries. It has 34 administrative disticts.

Table 2. Population of Bangladesh

Population	**Million People**	**156,594,962**
Urban	% total Population	32.753
Rural	% total Population	67.247
Urban Population Growth	% Annual	3.578
Rural Population Growth	People /km^2	1,203.0

Source: UNISDR, Prevention Web (2014)†

Table 3 depicts major economic indicators of Bangladesh. Though per capita GDP of Bangladesh has doubled since 1975 it has very high poverty rate, which affects the copying capacity of the people at the large.

Table 3. Economic Status of Bangladesh

Gross Domestic Product (GDP)	**Million USD**	**129,856.605**
GDP Per Capita	Per Capita USD	957.82
Capital Stock	Million USD	381,432
Gross Fixed Capital Formation (GFCF)	Million USD	34,855.636
Social Expenditure	Million USD	6,398
Gross Saving	Million USD	53,137.898
Total reserves	Million USD	17,564.380

Source: UNISDR, Prevention Web (2014)

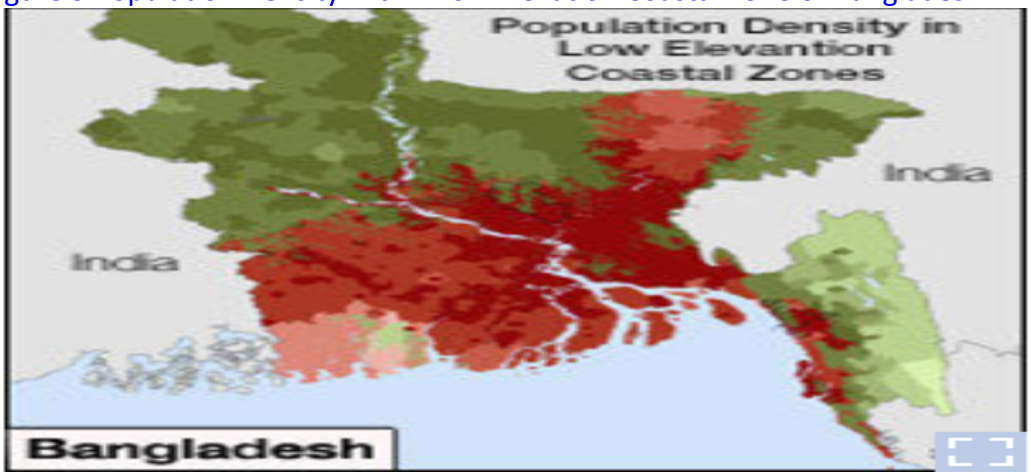
According to the world Bank, the country has made significant progress in the areas of literacy, gender equality in education and reducing population growth (20) however, still it faces a number of important challenges, including widespread corruption in politics and bureaucracy, economic competition in relation to the rest of the world, overpopulation, widespread poverty, unequal distribution of land and the growing threat of a water crisis caused by the climate change.

† http://www.preventionweb.net/countries/bgd/data/

Since Bangladesh is among the top 10 countries having coastal areas less than 30 feet the sea level and with a large proportions of their population living in the coastal areas, the risk profile of Bangladesh is of great interest. It is one of the world's poorest nations and also the country most vulnerable to sea-level rise. Its population is already severely affected by storm surges. Catastrophic events in the past have caused damage up to 100 km inland. It is hard to imagine to what extent these catastrophes would be with accelerated sea-level rise.

Figure 5 depicts Population Density in Low Elevation Costal Zones of Bangladesh. The red area indicates populations living within a low-elevation coastal zone. The green area indicates populations living outside low-elevation coastal zones. Forty-six percent of the Bangladeshi population lives within 10 meters of the average sea level.

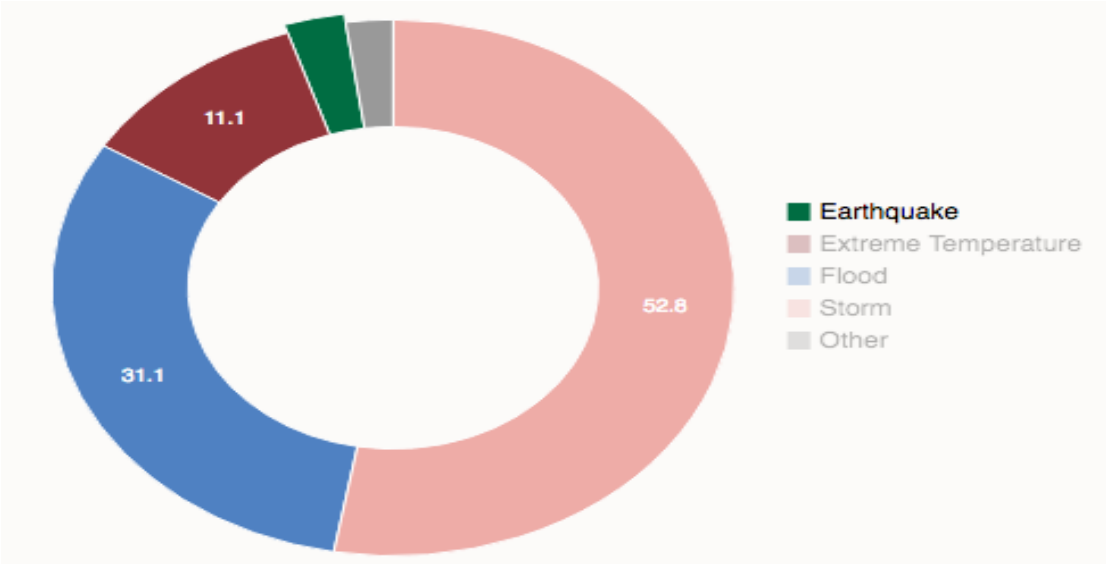
Figure 5 Population Density within Low Elevation Coastal Zone of Bangladesh.



Source: The Center for International Earth Science Information Network, Columbia University (2007).

As per another estimates from Low-lying Bangladesh with its 230 rivers and dense population of over 150 million has long been prone to flooding, soil erosion and saltwater intrusion. According to data from the government's Centre for Environmental and Geographic Information Systems (CEGIS), two-thirds of the country is only five metres above sea level, rendering it particularly vulnerable to sea level rises and tidal waves(21). Figure 6 depicts that around 83 percent of the disaster events were related to climate change which could be linked to rise of sea level in which a total of 4,93,734 people died during 1970 and 2015 (Table no.4).

Figure 6. Frequency of Disaster Events in Bangladesh During 1970-2016



Source: CRED EM-DAT (Feb. 2015): The OFDA/CRED - International Disaster Database www.emdat.be Université catholique de Louvain Brussels - Belgium.

Table 4. Impact of Rise of Sea Level in Bangladesh: Disaster Type and Total Deaths During 1970-2016

Disaster No	Type	Date	Totals deaths
2007-0556	Storm	15/11/07	4234
1991-0120	Storm	29/04/91	138866
1988-0242	Flood	00-06-1988	2379
1987-0132	Flood	22/07/87	2055
1985-0063	Storm	24/05/85	15000
1974-0042	Storm	00-08-1974	2500
1974-0034	Flood	00-07-1974	28700
1970-0063	Storm	12/11/70	300000

Source: Emdatabase

As per INFORM (table 5) for 2016 data the hazards value of the Bangladesh is 8.0, vulnerability is 4.67 and copying capacity is 5.84.

Table 5. Risk Index of Bangladesh on INFORM INDEX in the Year 2016

	Value	Rank	Trend
INFORM	6.02	20	EQUAL
Hazards	8.00	8	EQUAL
Vulnerability	4.67	56	EQUAL
Copying Capacity	5.84	64	EQUAL

Source: INFORM

3.4 Institutional Structure to Fight Effect of Rise of Sea Level In Bangladesh

Despite being one of the most disaster-prone nations in the world, initially Bangladesh (GoB) adopted reactive approach towards handling natural disasters which focused on relief and rehabilitation activities (22). In the year 1990 It framed its Comprehended Disaster Management Program (CDMP) (23). The Programme was designed to have two phases, the first to create the necessary systems and the second to put them into operation. Phase I was completed in 2009. Its disaster management programs are coordinated by Ministry of Food and Disaster Management. There is no separate policy on disaster management or challenges for issues related to rise of sea level.

All the maters related to disaster management is dealt through a Standing Orders on Disaster issued by the Government of Bangladesh in 1997 which provides a guide for disaster risk reduction and emergency management activities. It defines the duties of relevant government entities responsible for disaster management at two levels of governance such as national level and subnational level. These government-mandated bodies are tasked with disaster management activities. Their summarized roles are given below.

3.4.1 Roles of National Level Bodies:

- **National Disaster Management Council (NDMC)** headed by the Prime Minister to formulate and review the disaster management policies and issue directives.
- **Inter-Ministerial Disaster Management Co-ordination Committee (IMDMCC)** headed by the Minister for Food and Disaster Management to implement disaster management policies and decisions of NDMC/Government.
- **National Disaster Management Advisory Committee (NDMAC)** headed by an experienced person nominated by the Prime Minister.
- **Cyclone Preparedness Programme Implementation Board (CPPIB)** headed by the Secretary, MoFDM, to review the preparedness activities at the initial stage of an impending cyclone.

- **Disaster Management Training and Public Awareness Building Task Force (DMTATF)** headed by the Director General of the Disaster Management Bureau (DMB) to co-ordinate disaster related training and public awareness activities of the government, NGOs and other organisations.
- **Focal Point Operation Coordination Group of Disaster Management (FPOCG)** headed by the Director General of the DMB to review and co-ordinate the activities of various departments and agencies working on disaster management and also to review the Contingency Plan prepared by relevant departments.
- **NGO Coordination Committee on Disaster Management (NGOCC)** headed by the Director General of the DMB to review and co-ordinate the activities of NGOs working on disaster management.
- **Committee for Speedy Dissemination of Disaster Related Warning/Signals (CSDDWS)** headed by the Director General of the DMB to examine, ensure and identify the ways and means for speedy dissemination of warnings and signals to the population at risk

3.4.2 Roles of Sub-national Level Bodies:

- **District Disaster Management Committee (DDMC)** headed by the Deputy Commissioner (DC) to co-ordinate and review the disaster management activities at the district level.
- **Upazilla Disaster Management Committee (UZDMC)** headed by the Upazilla Nirbahi Officer (UNO) to co-ordinate and review the disaster management activities at the Upazilla level.
- **Union Disaster Management Committee (UDMC)** headed by the Chairman of the Union Paris had to co-ordinate, review and implement the disaster management activities of the concerned union.
- **Pourashava Disaster Management Committee (PDMC)** headed by the Chairman of Pourashava (municipality) to co-ordinate, review and implement the disaster management activities within its area of jurisdiction.

- **City Corporation Disaster Management Committee (CCDMC)** headed by the Mayor of City Corporations to co-ordinate, review and implement the disaster management activities within its area of jurisdiction.

To provide authenticated and continuous database the government and to help government take informed decisions Bangladesh has set up The Disaster Management Information Centre. It is kept operational 24/7 during emergency situations. This allows it to monitor and report on all types of natural hazards as they unfold, including earthquakes and tsunamis ([24]).

3.5 Impact of Rise of Sea Level In Bangladesh

Bangladesh with two third of this population living in coastal areas is greatly affected by rise of sea level. The Centre for Research on Epidemiology of Disasters estimates that from 1979 to 2008 over 191,415 people were killed and about 229 million directly affected by natural disasters in Bangladesh. It also estimates that the economic damage caused by these natural disasters was about USD 5.6 billion (Project Document, n.d., 5). The impact of these disasters can be understood by the fact that nearly 40 percent of the Bangladesh's population lives below the poverty line (25).

Figure 7 depicts the causal loop diagram of sea level rise impact on coastal areas. Major impact of rise of sea level are increase in cyclone frequency, increase of flood, increase in salinity intrusion. All these affects the costal fisheries which causes loss in foreign funds due to lesser fisheries production and loss of protein sources for locals. Loss of protein deficiency in turn increases the health hazards and all these together increases the poverty of the people living in the coastal areas.

Figure 7. Causal Loop Diagram of Sea level Rise Impacts on Coastal Areas

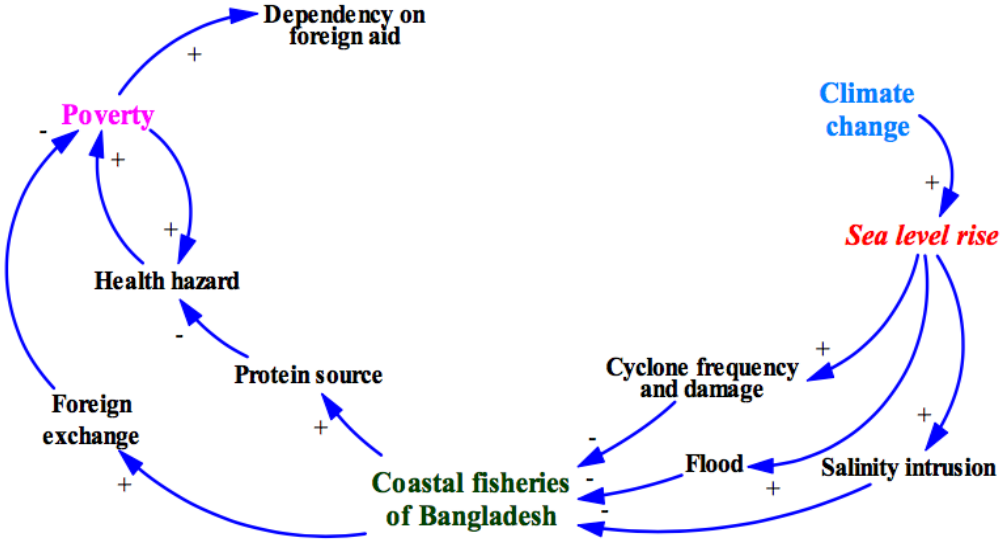


Table 6. depicts Sea Level Rise (SLR) in Bangladesh and Its Possible Impacts estimated by the world bank. It is clear that there will be 10 cm, 25cm and 1 m rise in sea level of Bangladesh by 2020, 2050 and 2100; affecting 2%, 4% and 17.5% of total land mass respectively. Another study reported 1.0 cm per year sea level rise in Bangladesh (26).

Table 6. Sea Level Rise (SLR) in Bangladesh and Its Possible Impacts

Year	2020	2050	2100
Sea level rise	10cm	25cm	1 m (high end estimate)
Land below SLR	2 % of land (2,500 km^2)	4 % of land (6,300 km^2)	17.5 % of land (25,000 km^2). Patuakhali, Khulna and Barisal regions will be most affected
Storm surge		1991 cyclone happens again with a 10 % increase in intensity, wind speed increases from 225 to 248 km/h; storm surge goes from 7.1 to 8.6 m with 0.3 m SLR.	Storm surge goes from 7.4 to 9.1 m with 1 m SLR.
Flooding	20% increase in inundation.	Increase flooding in Meghna and Ganges floodplain. Monsoonal	Both inundation area and flood intensity will increase tremendously.

		floods increase yield loss.	
Agriculture	Inundate 0.2 Mmt. of production; < 1 % of current total.	0.3 m SLR inundate 0.5 Mmt. of production; 2% of current total.	Devastating flood may cause crop failure for any year
Ecosystem	Inundates 15% of the Sundarbans	Inundates 40% of the Sundarbans.	The Sundarbans would be lost. Loss of the Sundarbans and other coastal wetlands would reduce breeding ground for many estuarine fish, which would reduce their population.
Salinity	Increase	Increase	Increase

Source: Adapted from World Bank, 2000

Bangladesh will be among the most affected countries in South Asia by an expected 2°C rise in the world's average temperatures in the next decades, with rising sea levels and more extreme heat and more intense cyclones threatening food production, livelihoods, and infrastructure as well as slowing the reduction on poverty, according to a new scientific report released today by the World Bank Group (27). "It faces particularly severe challenges with climate change threatening its impressive progress in overcoming poverty," said Johannes Zutt, World Bank Country Director for Bangladesh and Nepal.

Melting Himalayan glaciers and an encroaching Bay of Bengal in the south, further increase the risk of flooding. Increase in monsoon rainfall across South East Asia and melting Himalayan glaciers will result in increased water volumes in rivers that flow into Bangladesh from India, Nepal, Bhutan and China (18).

Evidence is presented from three estuarine tide gauges located in the Sundarban area of southwest Bangladesh of relative sea level rise substantially in excess of the generally accepted rates from altimetry, as well as previous tide-gauge analyses. It is proposed that the difference arises from the use of relative mean sea level (RMSL) to characterize the present and future coastal flood hazard, since RMSL can be misleading in estuaries in which tidal range is changing. Three tide gauges one located in the uninhabited mangrove forested area

(Sundarban) of southwest Bangladesh and other located in the densely populated polder zone north of the present Sundarban, show rates of increase in RMSL ranging from 2.8 mm a^{-1} to 8.8 mm a^{-1}. However, these trends in RMSL disguise the fact that high water levels in the polder zone have been increasing at an average rate of 15.9 mm a^{-1} and a maximum of 17.2 mm a^{-1}.

In an area experiencing tidal range amplification, RMSL will always underestimate the rise in high water levels; consequently, as an alternative to RMSL, the use of trends in high water maxima or 'Effective Sea Level Rise' (ESLR) is adopted as a more strategic parameter to characterize the flooding hazard potential. The rate of increase in ESLR is shown to be due to a combination of deltaic subsidence, including sediment compaction, and eustatic sea level rise, but principally as a result of increased tidal range in estuary channels recently constricted by embankments. These increases in ESLR have been partially offset by decreases in fresh water discharge in those estuaries connected to the Ganges. The recognition of increases of the effective sea level in the Bangladesh Sundarban, which are substantially greater than increases in mean sea level, is of the utmost importance to flood management in this low-lying and densely populated area (28).

3.4.1 Effect of Rise off Sea Level on Salinity Intrusion

One of the main effect of sea level rise are intrusion of salinity and hence deduction in fresh water availability in the coastal areas. Increase in water salinity along the coastal areas causes increase in soil salinity. Rise water salinity and soil salinity destroys normal characteristics of coastal soil and water. A water salinity map for the period of 1967 and 1997 produced by Soil Resources Development Institute (SRDI, 1998a) shows that the problem is already on the way. Comparison of Soil Salinity map of SRDI (1998b, 1998c) for the period of 1973 and 1997 shows that salinity intrusion in soil is much higher than water salinity. The comparative maps of SRDI shows that soil of Jessore, Magura, Narail, Faridpur, Gopalgonj and Jhalokati was newly salinized in 24 years of time expansion. A one meter sea level rise will expand the soil and water salinity area at a faster rate.

3.4.2 Impacts on Fisheries and Aquaculture

Rise of sea level greatly affect the fisheries and aquaculture, which is the main source of food and economy of the people living in this zone. When the sea level rises it changes the location of the river estuary, causing a great change in fish habitat and breeding ground. For example, Penaid prawns breed and develop in brackish water (where salt water and fresh water mix). Due to rise of sea level this interface is pushed backward, changing habitat of prawn.

All the districts that are located in the coastal zone vulnerable to sea level rise, shrimp hatcheries and shrimp fields are also vulnerable to the phenomena. However, sea level rise is helping shrimp farming by introducing salinity in the coastal area, but it is also harmful. If we consider another sea level rise phenomena, for instance flooding; it is doing massive harm to the sector by overflowing shrimp pond and let the shrimps to set free in open water.

There are 21 government fisheries service centres in the coastal zone. These centres facilitate the fishery sector with fuel supplies, landing, whole sale, icing, inland transportation and other activities with an aim to improve the yield of the sector. These service centres are much closed to coastline or estuaries and are potential to be inundated by sea level rise. There are some areas in the coastal zone that are far from city or fisheries service centre and have no icing facilities. Fishermen of such areas dry fishes in open sunlight to avoid spoilage. Locally these dry fishes are known as ‘Shutki’. Dry fishes are rich in nutrient value and a popular dish among the coastal people, especially in the southeastern coastal zone. The dry fish industry will also be affected by anticipated sea level rise.

3.4.3 Effect on Agriculture

The affect of rise of sea level on agriculture is linked to increase in soil salinity and increase in water salinity. Salinity intrusion due to sea level rise will decrease agricultural production by unavailability of fresh water and soil degradation. Salinity also decreases the terminative energy and germination rate of some plants (29). Table 7 depicts loss of rice production in a village of Satkhira district in 2003 against total rice production in 1995 (30). Out of the total decreased

production over 75 per cent was due to conversion of rice field into shrimp pond and 23 per cent was because of yield loss.

Table-7: Declining rice production because of soil degradation

	Year	**1985**	**1990**	**1995**	**2003**
Area & months under rice and shrimp farming in ha (% crop land)	HYV Aman July - Nov.	345.5 (100)	344.6 (100)	332.4 (97.0)	314 (91.9)
	HYV Boro Dec. - May	200.4 (58)	269.6 (78.2)	122.4 (32.8)	58.2 (17)
	One shrimp cycle Dec. – Jan.	36.5 (10.6)	75.0 (21.8)	210.0 (67.2)	255.8 (91.0)
	Two shrimp cycle Dec. – Nov.	0	0	20.6 (3.0)	20.6 (3.0)
Expected total rise production		1373	1689	1679	1673
Observed total rise production		1265	1260	745	5265
Decline in rice production due to loss of	Area	108	221	670	890
	Yield	-	208	264	261
Total loss in rice production		108	429	934	1151

(Source: Golam Sarvar, 2005)

Sea level rise affects coastal agriculture, especially rice production in two ways. Salinity intrusion degrades soil quality that decrease or inhibit rice production. Secondly people start converting rice fields into shrimp ponds, total rice production decreases because of degraded soil quality. Increased salinity from a 0.3 meter sea level rise will cause a net reduction of 0.5 million metric tons of rice production. (31).

"Our fields are dying because of the salty water… It is impossible to grow anything in them any more," lamented Abbasuddin Mollah, a 60-year-old farmer from the coastal district of Bagerhat. "Without the dykes to protect us, the tides rush in twice daily and swamp the croplands," he told IRIN.

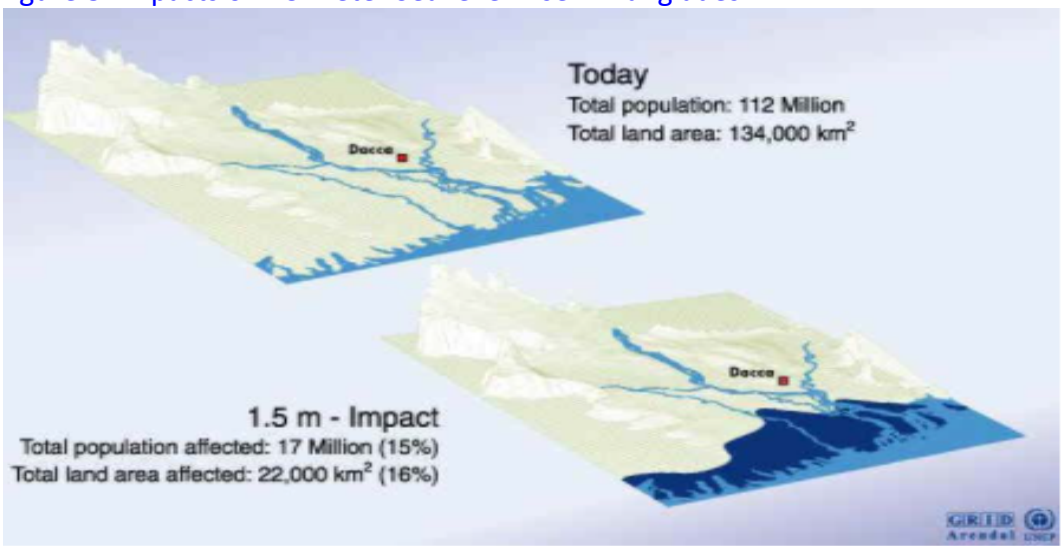
3.4.4 Impact on Landmass and Settlement

The SLR will inflict its impacts on Bangladesh in the coastal area and through the coastal area, on the whole of Bangladesh. About 2,500, 8,000 and 14,000 $km^2$of

land (with a corresponding percentage of 2%, 5% and 10% with respect to the total land area of the country) will be lost due to SLR of 0.1m, 0.3m and 1.0m respectively (32).

The potential land loss estimated by GRID (Figure 8) suggest that 16% of total areas and nearly 15% of the population will be affected due to rise of sea level. Increase in affected land areas will lead to loss of agricultural land, loss of road and other communication infrastructure and above of loss of wide range of biodiversity.

Figure 8. Impacts of 1.5 meter Sea level Rise in Bangladesh



Source: GRID

Sea level rise will play important role in erosion processes in the coastal zone. Raised water level wash out the loose top soil of the coast, making the coastal region steeper. Backwater effect is accelerated by sea level rise that also cause erosion. Silt or other particles eroded from the surrounding areas are deposited when the lowlands of the coastal areas are filled with water.

Coastal areas of Bangladesh are formed of silty and sandy soils which make them vulnerable to sea level rise. Sandy and silty shores are easily eroded by sea level rise. stating that sea level rise of 1.0 meter will cause an erosion of a sandy shore in the order of 100-500 meter. Erosion rate due to sea level rise along the Bangladesh coast is high (33). The most obvious effect on land erosion will be migration of people living in coastal areas to other areas and poor people in coastal areas will become refugee in their own country because they may not have money to build get another land and to make their house.

Sea level rise will increase morphological activities in the river, inducing increased river flow. Accelerated river flow will increase river bank erosion too (34) and river bank erosion is severe in char areas and sometimes it may wipe out chars from the map of Bangladesh. Char area protects inland areas from tidal surge. It also helps accretion process along the main land. If char areas are eroded, mainland will be affected seriously by tidal surge. When all chars disappear, the mainland will be eroded rapidly reducing land area of Bangladesh year after years (35).

Net-like spread root system of mangrove acts as coastal stabilizer and binder (36) that protects soil erosion in the coastal area. Salinity intrusion will harm mangrove forest of the area. Decreased mangrove will result in breaking soil composition. Thus sea level rise will accelerate soil erosion in the coastal area by reducing mangrove forest. High population density means many Bangladeshis are forced to live on and cultivate flood-prone land.

3.4.5 Effect of Rise of Sea Level on Health People in Bangladesh

Rise of sea level increases salinity of water and most of the salt present in the form of sodium chloride (NaCl) breaks up into Na+ and Cl- ion when dissolved in water. Therefore, coastal area is breeding and nursery ground of cholera disease. Sea level rise may increase the risk of health hazards like diarrhea, cholera, etc. in the coastal area of Bangladesh.

Outbreaks of cholera also occur after flooding, because the water supply becomes contaminated (Eco-health Glossary, 2005). Thus, sea level rise, by increasing flood risk, increase the risk of cholera outbreak too.

Increased unavailability of fresh water will force people to drink contaminated water leading to cholera, diarrhea and other water born diseases. Again, increased salinity in the coastal zone will decrease food production in the area, causing reduction of availability of protein and increase of malnutrition for the coastal people. So, sea level rise will accelerate water born diseases and malnutrition in the coastal area.

3.4.6 Effect of Rise of Sea Level on Ecosystem of Bangladesh

Rise of sea level will have huge impact on ecosystem of the Bangladesh. As per World bank report 2000, page 63 some potential impacts are given below:

- 10 cm SLR will inundate 15% of the Sundarbans

- 25 cm SLR will inundate 40% of the Sundarbans
- 45 cm SLR will inundate 75% of the Sundarbans
- 60 cm SLR will inundate the whole Sundarbans
- 1 meter SLR will destroy the whole Sundarbans
- Species like Sundari, main economic species in the Sundarbans, would be replaced by less valuable Goran and Gewa.
- Human habitation possible prevents inland migration.
- Loss of the Sundarbans and other coastal wetlands would reduce breeding ground for many estuarine fish, which could reduce their population. Sea level rise would result in saline water moving further into the delta. This would reduce the habitat for fresh water fish, although it could increase the habitat for estuarine fish.

The Sundarbans mangrove forest is the world's biggest unique chunk of mangrove forest and very rich in biodiversity. It is located at the south of the tropic of cancer, the southwest part of Bangladesh. Sea level rise will cause rise in the salinity concentration in the water and soil of the Sundarbans. Increased salinity will change the habitat pattern of the forest. Aquatic organisms will migrate inward, because of increased salinity too.

It is the hotspot for vast amount of flora and faunas. It is the last habitat of Royal Bengal Tiger. At this transitional zone between freshwater supplied by rivers and saline water pushed by high tides from open sea, many fish species depend for spawning and juvenile feeding on the Sundarbans aquatic habitat. The Sundarbans is also a habitat of some important species like- Wild boar, Spotted deer, Barking deer, Rhesus macaque, Jungle cat, Leopard cat, Otter, Squirrels and the Indian porcupine. The forest also supports habitat to marine turtles, crocodiles, frogs, and fresh water dolphins. With the loss of the Sundarbans, habitat of these species are also likely to get affected.

3.4.7 Effect on Food, Education and Cloths Availability in Bangladesh

Rise in sea level will cause massive reduction in land mass in the coastal areas, which will damage educational institutions, beside affected population will have to keep on changing their houses and hence it will increase poverty and therefore reduce access to education and availability of house, cloths and education. Country may have to hugely depend on foreign aid.

3.4.8 Effect of Rise of Sea Level on Economy and Life of Bangladesh

Rise in sea level due to climate affects and gets affected by the ecosystem of a country along with their hydrology and water resources, food and fiber production, coastal systems, human settlements, human health, and other sectors or systems (including the climate system) important to 10 regions that encompass the Earth's land surface.

Ecosystems are of fundamental importance to environmental function and to sustainability, and they provide many goods and services critical to individuals and societies. These goods and services include:

(i) providing food, fiber, fodder, shelter, medicines and energy;
(ii) processing and storing carbon and nutrients;
(iii) assimilating wastes;
(iv) purifying water, regulating water runoff and moderating floods;
(v) building soils and reducing soil degradation;
(vi) providing opportunities for recreation and tourism; and
(vii) housing the Earth's entire reservoir of genetic and species diversity.

Nearly 40% of productive land of Bangladesh is projected to be lost in the southern region of Bangladesh for a 65cm sea level rise by the 2080s. About 20 million people in the coastal areas of Bangladesh are already affected by salinity in drinking water. Rising sea levels and more intense cyclones and storm surges could intensify the contamination of groundwater and surface water causing more diarrhea outbreaks.

Table 8 shows the average annual loss by hazards due to rise of sea level and figure 9 shows the hazards contribution to Average Annual Loss.

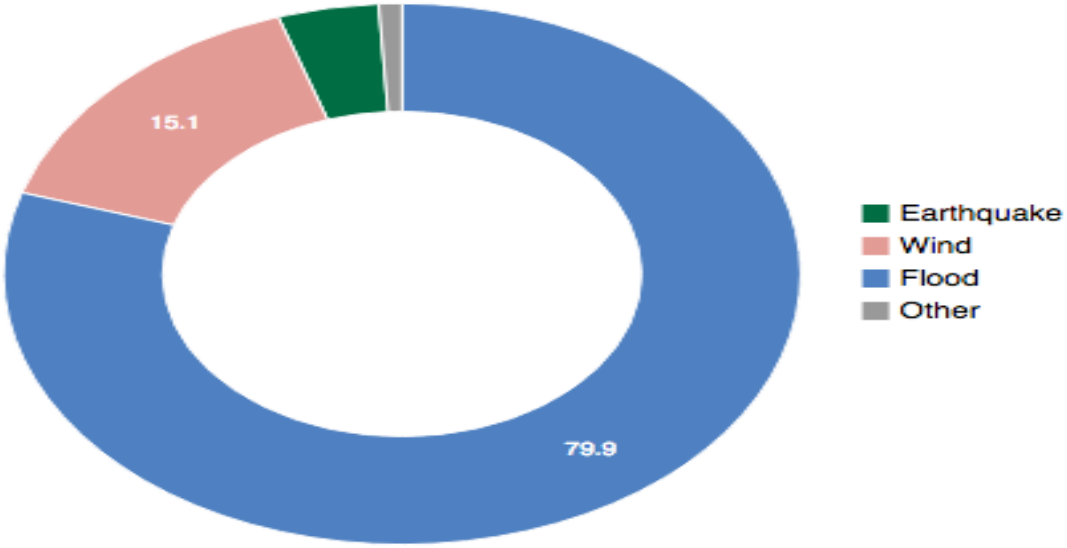
Table 8. Average Annual Loss (AAL) by hazard

Hazard	Absolute [Million US$]	Capital stock [%]	GFCF [%]	Social exp [%]	Total Reserves [%]	Gross Savings [%]

Earthquake	126.46	0.033	0.363	1.977	0.720	0.238
Wind	465.85	0.122	1.337	7.281	2.652	0.877
Storm Surge	23.35	0.006	0.067	0.365	0.133	0.044
Tsunami	5.50	0.001	0.016	0.086	0.031	0.010
Flood	2,463.17	0.646	7.067	38.500	14.024	4.635
Multi-Hazard	3,084.33	0.809	8.849	48.209	17.560	

Source: Source: UNISDR, Prevention Web (2014)‡

Figure 9. Hazard contribution to Average Annual Loss



Source: EMDATA

Large numbers of people also are potentially affected by sea-level rise—for example, tens of millions of people in Bangladesh would be displaced by a 1-m increase (the top of the range of IPCC Working Group I estimates for 2100) in the absence of adaptation measures.

For Bangladesh the high cost of providing storm surge protection would make it essentially infeasible, especially given the limited availability of capital for investment. Beaches, dunes, estuaries and coastal wetlands adapt naturally and dynamically to changes in prevailing winds and seas, as well as sea-level changes; in areas where infrastructure development is not extensive, planned retreat and accommodation to changes may be possible

Looking in to resource condition without any international support accommodation and planned retreat are not viable options, and protection using

‡ http://www.preventionweb.net/countries/bgd/data/

hard structures (e.g., dikes, levees, floodwalls and barriers) and soft structures (e.g., beach nourishment, dune restoration and wetland creation) will be necessary. Factors that limit the implementation of these options include inadequate financial resources, limited institutional and technological capability, and shortages of trained personnel. In most regions, current coastal management and planning frameworks do not take account of the vulnerability of key systems to changes in climate and sea level or long lead times for implementation of many adaptation measures.

3.6 Measures Adopted in High Risk Countries

The measures to manage the impact of rise of sea level could be categorised in to

i) Mitigation and

ii) resiliencies efforts.

The risks of sea level rise to coastal cities must be taken seriously, and the kinds of concrete, specific, individually tailored flood resilience plans illustrated here are a very positive step. While emissions reductions can lessen the magnitude of this impact, some rise is going to occur. It is imperative for areas at risk to adapt to this new hazard, and fortunately, they are beginning to do just that. These pioneering coastal cities have created plans that offer excellent guidance. Hopefully, resilience planners in other locations around the world will follow their lead.

Strategies for Increasing Resilience

a. Protect natural Barriers
b. Create/Harden artificial Barriers
c. Educate People About the Threat, Assist the most vulnerable

3.5.1 Coastal Resilience

As noted above, hard stabilization usually affects areas in the down drift direction of the longshore current. The net result being that some areas of a coastline are protected while other areas are destroyed. Nearly all human intervention with coastal processes interrupts natural processes and thus can have an adverse effect on coastlines. Three examples of human interference are discussed below Barrier Islands along the North Carolina Coast show a noticeable difference among the islands that have been built upon and those that have not. The undeveloped islands have beaches 100 to 200 meters wide, while the developed islands have beaches with widths less than 30 m

In order to protect southern California cities from flooding caused by heavy rains, most of the streams draining into the ocean have been dammed. The dams trap sediment that would normally be carried to the ocean by stream flow. Since this sediment is not being supplied to the ocean, longshore currents cannot resupply the beaches with sediment, but do carry the existing sediment in the down drift direction, resulting in significant erosion of the beaches.

Most of the state of Louisiana has resulted from the deposition of sediments by the Mississippi River during floods over the last 10,000 years. Humans, however, have prevented the River from flooding by building a levee systems that extends to the mouth of the River. As previously deposited sediments become compacted they tend to subside. But, since no new sediment is being supplied by Mississippi River flooding, the subsidence results in a relative rise in sea level. This, coupled with a current rise in ecstatic sea level, is causing coastal Louisiana to erode at an incredible rate, estimated at 25 square miles a year (equivalent to the area one football field disappearing every 45 minutes). An excellent series of articles concerning the coastal erosion problem in Louisiana was published recently by the Times-Picayune newspaper.

In response to the flood analysis and the destruction wrought by Sandy, the Newyork city developed a comprehensive plan. In this plan, the city specifically analyzed the effects of Sandy as a near-worst-case impact and the projected future flood zones. It determined several actions to take to minimize the risks. To protect coasts against tidal flooding, the city plans to reinforce beaches, build bulkheads, and protect sand dunes that act as natural

barriers. The city may also enact rock breakwaters offshore to attenuate waves associated with storms, and erect storm walls and levees in areas that are particularly vulnerable to storm surge.

The city's plan contains a rigorous geological analysis of the landscape and makes recommendations specific to boroughs and neighborhoods based on what types of mitigation strategies the rock and soil in each locale can support.

As we have seen, governments at all levels are assessing the dangers for specific locations and analyzing the current infrastructure the world over. It is possible to model expected flood risk at an extremely high resolution and perform engineering analyses on existing infrastructure—natural and manmade—with a great degree of precision. The results are a set of plans tailored for the specific needs and capabilities of each location.

Climate change does not affect all parts of the earth in the same way, and even sea level rise will not be globally uniform, so highly individualized resilience planning is a must. Their diversity notwithstanding, however, the plans do have some things in common. The ideas that appear repeatedly, in resilience plans around the globe, do so because they are broadly applicable, and in many cases, planners have arrived at them through past experience. Cities that wish to develop their own coastal resilience plans should look to these repeat ideas as guidance.

First, coastal cities at particular risk of flooding should protect any natural barrier islands that are present. These islands are the first line of defense against storm surge, whether from tropical cyclones or other storms at sea. Cities that can afford it, and can do so in an environmentally friendly way, might follow the example of New York City and erect artificial breakwaters offshore if they do not have any natural barrier islands. These structures could also serve as artificial reefs for marine life if oceanic conditions permit.

Many coastal cities have artificial seawalls and levee structures. These structures tend not to be as robust against extreme events as natural barriers, but cities that have them should follow the example of Sydney and examine them in

close detail to determine their robustness. Of course, to be fully effective, civil authorities should conduct this type of analysis with an eye to the specific level and type of risk that a given city is expected to face from sea level rise. Resilience planners in very low-lying locations should also keep in mind the lessons of New Orleans and Rotterdam, emphasizing shoreline and wetland restoration as the first and best defense instead of relying wholly on a system of levees to fight the natural course of rivers. For locations that are below sea level, natural restoration approaches are more robust against flooding and have proved far better for surrounding ecosystems. Cities should not neglect existing seawalls and levee structures, but they should be part of a broader strategy.

Finally, resilience analysts should always consider the human factor, particularly in the context of extreme flood events that would pose a high threat to life and require partial or full evacuation of the city during the emergency. This type of risk is especially acute for cities that are low-lying, prone to storms, or located at the mouths of significant river systems. Officials should take guidance from Boston's plan, which emphasizes promoting community education about the flood threat and devoting special attention to vulnerable populations that rely on public services. The plan for Tybee Island, a much smaller municipality, takes into account its reliance on tourism and the dependence of its evacuation route on a single highway. Planners should always consider the specific local needs of a city, whatever its size.

3.5.2 Coastal Resilience Around the Globe

Cities elsewhere around the world have begun to grapple with the risks of sea level rise as well. In Australia, coastal cities face the threats of tidal flooding, non-tropical storm flooding, and tropical cyclone storm surge just as cities in the U.S. do. Australian states and municipalities also have significant authority over their own policies, comparably to the U.S. The national government of Australia has issued a strategic plan for climate resilience and adaption, which recommends procedures to states and municipalities.

The Australian resilience plan acknowledged that coastal cities were built with the assumption that weather and tidal conditions would fall within a known

historical range that includes a stable sea level, and therefore that expected rises from climate change pose a threat. The government of Australia is in the process of developing an online tool, known as Coast Adapt, that will help local officials understand specific risks their areas face and provide specialized information about resilience options.

A specific example of this type of local resilience planning is the analysis of seawalls in Sydney. The city has several older seawalls, and authorities were unsure of their reliability in the face of climate change and extreme events. The government of Australia oversaw a project to assess the seawalls for their current condition that included analysis of the materials used in the seawalls, maintenance, stability, and strength. The project officials then proposed improvement suggestions for each seawall examined.

Many cities in Europe are also vulnerable to sea level rise. European cities are not at risk of hurricane storm surge due to their northerly latitudes and location on coastlines that do not experience tropical cyclones, but they are vulnerable to tidal flooding and non-tropical storm flooding. Some are also built below sea level and rely on levees for protection.

An example of the latter is the city of Rotterdam in the Netherlands, which is 90 percent below sea level and surrounded by several rivers. Dikes protect the city from inundation. In 1953, Rotterdam suffered an extremely deadly flood that breached the dikes, killing 1,800 people, a tragedy that foreshadowed Hurricane Katrina in New Orleans fifty-two years later. In response, the Dutch government directed funding to a massive project to build dikes around areas of the city. Unfortunately, over the years the structures have damaged the environment and aquatic ecosystems. In a more sustainable, ecologically sound, and physically robust plan, the government is now shoring up the natural coastline of the city by rebuilding sand dunes and expanding shores with sediment.

3.5.3 Coastal Resilience in the United States

Several American coastal cities have begun plans to minimize the effects of sea level rise. In New York City, the areas of the city that are in the "100-year flood

zone" and "500-year flood zone"—in other words, that have a 1 percent chance and 0.2 percent chance of flooding each year—are expected to expand. Figure 10 shows a map of New York City with expected flood zones that are based on the projection of 2.5-foot global sea level rise by the year 2050.

Figure 10. Current and Projected Future Flood Risks for New York City.

Source: *Federal Emergency Management Agency/National Oceanic and Atmospheric Administration*

Boston is another American city that has developed a comprehensive climate resiliency plan. Since it is on a coastline, Boston's greatest risks from climate change are flooding and storm surge. Boston's plan emphasizes community awareness and education as critical tools for climate preparedness. As Brian Swett, a lead developer of Boston's climate plan and formerly the chief of Boston's Department of Environment, stated with regard to storm surge.

Everybody in Boston has a mental checklist (about place of the shovel; the streets not to park on because there'll probably be a parking ban; need to stock bread and milk; and need for salt for the walkway) to manage 20 inches of snow even in July. But people do not have such mental checklist for hurricanes and there is not drill either for it.

The Boston climate plan also puts emphasis on outreach to low-income households, small business owners, and other vulnerable residents, by working closely with other city departments that focus on these residents' concerns. Low-income residents in particular utilize public services such as buses more than

other residents, and as the tragedy of Hurricane Katrina in New Orleans showed, these residents are most vulnerable in the event of a needed evacuation.

Cities that have smaller populations than the East Coast metropolises and rely heavily on tourism for economic development are also making preparations. Tybee Island, a barrier island near Savannah, Georgia, is a popular tourist destination during the summer months. The sea level on this island's coastline has risen 10-11 inches since 1935, and as in most areas of the world, it is expected to continue rising. The city, also named Tybee Island, developed a resilience plan to cope with rising sea levels. The city has a single road that allows access on and off the island, so shoring up this road—U.S. Highway 80—and improving it to minimize traffic bottlenecks was a key part of the city's resilience plan. As in other cities, reinforcing natural barriers to inland flooding was also important, so protecting Tybee Island's beaches from erosion was another crucial part of the plan.

3.7 Efforts in Bangladesh

Bangladesh is paying its attention to minimize the impacts of sea level rise by either mitigation strategies (In relation to rise of sea level mitigation is defined as a response to the broad issue of climate change and it involves reducing or stabilizing greenhouse gas emissions or levels, in order to mitigate changes in climate) or adaptation strategies (which is referred to adjustments in ecological-social-economic systems in response to actual or expected climatic stimuli, their effects or impacts). During first four decades after its independence (that 1971-2011), Government of Bangladesh and its Development partners have invested over USD 10 billion in projects aimed at decreasing the country's vulnerability to natural hazards.

As per Dr Tanveer Ahmed Choudhury, Program Manager Non communicable Disease Control Program, Bangladesh Ministry of Health and Family Welfare "Having extensive experience with facing natural disasters, Bangladesh has developed a successful adaptation programme, which led to a significant reduction in casualties from extreme weather events,"(37). Some key interventions taken by Bangladesh are:

1. Dredging sediments from offshore and Pumping it onto the coastline
2. Creating network of Flood Embankment, cyclone and flood shelters; raising roads and highways above flood levels;
3. Early Warning System
4. WASH Strategy

3.6.1 Dredging Sediments from Offshore and Pumping it Onto the Coastline

In many places it has adopted soft stabilization by adding sediment to its coastline usually by dredging sediment from offshore and pumping it onto the coastline. Adding sediment is necessary when erosion removes too much sediment. But, because the erosive forces are still operating, such addition of sediment will need to be periodically repeated.

3.6.2 Embankments

Low-lying southern coastal regions are the most vulnerable and therefore 5,107km-long network of flood embankments have been created to protected these areas.

However, embankment are not a permanent solution as it get destroyed easily and require huge investment for its regular maintenance. Almost half of this embankment network was damaged by recent cyclones (Sidr and Aila), leaving the whole region vulnerable to the tides, according to Bangladesh's Comprehensive Disaster Management Programme.

3.6.3 Early Warning System

The Government of Bangladesh has installed warning systems; built shelters to protect people from extreme weather events, and planted saltwater-tolerant crops to protect food supplies. But more work will be required to further reduce climate risks.

3.6.4 WASH Strategy

Since coastal areas faces increased salinity which causes cholera outbreak. Working with the Government of Bangladesh, WHO Bangladesh has developed a Health National Adaptation Plan and a water, sanitation and hygiene (WASH) strategy; and launched a surveillance system to track and combat climate-sensitive diseases, like diarrhoea, dengue and malaria. WASH aims to ensure water remains safe during extreme weather events and reduce water borne epidemic.

4. Discussions:

Climate change is already causing sea levels worldwide to rise, and we can only expect this trend to continue. Our best, most current science predicts that ice cap melting and thermal expansion of seawater will produce a combined average rise of up to 6.6 feet by the beginning of the next century. This level of rise would inundate some beaches and overflow many barrier islands that serve as natural protection against storm surge from tropical and non-tropical cyclones.

Based on the analysis of the data on factors affecting rise of sea level and the impact of rise of sea level on economy, people's health, it is obvious that though global warming is the main cause of rise of sea level. It is also obvious that rise of sea level has devastating effect on human being specially the people living in low lying areas. The major impact of rise of sea level in Bangladesh are in the following areas:

- Less land for living
- Displacement by people in coastal areas
- Danger to flora and fauna
- Danger to many endangered species
- Low agriculture produce
- Saline water not good for fish breeding
- Saline Water harbors cholera virus
- Damage to basic Infrastructure, school, hospitals etc.
- Increased poverty increased dependency on foreign aid

The rise of Sea level of Bangladesh is primarily due to tidal waves due to global warming, therefore all efforts must be made to reduce the global warming. Developed countries under the aegis of United Nations (UN) must provide low cost technology to Bangladesh and other developing countries for reducing global warming effect, which will ultimately benefit entire earth and mankind.

Policies targeted at trying to help this situation through emissions reductions seem futile. But of even greater concern are World Bank and other adaptation strategies for Bangladesh will not be adequate if they are targeted only at the

global warming piece of the problem. This is a very large geo-political issue with regards to the substantial international (UN, WorldBank) funds targeted at climate change adaptation. UN/WB adaptation solutions will be inadequate to help them deal with their sea level rise problem, or that Bangladesh will find itself ineligible for international climate adaptation funds.

Weather forecasts in Bangladesh (Radio) and Bangladesh Television, are delivered in a language which fisher and farmer communities don't understand for example radio announces danger to El-Niño or Nimnochaap (Depression) but the coastal people do not understand what is El-Niño and Nimnochaap therefore majority fail to follow the instructions.

5. Recommendations:

First and foremost, there is a need that Bangladesh's government makes a comprehensive policy on reducing impact of rise of sea level. Other recommendations may be classified into three categories. 1) reducing impact of environment on rise of sea level 2) Measures for improving the resilience power of the people living in the Low Sea Level and 3) Adaptation to rise of sea level. The brief recommendations under the three above mentioned categories are given below.

5.1 Reducing Speed of Rise of Sea Level

The first priority while fighting impact of rise of sea level may be to reduce the speed of rise of sea level by reducing global warming and reducing changes in environment. Since Bangladesh's contribution to emission is very less, more on this has to be done by developed countries themselves. The important measures related to environment are given below:

- Developing Low Cost Renewable Energy such as solar and wind energy.
- Transfer of technology from developed countries to Bangladesh and other developed countries at free or very low cost.
- Reduction in Population size which will reduce stress to the ecological system and infrastructure.

5.2 Suggestions for Improving Resilience of People Living in Low Sea Level.

- Protect Natural Barriers
- Create/Harden Artificial Barriers
- Afforestation of the coastal areas
- Educate People about the threat, assist the most vulnerable
- Proper Monitoring of Sea level
    - Establishing Early Waring System
    - Establishing mechanism of data sharing mechanism among affected population
- Low Cost Rapid Public Transportation System

- Low cost community based Crop Insurance and General Insurance

5.3 Suggestions Adaptation to Rise of Sea Level.

- Better communication and public awareness program in coastal areas
- Promoting alternative mode of cultivation
- Promoting floating agriculture in lowlands, submerged by water. In the method, dried hyacinth is piled on a floating structure and seedlings are grown on it. This soil less agriculture may be promoted in coastal areas to reduce the impact on agriculture even if farmers' lands are submerged.
- Promoting Indian White Shrimp (P. indicus) and Western White Shrimp (P. vannamei) which are more flexible in terms of salinity tolerance.
- Promoting cage and pen culture in submerged and coastal areas with relatively weak water current. A cage is a net- built pocket submerged in water where fish could be cultivated.
- Pearl culture may be another option to be introduced in the zone.
- People should be motivated to consume seafood (e.g. crab, oyster, etc.).
- Tourism and other coastal infrastructure should be built, considering sea level rise.
- Strengthening WASH program with more water treatment and toilet facilities in coastal areas so as to improve health conditions.
- A research unit may be established to study the impact of various new measures on coastal life.

6. Conclusions

Rise of sea level is global challenges. It is more challenging for people living in the low sea level and particularly in costal areas with high population density. Therefore a conscious efforts must be taken to reduce the impact of environment on ecstatic sea level rise, tidal range amplification and a decrease in fresh water input and also improve the resilience of people living in the low sea level so that in case of any disaster like situation people the loss to life and properties both may be minimised. Need for global and united fight for this change in environment can thus never be overemphasised.

In that context, Bangladesh needs to consider both mitigation and adaptation options, even though the country has very limited scope for mitigation. This is because mitigation involves global efforts to execute and adaptation is more local. So, government must develop a policy framework on rise of sea level in Bangladesh and accordingly effective adaptation and mitigation measures should be developed and implemented to minimize the effect of sea level rise in Bangladesh.

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