

Sea-Level Extremes and Change- Example of Bangladesh

Cansu Karsili¹, I. B. Muhit², Mohammad Emdadul Hoque¹, Sohedul Islam¹

¹Graduate student, Department of Physical Geography and Ecosystem Analysis, Lund University, Sweden

²Department of Civil Engineering, Chittagong University of Engineering & Technology, Chittagong-4349, Bangladesh

E-mail: imrose_cuet@live.com

Abstract

The effects of climate change are significant for worldwide. In future, climate will most likely continue to change dramatically. During the last 100 years sea levels has already risen globally. There will be significant impacts on several countries due to sea-level rise. However some countries such as Bangladesh which is settled on a delta will be influenced more tragically because deltas are not suitable places to be settled on as they are subsides each year. Bangladesh is in the top row of the list of countries which will be influenced by sea-level rise. That is why in this study is based on Bangladesh which is the world's biggest delta and it acquires important agriculture land. The coast of Bangladesh, meets important food requirement of Bangladesh. If sea-levels continue to rise in the future-which likely seems will- people who are living near the coast will be influenced badly. Unfortunately sea-level rise will increase salinization of ground water and that will involve water scarcity in Bangladesh. It seems the sea level rise will mostly influence humans in Bangladesh. This paper shows the impacts of sea level rise in Bangladesh such as salinity intrusion, agriculture and ecosystems. To prevent these impacts some precautions should be taken, some of these are Adaptation and Mitigation.

Keywords: sea-level rise, Bangladesh, vulnerability, adaptation, mitigation

1. Introduction

In the past, the main causes for climate change and sea level fluctuations were due to natural processes such as orbital variations of earth. However, today the main reason of this problem is clearly humans. Earth is getting hotter day by day due to different kinds of human activities which are lead to increase the global warming. And this rising temperature leads to raise the sea level and affect the low lying part of coastal areas of the world. Among all low lying areas, Bangladesh is the most affected by sea level rise, that's why this area has considered as our study area. Besides the global warming, sea level rise also depends on regional continental drifts. For instance, some land of river deltas has subsided by several millimeters because of sediment folding. That intensifies the existing effect of sea level rise in that region. On the other hand, some regions are remaining unnoticed because the land is also rising in the same magnitude or more. Bangladesh is one of the most populated countries in the world and it is settled just above the sea which is located in the mouth of three rivers: Brahmaputra, Ganges and Meghna [1]. About 150 million people are living around these delta regions (Houghton, 2010). Another threat for Bangladesh is impacts of cyclonic storms and monsoon. These storms causes extreme sea level rises and floods in Bangladesh and of course affects lots of people. Sea level rise will cause loss of one fifth of the land and many diseases will affect many peoples. Also another consequence of sea-level rise will be the salinization of ground water and this will affect humans negatively by causing diseases. Also there will be ecosystem lose due to the rising of sea [1]. The vulnerability of Bangladesh will be increased due to the cyclonic storms, subsidence of delta and salinization of ground water. Due to increasing carbon emission rate the atmosphere will continue to warm, as a result sea levels will continue to rise. Because of that we have to find some solutions for this important problem. Adaptation and Mitigation [2] can be some of the solutions for Bangladesh. In this study we will try to explain in what terms Bangladesh will be affected and what can be done for least damages.

2. Aim of Study

The aim of this study is to explain reasons of extreme sea level rise, rising rate and its impacts in Bangladesh. We want to mention some of the possible and current impacts of sea level rise in the coastal zone of Bangladesh

in order to suggest some solutions. We mention only some of these impacts such as; agriculture, salinity intrusion and ecosystem. But there are much more important impacts like on ground water, humans, health, economy, settlements, fisheries, security and etc. People are vulnerable especially in the coastal zone of Bangladesh and it is likely that in the future there can be disastrous impacts on all of these parameters. Because of that, some possible solutions for Bangladesh within the framework of our aim is suggested. These solutions are Adaptation and Mitigation.

3. Methodology

Our methodology is based on literature review. In order to understand the impacts of sea-level extremes it is necessary to understand underlying causes of climate changes. The reasons of climate change and its impacts on sea-levels tried to be explained in this study. Therefore it is important to express the meaning of vulnerability to understand how this country will be influenced by sea-level extremes. Hereby, it is important to focus on impact on humans to produce some solutions. Also, sea-level rise will have a dramatic impact on the agriculture land and that will cause crucial problems for humans. We mention only some of the impacts in this study but it should be considered that all of the impacts are interrelated. Further study is required to understand all these impacts thoroughly. So, some suggestions were made for providing solutions to this problem.

4. Results

4.1 Causes of sea-level rise

Both natural processes and human activities are responsible for sea level rise. In a long time period, sea level rise is mainly due to changes in Earth's orbit which has a cyclic period causes changes in incoming solar radiation. As a result of this, earth experiences glacial and interglacial periods in 400,000 years cycles. During the glacial periods, due to the cooling of the Earth, sea levels decrease and in interglacial cycles due to warming of earth sea levels increase [3]. This sea-level change is fundamentally associated with ice forming and melting [4]. During the glacial cycles, cooling led to build up of ice on land, predominantly in the Northern Hemisphere, which makes the sea levels to decrease more than 100m. However, when the atmosphere begins to warm again, the ice caps start to melt and the ultimate result is sea level rising [5]. Fig. 1 shows the sea level changes over the past glacial-interglacial cycles and modern levels.

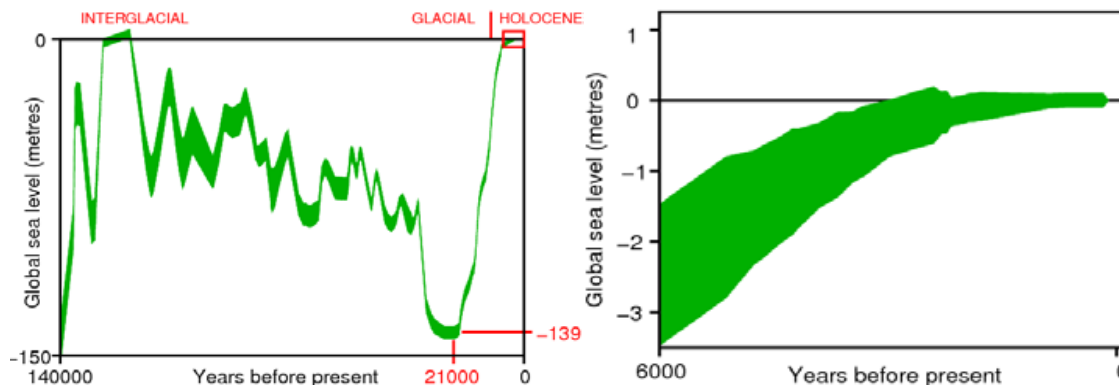


Fig. 1. Past and modern sea level changes; Source: Reference [6]

Since the last interglacial, there is a distinct global warming due to the warming of the Earth. However this warming rate is accelerated since the last century (Fig. 1). The reason of this sharp warming is strictly humans. Humans cause global warming by releasing CO₂ into the atmosphere. Concentration of CO₂ and other greenhouse gases are added to the earth's atmosphere and aggregately lead to warm up the atmosphere; the ultimate result is climate change. This rising temperature amplifies the volume of ocean water in two different manners. Such as, it causes melt of the ice in Polar Regions and thermal expansion of the ocean water. These two attributes are mainly accountable for increase the volume of ocean water of the earth as well as raise the sea level. If the earth's temperature keeps rising, the amount of ice sheet will decrease and after a certain time the total amount of ice will disappear, which will result with extreme sea level rise [9]. If the total ice sheet in Greenland and West Antarctic melt, sea level will increase 7m and 6m respectively [8], [9]. So, ice melting is the most important cause of sea level rise and the following table shown that how much sea level will rise if the ice caps on the earth's surface melt.

Another important cause of sea level rise is thermal expansion of ocean water, which is also happening because of global warming. Between the periods of 1961-2003, ocean thermal expansion contributed about 50% of total sea level rise [10] than estimated by the IPCC (2007). Beside ice melting and thermal expansion some other

regional factors also play a vital role for sea level changing process like as subsidence and uplifting of land and siltation on ocean bed [2]. Some climate models, satellite data and hydrographic observations reveal that the sea level rise is not equal all over the world. This rise is sometimes depends on regional tectonic movement, that's why some region's sea level is expected to rise slightly higher than others. For instance, because of sediment collapse, lands in some of river delta areas subside by several millimeters. In that case, sea level rise enhances the existing regional effects, meanwhile in some regions land is rising to the same rate or even more than sea level itself where sea level rise remain unnoticed [1].

4.2 Current sea level rise and future projections

From 1870 to 2004, the total global mean sea level has raised 195 mm at a rate of 1.44 mm per year, for the 20th century the sea level rise and the linear least squares trend was 160 mm and 1.7 ± 0.3 mm per year respectively [11]. According to IPCC, the global average sea level rate was of 1.8 (1.3 to 2.3) mm per year over the period 1961 to 2003 [2]. During 1993 to 2003, the rate is increased by 3.1 (2.4 to 3.8) mm per year (IPCC, 2007). In 1990, IPCC predicted that global sea level rise will be 9 to 88 centimeters by 2100. Later on again IPCC (2007) estimates that in the next decade global sea level would be rise about 0.03m and end of this century it will rise 0.2 to 0.8 m, if the CO₂ emissions keep continue like as it is now. Based on simple statistical model, Rahmstorf (2007) suggested a sea level rise over the 1990 to 2100 periods by 0.5 to 1.4 m. "A report prepared for the Dutch Delta Committee, which assesses post- Fourth Assessment Report publications on the impacts of recent warming trends on ice sheet dynamics, derives an upper bound of sea level rise of 1.1 m by 2100 [12]. In Bangladesh the average rate of sea level rise is averagely 1.0 cm per year (Milliman et al. 1998, cited in Frihy, 2003). According to SAARC Meteorology Research Center (SAARC, cited in Alam 2003, p 15) during 1977 to 1998 periods observed that sea level at Hiron Point, Char Changa and Cox's Bazar have been rising by 4 mm, 6 mm and 7.8 mm per year respectively. The rate of sea level rise is almost half in the western coast than that of the eastern coast of Bangladesh. This difference may be because of uplift or subsidence of land mass in different parts (SAARC, 2003). Although Singh (2002) noticed that this difference is mainly due to the subsidence of land.

World Bank (2002), mentioned that in 2020, 2050 and 2100 sea level will rise by 10 cm, 25 cm and 1m, which will be affected the 2%, 4% and 17% of total land mass of Bangladesh respectively. Whereas, sea level in Bangladesh coast will rise about 1.5 m by 2030, that will cause about 16% of total land mass to go under the water and affected 17 million people who are living along the coastal line [2].

4.3 Extreme sea-level rise in Bangladesh and its impacts

Due to the rapid climate change, Earth is experiencing extreme sea-level rising. Here, the word "extreme" means the unusual and unexpected sea level change and its catastrophic impacts on various regions of the world. Because Bangladesh is located on a delta where it subsides each year and lots of people are living on this delta will badly be affected by sea-level rise. Also this region is under the impact of cyclonic storms and monsoon. These factors increase the vulnerability of this country to the sea-level rise. High sea levels also changes the river flows by slowing down the drainage to the sea and causes catastrophic floods in Bangladesh.

According to SAARC Meteorological Research Council (SMRC) studies, sea level rise in Bangladesh during the last 22 years is much higher than last 100 years global trend [13]. But this sea level rise rate is not only due to the climate change it is also due to subsidence of the delta [14]. Actually most of the sea level rise in Bangladesh is due to subsidence of land [15]. But the contribution of sea level rise due to climate change in this region is non-negligible. Three different stations in different locations show different sea-level raises in Bangladesh such as; 7.88 mm, 6 mm and 4 mm [16]. Global sea-level rise during the last century's 1-2 mm per year which is lower than Bangladesh rate [17]. There is already significant sea-level rise in Bangladesh. Even now Bangladesh has been faced some problems because of sea level rise. But in the future all the projections predict higher sea levels which will cause more dramatic impacts in this region (Fig. 2). Based on some different reports for Bangladesh such as; IPCC and NAPA predictions are 14, 32 and 88cm sea level rise for the years 2030, 2050 and 2100, respectively [18]. Some of the impacts of sea-level rise are summarized below.

4.3.1 Salinity intrusion:

Sea level rise in the coastal zone of Bangladesh cause significant salinity increment on the water sources. This is a serious problem because it affects agriculture and ecosystems, which we also mention in the following parts. Salinity intrusion problem in Bangladesh is not dominated at the same rate all the year. It is mostly efficient in dry season which is in winter. It has also been affected in rainy season but in this season only 10% of the land is affected. However in dry season 40% of land has been affected by salinity intrusion. Increased sea levels affect salinity by the ingression in the rivers and this decreases fresh water contamination of rivers. This increased salinity of rivers will increase ground water salinity at the same time. This is the explanation of salinity intrusion

in rivers and ground water. There is also increased salinity in the soil due to increased evaporation in dry winters. We should consider that the salinity intrusion in soil is also due to sea level rise which is mostly affected by the saline ground water in winter. The other factor that increases the intensity of saline intrusion is tidal surges [16].

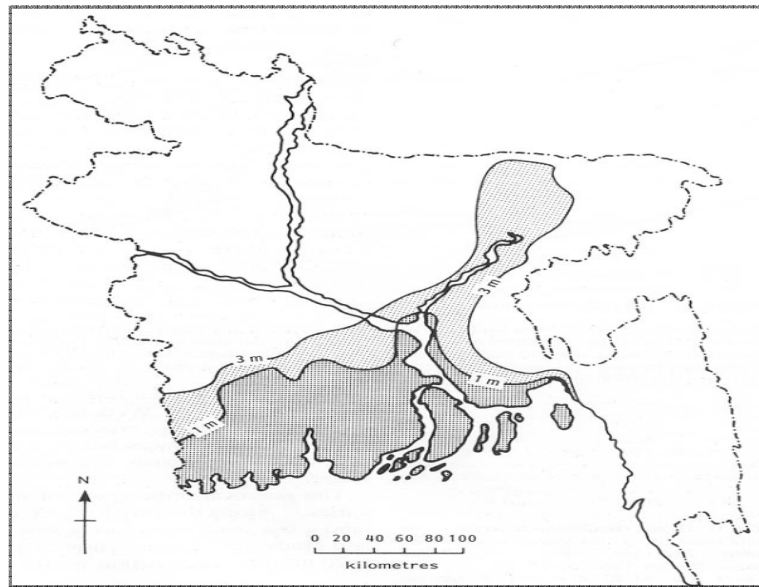


Fig. 2. Future sea-level predictions for the coastal zone of Bangladesh (1m and 3 m); Source: Reference [19]

In the coastal zone of Bangladesh there has already impact of salinity intrusion due to sea level rise which causes big problems. Especially in dry season saline water penetrates 240 km inland of the Bangladesh [16]. Salinity intrusion has serious impacts on many areas such as agriculture, fisheries, surface water, ground water, soil, ecosystem and etc. It affects agriculture mostly in dry seasons by causing increased irrigation of products with saline ground water because of not enough rain. However, watering with saline ground water decreases the productivity. Currently there is salinity intrusion problem in the some parts of coastal zone but in the future it will be more serious where its impact will reach more inland [16]. Salinity of ground water will influence humans negatively by causing serious drinking-water scarcity. In consequence of increased salinity on ground water, serious diseases will arise. Food productivity loss will cause nutrition disorder and will play an important role on human's health [2].

4.3.2 Impacts on agriculture:

Sea level rise impacts on agriculture are significant in Bangladesh because half of the population's economy depends on agriculture and 83% of population's livelihood comes from agriculture. With an increased climate change salt intrusion will increase significantly. If the sea level rises by 45 centimeters, it's been expected to lose up to 15,600 square kilometers of land [1]. Salinization of ground water and soil due to sea level rise will directly affect the agricultural production in the coast of Bangladesh. Rice production has already decreased in the coastal zones of Bangladesh due to decreased soil yield [2]. According to World Bank (2002) increased salinity (due to 0.3 meters sea level rise) will cause a net reduction of 0.5 million metric tons of rice production. As it mentioned before fresh water salinization will decrease rice productivity. Besides rice agriculture the coastal zone is also important for other goods such as oil seeds and vegetables. These products are also under risk of decreasing productivity because of salt intrusion [2]. Also sea level rise will increase storm frequency and more violent storms will cause catastrophic flooding.

4.3.3 Impacts on ecosystems:

Impacts of sea level rise on ecosystems can be classified in three, such as; wetland loss, salinity increment and beach erosion [19].

The coastal zone of Bangladesh has a very rich variety of species both for plants and animals such as mangrove forests, Sal forest, dipterocarp forest, bamboo bushes, freshwater swamp water forest, Bengal tiger, turtles, birds and etc. [14]. There will be lots of negative impacts on these species due to climate change but in our study we will focus on the impacts of sea level rise on these species. Salt intrusion will affect some species which can't survive from increased salinity of ground water and soil. As a result of salt intrusion these areas are being converted into saline water fields day by day. It is obvious that the salt intrusion will cause enormous loss of

biodiversity [2]. World Bank (2000) predicts that, in case of 1 meter sea level rise, Sundarban mangrove forests will be completely lost which is a very rich forest indeed. Even an increase of salt concentration in the soil and water will affect the habitat pattern of these forests [2]. Moreover, due to increased salinity in the inlands, aquatic organisms will move inlands. Sundarban is not only a simple forest at all; it includes lots of flora and fauna such as Bengal tiger which will be under threat of extinction from this forest [2]. Besides, increase of sea level will decrease photosynthetic productivity of marine corals and hence decrease the growth of corals [2].

4.3.4 Vulnerability:

It is important to explain the meaning of the word “vulnerability” in order to find out the reasons of extreme sea level rise impacts in Bangladesh. Vulnerability arises from the relationship between humans and their environments in the face of disasters [20].

Because being a low-lying country Bangladesh is highly vulnerable against the sea level raise. 80% of the country experiences flooding. Also, the economy of this country is not developed. Agrawala (2003) stated that, combination of low-level development with climate and topography causes high vulnerability in this country. It is a densely populated country and this high population rate also increases the risk of mitigation to other countries under any threats of sea level rise. 1/5th of the country’s economy is based on agriculture which will be affected by sea level rise.

4.4 Some solutions for Bangladesh

Due to the impacts of sea level rise that are mentioned above, some urgent actions should be taken to solve these problems in Bangladesh. Therefore, such solutions like adaptation and mitigation should be considered.

4.4.1 Adaptation:

Due to the global climate change sea levels will continue to increase and because of that adaptation process in Bangladesh is very important. However, it should be considered that the adaptation process requires long term and expensive studies [16]. Some of these adaptation strategies can be specified here. These are:

- ✳ Agricultural habitats can be changed. Improvements can be done in agricultural techniques.
- ✳ Crop patterns can be changed and high quality crops can be used for yield increment
- ✳ Planning can be done: embankment building to prevent flooding into the agricultural land, settlements.
- ✳ After salinity intrusion, usage of the area can be changed. For example agricultural land can be converted into fish farms.
- ✳ Settlements can be moved to safety places.
- ✳ People who are living in the coastal zone should be prepared to the disasters due to sea level rise.
- ✳ Regular surveys should be done in the fresh water to detect diseases. If some diseases germs detected in the fresh water urgent cautions should be taken to stop the epidemic of disease.
- ✳ If the capacity of country can be increased the vulnerability will decrease. This can be only done by economic recoveries. More capacity means less vulnerability [16].
- ✳ International organizations should inform people about the effects of population growth in the coastal zone and arrangements must be done to limit population growth (IPCC, 1990).
- ✳ International and national research programmes should be involved to observe impacts of sea-level rise in the coastal zone of Bangladesh (IPCC, 1990).

4.4.2 Mitigation:

It is clear to all that global warming has increased the level of ocean water and the main cause of global warming is emission of greenhouse gases to the atmosphere. IPCC Fourth Assessment Report (2007) Working Group III suggested some mitigation strategy for all country to reduce the greenhouse gas emission. Such as:

- ✳ Supply and distribution of efficiency should be improved. Switched fossil fuel to gas, nuclear power, renewable power (hydropower, solar, wind geothermal and bio-energy).
- ✳ Mode of transport system should be shifted from road transport to rail and public transport system.
- ✳ Stop deforestation by increasing more afforestation.
- ✳ Improve forest management system and produce more bio-energy by using forestry products.
- ✳ The function of lighting and day lighting can be used for electrical appliances, heating coupled with cooling devices, improved cook stoves also insulation, passive and active solar design in order to heat and cool, substitute refrigeration fluids, recovery and recycle of fluorinated gases.
- ✳ Crop and grazing land management must be improved in order to get more soil carbon storage, reestablishment of cultivated peaty land and degraded lands, improved rice cultivation techniques and livestock and manure management to reduce CH₄ emissions, improved nitrogen fertilizer application techniques to reduce N₂O emissions.

5. Conclusion

In Bangladesh the reasons of extreme sea level rise is due to subsidence of land, storm surges and flooding as well as thermal expansion and ice melting. Sea level rise rate is higher than the global trend because of its local characteristics. So, while the global trend of sea level rise is 1.8 mm per year (IPCC, 2007), it is averagely 7 mm per year in Bangladesh [16]. This extreme sea level rise in Bangladesh has serious impacts on important areas such as; salinity intrusion, agriculture and ecosystems.

Due to increased salinity intrusion 10% more land will be affected in Bangladesh (It is now 10% in rainy season and 40% in dry season). Salinity intrusion will also affect agriculture and ecosystems. It will decrease the productivity of agricultural land. Some species will disappear from ecosystems due to increased salinity and serious loss of biodiversity will be experienced. Humans will seriously be affected by water scarcity due to fresh water exiguity. Moreover, it will cause socioeconomic problems in Bangladesh [16].

It is obvious that, there will be huge economical loss due to impacts of sea level rise on agriculture. The main problems for agriculture on the coastal zone due to sea level rise can be summarized as; salt intrusion into soil and ground water, decreased soil quality, fresh water scarcity, increased flooding due to increased cyclonic storm frequency and loss of land [2]. Ecosystems will be affected in three ways. These are wetland loss, salinity increment and beach erosion [19]. Here it mentioned two solutions against these impacts. These are adaptation and mitigation.

6. References

- [1] Butzengeiger, S. and Horstmann, B., 2004, Sea-Level Rise in Bangladesh and the Netherlands One Phenomenon, Many Consequences, Germanwatch. <http://www.germanwatch.org/download/klak/fb-ms-e.pdf>
- [2] Sarwar, M.G.M., (2005). Impacts of sea level rise on coastal zone of Bangladesh, Lund University.
- [3] IPCC Fourth Assessment Report: Climate Change 2007: Working Group I: The Physical Science Basis
- [4] Antarctic Climate & Ecosystems (ACE), Cooperative Research Centre (2008), Position analysis: climate change, sea-level rise and extreme events, impacts and adaptation issues. Agrawala, S., Ota, T., Ahmed, A.U., Smith, J. and Aalst, M. (2003), Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sundarbans, OECD, France.
- [5] Harvey, N. and Nicholls, R. 2008, Global sea-level rise and coastal vulnerability. *Sustain Sci* (2008), vol 3, P.5–7 Alam, M., (2003). Bangladesh Country Case Study, National Adaptation Programme of Action (NAPA) Workshop, 9-11 September 2003, Bhutan.
- [6] Lambeck, K. and Chappell, J., (2001). Sea level change through the last glacial cycle. *Science*, 292, 679-686.
- [7] Williams, R.S., and D. K. Hall, *Glaciers. Atlas of Satellite Observations Related to Global Change*, R. J. Gurney, J.L. Foster and C. L. Parkinson, Cambridge University Press, London, 401-422.
- [8] Church, J.A., Gregory, J.M., Huybrechts, P., Kuhn, M., Lambeck, K., Nhuan, M.T., Qin, D. and Woodworth, P.L., 2001. Changes in Sea Level.
- [9] IPCC, "IPCC Fourth Assessment Report. Asia," in *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of Intergovernmental Panel on Climate Change* (Cambridge, UK: Cambridge University Press, 2009).
- [10] Domingues C.M., J.A. Church, N.J. White, P.J. Gleckler, S.E. Wijffels, P.M. Barker and J.R. Dunn, 2008. Improved estimates of upper-ocean warming and multi-decadal sea-level rise, *Nature* 453 1090-1093, doi:10.1038/nature07080
- [11] John A. Church, Neil J. White, John R. Hunter, 2006. "Sea-level rise at tropical Pacific and Indian Ocean islands". *Global and Planetary Change*, Volume 53, Issue 3, September 2006, Pages 155–168
- [12] Velinga, P. (2008) *Klimaatopwarming maakt voorbereiding in Nederland urgent* [Global warming makes preparation in the Netherlands urgent] (in Dutch). (Speech).
- [13] SMRC, (2003). *The Vulnerability Assessment of the SAARC Coastal Region due to Sea Level Rise: Bangladesh Case*, SMRC-No.3, SMRC Publication, Dhaka, Bangladesh
- [14] Ministry of Environment and Forest Government of the People's Republic of Bangladesh, (2005). *National Adaptation Programme of Action (NAPA)*.
- [15] Warrick, R.A., Bhuiya, A.H., Mitchell, W.M., Murty, T.S., Rasheed, K.B.S., 1996. *Sealevel changes in the Bay of Bengal*. In: Warrick, R.A., Ahmad, Q.K. (Eds.), *The Implications of Climate and Sea-level Change for Bangladesh*. Kluwer, Academic Publishers, Dordrecht.
- [16] Shamsuddoha Md. And Chowdhury, S. (2007), *Climate Change Impact and Disaster Vulnerabilities in the Coastal Areas of Bangladesh*, Coast Trust, Dhaka.
- [17] M. F. Karim and N. Mimura (2008). Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh, *Global Environmental Change* 18, 490-500.
- [18] MOEF, (2005) *National adaptation program of action. Final Report*, Ministry of Environment and Forest, Government of Bangladesh
- [19] Titus, J.G., 1990. Greenhouse effect, sea level rise and land use, *Land use policy*, vol. 7: issue 2, pp. 138-53
- [20] Bankoff, G. Frerks, G., and Hilhorst, D. (eds). 2004. *Mapping vulnerability: Disasters, development and people*. London: Earthscan. 236 p.