Salinity-Induced Livelihood Stress in Coastal Region of Bangladesh

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CHAPTER 7

SALINITY-INDUCED LIVELIHOOD STRESS IN COASTAL REGION OF BANGLADESH

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ABSTRACT

Salinity is one of the major problems in the coastal region of Bangladesh that contributes to 20% of the total land area. About 53% of the coastal region is affected by different degrees of salinity. Salinity intrusion in this area is mainly derived through climate change as well as anthropogenic factors that make this region more vulnerable. Hence, salinity intrusion has adverse effects on water, soils, agriculture, fisheries, ecosystem, and livelihoods of this region. To ensure the availability of food as well as drinking water, this chapter highlights how individual and community people have endeavored several adaptation measures to minimize salinity effects. Moreover, it further discloses governmental and other development organizations' actions toward salinity to reduce its impacts.

Keywords: Salinity intrusion; sea-level rise; agriculture; livelihood; coastal Bangladesh

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INTRODUCTION

Bangladesh has been experiencing higher rate of salinity intrusion in recent years. It is very seasonal in the coastal area of Bangladesh. Although the coastal area covers about 20% of the country of which about 53% is affected by different degrees of salinity (Haque, 2006), both water and soil salinity has increased in an alarming rate during the last couple of decades. In terms of soil salinity, about 1.2 million hectares of arable land are affected by soil salinity out of 2.85 million hectares of the coastal land. On the other hand, soils of coastal areas are affected by varying degrees of salinity. For instance, in the southwestern part of the coastal area, about 203,000 hectares are affected very slightly, 492,000 hectares slightly, 461,000 hectares moderately, and 492,000 hectares strongly (Islam & Gnauck, 2010). The severity of the salinity problem has increased over time with the desiccation of the soil.

Apart from this, approximately 20 million people living along the coast are affected by varying degrees of salinity in drinking water obtained from various natural sources (MOEF, 2006). This is because the coastal population of Bangladesh relies heavily on rivers, tube wells (groundwater), and ponds for washing, bathing, and obtaining drinking water. Domestic ponds, which take up 10% of the total land area (excluding rice paddies), are primarily rain fed but can also mix with saline water from rivers, soil run-off, and shallow groundwater (Rahman & Ravenscroft, 2003). Intrusion of saline water is minimum in the rainy season (June–October) due to extreme flow of freshwater, but in the dry season, especially in winter, saline water increases gradually.

Tidal flooding during the wet season, direct inundation by saline or brackish water, upward or lateral movement of salinity in groundwater during the dry season, and inundation with brackish water for shrimp farming are the key causes for salinization of coastal land. Moreover, salinity ingress has been observed as a consequence of reduced dry season flow of the major distributaries of the Ganges River. This started with the diversion of the Ganges' flow by India following the construction of Farakka Barrage (Mirza, 2004). In addition, Ahmed, Neelormi, and Adri (2007) argued that the adverse effect of sea-level rise would further aggravate salinity ingress along the coastal rivers. The severity of the salinity problem has increased over the years and is expected to increase in the future due to rising sea level. Therefore, it has been reported by Karim and Iqbal (2001) that only 0.83 million ha of coastal land has been subject to various degrees of soil salinity in the late 1980s; by 2002 the total coastal land under various degrees of soil salinity has increased to 3.05 million ha. Furthermore, CEGIS (2006) mentioned that the 5 ppt isohaline line would show northward shift by about 90 km inland due to sea-level rise by 2070s.

For the coastal people of Bangladesh, there are two major dimensions of salinity intrusion: (a) the productivity of saline-affected people's food security and livelihood (b) salinity intrusion causing significant problems of safe drinking water, which affects people's health, especially that of women. Nevertheless, increased salinity adversely affects agricultural, forestry, industrial production, and drinking water (Khan, 1993). According to Hannan (1980), the estimated agricultural production loss was 647,000 tons in 1976, of which the increased salinity-related loss was 21%. Salinity ingress directly affects the yield of the most preferred crops generally observed in the coastal zone (Karim, Hussain, & Ahmed, 1990), and also declines the yields of important crops such as paddy and vegetables, coconuts, betel nuts, fruit, and even grass and hay for livestock. Native fish species disappear. Besides drinking water, both surface and groundwater have become unfit for human consumption (Khan, 1993). Lack of access to potable water poses threat to public health and security particularly to that of women and young girls. Furthermore, saline water intrusion into the inland freshwater sources is causing a severe threat to the lives of the people and species living around the world's greatest mangrove forest, the Sundarbans.

Since salinity intrusion is more frequent in the coastal area, the main purpose of this chapter is to discuss (i) the overall salinity scenario of Bangladesh, (ii) its causes and impacts on different sectors, and (iii) how livelihood in these areas copes with this silent hazard, and then draw a concluding remark.

OVERALL SALINITY SCENARIO IN COASTAL BANGLADESH

Both water and soil salinity is a normal hazard in many parts of the coastal area in Bangladesh. Comparing soil and water salinity, SRDI mentioned that salinity intrusion in soil is much higher than water salinity. However, the distribution of soil salinity for 1973, 1997, 2000, and 2009 showed that the spatial extent of the salinity has seen an increasing trend and has reached up to Magura district (Figs. 1 and 2). Furthermore, the saline-affected area has increased by 35,440 ha (3.5%) during the last nine years

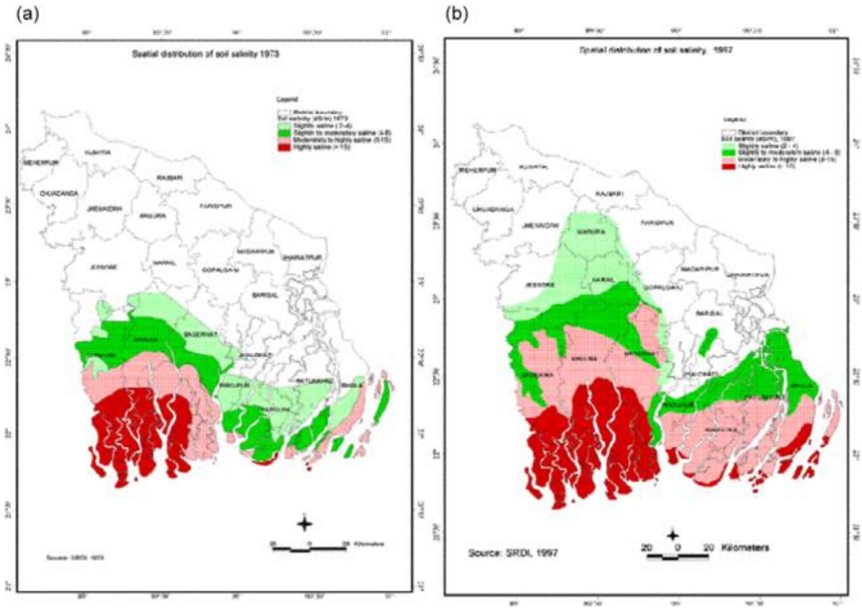

Fig. 1. Spatial Distribution of Maximum Soil Salinity in Dry Season, (a) 1973 and (b) 1997. *Source*: SDRI.

(2000–2009) whereas it has increased by 222,740 ha (26.7%) during the last 36 years (1973–1909) (The Daily Ittefaq, 2011). Moreover, the recent soil salinity map developed by SRDI (2009) showed that some of the new land of Satkhira, Patuakhali, Barguna, Barisal, Jahalakathi, Pirojpur, Jessore, Narail, Gopalganj, and Madaripur districts of the coastal region are affected by different degrees of soil salinity. But the worst salinity conditions are reported in Khulna, Bagerhat, Satkhira, and Patuakhali districts of southwestern Bangladesh (SRDI, 2010). Moreover, Fig. 3 represents that the soil salinity area has increased substantially in 1997, slightly decreased in 2000, and again increased in 2009.

Soil and water salinity in Bangladesh varies throughout the year and in the dry season (January–July) the salinity is generally high, but during heavy rainfall from August to December the salinity is low (SRDI, 2006). Saline water intrusion occurs in the months of March–May and salinity concentration in the river and canal becomes highest in the month of May. In the rainy season (June–October), saline water ingresses to 10% of the country's area because of extreme flow of freshwater, while in the dry

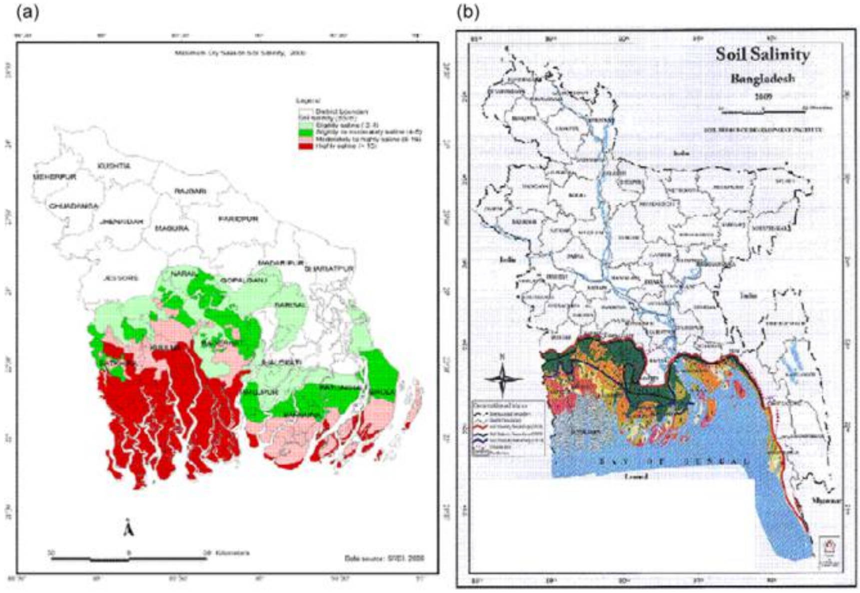

Fig. *2*. Spatial Distribution of Maximum Soil Salinity in Dry Season, (a) 2000 and (b) 2009. *Source*: SDRI.

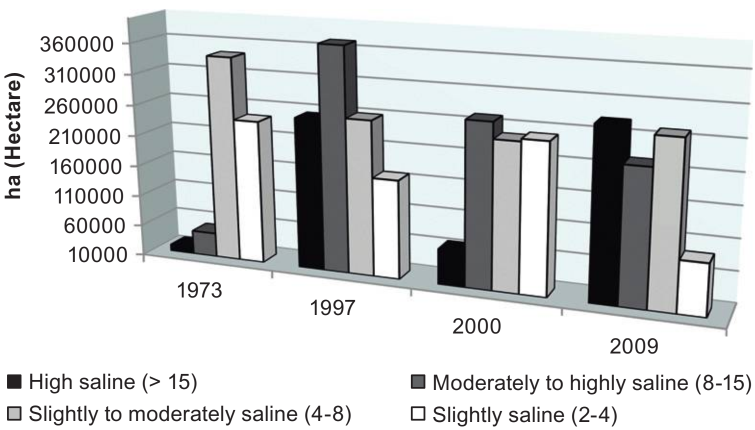

Fig. *3*. Different Classes of Soil Salinity Areas, 1973, 1997, 2000 and 2009.

season saline water reaches to country's 40% area even due to gradual upward movement of saline water. Therefore, the salinity problem becomes intense in agriculture and lack of saline-free water becomes an acute problem for the households during the dry season. This is particularly true in Satkhira and Khulna districts. Salinity ingress causes major problems in the southwestern region of Bangladesh as in Satkhira, Khulna, and Bagerhat districts and comparatively less complicated ones in the coastal reaches of Borguna, Pirozpour, Barisal, Bhola, Laxmipur, Noakhali, Chittagong, and Cox's Bazar districts.

CAUSES OF SALINITY INTRUSION

Water circulation in the coastal zone and in the Meghna estuary in Bangladesh is largely dependent on factors like freshwater flow from the river, penetration of tide from the Bay of Bengal, and meteorological conditions like low pressure systems, cyclones, and storms surge and wind (MoWR, 2003). Both climatic and anthropogenic factors are responsible for causing salinity in the coastal region of Bangladesh. However, climate-induced factors such as sea-level rise is the most pressing cause of salinity in coastal areas.

Sea-Level Rise

Sea-level rise has direct influence on salinity intrusion in the exposed and interior coast. A direct consequence of sea-level rise would be intrusion of salinity with tide through the rivers and estuaries. About an additional area of 327,700 ha would become high saline water zone (>5 ppt) during dry season due to a 60 cm sea-level rise (IWM & CEGIS, 2007). It would be more acute in the dry season, especially when freshwater flows from rivers would diminish. According to an estimate of the Master Plan Organization (MPO), about 14,000 km^2 of coastal and offshore areas have saline soils and are susceptible to tidal flooding. If some 16,000 km^2 of coastal land is lost due to a 45 cm rise in sea level, the salinity front would be pushed further inland. The present interface between freshwater and saline water are 120–160 km^2 inland in the southwest, and this could well be pushed northward as far as central Jessore region in the event of a sea-level rise. The rise in sea level will bring more coastal area under inundation. This coupled with reduced flows from upland during winters will accelerate saline water intrusion inland. Coastal waters will become more saline and soil salinity will increase. Not only that, even groundwater aquifers will bear the brunt of salinity intrusion.

Farakka Barrage

Salinity increases in the coastal region of Bangladesh because of decreasing upstream flow in the Ganges River. This is occurring because of the establishment of the Farakka Barrage in the upstream Ganges River. In 1974 India built the Farakka Barrage for diverting water from upstream Ganges to the Hugli River (Gain, Aryal, Sana, & Uddin, 2007). As Bangladesh is downstream, the effects were significantly decreased water supply that caused increasing entry of seawater into the Ganges basin. Eventually it increased river and groundwater salinity (Gain et al., 2007; Shamsuddin, Xiaoyong, & Hazarika, 2006). However, salinity in the southwest region of Bangladesh increased significantly during the post-Farakka period (Fig. 4). For example, at the Khulna station, the average monthly maximum salinity for April in the pre-Farakka period was 1,626 μmho/cm. During 1976, when the Gorai discharge dropped to 0.5 m^3/sec, maximum salinity in April increased to 13,000 μmho/cm.

Expansion of Shrimp Cultivation

Increased water salinity has created good conditions for shrimp cultivation (Haque, Bhatta, Hoque, Rony, & Rahman, 2008). Shrimp cultivation is

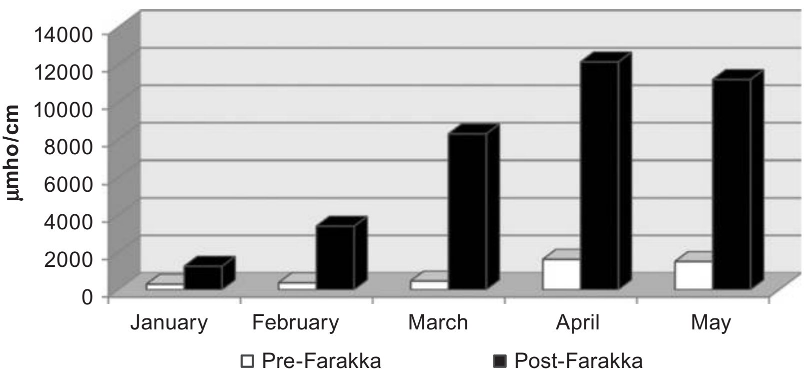

Fig. 4. Pre-and Post-Farakka Average Monthly Maximum Salinity at Khulna Station in Southwest Coastal Bangladesh. *Source*: Mirza (1998).

concentrated in the southern coastal belts of Cox's Bazar (20% of the area) and Bagerhat, Khulna, and Satkhira (80% of the area) in Bangladesh. The expansion of shrimp cultivation has witnessed a threefold increase in the last decade. Figure 5 represents the quantity of shrimp and fish production from 1991–1992 to 2009–2010, where shrimp and fish production contributes 80% and 20%, respectively.

As a consequence of shrimp cultivation in saline water, it plays a major role in increasing salinity, particularly in the southwestern region of Bangladesh (Haque, 2006). Moreover, it has been reported by Islam (1999) that salinity in shrimp cultivating areas may be 500% higher than in non-shrimp cultivating areas. Therefore, this practice is considered as one of the main reasons for increased soil salinity in southern Bangladesh (Dutta & Iftekhar, 2004; Fleming, 2004). For example, in greater Khulna alone, about 31,200 ha of land in 1982–1983 and 94,850 ha of land in 1993–1994 were brought under shrimp cultivation (Haque, 2006). Thus, it ultimately leads to increased salinity of the adjacent freshwater ponds and shallow aquifers through seepage.

Reduced Dry Season Flow in the Gorai River

The Gorai River is one of the major distributaries of the Ganges. Generally, a vast network of rivers in the southwest region of Bangladesh is dependent on the water supply through the Gorai River. Usually the Gorai's flow

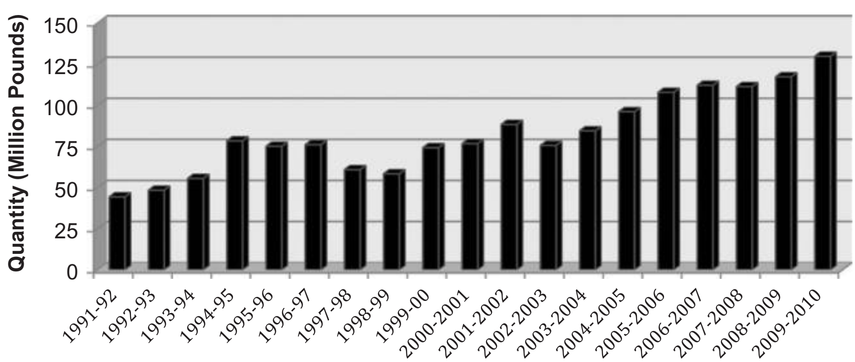

Fig. 5. Frozen Shrimp and Fish Exports from Bangladesh (1991–1992 to 2009–2010). *Source*: Data used from Bangladesh Frozen Foods Exporters Association, accessed on February 17, 2013.

pushes away the saline water of the Passur River, near Khulna. However, in the dry season, reduced flow in the Gorai River exacerbates problems of salinity in the southwest region of Bangladesh. Because of the decreasing Gorai flows during the dry season, the average salinity starts to increase at Khulna and adjacent areas and so a very large increase in salinity is noticed during spring tides. Stronger spring tides push more saline water into Rupsa−Pussur River, but during the following neap tide, the salinity is not totally flushed out. Therefore, a successive buildup of salinity occurs with each tidal cycle, which requires a sufficient supply of water from the Gorai River to flush out (MPO, 1987).

Tidal Flooding

High tidal waves, storm surges, and tidal flooding increases the salinity of freshwater in low-lying areas. The increased frequency of tropical storms in the Bay of Bengal (Singh, Masood, Khan, & Rahman, 2001) and tidal floods due to cyclone have pushed the salinity front further into the groundwater (Shamsuddin et al., 2006).

Excessive Use of Groundwater

Since the 1980s vast land in the southwest coastal region, except the slight saline wetland, has been brought under irrigation for cultivating boro rice through extraction of underground water in the dry season. The lack of surface water for irrigation during dry season has compelled the farmers to exploit underground water extensively resulting in a lowering of underground water table. Shamsuddin et al. (2006) argued that the excessive amount of water pumped up from the Bangladeshi aquifer in relation to the amount recharging it increases the entry of saline water into freshwater aquifers.

Faulty Management of Coastal Polders

Coastal polders were built to prevent tidal intrusion aiming to boost agricultural production. However, Islam (2004) found that many polders were out of function due to undesired breaching to promote shrimp culture that resulted in crop damage. Waterlogging in the sluice gates of polders or dikes is likely to increase the salinity in the coastal zone.

IMPACT OF SALINITY INTRUSION

Whatever happens due to salinity, it subsequently affects various other sectors. All these are important because these affect the lives and livelihoods of the coastal people. Therefore, this section explores how salinity has various impacts in this locality through drinking water, soils, agriculture, fisheries, ecosystems, and livelihoods of communities and households.

Agriculture

Agricultural production is greatly hampered by salinity in the coastal region in general and in the southwest and south central regions in particular. It decreases agricultural production due to unavailability of freshwater and soil degradation, which in turn reduces rice production. A study conducted by the World Bank (2000) shows that increased salinity from a 0.3 m sea-level rise will alone reduce the net production of rice by 0.5 million metric tons. Another study by BARC estimated that land degradation due to salinity itself causes a net loss of 4.42 million ton of wheat per year, which is equivalent to US$587 million. Furthermore, Ali investigated the loss of rice production in a village of Satkhira district and found that rice production in 2003 was 1,151 metric tons less than the year 1985, corresponding to a loss of 69%.

There is growing documentation on the adverse effects of high salinity levels on rice; also high soil salinity prevents growth, reduces germination, causes browning of rice fields (Gain, 1995), and decreases rice production (Ali, 2006). Rice production reduces by 10% and 50% due to salinity greater than 20,000 mS/cm and 48,000 mS/cm, respectively (Chaaffey, Miller, & Sandon, 1985). Following the onset of shrimp culture, reduced rice yields (Ahmed, 2001; BCAS, 2001) and soil fertility (Lewis & Ali, 1990) as well as increased occurrence of "stem root" virus (UNEP, 1999) have been reported. Rice production in Khulna, Satkhira, and Bagerhat is declining at high rates due to salinity (Boromthanarat, 1995). Already 19 of the 40 local rice varieties are extinct, and 4–5 varieties have become rare (Ahmed, 2003). Salinity also decreases the terminative energy and germination rate of some plants (Ashraf, Sarwar, Ashraf, Afar, & Sattar, 2002; Rashid, Hoque, & Iftekhar, 2004). In addition, salinity has caused increased insect and disease infestation in field crops in the coastal areas (Miah, Mannan, Quddus, Mahmud, & Baida, 2004).

Aside from this, most of the lands in saline-affected areas remain fallow in the dry season (January–May) because of soil salinity and the lack of good-quality irrigation water (Karim et al., 1990). In general, soil salinity is believed to be mainly responsible for low land use as well as cropping intensity in this area (Rahman & Ahsan, 2001). Moreover, converting the rice fields into shrimp ponds, the area of total rice production is decreased accordingly. It is reported that in the fiscal year 1997–1998, the area of rice production decreased by 1% compared to the fiscal year 1993–1994, while the total rice production declined by 26% during the same period (Islam, 2004).

Fisheries

Increased salinity has significant impacts on fisheries sector. It affects spawning ground, leading to substantial reductions in the inland open water fishery (Rabbi & Ahmed, 1997). Various fish species cannot get feasible environment in this region for reproduction (Ali, 1999). Adding together, fish resources have been depleted due to unscientific catching of fingerlings by shrimp fry collectors. The fry collectors keep the larvae of tiger shrimp only and throw all other species on ground and thus destroy the coastal fisheries resources. A recent report shows that about 138,600 ha of land are under shrimp farming in the ecologically sensitive regions of southwest Bangladesh (EGIS, 2001). Out of that about 42,550 ha, 36,500 ha, and 49,550 ha of land of Satkhira, Khulna, and Bagerhat districts are under Bagdha shrimp cultivation, respectively. Therefore, increase of shrimp culture may hamper of fish production as there will be more diseases due to salinity and destroy the crops in the future. Moreover, Miah et al. (2004) show that native freshwater fish species, such as *ruhi, katla, boal, tengra, koi, shing*, etc., are disappearing gradually due to increased salinity.

Livestock

Salinity has negative impacts on domestic cattle in the coastal area in terms of deterioration of milk productivity and reproductive health. Due to increased salinity, availability of water and destruction of pasturelands for livestock will lead to decrease of livestock resources in this region.

Drinking Water

Safe drinking water is a major problem for the population of coastal region, particularly in the southern part of Bangladesh. A large number of people are now suffering from drinking water problems due to inaccessibility to nonsaline water. It is reported that about six million people are deprived of safe nonsaline drinking water in southwest region (Ahmed, 2008), because the surface water is not only saline but also contains dirt and pathogens. Therefore, people cannot simply use the surface water sources for drinking purposes. Occasional inundation of water shortage like ponds and artisan wells often turn saline when the area is hit by tidal surge or embankment failure. Moreover, the situation has become worse because of the introduction of shrimp farming and the consequent intrusion of brackish water far inside the coast.

Health

High salinity in both surface and groundwater sources in the coastal region, particularly in southwestern areas of Bangladesh, is affecting human health. Drinking saline water has numerous direct and indirect impacts on health. Human health is especially influenced by the sole dependence on saline water for domestic purposes. As a consequence of drinking saline water, various waterborne diseases like diarrhea, cholera, etc. spread. Besides, various skin diseases erupt due to drinking contaminated water. Moreover, Khan et al. (2011) argued that the high level of salinity in drinking water might cause an increased rate of pre-eclampsia and gestational hypertension in pregnant women. A report of SRTT (2011) found that salinity in drinking water also causes diseases like kidney stone and rheumatism.

Women's Hardships

Usually women and adolescent girls carry out the task of collecting drinking water from distant sources. This may take three to four hours at a day. As a result, they do not have enough time or energy to carry on other household duties like cooking, cleaning, washing clothes, and taking care of elders including themselves. On the other hand, women in their advanced stages of pregnancy and lactating mothers find it difficult to carry on such duties (Ahmed, Neelormi, & Adri, 2007b). In salinity-prone regions, therefore, women have to curtail extra hours from their household work to combat salinity problem. As a result, women become tired after the daily ordeal and cannot concentrate fully on their mental and physical health. There are some cases where husbands complain about not serving food on time and also physically assaulting their wives for this reason (Ahmed, Neelormi, Adri, Alam, & Nuruzzaman, 2007a).

Social Consequences

Salinity not only increases hardships of women and adolescent girls, it also causes them social harassment. Sometimes when they go to collect water from long distances they are harassed by boys and men. Women and girls, therefore, feel uneasy and threatened while collecting water from distant sources. Besides, the skin of adolescent girls becomes rough and unattractive due to the effect of saline water. Hence, men from outside the area do not show interest in marrying these young girls (Ahmed et al., 2007). Even within the area, girls from poor families are neglected by rich families for matrimonial alliances. Not only social harassment but people sometimes also engage in conflict. Because shrimp culture is highly controversial, there are many disputes between local and outside landowners, and therefore conflicts arise between rice and shrimp producers.

Extra Burden on Poor People

In some areas, salinity forces people to buy freshwater from vendors, which creates an extra burden for them, especially the poor. Because a poor family cannot afford to collect water due to sickness or does not have any member in the family to do the job, they have to buy water from the vendors at Tk 10 per pitcher. It is very difficult for them to spend Tk 300 per month for drinking as their monthly income is typically Tk 500−1,500. Therefore, it creates extra pressure on them to survive without freshwater. Moreover, due to the scarcity of nonsaline irrigation water, it is expensive for the farmers to irrigate their cropping land through STW or DTW below 1,200 feet from the surface.

Ecosystem

The Sundarbans is the largest mangrove forest in the world that is importantly affected by increasing salinity, which will change the habitat pattern of the forest. This is because the loss of the Sundarbans means great loss of heritage, biodiversity, fish resources, life and livelihood, and indeed of a very high productive ecosystem. Due to the salinity penetration in the Sundarbans, the majority of the moderately saline zones will be transformed into saline areas, while relatively freshwater areas would be reduced to only a small pocket along the lower-Bales war river in the eastern part of the forest. Furthermore, it is claimed by Shamsuddoha and Chowdhury (2007) that increased saltwater intrusion is considered as one of the main causes of death of the Sundari trees. The adverse effects of increased salinity on the ecosystem of the Sundarbans can be seen by the dying top of Sundari trees, retrogression of forest types, slowing of forest growth, and reduced productivity of forest sites (MPO, 1986). Moreover, rapid growth of unplanned brackish water shrimp cultivation seals off the capacity of natural resistance against increased level of water and soil salinity in the Sundarbans.

Besides, the increase of salinity in the adjacent river channels hampers the growth of the forest species. Reduction of freshwater, salinity intrusion, along with soil quality depletion slow down plant growth and reduce productivity that have adverse effects on biodiversity and the wildlife.

Environmental Degradation

Environmental degradation caused by salinity intrusion is a major problem in southwestern coastal Bangladesh. The reduced flow of the Ganges in the dry season has exacerbated the process of northward movement of the salinity front, thereby threatening the environmental health of the region.

Soil Degradation

Salinity enhances soil degradation. The fertility status of most saline soils range from low to very low with respect to organic matter content, nitrogen, phosphorus, and micronutrients like zinc and copper. Estimates of the area affected by nutrient depletion and other forms of degradation are about 5.6 million ha in Bangladesh, although about 0.83 million ha of land is affected by salinity at various degrees. With the climate change saline water may come up to nonsaline land, which ultimately affects crop production.

Industry

Industrial production is reduced when saline water from river is used to cool condensers or to keep turbines running. Salinity restricts the usability of river water for industrial purposes and causes leakages in equipment and production loss, and also increases production cost by compelling the producer to import freshwater for avoiding corrosion and leakage. For instance, Pakshi paper mill closed down during 1993 due to salinity intrusion in the north of Khulna (Mirza, 1998).

Based on the previous discussion, Fig. 6 illustrates the overall causes and impacts of salinity intrusion in coastal Bangladesh. From this figure, it

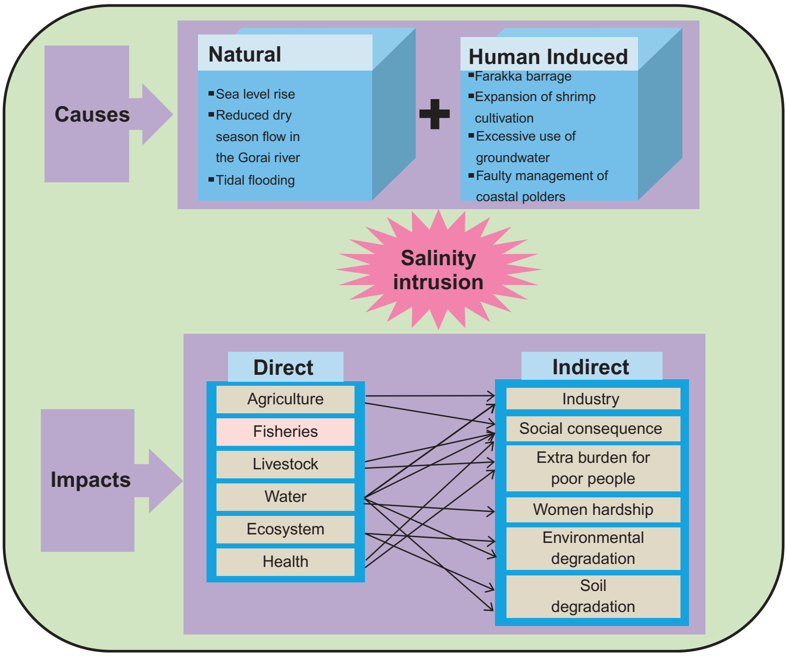

Fig. 6. Causes and Impacts of Salinity in the Coastal Region of Bangladesh.

can be seen how salinity intrusion accelerates in this area through climatic as well anthropogenic factors and what the impacts on livelihood that have been experienced through various sectors of this region are.

ADAPTIVE RESPONSES TOWARD SALINITY

There are a number of strategies and practices that have evolved over time to deal with the adverse effects of salinity. A wide variety of adaptive measures are carried out by institutions as well as communities to deal with this silent hazard. These are briefly described under the following subheadings.

In Terms of Agriculture Sector

At Institutional Level

Different organizations are working together on these issues. National Agricultural Research System (NARS) have given special thrust to develop salt-tolerant crop varieties suitable to cultivate in this region. As a result, Bangladesh Rice Research Institute (BRRI) and Bangladesh Institute of Nuclear Agriculture (BINA) have developed some saline-tolerant rice varieties that perform well in the coastal region. Some of the rice varieties for boro season are BRRI dhan-47 and BINA dhan-8. On the other hand, BR-23 and BRRI dhan-40, 41, 44, 53, and 54 are getting popular as aman varieties. BRRI dhan-55 is a newly developed variety that can be grown in both aman and boro seasons.

With this contrast, Bangladesh Agricultural Research Institute (BARI) has developed a number of crop varieties other than rice suitable to cultivate in Southern Delta. BARI-developed mung bean varieties like BARI Mug 5 and 6 are suitable to grow in this region. Oilseed Research Centre of BARI developed some other crop varieties of oil crops, soybean, and groundnut. BARI introduced maize, potato, and sweet potato varieties that are very popular in this region. It also developed some fruits like hug plum (amra), coconut, guava (peyara), and some vegetable varieties that are performing well in this region. BARI Halud is very popular there. Moreover, BARI even developed a lot of production practices for the region. The different saline-tolerant varieties invented by the research institutes are presented in Table 1.

In addition, the Department of Agricultural Extension (DAE) of the Ministry of Agriculture (MoA) in Bangladesh disseminates these salt-tolerant

Table 1. Name of the Saline-Tolerant Varieties Introduced by Research Institutes.

No.	Name of the Crop	Name of the Variety
1.	Rice	BRRI dhan-47, BRRI dhan-53, BRRI dhan-54, BRRI dhan-40, BRRI dhan-41, BINA-8, BINA-9
2.	Potato	Saikat
3.	Tomato	BINA Tomato-6
4.	Sweet potato	BARI Sweet potato-6, BARI Sweet potato-7
5.	Mustard	BARI Sarisha-10
6.	Wheat	BAW-1059, BARI Triticale-1, BARI Triticale-2
7.	Mung bean	BARI Mungbean
8.	Turmeric	BARI Halud

varieties into farmers' fields and they also train farmers on how to cultivate these saline-tolerant varieties in their cropping field.

At Individual and Community Level

A number of adaptive actions are taken by the individual and community to cope with or overcome adverse effects of salinity on agriculture. At the level of agricultural farms, adjustments may include the introduction of new crop varieties or species, switching cropping sequences, sowing earlier, adjusting timing of field operations, various fertilizer and pesticide use, conserving soil moisture through appropriate tillage methods, and improving irrigation efficiency. Some options such as switching crop varieties may be inexpensive while others such as introducing irrigation (especially high-efficiency, water-conserving technologies) involve major investments.

Due to high salinity levels, it is difficult to cultivate any high yield variety (HYV) crops, such as HYV aman and HYV boro. To ensure food security, the farmers in this area cultivate 13 local saline-tolerant varieties of rice that are especially suited to the current circumstances of this area. These rice varieties include *jotabalam, ashfall, ghunshi,* and *benapol*. Based on the land type, some of these local rice varieties are categorized for shrimp farms and for other agricultural land. For example, *Jotabalam* and *Ghunshi* varieties are selected for cultivation in the shrimp farms. On the contrary, *Ashfall* and *Benapol* varieties are destined for other agricultural farms.

Aside from this, the communities have adapted special mechanisms and raised their homestead to some extent and manage soil in a different way, such as mulching for vegetable growing and selecting salt-tolerant varieties. They utilize rainy seasons for vegetable cultivation and grow some selected species, such as creepers (*Puishak*, *Jhinge*, *guard*, *bitter gourd*, etc.), okra, chilies, cauliflowers, cabbages, radishes, etc. from July to March. They grow salt-tolerant tree species locally called rain trees such as *babla*, *khoibabla*, *tentul*, *kewra*, *coconut*, *koroi*, *khejur*, *paroshpipul*, and a few mangrove species with fruit species like *sofeda* and *peyara*.

In Terms of Drinking Water Supply

At Institutional Level

Various local and international NGOs such as SPS Khulna, Uttaran, ActionAid, Concern Worldwide, UNICEF, USAID, and government organizations such as DPHE and CDMP to receive their experiences and lessons learned on supplying drinking water and sweet water for irrigation in the region have provided insights into existing technologies. These technologies have been implemented by governmental and various nongovernmental organizations in the coastal areas of the country. These are:

Pond sand filter (PSF): This is a popular option of potable water supply through treatment of surface water in coastal belt. Intervention of PSF by UNICEF and DPHE was carried out along the coastal belt. The technology is very well adapted to coastal areas which are not feasible for Deep Tube Well (DTW) installation because of non availability of suitable aquifer producing acceptable quality and quantity of water; where the shallow aquifer is contaminated with arsenic or existence of excessive salinity in the groundwater, where there is no available safe water sources and where the sources are far from the users households. However, regular operation and management mechanism of the ponds and PSFs has been ensured by paid caretakers under the supervision of a management committee (Sarwar, 2005).

Rainwater harvesting (RWH): This has been modified through different nongovernmental organizations to provide the needy at affordable costs so as to harvest rainwater for drinking. For instance, SPS Khulna set up concrete tanks that are used for RWH, costing Tk 15,000 per family while some local earthen containers (namely motka) that cost individual families Tk 1,000 are also used. ActionAid installed an RWH system in Khulna.

Figure 7 represents RWH operated in the coastal area through concrete tank or plastic tank.

Excavating or renovating ponds: Excavating or renovating ponds on higher ground is another means of producing an access to sweet water for drinking through building strong and high embankments. The Bangladesh Disaster Preparedness Center (BDPC) used this solution in Morrelganj of Bagerhat district, where they were re-excavating some derelict ponds.

Rooftop catchment areas: Rooftop catchment areas are set up in roves of homestead by Comprehensive Disaster Management Program (CDMP) with DPHE, some of which are implemented in Satkhira District of the coastal belt.

Plastic sheets with a hole: During disasters, many NGOs provide plastic sheet with a hole in the middle to collect rainwater when scarcity of water is high. This sheet is set by spreading it on four bamboo poles or on a thatched roof to collect rainwater.

Fig. 7. Rainwater Harvesting Operates through Concrete or Plastic Tanks in Coastal Area. *Source*: Umma Habiba.

Shallow and deep tube wells: As per the document, shallow and deep tube wells generally extract groundwater from aquifers with depths of 300 feet and 1,000 feet, respectively. Various NGOs and the Government of Bangladesh have set up such tube wells in different regions of the coastal area mostly as temporary solutions.

Solar-powered desalination plants and reverse osmosis (RO): High-tech and high-cost drinking water solutions such as solar-powered desalination plants and RO machines are both options to reduce the salinity of water. One of the local NGOs installed four RO machines along the coastal region, which treat saline water and produce pure drinking water.

Others: Some other very expensive options include "sky water harvesting," "air to water" technology (collecting water from vapor), membrane-based water technology, and piping water in from areas that have sweet water sources. All of these options have very high installation costs. In Shyamnagar upazila (sub-district) of Satkhira district, the local NGO Shushilan along with Dhaka University is piloting an initiative that drives rainwater into shallow pockets of aquifers to recharge groundwater. Moreover, to prevent the entry of brackish water into freshwater ponds by the high tidal surge during a disaster, a durable solution has been experimented by WaterAid Bangladesh and Shushilan by raising embankments of the ponds to a height above the highest tidal surge.

At Individual and Community Level

PSFs are considered most suitable of all the safe drinking water options in coastal areas of Bangladesh. Ponds with PSFs and RWH in households and community level are now the only major sources of safe drinking water. Figure 8 shows how the community people collect safe drinking water through PSFs. The government-, INGOs-, and local NGOs-introduced provisions of safe drinking water supplies are made use of with the cooperation of the community people in this area. Only very few people have the ability to buy purified water from different water treatment plants or shops, and most of the people cannot afford to buy safe drinking water.

In Terms of Shrimp Cultivation

At Institutional Level

The government has carried out several projects such as shrimp culture project, third fisheries project to develop water management infrastructure

Fig. *8*. Community People Collect Safe Drinking Water from Pond Sand Filter. *Source*: Umma Habiba.

Fig. *9*. Shrimp Cultivation by the Community People in Gabura Village of Satkhira District. *Source*: Md. Anwarul Abedin.

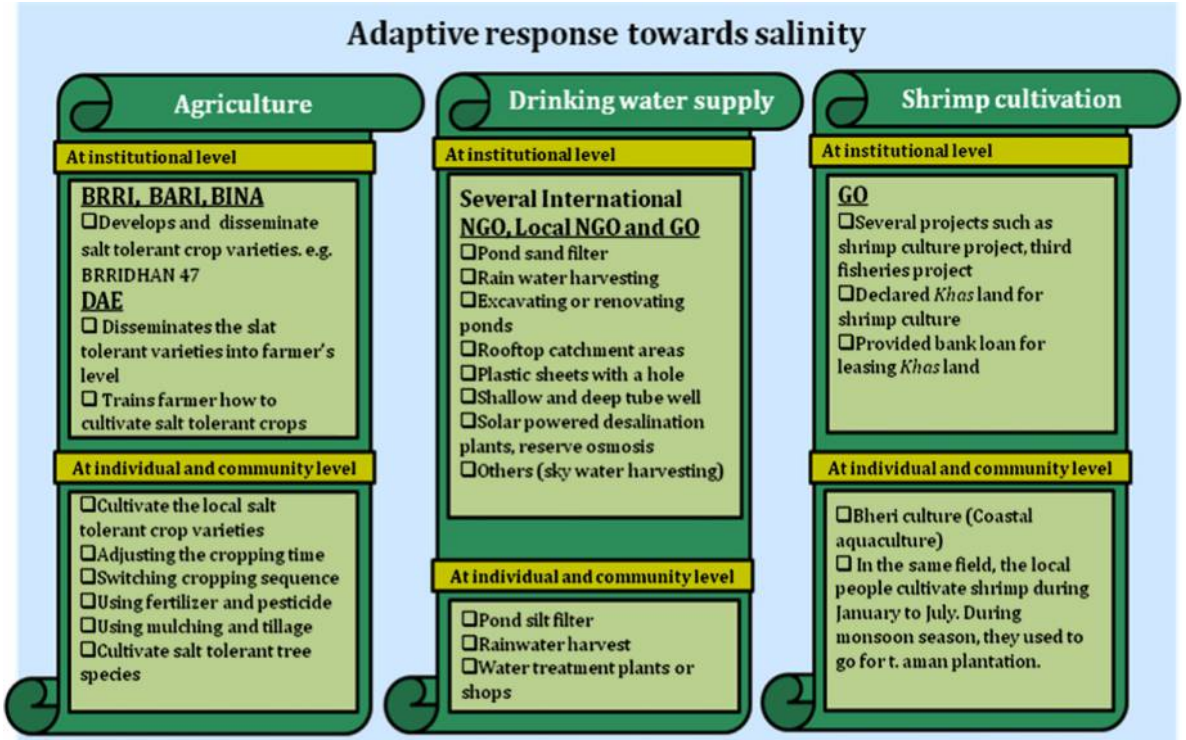

Fig. 10. The Overall Adaptive Responses in Saline-Affected Areas.

for shrimp farming. The government has declared *khas* land suitable for shrimp culture as "Chingri Mohal" (Shrimp Estate) and introduced a new leasing system of *khas* land for shrimp culture. In 1995 the Ministry of Land declared intensive and semi-intensive shrimp culture land as "Shrimp Industry Land" in the coastal districts of Bangladesh providing various facilities including the provision of letting *khas* leased as collateral against bank loans.

At Individual and Community Level
The local people in coastal region practice traditional coastal aquaculture locally called "*Bheri culture*" (Fig. 9). They bring tidal water within the paddy fields during January/February to June/July for aquaculture and during monsoon season they go for t. aman plantation. At the end of November and December they catch fish excluding shrimp and then harvest paddy. A few months later, they collect shrimp and make their land ready for another term. In this way they can produce rice as well as fish and gain profit.

Based on the previous discussion, Fig. 10 briefly illustrates the ongoing adaptation measures that are followed in the salinity area.

CONCLUSION

According to the Fourth Assessment Report of the IPCC, marine and coastal ecosystems in South and Southeast Asia will be affected by sea-level rise as a consequence of climate change (Parry et al., 2007). Therefore, slightly saline areas will become moderate to highly saline and surface-based irrigation will not be possible. According to MOEF (2006), the distance of the salinity intrusion inland, as well as the extent of salinity in the coastal areas, is expected to increase with rising sea levels. The estimates of the amount of sea-level rise over the coming century ranges from 0.2 to 0.6 m (Parry et al., 2007). Among various hazards, salinity intrusion is increasingly becoming a severe problem in the coastal region of Bangladesh, particularly in the southwestern part.

From this discussion, it has been concluded that the present salinity scenario has already posed a threat to crop production and also drinking water source. Moreover, it has been predicted that the increasing concentration of salinity will put more pressure on the people by reducing yield. Additionally, it will be threatening livelihood, income generation, and food security of coastal people. Nearly about 40 million people are directly affected by water and soil salinity and another 20 million are at risk.

Salinity issue so far did not get much importance in the government's disaster management policy. During 1980s salinity problem received very little attention in Bangladesh. Government has developed "Coastal Zone Policy-2005" that did not take into account salinity issue. In case of water, it has been seen from the Coastal Zone Policy (2005) that, "Rainwater harvesting and conservation shall be promoted; ponds and tanks will be excavated for conservation of water and local technology for water treatment (such as, pond sand filtering – PSF) will be used for the supply of safe water; step will be taken to ensure sustainable use and management of ground water." On the other hand, the National Adaptation Program of Action (NAPA) briefly explains the causes and impacts of water salinity on the coastal economy, whereas much focus was given on climate change and sea-level rise. In this respect, it needs more attention by government as well as other international NGOs to overcome the salinity situation in the future.

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