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RESEARCH ARTICLE

Resource degradation and livelihood in the coastal region of Bangladesh

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Abstract A study was conducted in four selected upazilas under four coastal districts through participatory rural appraisal (PRA), household survey and monitoring, sampling, focal group discussions, personal interview, on-farm field visits, institutional consultations, and secondary information. The investigation revealed that the valuable natural resources of the whole region are at the verge of serious degradation. Various causes have been identified, which are responsible for degradation of both resources and production environments. These causes include human population growth, coastal embankment, upstream withdrawal of Ganges water, brackish water shrimp farming, salt production, use of agro-chemicals, industrial activities, commercial activities, over-exploitation, etc. The study also showed that the degradation of natural resources is the reason behind the squeezing of historically dominant livelihood opportunities of the coastal communities. The current scenarios of the coastal ecosystem urge necessary steps to be taken for sustainable management of valuable resources and to create alternative livelihood opportunities for the coastal communities.

Keywords coastal region, resource degradation, livelihood

1 Introduction

The coastal region of Bangladesh is about 710 km long and covers about one-fifth of the country's landmass. The region hosts a unique diversity of ecosystems and is known as the zone of opportunities. It has diverse coastal and marine resources including mangroves, fisheries, agriculture, shrimp, crab and salt, as well as on-shore and off-shore oil and gas fields. There are two sea ports located in the coastal area, namely Chittagong (southeast zone) and Mongla (southwest zone). A considerable number of industrial plants are situated in the coastal region. The Sundarbans mangrove forest is a notable place for forest products, wildlife and eco-tourism. About 36 million people live in the coastal area and their livelihoods largely depend on agriculture, fishery, forestry, transportation, salt farming, etc. The region was once diverse with various natural resources such as forest vegetation, fishes, crops, poultry, livestock and wildlife; presently, the whole region is on the verge of degradation largely because of frequent natural disasters, human activities and global climate change.

The geographical location and geomorphological conditions of Bangladesh have made the country's coast one of the most vulnerable in the world to disasters. It is the most hazardous coast in the world in terms of the number of lives and properties that suffer from various types of natural calamities every year. The region faces severe natural disasters such as cyclones, storm surges, floods, drainage congestion, salinity, drought, etc. The coastal zone of Bangladesh is perceived as a zone of multiple vulnerabilities. In combination with other natural and man-made hazards such as erosion, high arsenic content of groundwater, waterlogging, water and soil salinity, and various forms of pollution, these have made coastal dwellers very vulnerable (Islam, 2004) and threatens the whole coastal and marine environment. It is the ultimate recipient of pollution load that comes with the sediment from upstream through the major river systems. The government of Bangladesh has already identified the region as 'vulnerable to adverse ecological processes'.

It is evident that the degradation of the coastal ecosystems started with the establishment of flood control embankments under the Coastal Embankment Project (CEP) during the early 1960s. Protected land areas inside the polders/embankments encouraged brackish water shrimp farming. Eventually shrimp farming emerged as a

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major form of land use by replacing crop agriculture in the whole region. Continuous transformation of agricultural and grazing lands into permanent shrimp farms have increased soil and water salinity manifolds resulting in lower production of rice, vegetables and other agricultural commodities as well as mangrove forests. Apart from shrimp farming, other severe human activities such as upstream withdrawal of Ganges water, salt production, indiscriminate use of agro-chemicals, unplanned industrial and commercial activities, etc., have been playing vital roles in degrading the coastal ecosystems. All these activities along with recent climate change impacts have been reported to cause unrecoverable damages to the whole coastal ecosystem and livelihoods.

This article aims to characterize the resources in the coastal region of Bangladesh and their extent of degradation, and to identify the causes of degradation of those natural resources. Moreover, the article will also describe the status of livelihood activities under the scenario of gradual degradation of coastal resources.

2 Methodology

The study was conducted in four selected Upazilas, i.e., Shyamnagar, Paikgacha, Rampal and Chakaria under the Satkhira, Khulna, Bagerhat and Cox's Bazar districts, respectively, in the downstream coastal region of Bangladesh. The primary data were collected through: 1) Participatory Rural Appraisal (PRA) approach; 2) Questionnaire Survey from the respondents of 150 households in each site, and 3) Focal Group Discussion (FGD) with different stakeholders. Data on soil and water salinity were taken at field level. Secondary data were also utilized for the region as a whole.

3 Coastal region of Bangladesh

PDO-ICZMP[1)] classified the coastal area of Bangladesh into two broad categories viz. interior coast and exterior coast. Out of 147 upazilas under 19 coastal districts, a total of 48 upazilas in 12 districts that are adjacent to the sea and at lower elevation are marked as the exposed coast, and the remaining 99 upazilas of the coastal districts are termed as the interior coast (Fig. 1). Geomorphologically, the coastal region of Bangladesh is broadly divided into three distinct sub-zones, namely the western, central and eastern sub-zones. The western sub-zone is very flat and low and is crisscrossed by numerous rivers and channels. It hosts the

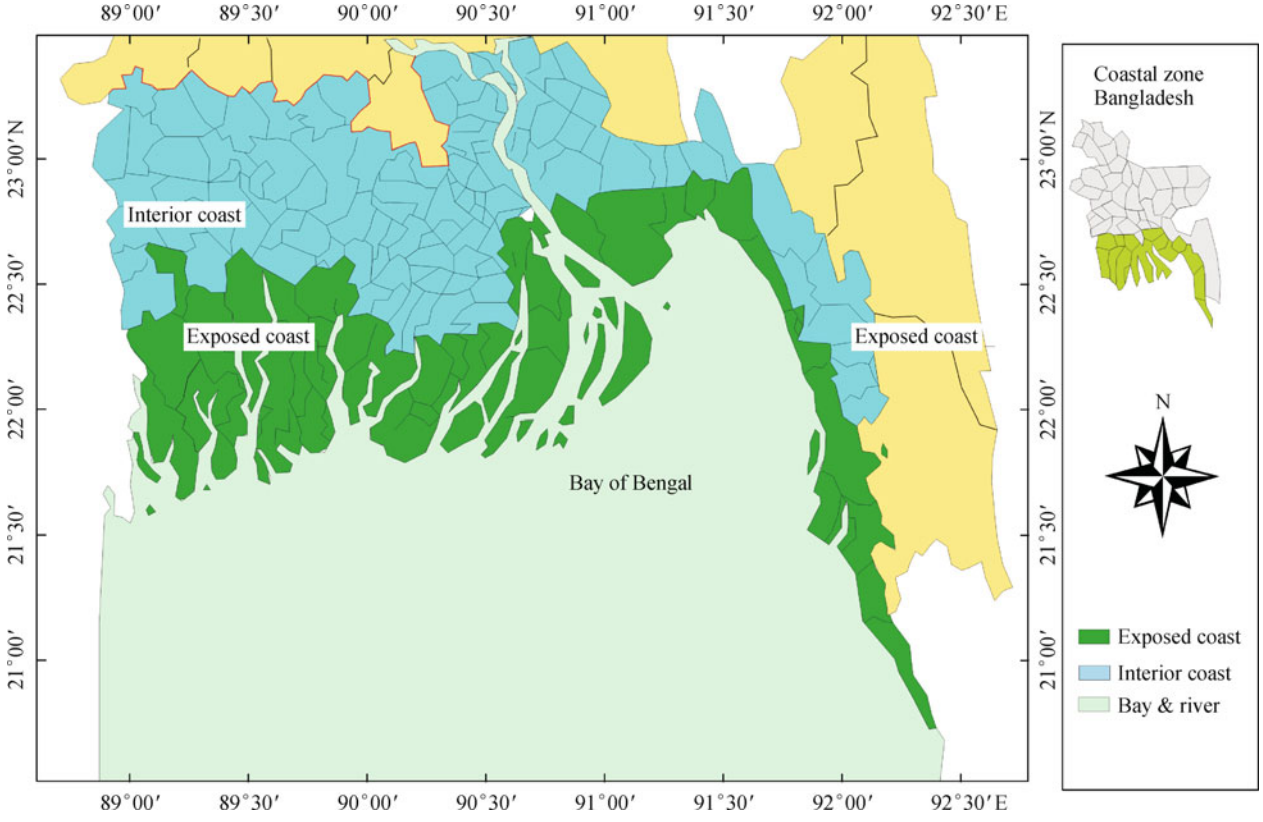

Fig. 1 Coastal zone of Bangladesh

1) A system analysis of shrimp production. Program Development Office for Integrated Coastal Zone Management Plan. June 2003

famous mangrove area called the Sundarbans. The central zone is the most active one and has a continuous process of accretion and erosion. The eastern zone is covered by hilly areas and it is stable, with the presence of a long beach. The topography of the coastal area is flat low-lying land having an elevation mostly 3 m above the mean sea level (msl). Geologically, the area suffers from subsidence to some extent, and this is due to consolidation of the new deposits of sediments and settlement of the base strata (Hoque, 1992). It is a part of the humid tropics with the Himalayas lying in the north and the funnel shaped coast touching the Bay of Bengal in the south. This type of geography of the country produces life-giving monsoons but also catastrophic ravages of disasters. Monthly variations in temperature indicate that maximum temperature is in a higher range in the districts in the southwest region compared to Cox's Bazar (Fig. 2). It might be due to the Cox's Bazar being closely adjacent to the Bay of Bengal, whereas the other three districts are somewhat far from the seashore. Thus, there might be higher cooling effects of the sea in Cox's Bazar compared to the other districts. Again, lesser vegetation cover in the southwest region accompanied with vast areas under shrimp ponds might be the reason behind higher temperature levels in this region.

The coastal morphology of the country is a very complex and dynamic system undergoing continuous changes as a result of active delta building processes by the action of the Ganges, the Brahmaputra and the Meghna (GBM) river system. In each year the GBM system carries about 1.7×10^9 t of silts during monsoons, causing severe turbulence in the rivers (Shamsuddoha and Chowdhury, 2007). This results in gradual undercutting of river banks leading to erosion. Erosion is caused by a number of factors such as high monsoonal wind waves and currents, high river discharge currents, strong tidal actions and storm surges. Massive changes have occurred in the coastline over the last two centuries due to land erosion coupled with land accretion. A huge land of 86366 ha eroded during 1973–2000[1]. By river bank erosion Bhola island has suffered a loss of about 227 km^2 in the past 50 a, *Hatiya* island has been reduced from 1000 km^2 to only 21 km^2 in the past 350 a, and Swandip island has lost 180 km^2 in the past 100 a. Land erosion adversely affects the ecosystem, navigation, planned agriculture development, and drainage systems. It also affects inland navigational routes in terms of shifting and migration of channels. Apart from this, the GBM also carries 6 million cusecs of water with 2.18×10^6 t of sediments each year, causing waterlogging and flooding during the rainy season (Shamsuddoha and Chowdhury, 2007). Siltation raises the river bed up, which reduces the intensity of water flowing as well as hampering the breeding and nursing ground of major open water fisheries in Bangladesh. As the force of upstream water flow is reduced, seawater tends to flow upstream. Such intrusion of saline water affects coastal agriculture.

4 Natural resources and degradation

4.1 Land

Land is the most important resource in the coastal region as people depend directly or indirectly upon its outputs. Available secondary information and this field study show that availability of land area has been declining throughout the coastal region. Human population growth, establishment of industries and commercial activities, unplanned settlements and road networks are also likely to increase pressure on available land area. Land quality/fertility, particularly soil organic matter and soil salinity, are the major factors for productivity of the coastal land. Estimation of soil organic matter content in selected locations reveals a decline by 12%–48% compared to 1999 levels across the region, with the highest in the south-west region (Fig. 3). Quantum increase in soil salinity (Fig. 4) throughout the region has been found to decrease the land quality and fertility. This is due to reduced flow of upstream fresh water, perennial type shrimp farming and sea level

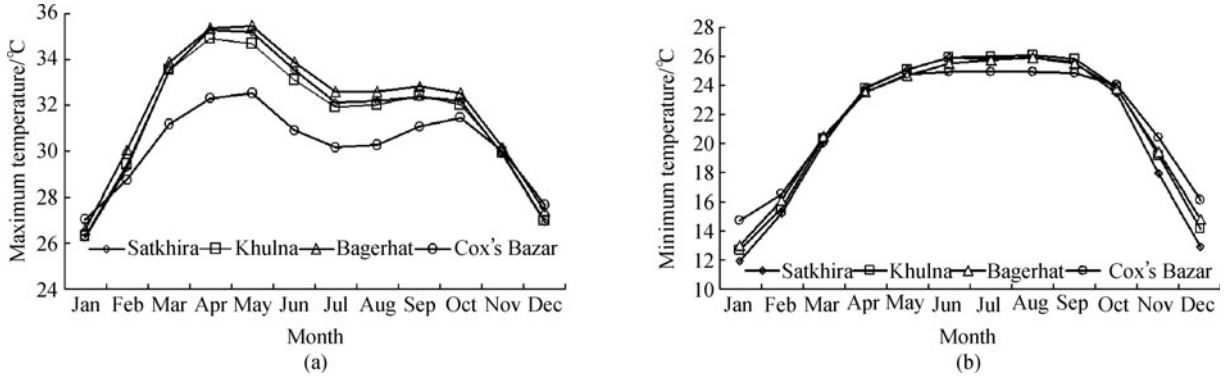

Fig. 2 Monthly variations in maximum (a) and minimum (b) temperature in the study region

1) Meghna estuary study project: hydro-morphological dynamics of the Meghna estuary. Bangladesh Water Development Board, Ministry of Water Resources. June, 2001

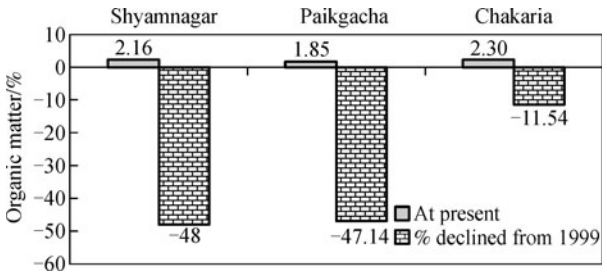

Fig. 3 Soil organic matter content at present (2008) and percent decline from 1999

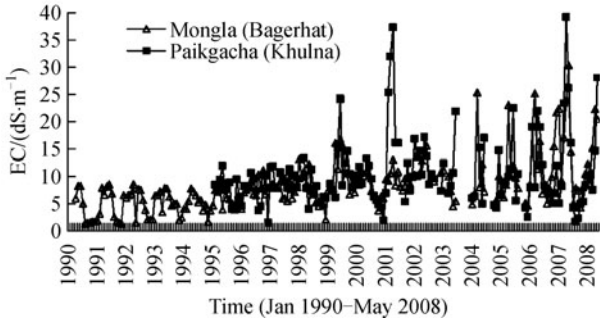

Fig. 4 Trends in top soil salinity in Khulna and Bagerhat Districts (SRDI, 2009)

rise. Field estimates reveal a strong negative relationship between soil salinity and organic matter content throughout the study areas (Fig. 5), indicating adverse impacts of salinity on soil organic matter content, thus lowering productivity potential. Open field brick burning activity has been growing in the coastal region. Almost all of the brick fields have been using top soils from crop fields, thus lowering the fertility status of agricultural soils, which protected the productivity of those lands for many years.

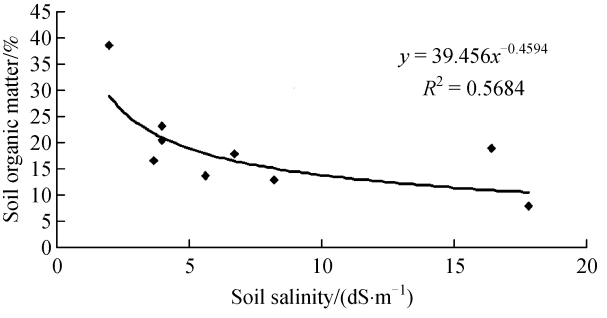

Fig. 5 Relationship between soil salinity and soil organic matter content in the study

4.2 Water resources

The coastal region is crisscrossed by numerous rivers and their tributaries. There were about 120 rivers in the coastal areas. These rivers have been providing enormous opportunities for various fisheries, aquatic resources, riverine transportation, agricultural production (especially rice production) and mangrove forests. Coastal water resources have been supporting the livelihoods of the poorer sections of society. However, these rivers and water channels are now fully or partially dead because of man made activities. Data in Table 1 provide an account of the status of water resources in selected study locations.

The major causes behind degradation of coastal water resources are the changes in river morphology, aggravated river beds due to obstacles to their diurnal tidal behavior as a result of coastal embankments, the river dying due to illegal grabbing, brackish water shrimp farming, withdrawal of water from the Ganges, poisonous sediments from agro-chemicals, industrial residues, farm effluents and sewage disposal, ground water contamination, oil spills from marine transportation, and toxic materials released from ship breaking, etc. Siltation and aggravated river beds are now creating multifarious problems from permanent water logging to crises in irrigated farming as well as creating doubts on the safety of drinking water.

The main visible reason behind degradation of water resources is the quantum increase in water salinity. Sea level rise has been bringing more coastal areas under potential inundation. Drainage congestion and water logging, which are outcomes of coastal embankment, have started to build up salinity in the polder areas across the south-western region. Meanwhile, upstream withdrawal of Ganges water at Farakka plays a significant role behind quantum increase in soil and water salinity by reducing upstream flow and thus introducing the salinity gradient further inland. The salinity problem is further severely aggravated by the long nature of brackish water shrimp farming. Gradually, salinity has increased beyond tolerable limits for agricultural crops and other vegetation.

Long-term trends in major river water salinity (Fig. 6) show that the upper limit (30–45 dS/m during the peak period) is beyond the tolerable limits for crops and vegetation. It is evident that water salinity of 7.5 dS/m and above is harmful for rice cultivation. This very high salinity has been found to affect both floral and faunal resources adversely at both terrestrial and aquatic ecosystems.

4.3 Forest resources

Forests, especially the mangrove forest, are the unique resource of the coast of Bangladesh. The major portion of the mangrove forest is located in the south-west part, which is popularly called the Sundarbans, and the other part is located in the south-east part and is called the Chakaria mangrove forest. The Sundarbans is the largest mangrove forest in the world, and has been providing livelihood and employment to thousands of families (Khan, 2001) aside from providing ecological benefits

Table 1 Status of rivers in the studied sites of the coastal region of Bangladesh

Location	Water body	Total No.	Dried/silted up	Transformed	
				Shrimp farm	Other uses
Shyamnagar	River	26	18	18	–
	Canal	131	–	131	–
	Beel	44	19	25	19
Paikgacha	River	28	06	18	01
	Canal	132	–	63	–
	Beel	55	–	55	–
Rampal	River	10	06	06	–
	Canal	154	25	53	–
	Beel	30	–	30	–
Chakaria	River	02	01	01	–
	Canal	74	04	30	–

(Miah and Bari, 2002a). The Sundarbans reserved forest used to be rich in various quality timber tree species and non-timber forest products such as wax, honey, vines, and fishes, etc. However, this forest has been under severe pressure from ecological changes and natural calamities as well as man-made activities. The most alarming threat to the Sundarbans is over-exploitation, both of the timber resources and of the fauna, because 500000 families including 200000 fishermen are dependent on this forest (Miah and Bari, 2002b). The current study identifies manifold increases in soil and water salinity to be responsible for threatening the Sundarbans forest resources. The increased salinity has affected the natural regeneration of mangroves, and in some areas there is very scattered regeneration. To save the Sundarbans and its unique resources the Government of Bangladesh has recently banned all types of resource collection from the Sundarbans.

The 18000 ha Chakaria Sundarbans, another unique mangrove forest, was encroached at both government and private initiatives for the expansion of brackish water shrimp farming during the period from 1975 to 1999. Currently, no patches of land under tree cover is present in the area except for some isolated trees standing sporadically[1]. Encroachment of the mangrove forest created multifarious impacts on both resources and livelihoods of the local inhabitants.

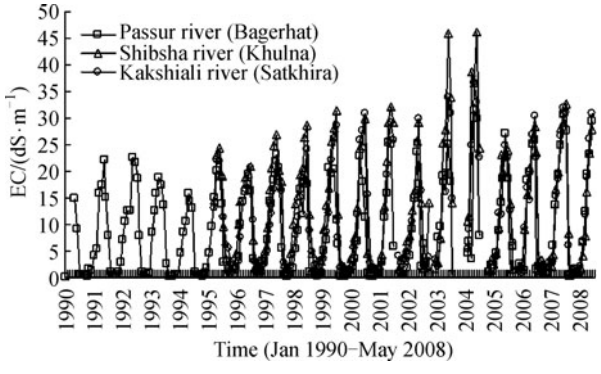

Fig. 6 Long-term trends in water salinity in selected rivers in Satkhira, Khulna and Bagerhat Districts (SRDI, 2009)

Apart from ecological impacts, e.g. cyclonic storms, flooding and soil erosion, diverse livelihood activities of the local inhabitants in its vicinity were lost. Thus, pressure has been building on the remaining reserved forest resources. Data provided in Fig. 7 indicate that the area under other reserved forests in Chakaria has been declining gradually due to mounting pressure from local households, illegal loggers and tobacco curing firms for firewood and timber.

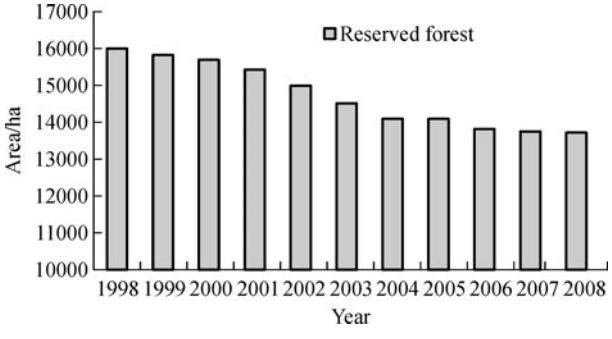

Fig. 7 Depletion of Chakaria reserved forest over time

4.4 Biodiversity

The coast of Bangladesh is the house of biodiversity, but the growing population, increase in soil and water salinity and over-exploitation have affected the biodiversity of the region at an unprecedented rate. It is also reported that most of the local flora and fauna have been affected

1) Report on study on denudation of mangrove forest due to shrimp farming using remote sensing and GIS in the Bangladesh coastal region, 2001. Space Res. And Remote Sensing org., Dhaka, Bangladesh. 2008

severely as the rivers were encroached and dried up[1]. Once, the region was in abundant supply of traditional local rice varieties, but the present field study shows that around 32 local rice varieties have disappeared from the study sites, while 27 varieties are near extinction. A similar situation is also found in the case of vegetables, fishery resources and other aquatic resources e.g. sweet water turtles and tortoises, snails, molluscs, and water lilies, etc. It is reported that water pollution coupled with other activities has already led 130 fish species to extinction and another 15 to near-extinction among the 200 fish species inhabiting the *Karnafuli* river along the Chittagong coast[2]. Wild life biodiversity has also been under increasing threat. Further, fishing and hunting with the help of agrochemicals and other poisonous compounds have been putting adverse impacts on wild life as well as aquatic living beings in the estuarine areas. Again, indiscriminate collection of snails has already caused depletion of snails from the coastal region. Together, all of these have been causing irrecoverable losses to the ecosystem and to the livelihoods of the coastal communities.

5 Causes of resource degradation

5.1 Population growth

The growing human population has been identified as one of the major causes behind increasing pressure on the both resources and the environment, thus accelerating the degradation of resources and environmental production. The human population in Shyamnagar, Paikgacha, Rampal, and Chakaria is likely to grow by margins of around 59%, 105%, 50%, and 93%, respectively, with an annual growth rate of 1.6%, 2.5%, 1.4% and 2.3%, respectively (Table 2). Data indicates that this growing population will demand more land area, thus per capita land availability will be reduced by 38%–50% during the same time frame. Available data also indicated that the coastal population in 2050 will be around 60 million, with an estimated per capita land availability of only 0.025 ha compared to 0.056 ha in 2001 (Islam, 2004).

5.2 Coastal embankment

Degradation of the coastal resources and environment started with the establishment of the Coastal Embankment Project (CEP) during 1960s–1980s (Islam, 2006). A total of 123 polders with about 5017 km of embankment were constructed across the coastal region with the aim to protect agricultural lands from salinity intrusion (Table 3). Embankments, although initially helping increase crop production and preventing salinity intrusion, keeps saline water inside the embankments for longer periods. This opens an opportunity for brackish water shrimp farming at the same time. Shrimp farmers took advantage of legal sluice gates as well as creating illegal sluice gates to pour saline water into shrimp enclosures. The coastal embankment ultimately made the areas unsuitable for agriculture and was termed as a 'man-made disaster' (Rahman, 1995). Shrimp farming already has been reported to put major adverse impacts on forests and other natural resources, biodiversity, agricultural production, environmental pollution, as well as causing human and animal health hazards (Miah and Bari, 2002a, 2002b).

5.3 Brackish water shrimp farming

Polder areas encircled by coastal embankments as well as dried up rivers, canals and other water bodies encouraged unprecedented expansion of brackish water shrimp farming in the whole coastal region. The total area under brackish water shrimp farming was 51812 ha in 1984 and grew to over 217000 ha in 2008. The highest expansion took place in the SW region due to a favorable geophysical setup as well as easy availability of shrimp postlarvae in the Sundarbans estuaries (Fig. 8). In 1984, the area under shrimp farming in the SW region was 321239 ha, which grew to over 172000 ha by 2008. This practice has increased soil and water salinity, deterioration of soil fertility and productivity, insect pest and disease problems, pollution of soil and water ecosystems, depletion of forest and other natural resources, and loss of biodiversity (Miah and Bari, 2002a, 2002b).

Table 2 Change in population and per capita land area in the studied sites of coastal zone of Bangladesh

Upazila	Population		Change at current growth rate/%	Land/(capita ha)		Change/%
	2001	2030**		2001*	2030**	
Shyamnagar	313781	497215	59	0.138	0.086	−37.68
Paikgacha	248112	507738	105	0.155	0.076	−50.97
Rampal	178503	267114	50	0.155	0.103	−33.55
Chakaria	336198	650112	93	0.109	0.056	−48.62

Notes: * Estimated; ** Projected

1) Effects of salinity on the livelihood of Munda ethnic minorities. Amader Paribesh, September, 2008. Bangladesh Resource Centre for Indigenous Knowledge, Dhaka
2) Chowdhury N A. Fish destruction in Karnafuli river by industrial wastes. The Daily Amar Desh, 30 August, 2009

Table 3 Coastal embankment statistics in the study Upazilas

Upazila	Polder (No.)	Embankment length/km	Legal sluice gate	Illegal sluice gate and water inlets
Shyamnagar	02	217	107	284
Paikgacha	09	211	81	123
Rampal	01	40.35	11	40
Chakaria	04	268	202	80
Total coastal	123	5017	1039	–

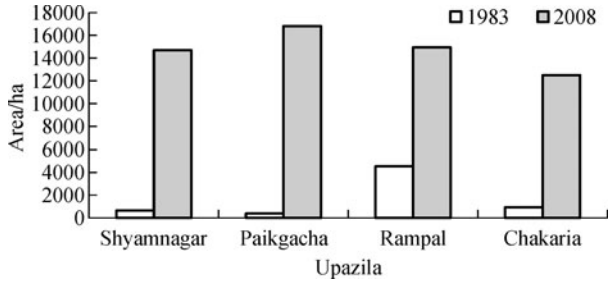

Fig. 8 Expansion of brackish water shrimp farming in the study Upazilas

5.4 Upstream withdrawal of river water

India built a cross dam on the river Ganges in *Farakka* upstream in 1974. Unilateral withdrawal of water from the Ganges caused a considerable reduction in the discharge rate of the Ganges through Bangladesh. Withdrawal of Ganges water upstream adds to the magnitude of degradation of the SW region by reducing the flow of *Gorai* and other rivers in the SW region. The average monthly water flow at the *Hardinge Bridge* point during dry season was 2674 m^3/s from 1935–1975, which went down to 1871 m^3/s from 1975–2004, indicating a 30% decline during the post-dam period. This changed river morphology and caused a decline in surface and ground water resources in association with inward movement of salinity gradients and arsenic contamination due to over exploitation of ground water resources. Reduction of fresh water during dry periods has increased the intensity and coverage of salinity and ultimately affect production environments and ecosystems.

5.5 Salt production activities

Salt production activities have dominated in Cox's Bazaar district. Salt production started in Cox's Bazaar district during the year 1960–1961 with an area of 2743 ha. Eventually it became a major land-use form in the region, covering an area of 28745 ha (Fig. 9) against the suitable land for salt beds of 7136 ha with an annual growth rate at over 1100 ha/a. In Chakaria upazila under Cox's Bazaar, the land area under salt beds in 1998 was 4655 ha, which grew to over 8900 ha in 2007–2008, an increase of over 91%. Once any agricultural land is converted to a salt bed, it becomes almost permanently unsuitable for any other vegetation. Data indicate that the salt production area has been increasing over time, implying more land area is unavailable for agricultural production activities.

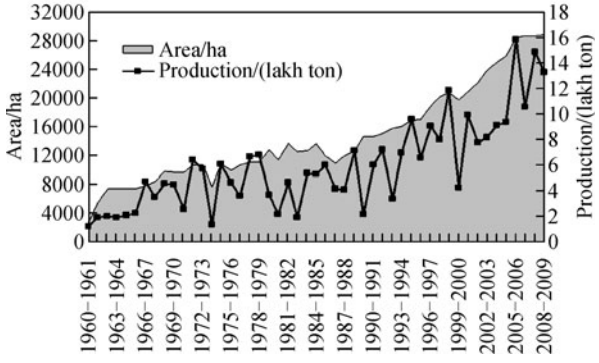

Fig. 9 Growth of salt production in Cox's Bazaar (BSCIC, 2009)

5.6 Pollution

Pollution of soil and water resources in the coastal region is also a major concern because of the growing number of industries, commercial activities and transportation systems. A total of 5873 industrial and manufacturing plants are situated in the coastal region out of a total of 24934 in Bangladesh as a whole. Most industrial developments, however, are concentrated in Chittagong and Khulna due to port facilities in the vicinity of these large cities. In Chittagong, there are around 720 industrial installations of which 370 are considered as major polluters. In Khulna, out of 300 major installations, 290 are considered as major polluters. Around 200 shrimp processing plants are in operation in Khulna and Cox's Bazaar region. Moreover, 54 ship breaking yards are in operation along the coastline of Chittagong. These installations have been discharging wastes and pollutants into the rivers, which pollutes rivers, estuaries and marine ecosystems. High levels of organic, inorganic and radioactive pollutants in waste discharges from growing numbers of fish processing plants, industries and ship breaking yards are found to pollute the estuarine marine ecosystems (Islam, 2006). The growing expansion of ship breaking activities has posed a threat to the

continental shelf and the intertidal zone, which has already damaged the natural attributes such as mangroves and marine grasses[1]. One of the major environmental problems in the coastal zone is oil spill, which was reported to kill fishes including their fries, and also to destroy other aquatic living beings and sea birds.

Pollution from agriculture mainly results from the use of agro-chemicals, i.e. fertilizers and pesticides, with special emphasis on urea fertilizer and insecticides. Indiscriminate and excessive use of agro-chemicals in increasing amounts has been causing surface water pollution in the tidal floodplains in the coastal region. Quantum increases in insect pest attacks on crops in recent years have forced the farming communities to rely heavily on insecticides. The study reveals that farmers usually applied insecticides 2–7 times in a single rice crop against only one recommended use. Field estimates indicate that a total of 17–23 t of pesticides were used in T. Aman rice crop alone in 2008 (Table 4). Over 4520 t of pesticides are now being used in the agricultural areas of the coastal districts, 25% of which may reach surface water systems as residue during the rainy season[2].

Besides industrial and agricultural pollution, brick burning and tobacco curing have also been growing in the region. A total of 51 brick fields were found in operation in the study areas (Table 5), and the numbers are increasing. These brick fields burn around 3000 t of quality top soils from agricultural lands. Also, they burn around 766 t of firewood annually. Tobacco cultivation has been gaining momentum in the foothill areas of Chakaria and other Hill Tract districts due to cheaper lands and easy availability of firewood for the curing of tobacco. There are around 800 curing houses in Chakaria, which used around 4800 t of firewood as fuel material in 2007. Further, there are also around 8000 curing houses elsewhere in the Hill Tract districts, which are reported to burn around 20000 t of firewood for curing of tobacco annually. The main sources of firewood used for curing are the reserved forests of Chakaria. All the firewood was found to be collected illegally by clearing reserved forests.

5.7 Over-exploitation of natural resources

Over fishing and shrimp larvae harvesting, indiscriminate collection of snails and mud crabs, and illegal collection of timber, firewood and other forest products from the Sundarbans are also found to be responsible for resource degradation of the coastal region in Bangladesh. Approximately 150000 fishermen are engaged in artisanal fishing in the coastal waters, and another 40000 fishermen are engaged in fishing inside the Sundarbans. Between 1990–1991 and 2006–2007, the growth in industrial, artisanal and Sundarbans fishing increased by 30494 and 167%, respectively, indicating increased pressure on this sector, and thus raising concerns about its stocks and ecological limits. On a regional basis, there is an estimated number of over 450000 shrimp larvae collectors in the region, although around 200000 people collect shrimp larvae as

Table 4 Total insecticide use by rice farmers during Transplant Aman season, 2008

Upazila	Area under T. Aman rice/ha	Area under attack/ha	Percentage of Aman area under attack/%	Pesticide use/t
Shyamnagar	21100	6330	30	17.60
Paikgacha	16228	6491	40	22.39
Rampal	17810	2672	15	7.03
C hakaria	12110	8477	70	22.89

Table 5 Inventory of brick burning activities in the study Upazilas

Parameter	Upazila			Total
	Shyamnagar	Paikgacha	Chakaria	
Total No. of brick fields	17	26	08	51
Soil source/%	–	–	–	–
Crop land	100	75	80	–
River bank	–	25	–	–
Hill	–	–	20	–
Soil use/($t \cdot a^{-1}$)	671	1050	1213	2934
Fuel use/($t \cdot a^{-1}$)	190	276	300	766

1) Hossain M M, Islam M M (2004). A case study on the abundance and species composition of fish species in and around Ship breaking area, in the coastal area of Chittagong, Bangladesh, Institute of Marine Sciences, University of Chittagong

2) Department of Environment, Ministry of Environment and forests, Bangladesh. Bangladesh: National Programme of Action for Protection of the Coastal and Marine Environment from Land-Based Activities. Det Noerke Veritas, Norway, 2006

a main occupation. Around 300000 and 80000 people are involved in shrimp post-larvae catching in the coastal and the Sundarbans waters, respectively. In 2002 an estimated amount of 3000 million shrimp post-larvae were collected from the region. It was evident that during the collection of one shrimp post-larvae, hundreds of other fish seeds are destroyed with the present traditional type of collection. Despite an official ban on such type of collection from natural sources, shrimp post-larvae collection has been found to continue at full swing. Moreover, snail and mud crab collection has been growing around the Sundarbans estuaries. Snail flesh is used as feed in both Bagda and Golda shrimp farms. As a result, thousands of resource poor people have been engaged in snail collection in the region. Snail shell is also used as fish feed after grinding. Mud crab collection has been found increasingly throughout the coastal region due to its high demand as an export item. Forest department statistics indicate that the total collection of mud crabs in 1984 was 10 t, which grew to over to 1343 t in 2008. Officially, timber and firewood collection is banned from the Sundarbans Reserve Forest (SRF). However, due to the increasing crisis of biomass fuel in the coastal region, there is evidence of an ever increasing collection of both timber and firewood from the SRF. Timber and firewood collection has also been continuing at an accelerating rate from the Chakaria reserved forests. Moreover, game hunting with the help of insecticides as well as sedatives is also reported in the Sundarbans. Tigers, spotted deers, and birds are hunted with the help of insecticides, poisons and sedatives.

5.8 Settlement, urbanization and communication

Increases in human activities also facilitated the expansion of settlements, including housing and road networks in the study areas. Between 1998 and 2008, areas under housing and settlements increased by 40%–57% in the study upazilas (Fig. 10). Between 2001 and 2008, the increases in paved and semi-paved road networks were 72%, 48%, 241%, and 105%, in Shyamnagar, Paikgacha, Rampal, and Chakaria, respectively (Fig. 11). In recent years, there has been considerable growth in both road and marine transportation. The Chittagong port deals with 1500 vessels every year in addition to 40 oil tankers and 2500 registered vessels, while the Mongla port deals with 1500–1600 vessels and 12000 to 13000 cargo vessels annually. Besides, there are over 44000 mechanized boats and 200 fishing trawlers operating in the shallow coastal waters, of which only 6000 and 88, respectively, have registration. Oil spills and bilge water from marine transportation has been found to be seriously deteriorating both estuarine and marine ecosystems.

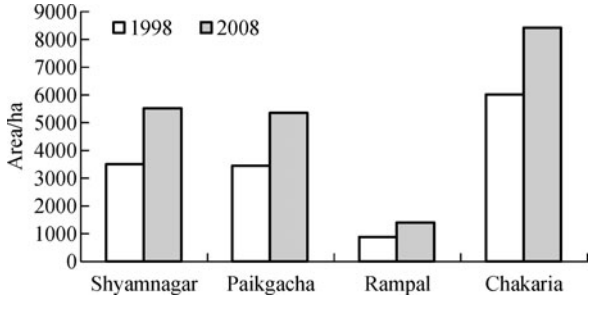

Fig. 10 Growth of settlements in the study Upazilas over time

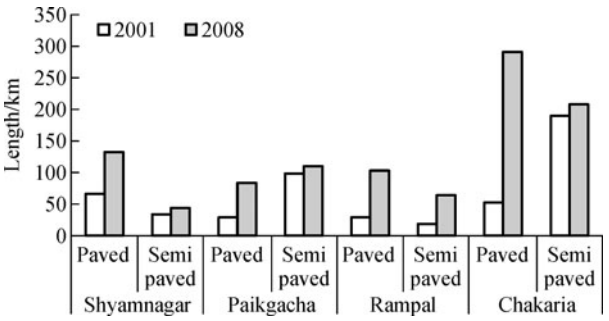

Fig. 11 Growth of road infrastructure in the study Upazilas over time

5.9 Climatic extremities

The coastal region has been experiencing increases in natural calamities and risks as an outcome of climate change. Alterations in temperature and rainfall patterns are indicated to accelerate flood, salinity, drought, cold injury, and cyclonic hazards, having detrimental impact on both resources and environments. Growth in frequencies of cyclonic storms as well as tidal surges implies that the region will be highly vulnerable to climatic extremities. The impacts are identified as the loss of land suitability, decline in agricultural production, crisis of safe drinking water, and health-related complications. The resultant impacts are increasing food insecurity and socio-economic suffering of the local communities.

6 Livelihood of the coastal communities

The total population living in the coastal zone is about 36 million, which represents 28% of the total population of the country (Islam, 2004). The average population density of the zone is 743/km^2, and the average figure for Bangladesh is 839. Population density in the interior coast is much higher than that of the exposed coast and the country average. There are about 6.8 million households in the zone, of which 52% are absolutely poor (Islam, 2004). Agriculture, fishing, shrimp farming, forest resource collection, salt farming and tourism are the main economic activities in the coastal area. The historical patterns of

livelihood and their current status are briefly discussed below.

6.1 Farming

Farming is the dominant livelihood pattern in the coastal region but it has become a fragile practice in the region. Among the different types of farming, rice cultivation is the main practice. Its acreage and productivity have been reduced gradually. The single most important factor is soil and water salinity leading to the adverse impacts on the growth and development of crops. The large farmers are mostly absentee landowners who do farming if it is highly profitable, and others have shifted to shrimp farming or other activities because agriculture is no longer a profitable activity. The numbers of small and marginal farmers are being diminished because of less profitability in farming, increased salinity, drainage congestion, and the high risk involved in farming due to frequent natural calamities. Tenant farming has been diminishing too because of the unfavorable tenancy arrangements and high risks in farming. Many wage laborers have diversified their livelihoods by moving into non-farming activities or shifting into cities or other areas.

6.2 Fishing

Fishing was a dominant livelihood activity throughout the coastal region next to farming. This opportunity has been decreasing progressively. The major causes behind depletion of inland open water fishery resources are siltation and drying of rivers, canals, beels, other water bodies, high water salinity, conversion of perennial water bodies into shrimp farms, and encroachment of water bodies to raise settlements and structures. Overfishing and fishing with insecticides are also identified as major problems behind the diminishing fisheries production in the region. Likewise, pond fishery has almost been eliminated from the study areas, particularly in downstream areas. Most of the homestead ponds are either unutilized or under-utilized. Due to increases in water salinity, pond fisheries have not been profitable in recent years. Extreme climatic events are also becoming dominant agents in recent years for reducing fish resources and productivity.

6.3 Shrimp post larvae collection

Shrimp post-larvae collection became a dominant livelihood activity after 1990 with the start of commercial shrimp farming. Currently, around 300000 and 80000 people are involved in shrimp post-larvae catching in the coastal and the Sundarbans waters, respectively. Particularly, resource-poor households, e.g. landless and marginal household members, are mostly involved in shrimp post-larvae collection. The Focus Group Discussion (FGD) with shrimp fry collectors revealed that shrimp fry availability is almost 25% compared to that in 10a before because of reduction in the population of mother shrimps and destruction of spawning grounds. It is mentioned that the collection process of shrimp post-larvae has also been leading to the destruction of numerous other fish-larvae, thus helping deplete open water fish resources. As a result, the government has placed a ban on shrimp fry collection from natural sources since 2002. Attempts have also been made to create alternate income generating activities for the larvae collectors, although they have failed. Having no other employment opportunities, landless and resource-poor people have since been forced to adopt such occupation till now.

6.4 Forest resource collection

Forest resource collection is another important livelihood activity in the south-west coastal region. The Sundarbans is a major source of subsistence for almost 10 million people. The main activities in the Sundarbans area are fisheries, wood collection and honey collection. The dependency on the Sundarbans has increased progressively but resource availability has been degraded accordingly. The reason behind increasing dependency in recent times is due to severe biomass fuel crisis, unemployment, as well as labor displacement from agricultural activities. Therefore, many people are engaged in resource collection from the Sundarbans reserved forest. The other reasons for resource depletion are the increasing soil and water salinity. Salinity has been causing transformation of the Sundarbans from a high density forest to low density vegetated land. Considering the severe resource depletion, the government has recently banned resource collection from the Sundarbans.

6.5 Salt production

Salt production in the south-east coastal region is also a notable livelihood practice. It was started in Cox's Bazaar district during 1960–1961 in around 2743 ha of land. Eventually, it became a major form of land-use in the region, covering an area of around 28745 ha in 2008–2009, with a total production of around 13.2 lakh ton, and the incremental trend has been continuing. Currently, about 38000 households are engaged in salt farming. Several problems exist with salt production with regards the livelihood of the workers and lease-takers at field level. Majority of the salt producers are poor and lease-producers, and use the traditional open bed method, i.e. without using polythene in the crystallization bed. The salts produced in the open bed are of lower price and benefit cost ratio is too low for their sustenance.

6.6 Snail and mud crab collection

Snail and mud crab collection has been growing in recent

years in the coastal region. Snail flesh is used as feed in shrimp farms and snail shells are also used as fish feed after grinding. As a result, thousands of resource-poor people have been engaged in snail collection in the region. There are around 30 informal markets in Khulna and Bagerhat where snails are traded regularly. However, the local source has been squeezed to almost nil in the coastal region. As a result, snails are being imported from other regions of the country every day. Crab is an edible aquatic resource that plays a vital role in earning foreign currency in Bangladesh. Collection of mud crabs has also been identified as a major activity particularly by resource poor households. About 50000 people in the Khulna, Bagerhat and Satkhira coastal districts depend on this resource by consuming, selling and exporting crabs that are harvested from the rivers and canals of the coastal zone. Because of high demand abroad, more people, particularly landless people, are being engaged in mud-crab collection. As a result, the mud-crab population has been declining.

7 Conclusion

The findings of the present study reiterate that the rich coastal region is now at a critical stage of degradation by both intensifying man-made activities and climate change induced extremities. Once, the region was rich with various resources. Land, mangrove forests, fisheries, agriculture, homestead vegetation, livestock and poultry, rivers etc. are the major resources in the coastal region. The resources, however, have been getting depleted at an alarming rate due to various factors, primarily including population growth, coastal embankment, upstream withdrawal of river water, shrimp farming, salt production, use of agrochemicals, soil salinity, pollution, and over exploitation etc., which has been defined as the major cause for deteriorating natural resources and livelihoods. Emergent countermeasures should be taken at prioritized basis for sustainable management of current resources, in order to create alternative livelihood opportunities for coastal communities.

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