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RESEARCH ARTICLE

SOIL AND WATER SALINITY, THEIR MANAGEMENT IN RELATION TO CLIMATE CHANGES IN COASTAL AREAS OF BANGLADESH

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Abstract: Climate change due to global warming and its negative consequence on environment and agro ecosystem is a serious concern of global community of current age. To assess the present soil and water salinity status in coastal areas a soil survey work following standard methods has been completed by Soil Resource Development Institute (SRDI) in 2009. It was observed that out of 2.86 million hectares of coastal and offshore lands about 1.056 million ha of arable lands are affected by varying degrees of salinity. A comparative study of the salt affected area between 1973 to 2009 showed that about 0.223 million ha (26.7%) new land was affected by various degree of salinity during last four decades . It was also observed that about 0.035 million hectares of land (3.5%) new land was affected by various degrees of salinity during last 9 years only (2000-2009). High amount of S and high pH may be the possible causes for P deficiency in coastal areas. Coastal soils are rich in micronutrient elements except Zn. In shrimp cultivated areas flooding with high saline water for a considerable time in each year causing higher soil salinity in all the horizons. A long term soil and water salinity monitoring data of SRDI shows that soil and water salinity between 1991 and 2008 has increased at least 2-10 times. Several common and location specific agricultural constraints have been identified in the field through field investigation/observation and farmer's interview. Proper fertilizer management practices need to be addressed in coastal saline areas.

Key word: Climatic change, coastal area, soil and water salinity, nutrient deficiency, fertilizer management

Introduction

Bangladesh, a deltaic plain, has a very flat and low topography except in the northeast and southeast region. About 10% of the country is hardly 1m above the mean sea level and one-third is under tidal excursions. It has 710 km long coastline running parallel to the Bay of Bengal.

Climate change due to global warming and its negative consequence on environment and agro ecosystem is a serious concern of global community of current age. It is considered as one of the most serious threats to the environment with its potential negative impacts on food security, agriculture, fisheries, human health, biodiversity, water and other natural resources. The broad spectrum objectives of this study are a) updating the soil salinity map and total saline area in coastal areas of Bangladesh and b) identification of agricultural constraints and present land use patterns in coastal area.

The coastal and offshore area of Bangladesh includes tidal, estuarine and meander floodplains. The tidal floodplain land occurs mainly in the south of the Ganges floodplain and also on large parts of Chittagong coastal plains. The Ganges tidal floodplains constitute about 49% of the coastal areas. The tidal lands on the coastal plain including the Chittagong coastal floodplain and the Matamuhuri tidal floodplain occupy less than 6%. Estuarine floodplains occupy about 18% of the total coastal area located in greater Noakhali, Barisal, Patuakhali and a smaller area of Chittagong districts (Karim *et al,* 1982).

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Agriculture is a major sector of Bangladesh's economy and the coastal area of Bangladesh is suitable for growing rice. More than 30% of the cultivable land in Bangladesh is in the coastal area. Out of 2.86 million hectares of coastal and offshore lands about 1.056 million ha (SRDI, 2009) of arable lands are affected by varying degrees of salinity. Farmers mostly low yielding, traditional rice varieties during wet season. Most of the land remain fallow in the dry season (January- May) because of soil salinity, lack of good quality irrigation water and late draining condition (Karim *et al*., 1990; Mondal,1997 and SRDI, 2001). Crop production of the salt affected areas in the coastal regions differs considerable from non saline areas. Because of salinity, special environmental and hydrological situations exist, that restricts the normal crop production throughout the year. In the recent past, with the changing degree of salinity of some areas due to further intrusion of saline water, normal crop production has become very risky. Crop yields, cropping intensity, production levels and people's quality of livelihood are much lower than in other parts of the country, which have enjoyed the fruits of modern agriculture technologies- high-yielding varieties, improved fertilizer and water management and improved pest and disease control measures (BBS, 2001). At the same time food demand in the area is increasing with the steady increase in human population. The present paper analyze the soil and water salinity intensity, extent, constraints and possible soil and water management practices to be followed in coastal areas of Bangladesh .

Materials and Methods

The Study area: The study area lies between 20º25´ and 23 º20´ N latitude and between 88 º25´ and 92º 24´ E longitude. The area bound by Kushtia, Chuadanga, Faridpur, Sariatpur, Chandpur and Comilla district on the north, Rangamati, Bandarban districts and Naf river on the east. Bay of Bengal and the Sundarbans on the south and India on the west. Within the study area 93 Upazilas under 18 districts are affected by different degrees of salinity. The total rainfall ranges from 1682 mm to 3627 mm, mostly received during the later part of the summer, increasing from north-west to south-east

Methods: A special field survey was carried out in the south-western part of the coastal arable land excluding the *Sundarbans* by soil survey team of SRDI in May, 2009. During field survey different base materials were used. The traverse lines parted 3-4 kilometers from each other. Along the traverse line a total of 2500 soil samples were collected. During field survey soil samples were collected from both outside and inside the polder. Traverse routes followed the catena, from the bank of the river to the centre of the polders. From each catena 6 soil samples (topsoil, subsoil and substratum) from ridges and basins were collected by auger. Surface salt crust was also collected separately. Number of spots varies according to complexity of the soil and shown on Soil Salinity map 2009.

Chemical analysis of soil and water was done following standard methods. On the basis of the soil survey information, a Soil Salinity map (1:2.8) million) is prepared delineating 5 mapping units. Soil salinity boundary of 1973 and 2000 shown too on present Salinity map (1:2.8 million). Coastal boundary is also shown on salinity map. Using the salinity map, present extent of saline soils was calculated cartographically.

Results and Discussion

Land characteristics: The areas are subjected to flooding in the monsoon season and water logging in parts of basin areas in most parts of the dry season. Tidal flooding through a network of tidal creeks and drainage channels connected to the main river system inundates the soil and impregnates them with soluble salts thereby rendering the topsoil and subsoil saline. After the construction of polders, the daily inflow of tidal water reduced and consequently the active sedimentation and erosion process has almost ceased except in brackish water shrimp cultivation area. Within the polders sedimentation and inundation process are still active with saline water in brackish water shrimp cultivation. At present, northern part of the area within the polder is flooded mainly with rain water. The most significant feature of hydrology in relation to agricultural development is the seasonal shallow flooding. Highland, medium highland and medium low land occupies about 4%, 64% and 13% land respectively, in coastal areas. In these areas, flood water recedes from about 24% area within October, from 53% area in November to mid December and from 23% area in late December (SRDI, 2001) or in early January, particularly in the southeast coastal areas (Sattar, 2002; Sattar and Mutsaers, 2004).

Soil characteristics: Coastal chars are formed as a result of alluvial deposition of silt and clays and are considered as young soils without having differentiated horizons. Mechanical analyses show that the coastal soils are mostly heavy textured varying from silty clay loam to silty clay. Soils of the relatively newer chars are dominated by clay fraction while those of the older ones have more silt. In general, coastal soils are almost devoid of sand. With the exception of a few pockets, percent sand varies from 1 to 4 in the coastal chars while percentage of silt varies from 69 to 78 and that of clay varies from 21 to 32 (SRDI,2009).

Ganges meander floodplain soil is olive brown to dark grey, silt loam to clay, mostly calcareous, having weak to strong prismatic structure. Saturated percentage varies from 56-67%, CEC from 2.4- 41.6 cmol/kg. Soil having CEC 15.0 cmol/kg is considered as of poor status. Free calcium carbonate varies from 0.5-10.0%. Bulk density varied from 1.3-1.55 gm/cc. Ganges tidal floodplain soil are grey to dark grey, mainly silty clay loam to clay, calcareous to noncalcerous, having weak to strong prismatic structure. Saturated percentage varies from 39-85%, CEC from 10.4-36.8 cmol/kg. Free calcium carbonate varies from 0.5-8.0%. Bulk density varied from 1.39-1.58 gm/cc. Lower Meghna estuarine floodplain soils are grey to dark grey, silt loam to silty clay loam, mostly non calcareous, having stratified to moderate prismatic structure. Saturated percentage varies from 50-74%, CEC from 8.0-17.6 cmol/kg. Free calcium carbonate varies from 0.5-3.5%. Bulk density varied from 1.39-1.53 gm/cc (SRDI, 2009).

Soils are, in general, characterized by having high moisture retention capacity as has been reported by LRP [Land reclamation project] and low permeability. An analysis carried out by LRP in CBD-I showed that soil moisture is at 50 volume% up to pF 2 (pF 2 corresponds with a groundwater table at 1m). Further downward movement of the water table to 3 m (pF 2.5) only results in a decrease of equilibrium moisture retention to 30 – 40%. Upward movement due to evaporation will usually exceed downward movement due to a decreasing water table. This results in salt accumulation in the topsoil in the dry season unless evaporation is reduced by special measures, such as tillage and/or a soil cover.

Soils dry up very slowly after the harvest of transplanted aman rice and a moisture content of 25 to 32% in the top soil layer (0-13cm) are common in the southeastern chars during March. Nevertheless rabi crops suffers from physiological water stress due to strong influence of soil salinity on osmotic pressure (Sattar and Mutsaers, 2004).

Nutrient status: Analytical data of soil samples show that the pH value of the topsoil ranges from 4.0 to 8.5. Organic matter content of topsoil varies from 1.03 to 3.87%. Evidence of high soil pH may be due to high amount of Ca, Mg and K. Total N and P content is found very low in all the soils. High amount of S (150-460 ppm) may be one of the possible causes for P deficiency in coastal areas. Coastal soils are rich in all other nutrient elements, particularly B, Cu, Mn and Fe. Concentration of Zn varies considerably (0.14 to 6.22 ppm), even within a particular area (SRDI, 2009).

Present soil salinity status: It is anticipated that with the sea level rise both water and soil salinity along the coast of Bangladesh will increase. A water salinity map for the period of 1967 and 1997 produced from the salinity survey data shows that water salinity has intruded upward during this 30 years of period. A comparative study between Soil Salinity maps generated by SRDI of the period of 1973, 2000 and 2009 shows intrusion of soil salinity in the coastal region (SRDI, 2009). Fresh river water withdrawal from upstream, introduction of brackish water shrimp cultivation, faulty management of the sluice gates, regular saline tidal water flooding in unsoldered area, capillary rise of soluble salts etc. are the main causes behind this increase in salinity.

The present spatial distribution of saline soils is assessed through ground survey following reconnaissance soil survey technique using aerial photographs. Distribution of soils with different degrees of salinity is shown on Soil Salinity map, 2009 (Fig.1).

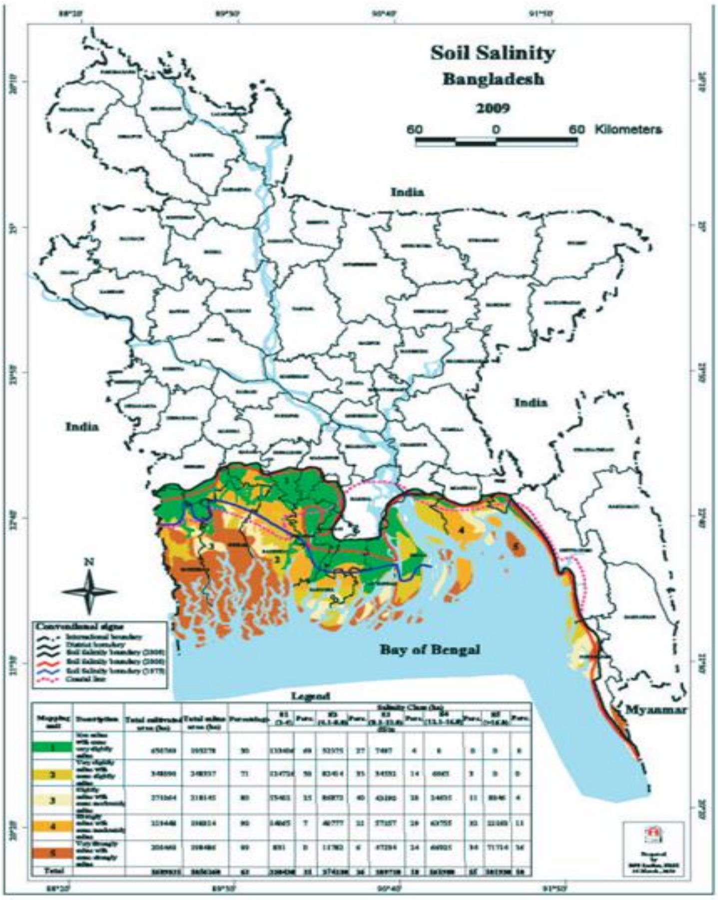

Fig. 1. Soils of coastal Bangladesh

Out of about 1.689 million hectares of coastal land 1.056 million are affected by soil salinity of various degrees. About 0.328, 0.274, 0.189, 0.161 and 0.101 million hectares of land are affected by very slight (S_1), slight (S_2), moderate (S_3), strong (S_4) and very strong salinity respectively (S_5). Some of the new land of Satkhira, Patuakhali, Borguna, Barisal, Jhalakathi, Pirojpur, Jessore , Narail, Gopalganj and Madaripur districts are affected by different degrees of salinity, which reduces agricultural productivity. Some 50% of the coastal lands face different degrees of inundation, thus limiting their effective use. This situation is expected to worse further because of the effects of climate change (Islam, 2006). Cropping intensity may increased in very light and slightly saline areas by adopting proper soil and water management practices with the introduction of salt tolerant of different varieties of crops.

Salt characteristics: Highest salt accumulation is observed in Ganges tidal floodplain. In this physiographic unit maximum EC is recorded in the surface soil at 49.5 dS/m. It varies from 0.9 to 49.5 dS/m. It decreases with depth and then increases again due to influence of saline ground water table. In shrimp cultivated areas flooding with high saline water for a considerable time in each year causing higher soil salinity in all the horizons. Na, Ca, Mg and K ions are the dominant cations in different saline areas. On the other hand $SO_4^=$,Cl^- and HCO_3^- ions are the dominant anions. In most of the saline soils the ionic preponderance decreased in the order of $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ and $SO_4^= > Cl^- > HCO_3^-$. But in the soils under prolonged brackish water shrimp cultivated areas ionic preponderance decreased in the order of $Na^+ > Mg^{2+} > Ca^{2+} > K^+$. Exchangeable sodium percent (ESP) ranges from 0.5-17.6% (SRDI, 2001). Highest soil salinity in the Meghna estuarine floodplain areas recorded is slightly over 67.0 dS/m with a mean varying, depending on locations, from 23 to 44 dS/m even within a single char.

Three characteristics of soil salinity are important for agriculture. These are intensity, spatial variations and annual cycle. Soil salinity begins to rise in February, reaches a maximum in March/April and declines with the start of monsoon rain in June/July. Salt tolerant rabi crops are successfully grown in high salinity level provided adequate management practices are adopted. Considerable variation in the levels of soil salinity can be observed within a distance of a meter or two in a single crop field (Fig. 2) (Sattar and Mutsaers, 2004).

Fig. 2. Spatial variation of soil salinity in a field at *Char Majid*

Extent of soil salinity in 1973 – 2009: Withdrawal of fresh river water from upstream, irregular rainfall, introduction of brackish water shrimp cultivation, faulty management of the sluice gates and polders, regular saline tidal water flooding in unprotected area, capillary rise of soluble salts etc. are the main causes of increased soil salinity in the top soils of the coastal region. A comparative study between Soil Salinity map of the period of 1973 to 2009 shows intrusion of soil salinity in the coastal region (Table 1). The map shows that soils of Satkhira, Jessore, Narail, Madaripur, Gopalgonj , Barisal, Jhalakati, Pirojpur and Patuakhali were newly salinized in 36 years of time expansion.

A comparative study of the salt affected area between 1973 to 2009 showed that about 0.223 million ha (26.7%) new land in effected by various degree of salinity during about last four decades (Fig. 3). It was also found that about 0.035 million hectares of new land in effected by various degrees of salinity during last 9 years only (2000-2009).

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Table 1. Extent of soil salinity during last four decades (1973-2009) in coastal areas

Salt affected area (000'ha)			Salinity class											
			S1 2.0-4.0 dS/m			S2 4.1-8.0 dS/m			S3 +S4 8.1-16.0 dS/m			S5 >16.0 dS/m		
1973	2000	2009	1973	2000	2009	1973	2000	2009	1973	2000	2009	1973	2000	2009
833.45	1020.75	1056.19	287.37	289.76	328.39	426.43	307.20	274.21	79.75	336.58	351.68	39.90	87.14	101.91

S3 = 8.1-12.0 dS/m ; S4 = 12.1-16.0 dS/m

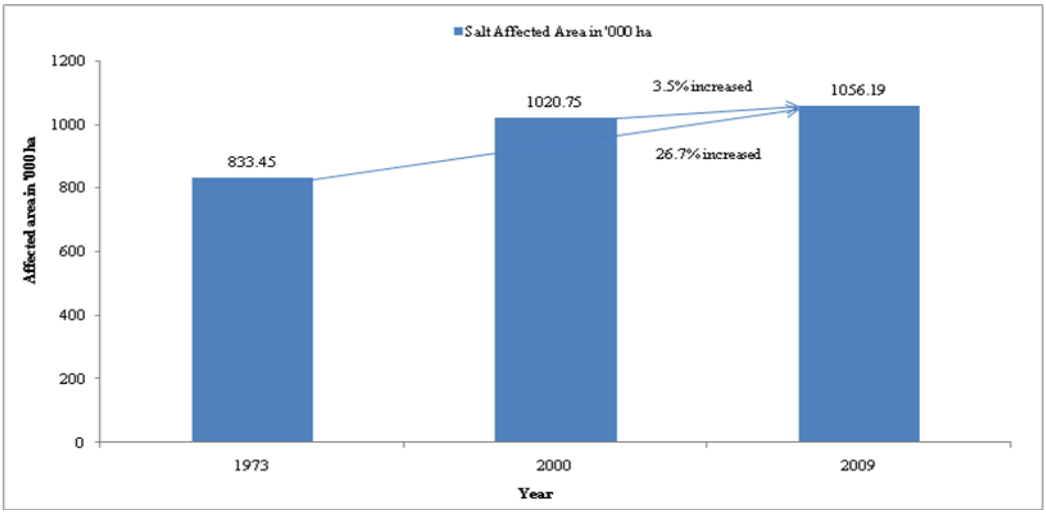


Fig. 3. A comparative study of the salt affected area between 1973 to 2009 in coastal areas.

Soil salinity intensity: A long term soil and water salinity monitoring data of SRDI shows that soil salinity between 1991 and 2008 in rice field has increased at least 2-10 times (Fig. 4-6). In agricultural land soil remain nonsaline at least 4-5 months in a year. But in brackish water shrimp farm soils remain saline throughout the year and no decreasing tendency is observed with soil depth. A clear evidence of salinization is observed in brackish water shrimp farm with time (Bhuiyan *et al*, 2001).

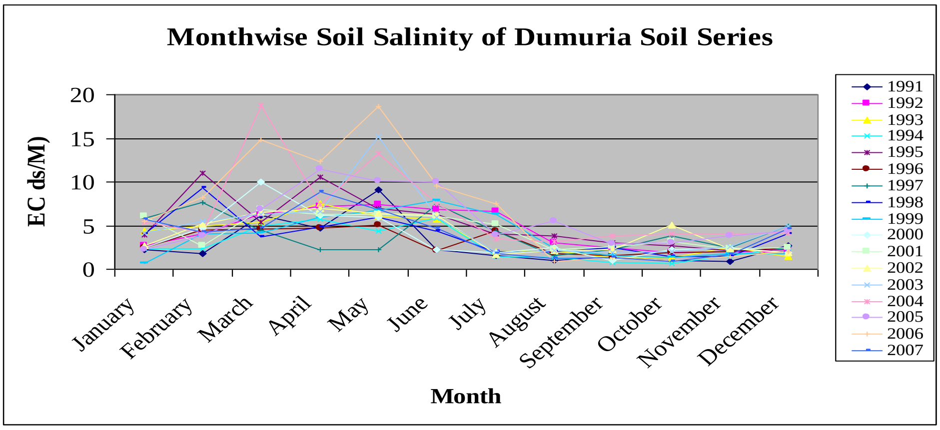


Fig. 4. Location: *Batighata*, Khulna.

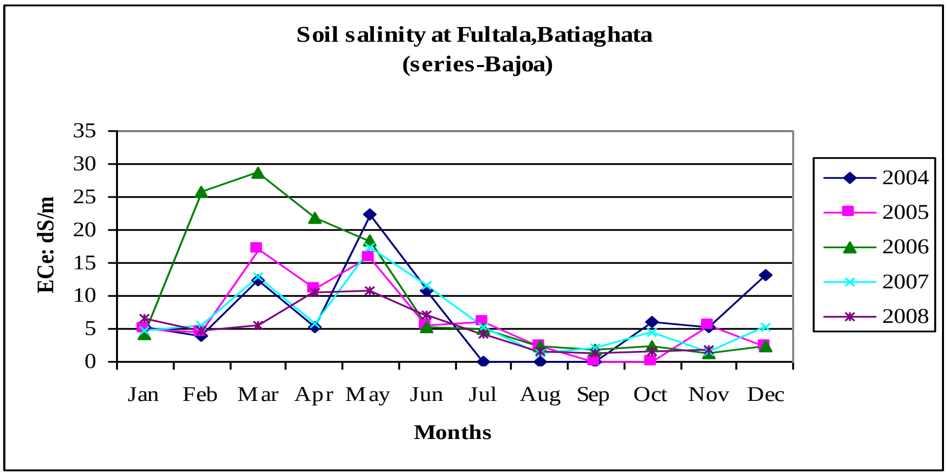


Fig. 5. Location: *Batighata*, Khulna.

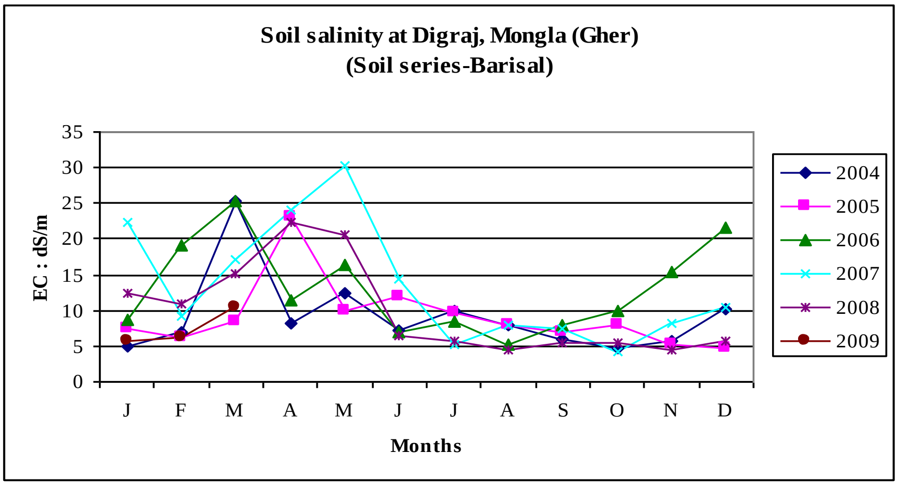
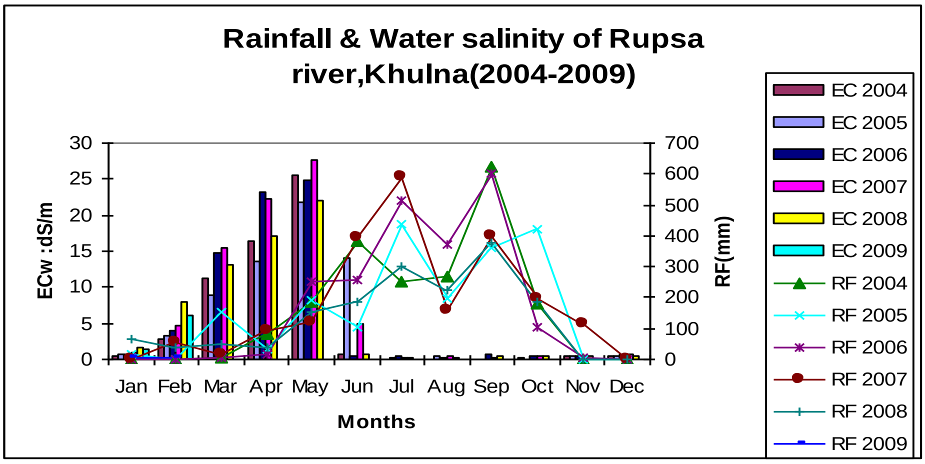


Fig. 6. Location: *Mongla*, Bagerhat.



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Water salinity intensity: Studies show a increase trend of river water salinity in south western part of the country. In May 1990 water salinity of Rupsha river near Khulna town was 10.5 dS/m which increased to 27.7 dS/m in 2007 i.e. 2.6 times higher than 1990 (Fig. 7).
Fig. 7. Location: *Rupsa ferryghat*, Khulna .

Madhumati river which was non-saline throughout the year in 1995 become saline in dry season after 2001 and highest 4.0 dS/m was observed in 2007 (Fig. 8) (SRDI,2009).

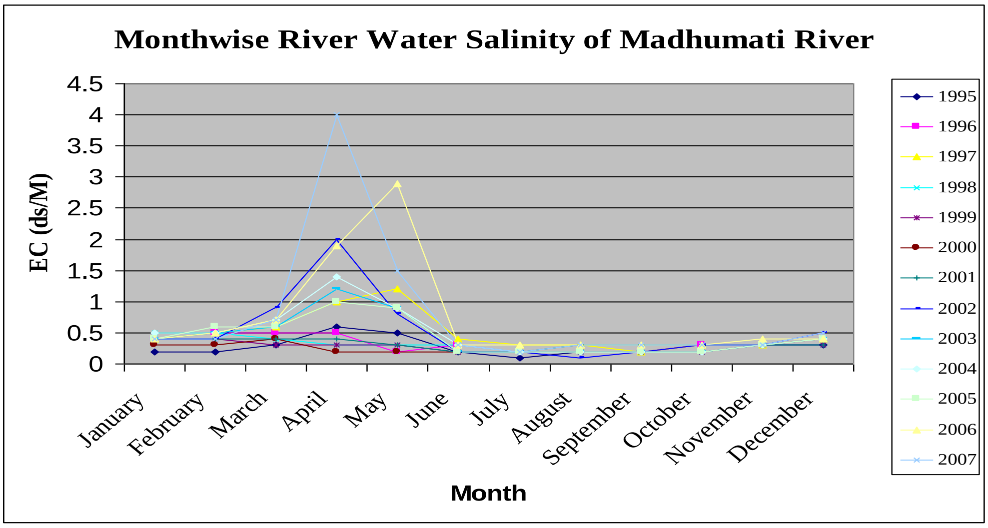

Fig. 8. Location: *Mollahat*, Bagerhat.

Present agricultural land use: Presently, cropping intensities has increased. The major cropping patterns identified in coastal areas are Fallow- fallow-transplanted aman (Local improvement variety[LIV]/Modern variety[MV]), Fallow-broadcast/dibbling aus (LIV)-transplanted aman (LIV/MV), Fallow-sesame-transplanted aman, Fallow-transplanted aus-transplanted aman (LIV/MV), Fallow-mixed broadcasted aus and aman, Wheat/ chickpea/ felon/ vegetables/ mustard/ grasspea/watermelon/chili-ibbling/broadcasted aus-transplanted aman (LIV/MV), Boro (MV)-fallow-transplanted aman (LIV/MV), Boro (MV)-fallow-fallow, Boro (LIV/MV)-shrimp (sweet water), Shrimp (brackish water) –transplanted aman (LIV/MV), Shrimp (brackish water/sweet water) –fallow, Planted & natural mangrove forest and Salt-bed.

Early winter vegetables are intensively cultivated through relay cropping with T.aus along with the cultivation of hybrid cowpeas, hybrid tomato, hybrid khirai, hybrid chili, hybrid raddish, hybrid watermelon in south east and southern part ,particularly in Cox's Bazar sadar, Chakaria, Maheshkhali, Kalapara upazilas. The main reason of changing crops/cropping patterns are climate variability, increased salinity and tidal surges, increasing demand of early winter vegetables in the market, increased demand of cash/high value crop, changed/increased demand of food crops, intrusion of saline water/pushing saline water in a confined areas (gheer areas) for brackish water shrimp cultivation and introduction of salt tolerant rice varieties.

Constraints and management

Common constraints: Several common and location specific agricultural constraints have been identified in the field through field investigation/observation, farmer's interview and literature review. It is found that constraints increased with increasing salinity intensity. Some common identified constraints on climate, natural and social aspects are a) Soil and water salinity, b) late draining condition, c) high flooding depth in monsoon at the time of transplantation, d) presence of saline ground water table almost throughout the year within 1.0 meter depth, e) heavy soil consistency, f) poor nutrient status, g) late transplantation and harvesting of aman rice, h) poor polder management, i) shorter winter period, j) narrow technological and germplasm bases for salt tolerant crops, k) negative consequence of climatic change, l) unfavourable land tenure system, m) difficult communication, n) poor marketing facility and m) social conflict (Karim *et al*, 1982 and SDRI, 2001).

Permanent water-logging: Human induced land degradation like localized water logging has developed an adverse affect on the environment and socio-economic condition of the people. In the present days, due to siltation in the intake channels, excessive losses from neighbouring irrigation channels, poor management practices, ill planned infrastructure development, lack of proper maintenance and initiative for any effective amelioration measure caused perennial water logging in certain pockets of the area which restricted crop production, such as, in Keshabpur, Avoinagar, Sagardari under Jessore district and Tala under Satkhira district. Recently Government has taken some important steps to improve the situation.

Peat soils: The peat basins of about 0.09 m ha occupy extensive deep basin areas occur in the central east part of the southern coastal saline area of Bangladesh. The peaty or rather mucky materials having low bearing capacity, moderately deep to deeply flooded, very poorly drained, locally contain pyritic sulphides which may develop extreme acidity on drying. About 0.1 m ha of active and potential acid sulphate soil occur locally in the east and south-western part of the tidal floodplain (SRDI.1998).

Overall effect of climatic change: Increase of soil and water salinity, irregular rainfall distribution, thermal variability, permanent water logging due to drainage congestion, increased pest and insect infestation, quick reduction of agricultural land, sea level rising, yield reduction and migration from rural to urban area.

Management approaches

Bangladesh is an agro-based developing country having per capita agricultural land only 0.06 hectares which is one of the lowest in the world. Food supply for huge population is to be managed from this limited land resources. There is no other alternative option but increasing crop production and intensity per unit area of land for sustaining the natural productivity of soils for future generation. To accommodate diverse land uses, changed patterns of land and land suitability, zoning has been proposed as a management approach. Hossain and Lin (2001) suggested that, to reduce social conflict and promote effective and sustainable resource use land should be zoned on the basis of suitability; the most suitable zone, a moderate suitable zone and an unsuitable zone. The coastal zone policy states that 'actions shall be initiated to develop land use planning as an instrument of control of unplanned and indiscriminate use of land resources' and 'zoning regulation would be formulated and enforced in due course'. The key policy of Land-Use Policy (2001) are zoning based on land use, ensuring the best land use of land through zoning, and enactment of a zoning law to allow local government institutions to prepare zoning maps.

Indicative land zones: An indicative land zoning has emerged, identifying the following eight zones such as agriculture zone, shrimp (brackish-water) zone, shrimp (sweet-water) zones, salt-shrimp zone, forest zone, mangrove (including Sundarban) zone, urban and commercial (industrial, port, export processing zones and ship breaking yards) and tourism zone. Fertilizer management includes balanced use of fertilizer (site specific), efficient use of fertilizers, rationale, time and method of fertilizer application, fertilizer management in no-tillage/minimum tillage system, fertilizer management in problem soils and liming. Fertilizer management approaches includes N deficiency is high due to gaseous loss under high salinity. So, N requirement is high in saline soils than normal soils, high concentration of salts inhibit nitrification and resultant NH_4 accumulation. So, upland crop show N deficiency even it is present in the soil, pre-sowing irrigation will minimize N deficiency, availability of P increases up to a moderate level of salinity but thereafter decreases, due to antagonistic effect of Na and Ca on K absorption and/or disturbed Na/K or Ca/K ratio K deficiency occurs, under high salinity K application may give increased yield, Zn deficiency occurs due to higher pH value and no deficiency of S & B is observed, but in some cases in wetland rice crops S response may observed.

Reclamatory management practices for coastal saline soils: Construction/repair of protective embankment, provision of sluice gate on the protective embankment, operation of sluice gate properly and frequently, draining of the catchments, leveling of land, control of water through field bunds, storing of excess rain water reservoirs for irrigation, selection of modern *kharif* rice variety, introduction of a second crop in *rabi* season, keeping land covered in winter and summer months, introduction of winter rice (*Boro*) and shrimp (sweet water) cultivation and introduction and improvement of *Sharjan* technique .

Recommendations

Research aspects:

Development of salt and submergence tolerant modern rice and rabi crop varieties for coastal saline areas.

Screening different crops/varieties against different levels of soil salinity

Development of appropriate soil and water management technology for irrigated rice, dry land crops and aquaculture on moderately fine to fine textured soils.

Study on salt balance and the natural features affecting the salt regime to understand the process of salinization in order to device prevention/reclamation.

Enhancing coordinated inter-institutional coastal soil and water salinity monitoring to find out safe period of water use for irrigation of specific crops.

Surface water harvest technologies and their feasibility for irrigation in coastal saline areas .

Characterization of soil and water salinity and determination of the nature and amounts of salt present in different salinity levels and their relative effects on plant growth.

Studies on low cost reclamation measures including specific agronomic practices, leaching/washing of salts, drainage and control of water table.

Quality assessment of ground and surface waters for irrigation and their effect on soil properties in coastal saline areas.

Conjunctive use of saline water in irrigation and their effect on soil properties in coastal saline areas.

Study on nutrient interaction such as P-K interaction, mechanism of K/Na selectivity , pH Vs uptake of N, Na & Ca salinity Vs oxygen stress or oxygen supply to the plants.

Study on changes in the soil and ground water salinity under brackish water aquaculture.

Studies on the amount of plant available soil moisture under various levels of soil salinity and its relation with plant growth and performance.

Study on assessing the potentiality of storing enough water in the canals and creeks before rising salinity of the river water, preferably during the spring tide in late October.

Development aspects:

- Construction/repair/redesign of embankments along the coast.
- Development of green belt along the coast with mangrove vegetation.
- Conservation/storage of rain water in the re-excavated dead/dying river channels for more efficient water harvest.

- Study on development of **'Farm pond technology'** through minimizing flooding depth, improving drainage condition and providing fresh water source for crop production.
- Limited drainage of peat soil to avoid shrinkage and cracking and subsidence of ground level.
- Minimize excessive extraction of ground water to the extent to avoid abnormal sinking of ground water table which may cause deep cracking of heavy clays, probable ground subsistence and inland ingression of fresh water- salt interface and salinity up coning.
- Expansion of non-conventional salt resistant crop and adoption of planned agro fisheries in low lying coastal areas.
- Improvement of Boro-shrimp cultivation technique following "Lokpur model".
- Development and improvement of Sharjon technique.

Conclusion

Salinity intrusion already affected agro-ecosystem adversely in the coastal region of Bangladesh. As the intensity and degree of salinity are related to change in thermal variability, amount and distribution of rainfall and fresh water discharge from upstream resulted from global warming and some anthropogenic activities will also adversely affect the salinity intrusion scenario. Thus by affecting different livelihood activities and important ecosystem of the country, climate change will impose a grave threat to the economy of Bangladesh.

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