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REVIEW ARTICLE

SALINITY PROBLEMS AND CROP PRODUCTION IN COASTAL REGIONS OF BANGLADESH

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Abstract

Bangladesh is a deltaic country with total area of 147,570 km^2. The major part (80%) of the country consists of alluvial sediments deposited by the rivers Ganges, Brahmaputra, Tista, Jamuna, Meghna and their tributaries. Terraces with an altitude of 20-30 m cover about 8% of the country, while hilly areas with an altitude of 10-1000 m occur in the southeastern and northeastern part. The coastal region covers almost 29,000 km^2 or about 20% of the country. Again, the coastal areas of Bangladesh cover more than 30% of the cultivable lands of the country. About 53% of the coastal areas are affected by salinity. Agricultural land use in these areas is very poor, which is much lower than country's average cropping intensity. Salinity causes unfavorable environment and hydrological situation that restrict the normal crop production throughout the year. The factors which contribute significantly to the development of saline soil are, tidal flooding during wet season (June-October), direct inundation by saline water, and upward or lateral movement of saline ground water during dry season (November-May). The severity of salinity problem in Bangladesh increases with the desiccation of the soil. It affects crops depending on degree of salinity at the critical stages of growth, which reduces yield and in severe cases total yield is lost. Soil reaction values (pH) in coastal regions range from 6.0-8.4. The organic matter content of the soils is also pretty low (1.0-1.5%). Nutrient deficiencies of N and P are quite dominant in saline soils. Micro-nutrients, such as Cu and Zn are widespread. During the wet monsoon the severity of salt injury is reduced due to dilution of the salt in the root-zone of the standing crop. The dominant crop grown in the saline areas is local transplanted Aman rice crop with low yields. The cropping patterns followed in the coastal areas are mainly Fallow-Fallow-Transplanted Aman rice. Salinity problem received very little attention in the past. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increased production of crops. Thus is necessary to have an appraisal of the present state of land areas affected by salinity.

Introduction

The total area of Bangladesh is 147, 570 km^2. The coastal area covers about 20% of the country and over thirty percent of the net cultivable area. It extends inside up to 150 km from the coast. Out of 2.85 million hectares of the coastal and offshore areas about 0.83 millions hectares are arable lands, which cover over 30% of the total cultivable lands of Bangladesh. A part of the coastal area, the Sundarbans, is a reserve natural mangrove forest covering about 4,500 km^2. The remaining part of the coastal area is used in agriculture. The cultivable areas in coastal districts are affected with varying degrees of soil salinity. The coastal and offshore area of Bangladesh includes tidal, estuaries and river floodplains in the south along the Bay of Bengal. Agricultural land use in these areas is very poor, which is roughly 50% of the country's average (Petersen & Shireen, 2001).

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Salinity causes unfavorable environment and hydrological situation that restrict normal crop production throughout the year. The freshly deposited alluviums from upstream in the coastal areas of Bangladesh become saline as it comes in contact with the sea water and continues to be inundated during high tides and ingress of sea water through creeks. The factors which contribute significantly to the development of saline soils are, tidal flooding during wet season (June-October), direct inundation by saline or brackish water and upward or lateral movement of saline ground water during dry season (November-May).

Observations in the recent past indicated that due to increasing degree of salinity of some areas and expansion of salt affected area as a cause of further intrusion of saline water, normal crop production becomes more restricted. In general, soil salinity is believed to be mainly responsible for low land use as well as cropping intensity in the area (Rahman & Ahsan, 2001). Salinity in the country received very little attention in the past. Increased pressure of growing population demand more food. Thus it has become increasingly important to explore the possibilities of increasing the potential of these (saline) lands for increased production of crops. It necessitates an appraisal of the present state of land areas affected by salinity.

Physiography of the coastal area: Tidal and estuarine floodplains cover almost 98% of the coastal area. Small areas (2%) with river floodplains and peat basins are found in the northern part of the coastal area. Tidal floodplains occur in Satkhira, Khulna, Bagerhat, Pirozpur, Jhalukhati, Barisal, Patuakhali, Chittagong and Cox's Bazar district. They cover a total of 18,65,000 ha or about 65% of the coastal area. Estuarine floodplains occur in Noakhali, Bhola and Patuakhali districts and in the north-western part of Chittagong district. They cover about 9,37,000 ha or about 33% of the coastal area.

Land characteristics and hydrology of the coastal region: The coastal saline area lies about 1.5 to 11.8 meters above the mean sea level. The Ganges river meander floodplain systems are standing higher than the adjoining tidal lands. The tidal floodplain has a distinctive, almost level landscape crossed by innumerable interconnecting tidal rivers and creeks. The estuarine islands are constantly changing shape and position as a result of river erosion and new alluvial deposition. Peat basins are located in some of the low-lying areas between the Ganges river floodplains and tidal floodplains occurring in the western part of Khulna (Karim *et al.*, 1982). These areas are subject to flooding in the monsoon season and waterlogging in parts of the basin areas in 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 both the top and subsoil saline. The most significant feature of hydrology in relation to agricultural development is the seasonal shallow flooding (up to 90 cm) which affects about 64% of the total area. In these areas flood water recedes from October to late December. Depending on topographical position and drainage facilities, water recede from about 24% area within October, from about 53% area in November and mid-December and from about 23% area in late December.

Tidal effect: The effect of the tides is manifested in a regular alternation of rise and fall of the water level of the sea and the estuarine/tidal channels and creeks. The flow repeatedly inundates the soils and impregnates them with soluble salts, thereby rendering

the soils and subsoil water saline. The high tide during summer rises up to 1.3 meter above the general ground level. On the east coast of the Sunderbans, the highest tide could inundate lands up to a depth of 2.0 meter, where protective bunds were not erected.

Salinity built-up: The main obstacle to intensification of crop production in the coastal areas is seasonally high content of salts in the root zone of the soil. The salts enter inland through rivers and channels, especially during the later part of the dry (winter) season, when the downstream flow of fresh water becomes very low. During this period, the salinity of the river water increases. The salts enter the soil by flooding with saline river water or by seepage from the rivers, and the salts become concentrated in the surface layers through evaporation. The saline river water may also cause an increase in salinity of the ground water and make it unsuitable for irrigation. The increase in water salinity of these areas has created suitable habitat for shrimp cultivation. Along with other factors, shrimp cultivation played a major role to increase salinity, particularly in the south-western coastal regions. In greater Khulna alone, about 31,200 ha of land in 1982-1983 and about 94,850 ha of land in 1993-1994 were brought under shrimp culivation.

Extent of salinity: Coastal saline soils occur in the river deltas along the sea coast, a few kilometers to 180 kilometers. The landscapes are low-lying land, estuaries and inland along the seacoast of Bangladesh. According to salinity survey findings and salinity monitoring information, about 1.02 million ha (about 70%) of the cultivated lands are affected by varying degrees of soil salinity. about 0.282, 0.297, 0.191, 0.450 and 0.087 million hectares of lands are affected by very slight, slight, moderate strong and very strong salinity respectively. Cropping intensity may be increased in very slight and slightly alkaline areas by adopting proper soil and water management practices with introduction of salt tolerant varieties of different crops. To mitigate the demand of fresh water for irrigation, especial emphasis may be given to adopt rain water harvest technology.

Table 1. Salinity affected areas in the coastal and offshore regions of Bangladesh

Description	Total cultivated area	Saline area	Area of each salinity class (ha) (dS/m)				
			S_1 (2.0-4.0)	S_2 (4.1-8.0)	S_3 (8.1-12.0)	S_4 (12.1-16.0)	S_5 (>16.0)
Non-saline with very slightly saline	4,25,490	1,15,370 (27%)	82,260 (72%)	31,590 (27%)	1,520 (1%)	0	0
Very slightly saline with slightly saline	4,20,420	3,09,190 (73%)	1,70,380 (55%)	1,10,390 (35%)	29,420 (10%)	0	0
Slightly saline with moderately saline	2,57,270	2,40,220 (93%)	35,490 (15%)	1,13,890 (47%)	61,240 (26%)	25,870 (11%)	2,650 (1%)
Moderately saline with strongly saline	1,98,890	1,98,890 (100%)	1,630 (1%)	36,060 (18%)	73,400 (37%)	55,130 (28%)	32,750 (16%)

Source: Soil salinity in Bangladesh (SRDI) 2000

Fertility status of saline soils: Soil fertility is an important factor for crop production. In general the coastal regions of Bangladesh are quite low in soil fertility. Thus in addition to salinity, plant nutrients in soils affect plant growth.

Soil reaction values (pH) range from 6.0-8.4 with the exception of Chittagong and Patuakhali, where the pH values range from 5.0-7.8. Most of the soils are moderate to strongly alkaline, the pH values of the surface soils being lower than those of the sub-surface soils. In places with higher pH values, micronutrients' deficiencies are expected.

The soils are in general poor in organic matter content with the excepton of Paikgachha upazila of Khulna district, where the topsoils contain high organic matter (7%). The organic matter content of the top soils ranges from less than 1% to 1.5%. The low organic content in soils indicates poor physical condition of the coastal soils.

The CEC of the soils range from 9.4-40.6 m.e.%. The higher CEC values of Khulna and Bagerhat soils are due to finer texture and higher organic matter contents. Soils having CEC below 15.0 m.e.% is considered as of poor status (Singaraval *et al.*, 1996). The soils contain variable levels of exchangeable bases, but a general feature is the higher Ca and K saturation of the exchange complex compared to Na and Mg in most of the soils. The Na and Mg saturation of the exchange complex is harmful because they destroy the soil physical properties and offset plant nutrition. Magnesium has synergistic effect of plant uptake of Na as well as antagonistic effect on the uptake of Ca and K.

The total N contents of the soils are generally low, mostly around 0.1%. The low N content may be attributed to low organic matter contents of most of the soils. Available P status of the soils ranges from 15-25 ppm. Some deficient P soils are also found in Chttagong, Barguna, Satkhira and Patuakhali districts. Widespread Zn and Cu deficiencies have been observed in the coastal regions (Karim *et al*., 1990).

Table 2. Agro-chemical characteristics of soils in some of the coastal and offshore areas (saline belt) of Bangladesh

District	pH	OM %	Total N %	CEC m.e.%	Na m.e.%	K m.e.%	Ca m.e.%	Mg m.e.%	P ppm	Zn ppm	Cu ppm
Satkhira	6.2-8.4	1.8-2.2	0.9-0.3	14.2-25.5	0.5-0.6	0.2-1.2	6.3-16.2	2.8-11.4	12-24	0.1-0.8	0.08-0.30
Khulna	6.2-7.9	0.1-0.3	0.1-0.3	18.2-40.6	1.6-33.3	0.3-1.0	8.3-22.5	2.6-18.3	8-36	Tr-0.8	Tr-0.20
Bagerhat	6.0-7.8	0.3-2.8	0.1-0.2	15.9-37.0	0.6-7.0	0.2-1.0	9.4-24.2	4.2-17.7	6-26	Tr-1.6	Tr-0.40
Patuakhali	5.0-7.8	0.1-1.0	-	-	-	0.2-0.6	2.7-7.5	1.6-6.6	10-28	0.2-0.8	0.06-0.39
Barguna	6.3-8.0	1.2-2.3	0.1-0.1	12.0-22.0	2.5-21.7	0.2-0.7	11.5-28.8	3.9-18.2	4-14	Tr-3.0	-
Bhola	6.3-8.0	0.4-7.1	0.1-0.2	11.8-26.0	0.6-3.4	0.1-0.4	7.2-20.8	2.0-9.5	8-30	Tr-1.4	Tr-0.70
Chittagong	5.0-7.4	1.0-2.9	-	-	-	0.2-0.8	2.7-7.1	2.9-11.3	4-11	0.1-0.9	0.3-1.0
Noakhali	6.0-7.9	0.8-3.1	0.1-0.3	9.4-19.5	0.4-39.0	0.1-0.5	5.3-12.4	2.3-9.5	8-24	Tr-1.8	Tr-0.70
Feni	6.0-7.5	0.9-2.9	0.1-0.2	11.8-16.2	0.8-3.8	0.4-0.5	7.8-8.0	5.0-6.8	8-24	0.9	-

Sources: Annual reports of BARI, BRRI, BWDB and DU of the coordinated research project on production potentials of the coastal saline soils of Bangladesh (1987-1989).

Current agricultural land use: In the saline soils rice, jute, sugarcane, pulses, oilseeds, spices, vegetables and fruits are grown, but their contributions to cropping intensity vary greatly with regions. In salt affected highlands of Barisal, Khulna and Patuakhali regions, local transplanted Aman rice (July-November) is the dominant crop, whereas in the same land type of Chittagong region HYV Aman rice is the major crop. In medium highlands of Barisal, Khulna, Noakhali, Patuakhali and Chittagong regions the dominant crop is local transplanted Aman rice. The dominant crop in the medium low lands of the former three regions is broadcast aman rice, whereas in Chittagong region broadcast aus rice is the dominant crop.

During wet season, local aman rice is grown extensively in the coastal saline areas with normal yields between 2.5 and 3.0 tons per hectare. Transplanted aman-fallow is the most dominant cropping pattern in the Khulna, Barisal and Patuakhali regions. In Noakhali and Chittagong, aus-local transplanted aman pattern covers 25-28% area. Next to this is the transplanted aman-fallow pattern, represents about 18-20% area. Winter crops, such as wheat, potato and vegetables are grown, which cover a small area (11.5%). This is practiced in the district of Noakhali with transplanted aman-winter crop cropping pattern.

Adopting of HYV rice cultivars varied considerably in different salt affected regions. In Chittagong and Noakhali regions, there is substantial coverage of HYV rice in high and medium lands during both aus and aman seasons. Some coverage of HYV rice during aman season is also found in the highlands of Khulna, Barisal and Patuakhali regions. But almost no HYV aus rice is grown in Khulna, Barisal and Patuakhali regions. However, there is potential to HYV aman rice cultivation in the regions on highlands.

Most of the coastal areas are located over medium highlands, where flooding depth ranges from 0.3-0.9 meter. This category of land is suitable for minimum two crops and sometimes three crops with winter wheat or other winter crops. The low land use in saline area is mainly due to unfavorable soil salinity in dry season and unavailability of quality irrigation water. In addition to crop production, area of about 86,975 hectares supports brackish water shrimp culture farms, the major portion (62,120 ha) is in khulna district followed by Chittagong district (24,755 ha).

Constraints for agricultural development: The agricultural development in the coastal saline belt is constrained by various physical, chemical and social factors. In general, the major agricultural constraints identified that impede development are as follow:

- It has been found that constraints increased with increasing intensity of salinity. Soil salinity is the most dominant limiting factor in the region, especially during the dry season. It affects certain crops at different levels of soil salinity and at critical stages of growth, which reduces yield and in severe cases total yield is lost. A substantial area of land is tidally affected by saline water. Appropriate management practice for crop production in this area is not available.
- Fertility status of most saline soils range from low to very low in respect to organic matter content, nitrogen, phosphorus and micronutrients like zinc and copper. The crop yields obtained in these soils are also low.
- Scarcity of quality irrigation water during dry season limits cultivation of boro rice and rabi (winter) crops, and aus cultivation during kharif-1 (March-July) season.
- Variability of rainfall, uncertain dates of onset and recession of seasonal floods and risk of drought restrict cultivation of aus and aman rice. Uncertain rainfall delays sowing/transplanting and flood damages aus and aman crops. Heavy monsoon rainfall causes delay in transplanting of aman and sometimes flash floods washes away the standing crop.
- Narrow technological and germplasm bases for salt tolerant crops limit crop choices. On the other hand, due to extensive cultivation of a particular cultivar of crop year after year makes the crop susceptible to pests and diseases attack. Pests and diseases like hispa, leaf-hopper and tungro virus are prevalent in the region and extensive damage is caused by these almost every year.
- In the coastal saline belt with short winter season timely sowing/planting of rabi (winter) crops is essential but this is restricted by late harvest of aman rice.

- Presence of saline ground water table throughout the year within 1.0 meter depth is another factor affecting crop production in the saline belt.
- A considerable area of the coast is within the polders of different types. Soil salinity levels have not decreased considerably within the poldered areas. This seriously constrained the adoption of HYV aman and HYV aus in these areas.
- The texture of most of the saline soils varies silt clay to clay. Land preparation becomes very difficult as the soil dries out. Deep and wide cracks develop and surface soil becomes very hard. These also necessitate deep and rapid tillage operations.
- Perennial water-logging due to inadequate drainage and faulty operation of sluice-gate facilities restricts potential land use of the low lands within the poldered areas.
- Lack of appropriate extension programs for diffusion of modern technologies. Extension personal trained in saline soil management in also inadequate. This lacking retarded adoption of HYV technologies.
- Big land ownership and unfavorable land tenure system and dominance of absentee farmers discourage adoption of modern technologies.
- Difficult communication and remote marketing facilities also retard agricultural development of the region.

The above factors are more or less common to most of the saline prone areas in the south of the country along the seacoast. Often heavy monsoon rainfall, sever flash flood and exposure to cyclones with saline cyclonic storm surges add to the ongoing process of salinization in the coastal-belt.

Strategy for management of coastal saline soils:

1. **Protective embankment:** Land may be protected from inundation of saline water through establishment of embankment of suitable size. The recommended size should be 1 meter high above the high tide level.
2. **Provision of sluice gate on the embankment:** The should be provision of sluice gate in the embankment system to remove excess water and also to prevent ingress of saline water during high tide
3. **Leveling of land:** Slight variations in the micro-relief lead to salt accumulation in the raised spots. Land should be properly leveled to prevent accumulation of water in the low-lying patches with shallow ground water tables and to facilitate uniform drainage of excess water. It will help to apply irrigation water uniformly in the field in rabi season, facilitate uniform germination of seeds and better growth of crops.
4. **Storing of excess rainwater for irrigation:** A part of the excess water stored in pond after meeting the requirements of the kharif season can be utilized during the dry period for rabi crops.
5. **Selection of kharif rice variety:** Even though the coastal area is relatively flat, there exist elevation differences in areas, where depths of standing water ranges from 15-90 cm. Selection of rice varieties (BRRI dhan 23, 30, 40 and 41), available in the country on the basis of standing water and extent of salinity in the field can overcome the situation to a great extent.
6. **Introduction of crop in rabi (winter) season:** Cropping intensity can be increased in about 0.596 million hectares of very slight (S_1) and slightly saline (S_2) areas by adopting proper soil and water management practices with the introduction of salt tolerant crop varieties.

7. **Keeping land covered in winter and summer months:** Ground water is saline and present at a shallow depth (about 1.0 meter). Keeping lands fallow leads to high salinity in soil due to evaporation of excessive soil moisture. Therefore, it is recommended to avoid fallowing of lands during rabi season. Salt tolerant crops should be chosen and grown. This will lower the profile salinity.
8. **Fertilization of crops:** Since, soils in general are poor in fertility with low organic matter content, it is necessary to apply appropriate fertilizers to boost up crop production. Potash fertilizer has an added advantage under soil salinity. It lowers down Na uptake by plants and of course increases K uptake. Thus K fertilizzation protects crops from harmful effects of Na.
9. **Provision of sub-surface drainage:** In many parts of the coastal area, salinity is very high. To grow crops successfully in those areas, it is necessary to bring down the salinity by leaching the salts. It is also necessary to lower down the water table and maintain it blow the critical depth to prevent salt effect on crops grown. To achieve the objective, a proper sub-surface drainage has to be installed to keep the ground water at least 1 meter below the soil surface. This technology is effective but somewhat expensive.

Conclusion

Soil salinity is a worldwide problem. Bangladesh is no exception to it. In Bangladesh, salinization is one of the major natural hazards hampering crop production. Coastal area in Bangladesh constitutes 20% of the country of which about 53% are affected by different degrees of salinity. Agricultural land use in these areas is very poor. Declining land productivity with shift towards negative nutrient balance is among the main concerns with food security problem in the country.

Salinity problem received very little attention in the past. Nevertheless, symptoms of such land degradation with salinization are becoming too pronounced in recent years to be ignored. Increased pressure of growing population demand more food. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increased production of food crops. Thus combating land salinization problem is vital for food security in the country through adoption of long-term land management strategy.

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