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SOIL SALINITY MANAGEMENT PRACTICES IN COASTAL AREA OF BANGLADESH: A REVIEW

Mohammed Shawkhatuzzaman[1], Sumona Rani Roy[2], Md. Zahanggir Alam[2], Premangshu Majumder[3], Nushrat Jahan Anka[3] and Ahmed Khairul Hasan[4*]

[1]Principal Scientific Officer, [2]Senior Scientific Officer, and [3]Scientific Officer, Soil Resource Development Institute (SRDI), Bangladesh; [4]Department of Agronomy, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.

***Corresponding author:** Ahmed Khairul Hasan; E-mail: akhasan@bau.edu.bd

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ABSTRACT

Soil salinity is a significant threat to agriculture and livelihood, particularly in the Southern coastal areas of Bangladesh. Soil salinity is extended from 0.833 to 1.056 million hectares (about), with an increase of 26% between 1973 and 2009. Out of about 1.689 million hectares of coastal land, about 1.056 million hectares are affected by soil salinity of various degrees covering 49 Upazila (sub-district) of 19 districts. 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 (S_5), respectively. Data recorded by SRDI manifests new ingression of salinity in Narail (18.71 ha), Jashore (14.99 ha), Barishal (13.96 ha), Gopalgonj (6.27 ha), Jhalakati (4.69 ha), and Madaripur (0.72 ha) districts. Soil salinity also encroached a large area of Bhola (53.84 ha), Patuakhali (40.08 ha), Khulna (27.92 ha), and Bagerhat (23.14 ha), besides minor ingression in other districts. The salinity level is almost double (2.8-18.5 to 4.0-42.8 dS/m) from 1973 to 2009 in Sharankhola Upazila of Bagerhat district, Dumuria Upazila of Khulna district and Shyamnagar Upazila of Satkhira district (SRDI, 2010). Different causes are involved in increasing the water and soil salinity of the coastal area of Bangladesh, like withdrawal of fresh river water from upstream, irregular rainfall, faulty management of sluice gates and polders, regular tidal water flooding in an unprotected area, the capillary rise of soluble salts, decreased surface water availability, lowered ground water table, reduced soil moisture content, the introduction of unplanned shrimp cultivation, lack of drainage facilities. Some of the widespread soil and land management techniques adopted in the saline areas of Bangladesh to cope with the salinity are polder (123), farm-pond (khamar-pokor), sarjan procedure, usage of raised shrimp farm bund for year-round cropping, mulching (keeping land covered in winter and summer months), land leveling, pitcher (*kolosh*) irrigation to grow watermelon, dibbling method, the addition of organic matter, chemical fertilizers and cultivation of saline tolerant crop varieties, particularly rice.

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INTRODUCTION

Bangladesh is a tropical country with an area of 147, 570 km^2 located in the north-eastern part of South Asia with an interface of two significantly different environments: the Bay of Bengal in the south and the Himalayas in the north (Huq and Shoaib, 2013). Soil salinity problems are primarily associated with the coast of Bangladesh that spreads along the Bay of Bengal over approximately 2.83 million hectares in the Southern districts in a strip of land a few kilometers to 180 km along the sea coast and have a coastline of about 710 km, occupies about 20% of total land and 30% of net cultivable area of Bangladesh (SRDI, 2010). The whole region is nearly level (<2% slope), with low-lying, narrow ridges and broad basins crises-crossed by a large number of interlinked tidal river networks, a large number of islands between channels, a submarine canyon (Swatch of no Ground), the funnel-shaped part of the northern Bay of Bengal, a vast amount of sediment transportation approximately 525 m tons per year (Islam et al.,1999), most of the area is less than 3m above mean sea level (Allison,1998) and horrendous tidal surge or tropical cyclones. Saline water intrusion, water logging, late drainage, and capillary rising of groundwater affect soil salinity in this area. The coastal lands of Bangladesh are used for agriculture, shrimp and fish farming, forestry (mainly Mangrove), salt production, ship-breaking yards, ports, industries, human settlements, and wetlands, and that kicked off a different socio-economic environment of conflicts and competitions among different land users (Alam et al*.,* 2002; Islam, 2006). The initiative of saline soil reclamation in Bangladesh mainly focused on polder intervention (protecting land from saline water flooding), land management (washing salt) or abiotic approach, and salt tolerant cultivar introductions(Haque et al., 2019) by NARS institutions. Tidal River Management (TRM), Integrated Coastal Zone Management, and the recent Master Plan for Agricultural Development in the Southern Region of Bangladesh are the primary drives to address the challenges of the coastal region.

MATERIALS AND METHODS

This paper is based on available secondary sources on the causes of salinity intrusion and management on the coastal belt of Bangladesh. The study included collecting information on various factors of salinity intrusion and management practices, particularly in the coastal region of Bangladesh. The resources are collected from online publications, books, government reports, international reports, scientific journals, news articles, and socio-economic and statistical data from the Bangladesh Bureau of Statistics (BBS).

CHARACTERISTICS OF COASTAL ZONE

The Coastal Zone is defined as "an area affected by tidal changes in water level with annual average tidal cycle of 0.3m, that extends up to 180 km from the Bay of Bengal, where soil salinity of 4 dS/m, ground water salinity of 1.5-2 dS/m with the risk of cyclone and Tidal Surge" (SRDI, 2001; DANIDA, 1999; Uddin and Kaudstaal, 2003 and ESCAP/UN, 1987). It is broadly categorized into three distinct regions depending on river flow, flooding, and sedimentation.

i. Pacific type: The deltaic eastern region (Pacific type) includes Chittagong and Coxs Bazar district. Flush flood, elevation difference, and relatively coarser sediments from adjacent hills and piedmont are significant characteristics of this region that influence the ingression and intensity of soil water salinity (Islam, 2001). Fish farming, fishing in the bay, salt production and tourism are the main economic activities of the zone.

ii. Central region: The deltaic region includes Barguna, Patuakhali, Bhola, Barishal, Laxmipur, Noakhali, and Feni. More than 70% of the sediment load of the region is silt, with additional 10% sand (Coleman, 1969; Allison et al., 2003). Because of the sediment discharge and strong current, the morphology of the zone is very dynamic, and thus erosion and accretion rates in the area are very high. Many islands have been formed in this area by land accretion, and many have been eroded or disappeared (Rahman et al., 1993; Pramanik 1988, SDNP, 2004).

iii. Atlantic type: The stable deltaic western region (Atlantic type) includes Satkhira, Khulna, Bagerhat, and Pirojpur districts. It is a region of active subsidence due to the compaction of sediments (Minar et al., 2013) and a yearly subsidence rate of 10-12 mm observed by the Dhaka University Earth Observatory (DUEO) team (MoA and FAO, 2013). This region is almost disconnected from upper riparian river flow (URRF), and elevation differences are shallow as a result of more ingression of soil-water salinity in the other two.

SALINITY BUILT-UP, EXTENT AND INTENSITY

It is anticipated that the withdrawal of fresh river water from upstream, irregular rainfall, the introduction of brackish water for shrimp cultivation, faulty management of the sluice gates and polders, regular saline tidal water flooding in an unprotected area, the capillary rise of soluble salts etc. are the leading causes of increasing soil salinity in the top soils of the coastal region (Ahsan and Bhuiyan, 2010). Soils can be saline due to geo-historical processes or human-induced. 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. In the dry season water salinity of significant rivers is highest at EC>5.0 dS/m near the coast and 2.0 dS/m in the northern parts of the coastal zone (Karim et. al, 1982). The increase in these areas' water salinity has suitable habitat for shrimp cultivation. According to the Bangladesh Frozen Foods Exporters Association (BFFEA), today, shrimp are cultivated in 276,000 hectares of the 337,164 hectares of land available along the coast or 81% of the 195,000 hectares or 70.6% are in the districts of Satkhira, Khulna and Bagerhat. Saline soils of Bangladesh formed from seawater flooding or capillary rise from shallow groundwater. Out of about 1.689 million hectares of coastal land, about 1.056 million hectares 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 (S1), slight (S2), moderate (S3), strong (S4) and very strong salinity (S5) respectively. So far, 49 Upazilas (sub-district) of 20 districts of the country have been affected (SRDI, 2010).Soil Resource Development Institute (SRDI) has temporal and spatial data on regular monitoring of soil and water salinity since 1989, besides reconnaissance survey data from 1973. It was estimated in 1973 and 2009 that the area coverage of soils with different degrees of salinity is about 0.833 and 1.056 million hectares, respectively. Recent data recorded manifests new ingression of salinity in Narail (18.71 ha), Jashore (14.99 ha), Barishal (13.96 ha), Gopalgonj (6.27 ha), Jhalakathi (4.69 ha) and Madaripur (0.72 ha). Soil salinity also encroached a large area of Bhola (53.84 ha), Patuakhali (40.08 ha), Khulna (27.92 ha) and Bagerhat (23.14 ha), besides minor ingression in other districts. On the other hand, Chandpur district became non-saline, and the decrease in the saline area is documented in Laxmipur and Feni districts. The total spatial increase of saline area was about 26% from 1973 to 2009.Moderately to intensely saline (S3 and S4: 8.1-16 dS/m) soil class has increased predominantly about 272 ha (from 79 to 351 ha), and that of very strongly saline (S5>16 dS/m) class is 62 ha (from 39 to 101 ha) spreads proximity to the sea, mainly in the western region and offshore islands. The slightly saline area (S1: 2-4 dS/m) increased to 41 ha (from 287 to 328 ha) from 1973 to 2009. Slightly saline (S2: 4.1-8 dS/m) class reduced from 426 to 274 ha from 1973 to 2009 (SRDI, 2010).It was firmly felt that mapping the coastal saline area on a smaller scale with updated technology such as Geographic Information System (GIS) and remote sensing necessitates regular data acquisition and analysis (Huq and Shoaib, 2013).

SALINE SOIL RECLAMATION METHODS FOLLOWED IN BANGLADESH

As salinity is closely associated with water and irrigation systems, water management techniques have been used to reclaim short and long-term saline soil. Soil and land management techniques are popular practices in managing soil salinity in this region. Some of the standard practices are discussed below:

Polder

A polder is a low-lying tract of land enclosed by embankments (barriers) known as dikes that forms an artificial hydrological entity. Polders in coastal zone contributed to increasing production and changes in land use, increasing cropping intensity. Nevertheless, it also has a negative impact on the environment by making the area waterlogged and causing drainage malfunction. In coastal areas, polders have been established since the 1960s, and the total polder in Bangladesh is 123, of which the sea-facing polder is 59. The land mass in the polders protects from tidal floods, salinization and tidal surge/cyclone, which impede agricultural development. Active sediment deposition caused siltation outside polders and rivers/channel beds, significantly reducing their drainage capacity and the polders that de-linked the flood plains from the rivers (MoA and FAO, 2013).

Farm-Pond (Khamar-Pokor)

It is a newly developed technology or an approach to a land area for diversified crops/fruits/forest by digging a pond at medium-high (flooded up to 90 cm) to medium-low (flooded 90-180 cm) lands where due to wetness in the early dry season or during late drainage modern variety (Transplanted *Aman* rice) cannot be used. Generally, in ponds excavated up to 180 to 270 cm deep, the height and width of bunds/banks are about 90 and 120-150 cm, respectively. Topsoils are kept on top while excavated earth spreads over the rest of the land. This type of land use system is recommended by SMRC, SRDI, which has been practised (around ten years) in Batiaghata and Dacope Upazila under the Khulna district. In

Dacope, it is known as 'Kuni' technology. This type of technology helps to wash and leach out soil salinity. Transplanted *Aman* rice (MV), watermelon and vegetables on raised land area, tree (fruit/forestry) crops are grown on pond bund/bank and pond are used for fish culture (Silver carp: Hypophthalmichthys molitrix; Talapia: Oreochromismossambicus).

Sarjan procedure

Generally, this procedure is practiced in medium-high to medium lowlands having a late draining phase. In this case, the land is divided into several subplots. Between two subplots, there is a ditch for keeping water permanently. Every subplot is raised by taking the soil from the adjoining side. The optimum size of the plot is 8.0m X 2.5m to 4.5m. It may be changed depending on the size of the plot. The crops on the raised bed are mainly vegetables, sugarcane and dhaincha. Local fish are grown in the ditches between the two beds. Shallow Sarjan is suitable for cultivating year-round vegetables, and deeper Sarjan allows rice-fish or rice-duck farming besides vegetables/nurseries (Sattar and Abedin, 2012). Freshwater scarcity and high installation cost is the main limitation of this system.

Usage of raised shrimp farm bund for year-round cropping

Shrimp farm is used for shrimp cultivation. The boundary of shrimp farms is used to grow vegetables, fruits and also some tree species. Some Shrimp farm (Local name Gher) lands are used for transplanted *Aman* rice with shrimp/fish. Farmer dug a ditch along the boundary, in any corner of the field, or at the centre of the plot to preserve water and fish during the dry season. In some cases, farmers use shallow tube well water to sustain fish. Non-saline and slightly (S_2) to moderately saline (S_3) area is used for *Boro* (winter rice) sometimes. In Khulna-Bagerhat region, it is called "Lockpur model. The boundary is constructed above flood level approx. 60-90 cm, where ditches are 60-90 cm deep along the boundary, corner or centre. To grow vegetables, farmers use nylon nets as a trail for creeping supported by bamboo, dhaincha, or strings. The soil salinity from the bunds is washed away by rainwater, facilitating vegetable production. This technology is developed by SMRC, SRDI initiative, around ten years ago.

Double Layer Mulching

Reduced soil salinity (about 30%) was observed using double-layered mulch with straw at the top and bottom of a mini pit. Double-layer mulch technology is used for growing sweet gourd in the country's coastal region for higher yield (18.5 t/ha) performance. Farmers prepare their land by three ploughing by power tiller in this system. Pits are adequately excavated by maintaining pit-to-pit and line-to-line distances of 2.0 meters. Manure and basal dose of fertilizer are applied during pit preparation. Then germinated seeds are sown in a pit. Necessary intercultural operations are done when it is necessary. SMRC, SRDI, recommends this type of land use system.

Levelling of land

Slight variations in the micro-relief lead to salt accumulation in the raised spots. Land should be adequately levelled to prevent accumulation of water in the low-lying Patches and to facilitate uniform drainage of excess water. It will also help to apply irrigation water uniformly in the field during the rabi season. This technology is sporadically (as a pilot basis) used in the country's coastal area.

Keeping land covered during winter and summer

'Mulching' is an old way to control salinity by preserving soil moisture. Applying rice straw, rice husk and water hyacinth after the harvest of transplanted *Aman* and mixing it partially or wholly with topsoil by ploughing is how mulching is done. It will enhance the leaching of soluble salts and rice yield in the subsequent kharif season. Farmers are practicing ploughing and mulching cucumber and sweet gourd seeds with rice husk. The lands are medium highland-1(Flooded <30cm), and the soils are loam to clay loam. This technology is sporadically used (as a pilot basis) in Batiaghata and Dacope Upazila of Khulna district.

Pitcher (*Kolosh*) irrigation to grow watermelon

During the dry season, salinization increases, and land faces a scarcity of fresh water for irrigation. Pitchers, locally known as Kolosh, used to add water to crops like watermelon, sweet gourd, bitter gourd etc., in the dry season. Pitcher (Kolosh) irrigation technology introduced by SMRC, SRDI is well taken by local farmers of Batiaghata Upazila of Khulna and Fakhirhat Upazila of Bagherhat district for lands which become free by November. Pitchers are perforated to make a hole of about 1-inch diameter at the bottom, and a 0.5-1.0 meter long jute ribbon is inserted in the hole. The pitchers are then placed in pits (locally mada) at a depth of 5-9 cm, and the jute tapes spread at the same depth so that wet jute can moisten the soil and continuously decrease the soil salinity in the root zone. 3- 4 seeds of the crops planted in each pit around the Pitcher. Growing rabi crops in moderately saline areas is a deficient cost technology to produce watermelon, sweet gourd, and cucumber in the dry season in pits (*Mada*).

Dibbling Method

This type of system is generally practiced in Bhola on a large scale, Noakhali and Chittagong on a smaller scale. Soils are loam or clay loam, friable. Shaitta rice variety (local variety) is cultivated in pre-kharif (Aus) season. Dibbling is done in March-April. To skip salinity during March-April and germination problems due to surface crusting and to utilize soil moisture in situ dibbling method is used which facilitates soil moisture conservation. Rice seeds are put in a hole 3-6 cm deep and covered by loose soil. A peg of 2.5 to 5cm diameter is used to make a hole in the soil.

Agronomic

Even though the coastal area is relatively flat, elevational differences exist between the higher and lower parts of the catena, which causes standing water in the fields. The depths of standing water in the medium highland range from 15 cm to about 90 cm. At present, a number of salt-tolerant modern varieties are available in the country by different NARS institutions like BRRI dhan47, BRRI dhan53, BRRI dhan54, BRRI dhan55, BRRI dhan61, BRRI dhan97, BRRI dhan99 and BINA dhan-8, BINA dhan-10.Cropping intensity may be increased by about 0.602 million hectares of very slight (S1) and slightly saline (S2) areas by adopting proper soil and water management practices and introducing salt-tolerant varieties of different crops. Since a certain depth of irrigation water is kept in the field for growing successful rice crops, this practice helps leach soluble salts, consequently reducing soil salinity. The leaching of salts in this period is facilitated because of the relatively lower water table. However, it is a fact that the availability of good quality irrigation water is a severe limiting factor for growing rice crops in the winter season in the area. Raised dyke/ail/bund can be used for growing vegetables and horticultural crops efficiently.

The season-wise list of salt-tolerant crops grown in saline areas is (Aziz, 2013)

Crops in Rabi season: BARI Barly-6, BH-15,18; Chilli, Mung bean(BM-01,08); Til, Chickpea, Mustard (BARI Sharisha-9,11 relay crop), Cowpea (BARI Felon-1), Lentil, Maize (Barnali, Khaibhutta, BARI Hybrid Maize- 3,4,5, Pacific-11,60); Sweet potato, Grass pea, Ground nut, Khesari (BARI Khesari-1, BARI Khesari-2); Soybean (BARI Soyabean-5, Shohag), Methi, Sunflower, Watermelon, Vegetables and *Boro* (Varieties BRRIdhan-28, 29,47; BINA-8,9,10; Hybrid (Hira), Ratna, Minikit);

Crops in Pre-Kharif season: Sesame (Atshira), Broadcast *Aus* (Local) and Transplanted Aus (Varieties are, BRRI dhan26, BRRI dhan27, BRRI dhan28, BRRI dhan42, BRRI dhan43, BRRI dhan48; BR14, Mala; Mixed *Aus* & *Aman*);

Crops in Kharif season: Kharif Vegetables, Transplanted *Aman*: Varieties are BR10, BR11, BR22, BR23; BRRI dhan27, BRRI dhan28, BRRI dhan30, BRRI dhan33, BRRI dhan39, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan47, BRRI dhan53, BRRI dhan54, BRRI dhan55 and BINA dhan-7; Lambu, Shaheb, Chikon, Swarna, Ranjit, Ranisalut, Dud Kumar, Sadamota, Kachra, Bashful, Benapol etc.

Annual and Perennial crops: Fruits, Banana, Nursery etc. on raised beds.
Others: Mangroves, Shrimp, local fishes, and Salt bed (particularly in Chittagong coastal areas).

Addition of organic matter and chemical fertilizers

Organic manures are applied to reduce the salt effect of rice plants. Application is made just after 1st ploughing. Green manure, animal manure, paddy husk and rice straw are organic manure sources. Potash fertilizer has an added advantage under soil salinity. It lowers Na uptake by plants and, of course, increases K uptake. Thus K fertilization protects crops from the harmful effects of Na. Nitrogen losses through ammonia gas are high in saline soils where sodium carbonate is high. Therefore, the application of more nitrogen gives a better harvest. Compared to urea, ammonium sulfate is the best form of nitrogen fertilizer used sporadically in saline paddy fields.

Transplanting

Rice plants are more sensitive to salinity during the seedling stages. Younger seedlings are more sensitive than older seedlings. Therefore, planting seedlings older than 21 days will help rice plants to tolerate salinity. Instead of 2 or 3 seedlings on a hill, 3 to 4 seedlings should be planted per hill to keep the plant density average under saline conditions allowing some plants to die.

CONCLUSION AND RECOMMENDATION

In Bangladesh, salinity is one of the significant natural hazards hampering crop production. Out of about 1.689 million hectares of coastal land, about 1.056 million hectares are affected by soil salinity of various degrees. So far, about 19 districts of the country have been affected by soil salinity, and the problem has increased by about 26% from 1973 to 2009(SRDI). The coastal zone of Bangladesh covers 20% of the land area, inhabited by approximately 40 million people. About 64.7% of inhabitants depend on agriculture (BBS, 2010). Agriculture in this part has multiple limitations besides soil salinity, i.e. duration of flooding, soil texture, poor drainage, water logging etc., which directly influence agriculture development.

There are a few best practices that need more extension and follow-up. Polder, in any way, contributed to protecting land from seawater ingression, which deserves critical analysis and monitoring of existing land uses by modern technology like remote sensing and GIS, developing appropriate soil and water management technologies for irrigated rice, dry land crops and aquaculture on moderately fine to fine-textured soils, and developing salt-tolerant varieties. On the other hand, land grabbers' encroachment of rivers/canals also hinders development. Therefore, protecting land from tidal surges or cyclones and reinstalling river networks are the prerequisite of all interventions. Studies on low-cost reclamation measures, including specific agronomic practices, flashing/leaching/washing of salts, drainage and control of water table. Flash out the topsoil salinity with good quality water after ploughing, thereby reducing the negative impact on brackish water aquaculture, germination and crop seedlings. Since much of the cultivable land in the coastal area has become saline, abandoning some areas is possible. The efforts made by scientists towards reclaiming such lands have met with only partial success, as reclamation methods are costly and time-consuming. Since we cannot remove the problem altogether, we must depend on plant manipulations, select relatively tolerant crops, including vegetables and their varieties and try to further build up tolerance in them through physiological and breeding methods. Various agronomical techniques are also a great help in avoiding salt effects. However, there is enough to do in this new area as minimal efforts are being made.

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CONFLICT OF INTEREST

The authors have declared that no competing interest exists.

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