

Review Paper

Intervention of Soil Salinity in Agriculture of Indian Sundarbans: A review

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ABSTRACT

Sundarbans is the largest mangrove forest of the world and shared between India with a 40% of landmass and remaining with Bangladesh. The ecosystem of Sundarbans is dynamic and in the developmental stage by formation of new islands through soil erosion and sedimentation. It is a low-lying area with an average elevation below high tide line. Traditional method of rice-based farming system is common in low lying coastal land of Sundarbans. Climate change, rising of sea level and frequent cyclones have been changing the crop production and cropping pattern in the Sundarbans delta. The communities of Gosaba, Kultali, Kakdwip, Sagar, Patharpratima and Namkhana blocks of Sundarbans have been affected by climate change and soil salinity. The agricultural production system is totally hampered after the strike of cyclonic storm 'Aila' in 2009, and super cyclone 'Amphan' in 2020 due to high salinity and pH condition of soil. Human migration is very common in Sundarbans delta because of extreme poverty and at least one family member is working in other states of India in 75% of families. Crop cultivation is very challenging due to high salinity and changing climate in Sundarbans. Use of salt tolerant variety, land shaping, use of organic manure, rain water harvesting are the key elements to manage the saline soil of Sundarbans delta.

HIGHLIGHTS

- Ecological vulnerability and soil salinity are major problems of agriculture in Indian Sundarbans.
- All possible options including agronomic interventions as described are to be adopted for agricultural sustainability of Sundarbans.

Keywords: Sundarbans, Bangladesh, ecosystem, islands, crop cultivation, climate

Sundarbans, the largest mangrove forest of the world, lies between 21°30'N to 23°N latitude and 88°E to 89°E longitude. It is located in the delta of Ganges; Brahmaputra and Meghna rivers at Bay of Bengal, covering about one million hectares land (Gopal B. and Chauhan M., 2006). This UNESCO World Heritage site is shared between India (40%) and Bangladesh (60%). Sundarbans ecosystem is dynamic and in the developmental stage by formation of new islands through soil erosion and sedimentation. This unique ecosystem is known for Royal Bengal Tiger (*Panthera tigris tigris*). During

16th century, one of the Bara Bhuiyans (local chief) Rana Pratapaditya and Khan Jahan next to him, tried to make Sundarbans as agricultural land or 'Abad' (Ghosh and Mistri, 2020).

Sundarbans is a low-lying area with an average elevation below high tide line. It is therefore, very challenging and difficult to prevent the entry of

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saline water into the agricultural field (Das *et al.* 2012). Traditional method of rice-based farming system is common in low lying coastal land of Sundarbans (Bandyopadhyay *et al.* 2003). Most of the agricultural lands remain fallow during winter and summer months due to scarcity of fresh water for irrigation. Black gram, lathyrus and lentil are grown by using residual soil moisture after rice harvesting. Seasonal vegetables, cotton and chilli are grown with limited irrigation availability in Sundarbans (Maitra *et al.* 2001). Production of vegetables and red chilli has rapidly declined in Sundarbans (Samanta, 2018).

Climate change, rising of sea level and frequent cyclones have been changing the crop production and cropping pattern in the tropical coastal region (Gupta and Sarkar, 2015; Sagar *et al.* 2023). Further, degradation and depletion of natural resources are also major concerns of the present-day agriculture (Sairam *et al.* 2023). The agricultural production system of Sundarbans is totally hampered after the strike of cyclonic storm 'Aila' in 2009, due to high salinity and *pH* condition of soil (Debnath, 2013 and 2014). Cyclone 'Aila' have changed the soil characteristics due to the entry of saline water in agricultural lands of Sundarbans. Another super cyclone 'Amphan' hits on 16th May, 2020 with 105 miles per hour wind speed and damaged Sundarbans badly (India Today, 2.6.2020). Nearly 17800 hectares of agricultural land have been damaged due to the entry of saline water from sea to farm lands, rendering them uncultivable for coming few years (News 18, 21.05.2020).

Soil characteristics (acid saline)

Sundarbans soils are mostly loamy in nature with a varied soil texture from sandy loam to clay loam (Saha *et al.* 2019). The average organic carbon content, available nitrogen, available phosphorus and exchangeable potassium values of non-mangrove Sundarbans soil is 0.8 %, 80.1 (mg kg⁻¹), 13.3 (mg kg⁻¹) and 18.4 (meq/100 g soil), respectively. Whereas the electrical conductivity (EC), soil *pH* and cation exchange capacity (CEC) of non-mangrove Sundarbans soil is 25.9 (dsm⁻¹), 8 and 58.6 (me g⁻²), respectively (Dasgupta *et al.* 2018). Soil salinity is a serious problem in Sundarbans. During dry season, high soil salinization creates a white spot on the top of the soil, which gives an indication of soil

salinity. Soil acidity and salinity affect the chemical transformation and availability of plant nutrients. The soil of mangrove forest lands of Sundarbans is rich in organic matter content and high in available nitrogen and phosphorus content due to poor decomposition of plant parts and that's why the soluble salt concentration is lesser as compared to agricultural farm lands (Haldar and Debnath, 2014).

Impact of salinity on Agriculture

Salinity in agricultural lands of Sundarbans is the main important factor that limiting the crop yields. Many parts of Sundarbans became less productive due to increased salinity level. A study conducted by (Biswas *et al.* 2017) showed that, the salinity level of western part of Indian Sundarbans and eastern part (adjacent to Bangladesh) of Indian Sundarbans are relatively lower as compared to the central part Indian Sundarbans. It may be due to the discharge of Farakka barrage through Hoogly river at the western part of Sundarbans and receipt of maximum freshwater in Bangladesh Sundarbans from Himalayan glacier through Padma river. The salinity level remains minimum during post-monsoon season due to washout of soluble salts from the soil through rainfall while it is maximum during summer due to huge evaporation losses and salt deposition on the top soil (Nath and De, 1999).

Flooding, submergence, soil erosion and cyclonic storms are very common in the islands of Indian Sundarbans. In addition to this, increasing population growth in this environmentally sensitive area is the major threat to its existence (Ghosh, 2012). Monocropping with "Aman" paddy is very common in Sundarbans delta. Paddy is the main consumable crop of Sundarbans and plays a vital role in regional economy (Hajra *et al.* 2016a). The crop yield is decreasing day by day due to high soil salinity caused by embankment collapse, raising sea level and devastating cyclones (Danda *et al.* 2011). Rice plant can give normal crop yield up to a salinity level of 3 dSm⁻¹, above which the yield decreases by 12% with each unit of increase in salinity (Maas and Hoffmann). Due to the reduction of pre- and post- monsoon rainfall, the productivity of rice, vegetables and local fruits has been hampered (Nath *et al.* 2021). The communities of Gosaba, Kultali, Kakdwip, Sagar, Patharpratima and Namkhana

blocks of Sundarbans have been affected by climate change and soil salinity (Sahana *et al.* 2021).

Land use changes

Sundarbans delta is a large complex of many islands and those islands have been subjected to soil erosion due to various processes (Paul and Bandyopadhyay, 1987; Hajra *et al.* 2016b). Another major environmental issue is degradation of mangrove forest. It has been observed that the areas of agricultural field are shrinking gradually. The ecosystem of Sundarbans is changing drastically due to its location in the Bay of Bengal (Kumar *et al.* 2007). The Fig. 1, 2 and 3 have been prepared from LANSAT 5 and LANSAT 8 satellite image of the month of December 2008 (before *Aila*), 2013 (after *Aila*) and 2020 (after *Amphan*), respectively to study the land use changes of Indian Sundarbans. The LULC maps of the study area were generated from Landsat digital data for all three years. From the satellite data, it is observed that the land under agriculture is decreased drastically (Both mono cropping and double/ Multi cropping), whereas the land under water body and aquaculture is increased (Table 1). The area under mangrove forest cover is increased due to sea level rising and entry of saline water into the main land due to high tide and cyclonic storm *i.e.* *Aila*, *Amphan*.

Environmental migration and food security

The migration caused by environmental issues where environment adversely affects the livelihood is called environmental migration. Increasing vulnerability in crop yield by changing weather condition and extreme weather leads to increase human migration from rural to rural and rural to urban (Kumar and Viswanathan, 2015). Nearly

55% of male migrants send remittances to support their households in India (Bhagat 2014). The people of Sundarbans are mainly depending on natural resource-based activities *i.e.*, farming, fishing and honey hunting which are susceptible to climate change (Panda *et al.* 2022). Migration is very common in the livelihood strategy in Sundarbans. On an average, one person migrates from each house hold in search of job and male migrants are predominant (Mistri, 2013). Other factors *i.e.*, property possession, political issues and occupation are also responsible for human migration in Sundarbans. The peoples of Sundarbans are under extreme poverty and at least one family member is working in other states of India in 75% of families. (Hazra *et al.* 2014). The islands of Sundarbans are highly vulnerable and a huge land loss through cyclonic storm, flood and soil erosion leads to a large number of human migrations.

Table 1: Land use changes of Indian Sundarbans from 2008-2020

Land use pattern	Area (Ha.)		
	2008 (Before <i>Aila</i>)	2013 (After <i>Aila</i>)	2020 (After <i>Amphan</i>)
Agriculture (Single crop)	118138	117882	109548
Agriculture (Double / Multi crop)	142898	98200.8	106329
Aquaculture	46642.4	35154.8	60668.1
Waterbody	21209.1	20400.6	38587.9
Fallow land	184414	198675	129660
Mangrove (Forest)	164808	171666	199180

Source: U.S. Geological Survey (United States Geological Survey).

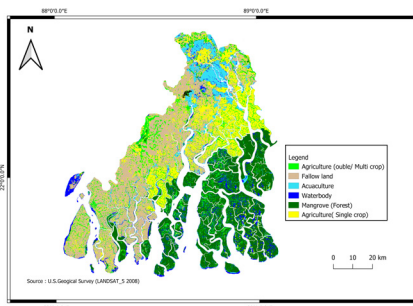


Fig. 1: Land use and land cover map of Indian Sundarbans, in 2008 before *Aila* storm

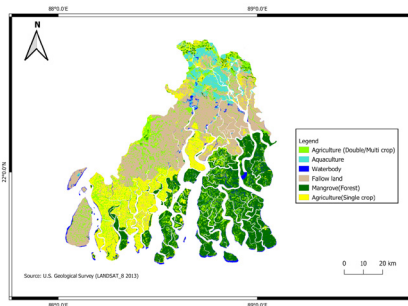


Fig. 2: Land use and land cover map of Indian Sundarbans, in 2013 after *Aila* storm

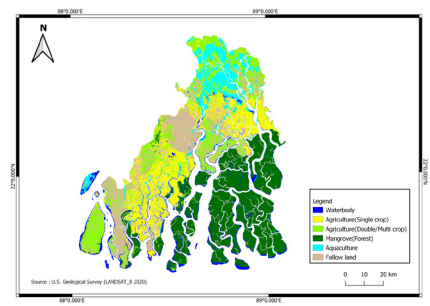


Fig. 3: Land use and land cover map of Indian Sundarbans, in 2020 after *Amphan* storm

Strategies for salinity management

Use of salt tolerant varieties

Agricultural activities carried out in the Sundarbans are very much complicated, diverse in nature, and hazardous as well (Saha, 1999). Natural hazards occurring on regular basis like storm surge, saline water intrusion, water logging, tidal floods and river erosion impose a persistent threat to agricultural productivity. Agriculture is become difficult to practice in the coastal Sundarbans due to continuous salt water ingress and land salinization hampering socio-economic growth of people living in the region. Soil salinity and alkalinity are the two distinct stress factors that affect the growth and development of agricultural crops in the coastal regions (Hussein and Rabenhorst 2001; Arun and Sridhar 2005). In the post monsoon season fresh water layers become contaminated by the salt reaches from the saline groundwater and dominant clay complex at the soil surface also get polluted through capillary rise and makes the soil saline and unproductive for agriculture (Ray *et al.* 2014). Therefore, introduction of salt tolerant varieties of rice especially the indigenous varieties *viz.* Dudheshwar, Annada, Hamilton, Talmugur, Kerala Sundari etc. corresponding to salinity of soils should be given priority in the region. Salt tolerant rice varieties, *viz.*, WGL-20471 (Lal-minikit),

Bidhan-2, Bina dhan-8, BRRRI dhan-47, Bobby, Lalat are some promising varieties under cultivation in the salinity affected soils of Sundarbans. The project titled "Conservation of Local Agro Biodiversity for Better Livelihoods through Use of Local Resources in Response to Poor Areas of Sundarbans", funded by the Ministry of Environment and Forests (Govt. of India) under the UNDP/GEF small grants programme (SGP) has undertaken the cultivation of fifteen (15) salt tolerant paddy varieties in the salinity affected areas of Sagar and Patharpratima block of South 24 Parganas, West Bengal and revealed that many of these varieties have medium to high salt tolerance with a good average paddy yield (Table 2). Three rice varieties tolerant to salt toxicity like Sumati, Bhutnath and Amal Mana have been developed and released by Regional Research Station at Canning Town, West Bengal for coastal saline soils of Sundarbans. Salt tolerant varieties of desi cotton (G. Cot 23) and wheat (KRL 210) are now a day successfully grown in the salinity affected soils. Salt tolerant fodder crop cultivation can also be practiced in the salinity affected lands which remained uncultivated for almost a decade in Satjalia island, Basanti and Hingalganj block of Sundarbans. In the Sunderbans ecosystem, fodder crop cultivation combined with selected animal husbandry can effectively results in agricultural sustainability. Few aromatic grasses such as vetiver, lemongrass,

Table 2: Production of salt-tolerant paddy varieties in Sagar and Patharpratima block of Sundarbans

Sl. No.	Paddy varieties	Salt tolerance	Maximum tillers found	Production (Kg/ha)
1	Hangra	***	23	3828.5
2	Hamilton	***	24	2595.5
3	Malabati	***	21	2595.5
4	Talmugur	***	23	2595.5
5	Dudheshwar	**	29	2964
6	Kalobakra	**	13	NC
7	Kerala Sundari	**	23	5557.5
8	Ranjit	**	27	3828.5
9	Chamarmani	*	26	3087.5
10	Lal Ghetu	*	14	NC
11	Nona Sampad	*	NC	NC
12	Nona Swarna	*	NC	NC
13	Patnai	*	15	NC
14	Sada Kalobakra	*	NC	2223
15	Sadamota	*	21	3211

NC = Not recorded; * = minimum tolerance; ** = moderate tolerance; *** = more tolerance [ECe (dSm^{-1})].

palmarosa and medicinal crops like isabgol, aloe, tulsi and senna could also be grown successively in salinity affected soils. Cultivation of fruit trees like *Feronia limonia*, *Zizipus mauritiana*, *Carissa carandus*, *Emblica officinalis*, *Aegle marmelos*, and forest trees like *Jatropha curcas* can also be promoted in the saline conditions.

Breeding and Biotechnological development

ICAR-NBPGR, New Delhi have released 21 salt tolerant cultivars in rice (10), wheat (5), Indian mustard (5), and chick pea (1) in the past five decades and all those cultivars are efficient to give high yields. Besides, two genotypes of sesbania/dhaincha (CSD 137 and CSD 123) with high salinity tolerance and more foliage yield have also been developed through breeding efforts by the institution (Billah *et al.* 2021).

Agronomical interventions

Diversification of agriculture has provided

opportunities for sustainable resource management in Sundarbans with the objectives of integrated sustainable production, reduced soil salinity, replenishes soil fertility and improves the coping strategies for the farmers. The salinity level of coastal soils can be minimized by leaching out the salts with good quality water. Leaching of salts can be a better option to reclaim the soils affected by salinity. So, to enhance the agricultural production systems, several alternate agricultural practices must be propagated for the farmers in the coastal areas of Sundarbans as:

- ♦ Cultivation of rice promotes the leaching of salts from coastal saline soils. That is why rice is the most preferable crop to be grown in the salt affected soils of the coastal regions. However, crop like barley, linseed, chilli, sugar beet can also be grown due to its high-density crop canopy that will reduce evaporation thereby declining the salinity level of coastal soils (Shankar *et al.* 2020; Midya *et al.* 2021).

Table 3: Salt tolerant cultivars released by ICAR-NBPGR, New Delhi

Name of crop	Name of variety	Year of release	Maturity period (days)	Salinity tolerance (EC, dSm ⁻¹)	Alkalinity tolerance (pH)	Yield (t ha ⁻¹)	
						Normal soil	Salt affected soil
Rice	CSR 10	1989	120	11.0	10.2	6.0	3.0
	CSR 13	1998	145	9.0	<11.0	6.0	3.5
	CSR 27	1998	120	10.0	<10.0	6.5	4.0
	CSR 30	2001	155	7.0	9.5	3.0	2.0
	CSR 23	2004	130	10.0	9.9	6.5	4.0
	CSR 36	2005	135	10.0	9.8	6.5	4.0
	CSR 43	2011	110	7	10.0	6.0	3.5
	CSR 46	2016	135	8	9.9	6.5	4.0
	CSR 56	2018	125	8	9.9	7.0	4.3
	CSR 60	2018	125	8	9.9	7.0	4.5
Wheat	KRL 1-4	1990	132	7.3	9.3	4.0	3.0
	KRL 19	2000	132	7.3	9.3	4.5	3.0
	KRL 210	2010	143	6.4	9.2	5.0-5.5	3.4
	KRL 213	2010	145	6.4	9.2	5.0-5.8	3.3
	KRL 283	2016	128-139	6.7	9.3	5.2-5.6	3.5-4.1
Mustard	CS 52	1997	135	9.0	9.3	1.8-2.0	1.5-1.6
	CS 54	2005	121	9.0	9.3	2.0-2.4	1.6-1.9
	CS 56	2008	132	9.0	9.3	2.2-2.6	1.6-1.9
	CS 58	2016	135	11.0	9.4	2.6-2.8	2.0-2.2
	CS 60	2018	125-132	12.0	9.5	2.5-2.9	1.9-2.2
Chickpea	Karnal Chana-1	1998	147	6.0	9.0	2.1-2.4	1.4-1.6

- ♦ For acid sulphate soils it should be kept wet to check formation of acids. On the other hand, adoption of suitable rice varieties for acid sulphate soils of coastal areas can increase the pH of soil reducing iron and aluminium toxicity.
- ♦ Paddy cum fish culture with rainwater harvesting facilities had already been introduced by Sundarbans Development Board (SDB) under the Government of West Bengal in which 2/3rd land is converted for practicing agriculture and remaining land to follow aquaculture. This rainwater harvesting method has been promoted in the regions by State Government to meet the demand for all agricultural land which generally remains fallow during dry season because of salinity build up by rising groundwater table.
- ♦ Vegetable farming, particularly in the Canning, Gosaba, and Basanti blocks of the Indian part of the Sundarbans, with the introduction of improved agriculture technology such as raised bed sowing, paddy straw mulching, deep ploughing, zero tillage, solar powered drip irrigation, and so on.
- ♦ Growing of vegetables like capsicum, cluster bean and palak are found economically viable to a greater extent using saline irrigation water with drip irrigation method.
- ♦ Cultivation of sugarcane with drip irrigation and mulch can give significantly higher yields under saline soil conditions.
- ♦ Cotton has also proven to be a very effective second crop in the mono-cropped Sundarbans because of its great tolerance for soil salinity and ability to grow successfully with residual soil moisture. Further, intercropping beet, sugarbeet, chilli, groundnut, lathyrus is also effective in cotton (Maitra *et al.* 1999; Panda *et al.* 2020).
- ♦ In the Indian Sundarbans' Gosaba island, relay cropping (paira/utera cropping) of lathyrus, locally known as khesari, is encouraged.
- ♦ On moderately salty soil crops like castor and sunflower have resulted as more profitable crops. Similarly, salvadora and halophytic grasses can be grown in very salty soils and results satisfactory yield.
- ♦ For achieving stable agricultural yields on salinity-affected soils, several soil and crop management strategies such as conjunctive use of saline and canal water in irrigation, low water-requiring crops and pressurized irrigation systems can be advocated.
- ♦ Regional Research Station, Lucknow has introduced and commercialized a number of microbial formulations, including CSR-BIO, HALO-PSB, and HALO-AZO, that operate as soil conditioners and nutrient mobilizers while also protecting plants against salt injury.

Land shaping

Salinity build up in the coastal soils generally results from the regular salt water intrusion from the sea during extreme weather conditions. It makes the groundwater saline which gradually accumulates salt to the surface soil through capillary rise. Salinity level of the surface soil can easily be minimized to some extent by leaching out the toxic salts through harvesting of excess rainwater that goes into the sea as runoff. Therefore, there is a need of proper land shaping techniques to be followed in the region to harvest this excess rainwater that can also be effectively utilized during the dry months as an alternative source of irrigation water. Rainwater harvesting through different land shaping models might be a good option alongside minimizing the problems of soil salinity (Panda *et al.* 2022). Different land shaping techniques developed with the objective of reducing the soil salinity along with augmentation of irrigation water availability include:

(a) Farm ponds: It may be created in about 20% of the land to harvest excess rainwater (Bandyopadhyay *et al.* 2009) and the excavated soil is mostly utilized for making of field bunds that can be further used for growing agricultural crops. This excess rainwater stored in farm ponds will meet the demand of water required for crop cultivation during dry season when crops generally experience toxicity from saline irrigation water as well as from salts accumulated in the surface soils otherwise. The stored rain water may at least provide supplemental irrigation at the critical stages of crop growth in dry season. Farm ponds can be utilized efficiently to practice other activities like fishery, duckery etc. Decline in soil salinity level through construction

of farm ponds can be helpful in diversifying the farming practices that ultimately results in increased cropping intensity, farm income and employment generation as well.

(b) Deep furrows and high ridges: Nearly 50% of the farm land has been shaped into high ridges and deep furrows alternately. Dug out soil from the furrows is used for construction of high ridges making it suitable for growing high value crops which generally not grown in normal land situation for salt toxicity. High ridges show lesser soil salinity due to increased distance between raised soil surface and saline groundwater, while furrows are utilized for harvesting of rainwater that helps in irrigating the crops during dry months of the year.

(c) Paddy cum fish cultivation: Trenches are constructed around the periphery of the farm keeping 3.5 m wide outer space from the boundary and the dugout soil is used for making bunds to check free flow of water within the area. Paddy is cultivated generally in the field, whereas two fish crops are taken from the trenches. Vegetables can also be grown in peripheral boundary to fetch additional income.

(d) Raised and sunken bed: The Water Technology Centre for Eastern Region (WTCER) has developed raised and sunken bed (RSB) technology for increasing the water productivity through effective rainwater harvesting in medium and lowlands of eastern region (Fig. 4). The RSB system has also the advantage of minimizing soil salinity and nutrient losses from crop fields (Rajput *et al.* 2009). This system is very much capable of saving about 35% irrigation water (Das and Goswami, 2018) and this saved irrigation water can effectively be utilized for growing high value crops like vegetables during summer months when the groundwater salinity increased usually due to cessation of monsoon

rains. The RSB system can be considered as the most feasible land configuration for inter-plot water harvesting which increased the depth and duration of submergence in sunken bed plots (Sharma, 2003; Das *et al.* 2021). This retention of moisture for longer periods of time within the soil profile of sunken plots can effectively be utilized to grow the dry season crops in coastal regions of Sundarbans.

Use of soil amendments

Soil salinity and alkalinity problems degrade almost 6.74 million ha of agricultural land in India (ICAR-CSSRI, 2019). On the other hand, per capita availability of arable land is projected to be 0.121 ha in 2025 and 0.087 ha in 2050 in comparison to the land availability of 0.163 ha during the year 2000. Nitrogen deficiency is most common in Indian soil while it is deficient in phosphorus and potassium to a lesser extent and this is now becoming a severe problem specifically in the coastal areas due to salinity. This results in lower crop productivity by making the land less productive limiting the availability of major nutrients required for plant growth and reducing the area of cultivated land as well (Shahbaz and Ashraf, 2013). These situations are now aggravated again due to inappropriate and unscientifically planned resource management practices followed in agriculture. Therefore, there is an immediate need of adopting appropriate soil restoration practices to cope with the salinity-alkalinity problems in the region. Use of different soil amendments is one of the important mitigation options for improvement and reclamation of soil quality. Application of various soil amendments like organic manure, green manures, bio-fertilizers, crop residues, gypsum, and agricultural lime must be followed to reduce the effect of soil related problems on crop plants. Incorporation of organic matter in the

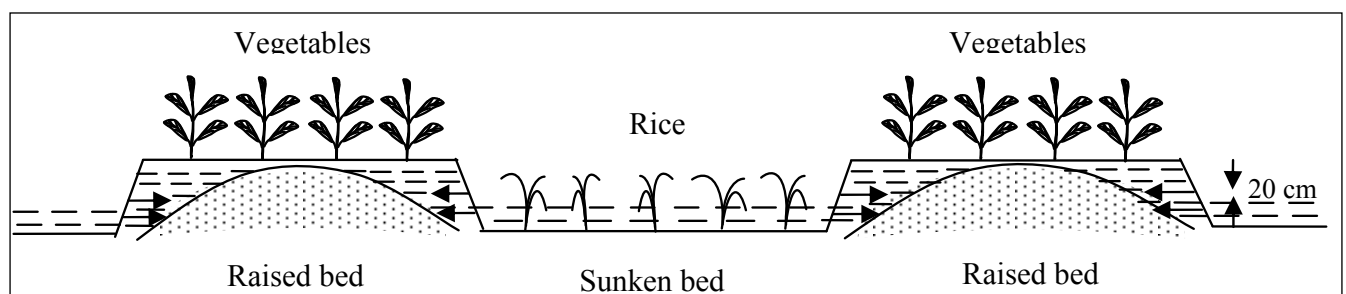


Fig. 4: Raised and Sunken Bed (RSB) system

soil effectively maintains the soil physical structure, increases the supply of available cations (like Ca, Mg, K etc.) and enhances the fertility status of saline and saline-sodic soils. An optimum balance between the soil macro and micro-pores through addition of organic manure can be obtained that ultimately results in higher permeability and increased water retention capacity of the soil. It thereby helps in fastening the infiltration rate of water into the soil that favours the leaching of excess salts from the crop root zone. Organic amendments are also very much useful to enhance the cation exchange capacity (CEC) of soil as well as the ion adsorption thereby reducing the concentration of soluble salts within the soil solution that minimizes the soil salinity. Again, inorganic amendments like gypsum (CaSO_4) are extensively used to reclaim the saline-sodic and sodic soils by replacing the exchangeable Na from the exchange site by Ca. Nearly 2.07 lakh ha area having alkalinity problem has been reclaimed by the application of gypsum and utilized wholly for agricultural crop production by CSSRI in the last few years. It can also reduce the aluminium toxicity from the subsoil layer. Some amelioration measurements like application of lime and rock phosphate have also been introduced to obtain sustained rice production from the acid sulphate soils. Recently several strategies involving the beneficial microbes likely plant growth promoting bacteria (PGPB) have been undertaken to cut the ill effects of soil salinity on plant growth. Utilization of PGPB has now become a promising alternative to mitigate plant stress resulting from high salinity (Yao *et al.* 2010).

APSIM model

At the dawn of the new millennium, we must acknowledge that a progressive transformation in agricultural system is urgently needed to keep the pace of food productivity for feeding the mammoth population where horizontal land intensification is next to impossible (Mondal *et al.* 2022). Improvement in cropping system with consideration of environmental sustainability, particularly in coastal track by crop intensification in post-rainy fallow might be the foremost option to overcome the aforesaid issue. An additional attachment of well-tested simulation model explores the scope of system productivity, assessing the environmental

impact with the changing of time (Mainuddin *et al.* 2020). Actually, simulation modelling provides the potential information regarding soil-plant-atmospheric system than traditional expensive field experiments. Among various modelling approach, the Agricultural and Production System Simulator Model is promising option for saline belt as it has been successfully calibrated, parameterised, and validated for large scale rice-based cropping system (Gaydon *et al.* 2017). The use of agricultural and production system simulator for rice-based farming is successfully calibrated and validated in wide region of S-E Asia, aiming to accelerate the productivity, cropping intensity without harming the environment (Sarkar *et al.* 2020). At recent past, APSIM model has been appraised in its performance in terms of geographical position, soil types, water availability, crops mixture and cultural practices with numerous possible combination (Amarsingha *et al.* 2015). Conventional practices of small holding farm families are easily captured by APSIM model with its flexible manager module (Khaliq *et al.* 2019). Additionally, this model helps to bring a small-scale experiment to broad spectrum within very short period of time. Moreover, it is a open source simulation model (software download and details technical procedure: www.apsim.info). This model has capacity to simulate soil water, nutrient dynamics and their interaction within farm production system (Holzworth *et al.* 2006).

Assessment of problems through APSIM in coastal area

In coastal zone, a wide range of area is cultivated under *kharif* rice and sometimes the crop suffers from abiotic stresses (Gaydon *et al.* 2012). APSIM successfully simulates the complex phenomena of rice ecology in flooded condition and role of aquatic floras on rice eco-system (Gaydon *et al.* 2012). APSIM-ORYZA combination also simulates the crop response under varied saline condition and their possible dynamics in ecosystem (Radanielson *et al.* 2018). This model successfully reveals the growth pattern, yielding potential, nutrients dynamics and loss for rice-based cropping pattern. Crop growth and yield under N limiting, water limiting or any other major inputs limiting condition could successfully judged by APSIM-ORYZA model (Li *et al.* 2017). Normally, understanding the salinity



stress on crops and soil in practical field is very expensive and, in this regards, APSIM-ORYZA simplifies the way by focusing on water availability effect only (Hochman et al. 2007). Interestingly, in recent time salinity effect on crops was simulated through APSIM-SOILWAT module by Radaneilson et al. (2018) and Sarkar et al. (2020) had attempt to find out the changes in ground water salinity and water table depth APSIM-SWIM module in coastal Bengal. This model could successfully predict the soil salinity dynamics and water table depth and their effect on cropping system in coastal saline zone in changing climatic scenario.

CONCLUSION

Because of global warming, the sea water level is raising throughout the world. The coastal agriculture in many developed and developing countries are under serious threat due to entry of saline water in crop fields. Managing salinity in coastal areas is very challenging but use of salt tolerant variety, proper nutrition, use of organic manure, land shaping and rain water harvesting are the key elements to cultivate crops successfully in coastal areas like Sundarbans.

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