Proceedings

Workshop on Up-scaling of agro-technologies for enhancing livelihoods in coastal regions of India under NAIP (Component 3, GEF Funded) subproject

on

Strategies for sustainable management of degraded coastal land and water for enhancing livelihood security of farming communities

CENTRAL SOIL SALINITY RESEARCH INSTITUTE
REGIONAL RESEARCH STATION
Canning Town - 743 329, South 24 Parganas, West Bengal, India

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20th August, 2013, Kolkata

Edited by

Subhasis Mandal
D. Burman

CENTRAL SOIL SALINITY RESEARCH INSTITUTE
REGIONAL RESEARCH STATION

Canning Town - 743 329, South 24 Parganas, West Bengal, India

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Compiled by :

S. K. Sarangi, U. K. Mandal, K. K. Mahanta and S. Rout

Editorial Assistance :

Sekhar Dey, Paritosh Patra and Sabyasachi Patra

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Editors

Rationale and Background of the Workshop on up-scaling of Agro-Technologies for Enhancing Livelihoods in Coastal Regions of India

Subhasis Mandal and D. Burman

Central Soil Salinity Research Institute Regional Research Station
Canning Town - 743 329

The workshop on '*Up-scaling of agro-technologies for enhancing livelihoods in coastal regions of India*' has been designed to understand several issues on large-scale technology dissemination covering the areas of input-supplies & management; market & marketing environment – the driver of change in cropping pattern and production; credit needs & absorption of the farmers, and the role of financial institutions therein; finally to highlight the grassroots level experiences, success stories and lesson learned.

Development of technologies by Scientists/researchers alone cannot solve the problem of farming communities unless the process of technology dissemination is complemented by desired policy initiatives. Very often the technologists failed to understand why despite being their technologies economically viable, farmers are reluctant to own that technologies. Is it because the farmers' behaviour is stubborn or irrational and they are afraid of any change? But the fact is farmers' have to operate their farming operation under host of socio-economic conditions that affects their decision to adopt new technologies. Socio-economic factors like input prices, market environment, fragmented and small/marginal land holdings, availability of own or hired human labour, labour wage rates, financial and credit needs, availability and capacity to absorb, risk preferences etc, all these factors affect the adoption behaviour towards new technologies. Resource poor farmers, particularly of coastal region are naturally risk averters and prefer to be safe than sorry. They tend to prefer a lower outcome that is relatively certain to the prospect of a higher return with a greater degree of uncertainty is attached. Farmers prefer stability of output even with a lower return rather than the high-cost-high-return technologies where the instability of output is much higher.

Deliberation in today's workshop has highlighted various socio-economic issues that are affecting the large-scale adoption of developed agro-technologies. Initiative will be taken up to address these issues through problem-solving research in future course with particular focus on small and marginal farmers dwelling in the coastal region of India. For example, steep rise in fertilizer prices likely to have adverse effect on overall agricultural production and productivity through reduced level of fertilizer consumption in these regions. But on the other hand it is also seen that the fertilizers are being sold at market with much higher prices in the event of short supply. Under this circumstances what has been the response of the Govt. as well as the corporate sector dealing these very important basic input of agriculture.

Existing market environment and marketing status of agro-products, particularly the un-processed commodities, availability of remunerative / reasonable prices are very crucial to change the cropping pattern towards high value crops and also crop diversification. Market prices are the key drivers to change the farm economy but we all are aware of the high price volatility in agri-marketing sector that adversely affect the up-scaling of these agro-technologies.

Conducting rice varietal trials and promotion of promising rice varieties is an important strategy to increase the food production in the coastal region and also to making good contribution towards national production. Continuous efforts are being made by national and international research institutes to evolve suitable rice varieties for coastal region that includes not only India's coastal areas but also in Bangladesh. Many of the rice varieties have been found promising in the coastal region of India and Bangladesh and are in pipeline to be released for the higher rice productivity and production.

Role of finance, credit needs and crop insurance are the major players to push the new technologies in farmers' field and in turn uplift the rural economy. It is important to understand the credit needs and credit absorption pattern in the rural areas for agri-enterprises development. Several initiatives have been taken by the policy makers and banking institutions for easy and low-cost financing to the agriculture sector. What have been the experiences and how far these initiatives have been contributing to the technology adoption is important to know.

Several success stories are available at grassroots level in the villages adopted under the NAIP sub-projects on '*Strategies for Sustainable Management of Degraded Coastal Land and Water for Enhancing Livelihood Security of Farming Communities'*, in *Sundarbans* and Andaman & Nicobar Islands. Under this project, technological, scientific and partial financial help have been extended to the resource poor farmers; particularly small and marginal categories and outcome of this project have been quite encouraging. Such help and co-operation, if extended to many other farmers in the coastal regions, many more success stories can be achieved. While taking up these technologies to many other farmers, there is a need of coherent collaboration from other sector concerned that includes input suppliers, marketing department, financial institutions and Govt. policy support. With the sincere efforts of all these sectors, the benefits of technologies can outreach to many other farmers and issues of up-scaling of technologies can be resolved.

Current workshop is likely to highlight all these scientific & socio-economic issues and finally to come out with some useful recommendations out of the deliberations and discussions, for up-scaling the agro-technologies in the coastal region of the country.

Coastal Agriculture in India – An overview

B. Maji and Uttam Kumar Mandal

Central Soil Salinity Research Institute Regional Research Station
Canning Town, West Bengal - 743 329

The coastal zone represents the transition zone between terrestrial and marine influence. India has an 8129 km long coastline. Its peninsular region is bounded by the Arabian Sea on the west, the Bay of Bengal on the east and Indian Ocean to its south. It has two island-ecosystems, the Andaman and Nicobar Islands in the Bay of Bengal and the Lakshadweep Islands in the Arabian Sea. Coastal areas, mostly saline in nature. The salinity problem in coastal soils is developed during the process of their formation under marine influence and subsequently due to periodical inundation with tidal water, and in case of lowlands having proximity to the sea, due to the high water table with high concentration of salts in it. On an average the marine influence with typical coastal flora and fauna exist approximately upto 50km inshore. Besides a number of soil and water related factors limiting productivity of food grain crops, the entire shoreline is extremely fragile in nature.

Fragility of the ecosystem

Owing to the peculiar climatic, edaphic and geomorphologic conditions the entire ecosystem is highly fragile and risk prone to degradation. The high intensity of heavy rainfall received during a short period coupled with impeded drainage causes prolonged waterlogging in several areas. The flash floods and water submergence reduce the input use efficiency, lower the crop yield and affect the human health. The coastal area along the shoreline is generally flat with slope towards the sea and is interspersed by innumerable river, deltas, channels, creeks, marshes, lagoons and other features. Though many places are protected from the tidal inundation by the embankments along the rivers and creeks, yet frequent breaches lead to seawater intrusion, causing heavy damage. Large scale human settlements, recreational activities and industrial development along the shoreline have been detrimental to the ecology of coastal tracts. The sediment movement resulting from the catchment erosion, addition of heavy metals and toxins through daily discharge of millions of litres of untreated effluents, thermal pollutants, etc. affect the water quality and marine life. Thus, the coastal areas are more vulnerable to the environmental effects with continued expansion of urbanization, industrialization, tourism and other activities.

The East Coast is more prone compared to the West Coast. An analysis of the frequencies of cyclones on the East and West coasts of India during 1891-2000 show that nearly 308 cyclones (out of which 103 were severe) affected the East Coast. During the same period 48 tropical cyclones crossed the West Coast, of which 24 were severe cyclonic storms. The west coast of India experiences high wave activity during the South-West monsoon with relatively calm sea conditions prevailing during rest of the year. On the East Coast, wave activity is significant both during South-West and North-East monsoons.

The Bay of Bengal is more turbulent and epicenter of frequent devastating Bay cyclones, sea surges etc. because of the special nature of the coastline, shallow coastal ocean bottom topography and characteristics of tide. Their coastal impact in this region is very large because of the low, flat coastal terrain, high density of population, low awareness of community, inadequate response and preparedness and absence of hedging mechanism. People can remember the devastation of cyclone Aila in West Bengal during 2009, super-cyclone in Odisha during 1999 as well as Tsunami in eastern coast during 2004 when thousands hectares of fertile agricultural land and adjoining mangrove forests were turned into a vast wasteland due to ingress of saline sea water.

A recent study of global deltas showed that the entire Bengal delta is sinking at a perilous rate due to sediment compaction from the removal of oil, gas and water from the inland delta's underlying sediments, the trapping of sediment in upstream reservoirs, flood plain engineering, and rising sea level (Syvitski et al., 2009; The Hindu, Chennai, September 21, 2009). Based on global sea level data and modeling, Eriscson et al. (2006) have estimated that the sea level rise of the Bay of Bengal is the World's highest, at >10 mm year^{-1}. Other studies have confirmed this trend, but with rates ranging from 4.0 mm year^{-1} in the Western zone to 7.8 mm year^{-1} in the Eastern zone (Han et al., 2010; Unnikrishnan and Shankar, 2007). A 2007 report by UNESCO "Case Studies on Climate Change and World Heritage" has predicted 45 cm rise in sea level likely by the end of the 21st century. The Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report presented similar observational evidence of climate change in the coastal regions and indicated the evidence of increased ocean temperature, changes in precipitation, corresponding upstream river discharge and rising sea level. This will generally lead to higher coastal flooding and increased salinity (Parry, 2007) (Table 1.1).

Table 1.1: Principal conclusions of the IPCC Fourth Assessment Report (IPCC, 2007)

Climate change impact and direction of trend	Probability of Trend[a]	
	Recent decades	Future
Warmer and fewer cold days and nights over most land areas	Very likely	Virtually certain
Warmer and more frequent hot days and nights over most land areas	Very likely	Virtually certain
Frequency of warm spells/heat waves increases over most land areas	Likely	Very likely
Frequency of heavy precipitation events increases over most land areas	Likely	Very likely
Areas affected by drought increases in many regions	Likely	Likely
Intense tropical cyclone activity increases in some regions	Likely	Very likely

[a] Probability classes: like>66% probability of occurrence; very likely>90% probability of occurrence; virtually certain>99% probability of occurrence.

Crops and cropping systems

2.1 Rice based

Rice production forms the backbone of the agricultural sector in coastal region. Rice is the predominant form of land use in many coastal and deltaic regions of the tropics. No crop other than rice can be grown under these adverse conditions of unstable water levels and highly saline locations. Mostly deep water and floating rice subjected to devastating floods and cyclone occupy the coastal rice. Because of prolonged waterlogging during the monsoon season, continuous monocropping of rice with long duration tall Indica varieties is practised in several coastal areas. India, as a whole has about 55 percent of the total rice area under lowlands, but the proportion is much higher in coastal tracts (Rai, 2004). West Bengal, having the largest share of coastal area, has about 90 percent of the total are under 30-90cm depth of water (Table 1.2) and the yield level is comparatively low in the region. However in Andhra Pradesh and Tamilnadu coast rice yield is one of the highest and there mostly irrigated rice through cannel system occupy the major cultivated area.

Table 1.2: Rice varieties suitable to different land situation in West Bengal

Land situation	Water depth (cm)	Salinity level (ECe:dS/m)	Suitable rice varieties
Upland	0-20	6-8	Canning 7, CSR-4(Mohan), CSR-36, Bidhan-2, CST 7-1
Medium land	20-40	4-6	CSR 1 (Damodar), CSR 2 (Dasal), CSR 3 (Getu), CSR 6 (Nonasal selection), Ulpala, Sumati, Bhutnath, Amal-Mona, Namita-Dipti (IET-17343), Bidhan-2, Patnai 23, Talmugur, Nona-Bokra
Low land	40-60	4-6	Malabati, Kalamota, Sadamota (Selection), Tilak kachari, FR 13A, Asfal, Najani, Kumragour, CSRC(D)-7-0-4, CSRC (D)-12-8-12

Even two or three rice crops are successively taken in the same field in a year in some areas where water is available for flooding. Monocropping leads to large scale virulence of pests and diseases, loss of genetic diversity, marked reduction in yield, and other ecological threats. Though rice is most adaptable crop in coastal ecosystem, the topographic settings and vicinity to the coast line render delta regions especially vulnerable to the consequences of climate change, namely, those of (1) sea-level rise and (2) storm surge (Wassmann *et al.*, 2009). Thus, any shortfall in rice production in this area through climate change would not only affect the economy and food security in the country but also have repercussions for the international rice market.

Before the Green Revolution, the Asian delta regions held a comparative advantage in rice production because of fairly productive—by contemporary standards—floating and deepwater rice systems. The early beneficiaries of the Green Revolution, however, were those areas where it was possible to irrigate two crops of rice with the construction of irrigation systems, as in Punjab. The deltaic regions initially were unable to take advantage of the new rice technologies, but have regained a comparative advantage over the past 15–20 years. Short duration cultivars facilitated an adjustment of cropping calendars to avoid excessive flooding; pumps are becoming increasingly popular to tap the shallow groundwater for irrigation during the dry season. However, rising sea level may deteriorate rice production in a sizable portion of the highly productive rice land in deltas. The "Aman" crop, is exposed to higher flood risk and experience severe cyclones over recent years causing enormous losses in rice production. With higher sea water levels and an increase in storm incidences, flooding and salinity stress for rice in delta areas are likely to worsen. In the Asian -deltas, rice is the dominant crop, and in most cases, the only crop that can be grown during the monsoon season. The heavy rains together with poor or non-existent drainage create serious water logging and sometimes complete submergence, or prolonged stagnant floods. In these areas, a slight reduction in rainfall may not affect the water supply and agricultural production in general; however, a small increase in rainfall may strongly affect farming because of the subsequent floods. Only a few low yielding landraces in these areas are evolved to withstand such conditions. Modern rice varieties are not adapted to these conditions and their yield is severely reduced because of high mortality, suppressed tillering ability, reduced panicle size, and high sterility. These are probably the reasons why farmers in affected areas still rely on low-yielding local landraces. Efforts are needed to screen large sets of diverse rice germplasm with a reasonable level of flood and salinity tolerance high yielding rice genetype.

2.2 Diversification of rice cultivation

There is a great scope of crop diversification of mono crop rice, based on soil salinity and water availability (Table 1.3). The scope to increase the cropping intensity and diversification in the coastal ecosystem depends largely on the soil salinity and irrigation water availability. With proper water management it is possible to incorporate pulses, oilseeds and vegetables in rice based cropping system. Among the important winter/summer crops are barley, cotton, chilli, sunflower, and a number of vegetables. Tomato, chilli, brinjal, cabbage, cauliflower, melons, onion, peas, beans, ladies finger and various leafly vegetables are produced in large quantities in coastal areas in the rice based cropping system. Rice-sunflower-cowpea at Navsari (Gujarat) and rice-tomato-okra at Bhubaneswar (Orissa) have been found promising. For Andaman and Nicobar Islands rice-rice-pulse (cowpea) rotation was reported to be most economic and feasible practice.

Table 1.3: Feasible crops for coastal areas

Types of crops	Name of crops
Oilseed crops	Linseed, safflower, sunflower, groundnut
Pulses	Field bean (at lower salinity not exceeding 5-6dS/m), Latthyrus
Fibre crops	Cotton (up to 13 dS/m)
Vegetable crops	Tomato, brinjal, knoll-khol, carrot, beet, lady's finger, chilli (up to 7 dS/m), spinach, cucurbits, amaranthus, ipomoea etc.
Root crops	Sweet potato, yam, colocasia
Spices	Fennel, black cumin, coriander
Aromatic	Lemon grass, aloevera, palma rosa, bhingaraj, mentha
Medicinal plants	Isabgul, sarpagandha
Fruit crops	Guava, sapota, banna
Fodder crops	Coix, paragrass (tolerant to both salinity and waterlogging)

2.2.1 Horticultural and plantation crops

The coastal ecosystem offers vast scope for commercial use not only for a wide variety of fruit and vegetables crops, but also plantation crops, spices and medicinal plants. Plantation crops, like coconut, arecanut, oil palm, cashew, coco, spices ginger, turmeric, and seed spices like cumin, coriander, fennel, fenugreek are high value commercial crops and coastal region have a great scope to cultivate commercially for all those crops. Both cashew and black pepper are good foreign exchange earners. India has emerged as the largest producer of coconut in the world, and coconut coir industry is a well established business. Cashew is cultivated mostly in the coastal areas. Release of improved varieties in all these crops and improved production technology has brought significant improvements in the production of these crops.

Medicinal and aromatic plants play important role in Indian traditional medicines. It is reported that over 2000 native plant species have curative properties, and another 1300 species are known for their aroma and flavour are native in coastal ecosystem. Medicinal and aromatic plants, like isabgol (Plantago ovate Forsk) and opium poppy are produced on commercial scale. Vegetable seed production is also a potential area in this region. Oil palm (Elaeis guineensis Jacq.) is recognised as the highest edible oil yielding crop, producing 4-6 tonne of oil per tree in 25 Years. Total potential area identified for growing oil palm is mainly along the coastal belt.

2.2.2 Forestry

The role of forestry in maintaining the level of CO_2 and other toxic gases in the atmosphere is well established and caught the attention of all concerned worldwide. The present status of forest area in the East and West coastal belts constitutes only about 18.7 and 29 percent, respectively, of the total geographical area of the region. The forest coverage in the A & N Islands, however, is as nearly

88 percent of its total land area. Mangroves growing under natural condition along the coastal shoreline occupy nearly 0.4 million hectare in the country. According to Government of India estimate mangroves are estimated to cover about 0.6 million hectare located in the alluvial deltas of rivers, such as the Ganga, Mahanadi, Godavari, Krishna and Cauveri, in the Andaman and Nicobar Group of Islands, and in minor patches in Maharashtra and Gujarat, comprising about 7 percent of the world's Mangroves (Rai, 2004) .

2.2.3 Agro forestry

Agro forestry systems are more common in India and other developing countries than in the developed countries. It has good prospect for the coastal ecosystem. Based on the nature of the components the common agroforestry systems in India are broadly classified as agri-silviculture (crop+trees), agri–horticulture (crops+fruits trees), agri-horti-silviculture (crops+fruits trees+multipurpose trees), silvipasture (trees+pasture+animals), homestead agroforestry (multiple combination of various components) and others.

2.2.4 Integrated farming

For coastal areas the integrated farming system combining crop production with sericulture, apiculture, dairy, poultry, duckery, aquaculture, agroforestry, etc have a scope. Vast potential exists for rice-based agro-silvicultural production systems in suitable coastal areas. Based on research, Acacia auriculiformis, Casuarina equisetifolia, Acacia nilotica and Prosopis chilensis, Prosopis juliflora are some of the promising tree species (Yadav, 2001). Fast growing Casuarina plantation as an excellent source of fuelwood and as stabilizer of sand dunes are popular even among the farmers of the coastal areas. Coix lacryma jobi has been identified as a suitable fodder species for the salt affected and waterlogged soils. Stylosanthes hamata is another protein rich leguminous fodder.

Rice-fish culture has assumed prominence in the recent years. The fresh water and brackish water aquaculture is one of the most important activities in the coastal areas for employment, income generation and supplementary food item. Promotion of prawn culture in brackish water has made tremendous change in the economy, especially in Andhra Pradesh, Orissa, and West Bengal in the recent years. Brackish water fish culture can be integrated with rice and coconut cultivation. Rice-fish inside the field and vegetables/fruits on the bunds or rice fields has shown great promise in coastal area of Orissa and Sundarban region of West Bengal. Coconut-based system is popular in Andaman and Nicobar group of Islands and in several parts of west and east coasts on the mainland. Homestead farming comprising of coconut, arecanut, other trees and species (black pepper, clove and cardamom) in different tiers around the houses is in vogue in Kerala state. These complex integrated farming systems, however, need further improvement through most efficient and cost effective management of soil, water, nutrient and other inputs, but the location-specific packages, thus developed should be socially acceptable.

Coastal soil

The areas along the coast in India are endowed with a variety of soils. Soils vary from alluvial to lateritic, coarse sand to clay, non-saline to highly saline, alkaline to highly acidic, well drained to poorly drained, low to high organic matter content, deficiency as well as toxicity of some elements, etc (Velayutham *et al.*, 1999). In India, the salinity status in coastal saline soils varies widely from ECe 0.5dS/m in monsoon to 50dS/m in summer. NaCl followed by Na_2SO_4 are the dominant soluble salts with abundance of soluble cations in soils are in general free of sodicity problem except in a few pockets in the south and west coast. the order Na>Mg>Ca>K with chloride as the predominant anion and bicarbonate in traces (Subba Rao *et al.*, 2011).

3.1 Acid Sulphate soils

Acid sulphate soils contain sulphides (mainly pyrites), which become very acid when sulphides are oxidized to sulphate on drying; and usually have a pH below 4 in water. Acid sulphate soils cover large areas of temperate lands. In India, presence of acid sulphate soils has been reported in the lowlying coastal areas of Kerala, Andaman and Nicobar islands, and in the coastal areas of Sundarbans, West Bengal (Bandyopadhyay and Maji, 1995). Acidification of these soils is caused by a combination of abiotic and microbial oxidation of pyrites (FeS_2). Many plants appear to be able to tolerate relatively large concentrations of H^+, although work using solution cultures indicates some root injury at low pH. It is probable that Al and Mn toxicity is more important than H^+ in those soils. In acid sulphate soils, phosphate deficiency is widespread and also there are deficiencies of Ca and K; whereas the levels of exchangeable Mg may be high (Sen, 2009).

3.2 Coastal sand dunes

Coastal sand dunes are deficient in plant nutrients due to extensive leaching which occurs during their formation, transport and deposition. Dune fertilization is a useful management tool for improving the establishment and growth of new plants. If fertilization of sand dunes with urea is contemplated as a management tool, it may be prudent to apply a nitrification inhibitor such as N serve in order to minimize NO_3-N losses. On the other hand, such a combination might enhance NH_4-N volatilization, thereby necessitating the addition of urease as well as nitrification inhibitor.

Soil and Water management

4.1 Drainage and desalinization

Leaching requirement depends largely, on the irrigation water quality and method employed, soil texture, salinity tolerance limit of the crop grown, etc. Adequate drainage for desalinization of the soil and removal of water congestion needs necessary attention along with appropriate flood control measures in the coastal low lying areas. It was suggested that the land should be protected from tidal inundation through protective embankments. Generally, with 3:1 slope at the river end and 2:1 slope in the country end having 1m free board above the high tide level. Brick pitching of the earthen embankments, wherever possible, and planting of wind breaks in areas having problems of coastal sand dunes proved useful. It was suggested to install one-way sluice gates on the river banks or any other suitable location to drain out excess water from the land during low tides in river.

4.2 Modelling for desalinisation

Significant efforts were mode to develop models to desalinize the salty soil through drainage under specified conditions. Different agro-hydro salinity models, viz. SALTMOD, DRAINMOD-S or SAHYSMOD have been developed. It was developed based on sound principles of moisture and solute transport, for unconfined and semi-confined aquifer, which have been tested in the field mostly under arid or semi arid conditions in order to predict the water distribution and salt balance in the soil profile following different practices of drainage and their response on crop function. SALTMOD model was also applied in coastal clay soils of Andhra Pradesh where subsurface drainage system was laid out at several drain spacing. The study suggested that the model could be used with confidence to evaluate various drain spacing of subsurface drainage system and facilitate reasonable predication of reclamation period.

4.3 Use of amendment

For non-saline sodic soil, incorporation of relatively soluble calcium salt like gypsum, phosphogypsum, iron salt like pyrite, $CaCl_2$, Sulphuric acid (H_2SO_4), or other acid forming materials like sulphur (S), lime-sulphur (9% Ca+ 25%S), ferric sulphate, aluminium sulphate, etc. to replace exchangeable sodium from the clay complex, along with recommended water and crop management practices, have been reviewed by many workers for reclamation of these soils in general. Occurrence of non-saline sodic soil is, however, much less in the coastal plain than in inlands, and in case of the former, attempts made for experimental verification have mostly been limited to the use of locally available organic waste like paper mill sludge or other industrial effluent as well.

4.4 Management for acid sulphate soils

For reclaiming the potential and young acid sulphate soils following approaches have been suggested) pyrite and soil acidity can be removed by leaching after drying aeration and ii) pyrite oxidation can be limited or stopped and existing acidity inactivated by maintaining a high water table, with or without iii) additional liming and fertilization with phosphorus, though liming may be often uneconomic in practical use. The reclamation method cited at ii) above for maintaining a high water table to stop pyrite oxidation and inactivate exiting soil acidity, has the advantage that its effects are usually noticeable much quicker. Upon water logging, soil reduction caused by microbial decomposition of organic matter lowers acidity and may cause the pH to rise rapidly to near-neutral values. The method is particularly suitable with rice cultivation. The crucial factor is of course, the availability of fresh water for irrigation. The less toxic and deeper developed older acid sulphate soils are moderately suitable for rice and can be improved by sound agronomic practises. Improved water management and intensive irrigation have dramatically increased the productivity of these highly acid soils.

Large scale engineering schemes for reclaiming potentially acid and usually strongly saline, coastal swamp are however rarely economic. The injudicious reclamation of seemingly suitable land in coastal swamps by excluding salt water through dicing and by excavating fishponds has led to the destruction and abandonment of thousands of hectares of mangrove land in Southeast Asia and Africa. However, unless sufficient fresh water is available and other prerequisites for good water management exist, the potential acid sulphate soils as young and strongly acidic in character should not be reclaimed, but are better left for other types of land use, say conservation, forestry and, sometimes salt pans, etc.

In India, for the coastal acid sulphate soils of Sundarbans, application of lime, super phosphate and rock phosphate have been found beneficial in improving the soil properties and rice growth. Application of Ca-rich oyster shell, which is available in plenty, was found beneficial if applied in powdered form, as an inexpensive alternative soil ameliorating agent. In this soil continuous submergence for one year could not improve the soil properties substantially.

For soils in Andaman Islands, application of lime and phosphorus found beneficial for lowland rice, but the soils should be leached of excess salts in case of high soils salinity before using these amendments. In another study on mangroves (Avecenia marina) mud's in this island, it has been reported that liming significantly depressed the concentrations of Al, Mn and Fe. Exchangeable Al content also decreased with lime application. The depression of exchangeable A1 may be due to precipitation of trivalent A1 and $A1(OH)_3$ in the presence of high concentration of OH^- ions. Lime application, in general, also reduced the exchangeable and extractable Fe contents of the soil.

4.5 Integrated water management

In majority of the cases, in coastal plains, fresh water aquifer presents at large depths which has no consequence to salt accumulation in the crop root zone, but are often combined with water table, rich in salts, present at a very shallow depth (generally not exceeding a depth of 2 m below the soil surface). The net salt loading in the root zone will be positive (salinity will build up) or negative (desalinization will take place) depending upon the relative rate of recharge of salts by upward rise to rate of downward flux of salts by leaching. The relative salt loading will thus be treated generally as positive during dry season, and negative (water logging on the surface) during wet season due to high rainfall, and the process will be repeated each year in a seasonally cyclic mode.

On the other hand, in view of susceptibility of the coastal plans to seawater intrusion and its adverse impact on soil and plant growth, the practice for use of ground water, even if in small quantity, for irrigations should be very carefully exercised. It should not be difficult to avoid using the underground water if properly planned, by increasing the surface storage of runoff water by an equivalent amount or more. Thus, water management in the coastal plains should principally revolve round creating more fresh surface water source and their proper management with little dependence on the subsurface source in order to maintain stability of the ecosystem. rainwater harvesting, dealing with on-farm harvest and storage of excess rainwater during monsoon, and recycling the same for irrigation for dry season (deficit water period) crops, with the objective to introduce multicropping in the otherwise predominantly monocropped areas are getting popular in entire coastal region particularly in Sundarbans and Orissa.

Ambast and Sen (2006) developed a computer simulation model and a user-friendly software 'RAINSIM' primarily for Sundarbans region for small holdings, based on the hydrological process, and the same tested duly for different agro-climatic regions in India. The software may be used for i) computation of soil water balance (ii) optimal design of water storage in the On-farm reservoir (OFR)'by converting 20% of watershed, (iii) design of surface drainage in deep waterlogged areas to reduced water congestion in 75% of the area and (iv) design of a simple linear programme to propose optimal land allocation under various constrains of land and water to arrive at contingency plan for maximization of profit. They also reported use of remote sensing and GIS in mapping lowland lands, vegetation, and crop yield estimation, along with performance assessment of irrigation/drainage systems.

4.6 Integrated nutrient management

Sources of biofertilizer viz. Rhizobium cultures for pulse or legume, and blue-green algae for waterlogged rice field may play a significant role in terms of integrated nutrient management for rice in coastal saline soils. Long term field experiment in coastal saline soils in India showed that rice and wheat yield could be maintained even at 50% NPK used in conjunction with FYM or green manure. Long term experiment in Sundarbans recorded that grain yield of crops in a rice-barley rotation increased significantly due to the application of N. A basal dose of 11kg P/ha for rice and 5.5kgP/ha for barley or for similar upland crops should maintain the fertility status of the soil, whereas the K application may be omitted without any detrimental effect on soil fertility or crop growth as the availability of K content was high in the soil. Green manuring with Dhaincha as summer crop is well suited in entire coastal belt.

In saline condition elevated Ca^{2+} protect the plant from NaCl toxicity. On the other hand, an increase in the Cl^- concentration, in the nutrient media may lead to a reduction in the NO_3^- content of plants. In coastal flooded saline soils measures should be taken to reduce volatilization loss, in particular, either through placement of N-source (urea) at subsurface depth, through application of slow release source, through use of urea inhibitor, or by adjusting the time of application coinciding with the plant's active growth stage, for higher N-uptake.

Under flooded condition, soil organic matter contributes to Fe and Mn availability through the formation of metallo-organic complexes with organic substances. Increased Fe and Mn solubility in flooded soil benefits rice, which has a higher requirement for these elements. For sustainable soil health in order to ensure improved plant nutrient status and its use by the plants the importance of improved soil quality in the coastal plains through higher soil organic carbon level of the soils, for which C sequestration is one of the important pathways, may be emphasized since low lying coastal soils may be a useful sink for higher organic and carbon pool for the terrestrial system. Direct seeded rice has a great scope for increasing soil carbon level as well as to overcome early flash flooding situation during July-August. Preliminary study in Sundarban region showed there was 15-20% yield increase and higher tillering in direct seeded paddy than conventional planting method.

Anthropogenic activities on the coast

The most damaging anthropogenic activities are: changes in land use, including draining wetlands and mangroves for use in agriculture, settlements and aquaculture (Atapattu and Kodituwakku, 2009). Mangroves have been converted to aquaculture agriculture development or degraded due to grazing and stall feeding of cattle. Mangrove forests are also affected by hydrological changes in the catchment basins, near shore coastal areas, and excessive pollution from upstream agricultural practices. The reduction in wetlands such as mangroves reduce the environmental services such as its ability to assimilate nutrients, function as sources of natural drainage and recharge, and support a nursery ground and shelter for many marine and estuarine fauna. Mangrove removal causes coastal erosion and changes in sedimentation patterns and shoreline configuration. In addition to the activities in the coastal area itself, the effects of increased freshwater use and human activities in the bordering river basins are major drivers for coastal change.

Because of non remunerative agriculture in the region and steady growth in fishery sector many agricultural lands is getting converted to modern commercially oriented, high output-intensive fish farming which causes severe environmental threats to the region. Reduced water flows and changes in flow patterns adversely affects fish habitats and breeding patterns including interactions between the ocean and inland coastal waters such as natural shrimp breeding which takes place in the inland coastal waters. Overall it can affect the habitat availability for fish and the fisheries water productivity. Agrochemical accumulation also adds to the deleterious, often lethal, effects of water pollution on fisheries at the coastal end. High loads of sediment and silt from ploughed land and changes in stream and river bank management can also damage fish spawning grounds as well as coastal habitats . In the Bay of Bengal where the natural upstream flows have been altered, the rivers and estuaries are silted up different to the natural silt regimes.

Irrigation development activities upstream have interrupted the biological processes of the earlier free flowing freshwater systems impacting on coastal and marine fisheries. River barrages and sluice gates obstruct the natural flows of sedimentation required for nourishment and essential nutrients for productive fisheries.

Aquaculture has recently become a common activity on the coastal regions of South Asia having significant impacts on surrounding ecosystems. Freshwater diversion from estuaries for aquaculture has resulted in significant losses in the delivery of water and sediment to nursery areas and fishing grounds in the coastal zone and to floodplains. Aquaculture round the year increases the salinity of the degraded soil and also contributes to nutrient over-loading especially with excessive use of feed. These pollutants eventually enter the water bodies that are connected within the river basin. Such practices have impacted the livelihoods of people who depend on coastal fisheries within the floodplains and also those that depend on flood-recession agriculture.

Conclusions

Multi-disciplinary resource inventory needs to be generated to facilitate micro level planning for higher and sustainable productivity in the region. Mapping of the coastal areas for the whole country in a smaller scale with the help of modern tools like remote sensing and GIS should be taken up for characterization of the coastal soil resources for effective coastal ecosystem planning for improved irrigation and land drainage practices, nutrient management and other land use options. The productivity growth in the favourably endowed and irrigated areas has already shown signs of fatigue. But the sizable coastal areas of currently low productivity offer tremendous opportunities to be harnessed with adoption of proper strategies backed by well-focussed action plans, such that agriculture is more productive, profitable, sustainable, competitive and eco-friendly.

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Managing natural resources in coastal India – Initiative by CSSRI and future strategies

D. Burman and Subhasis Mandal

Central Soil Salinity Research Institute Regional Research Station
Canning Town - 743 329 (West Bengal)

1. Introduction

High concentration of salts in the rootzone soil limits the productivity of nearly 953 million ha of productive land in the world. Australia, followed by Asia, has the largest area under salinity and sodicity. Most of the salt-affected soils and brackish ground water resources are confined to arid and semiarid regions and are the causative factors for triggering the process of desertification. The problem of salinity and sodicity has degraded about 6.73 million ha area in India (Singh, 2009).

The coastal agro-ecosystem of India occupies an area of about 10.78 M ha along the 8,129 km coastline (Velayutham *et al.*, 1998). The coastal eco-regions of India are marked as one of the traditionally backward and disadvantaged areas with low agricultural productivity. The cropping pattern is predominantly mono-cropped with low yielding traditional rice varieties in wet season. The farming community of the coastal regions is dominated by very poor, marginal and landless farmers with abject poverty, and the land holdings are generally small and fragmented. In the coastal region of India, agriculture and allied activities are the major livelihood of the people but the productivity is usually very low as it is hindered by cluster of problems. Degraded soil (saline, alkaline, acid sulphate, deep waterlogged, flood prone, and poorly drained) along with abundance of brackishwater that are not suitable for irrigation, coupled with climatic constraints and weather hazards, are some of the major problem areas. The area is otherwise normally endowed with rich biodiversity. The recent threat of sea level rise due to global warming has further aggravated the miseries of people living in the coastal areas and the trend may be on the increase in future. Of significant importance is the threat to the very stability of the ecosystem for which a large number of factors besides climatic are responsible. It is, therefore, of importance that perspective research initiatives at national level be taken up on priority to address the problems of coastal ecosystem.

2. Key Challenges for coastal agricultural development

Some of the key challenges and potentials for development of coastal agriculture in India has been reported in the CSSRI vision document (CSSRI 2012). These are

- *Degraded or poor quality of soil and water : Due to frequent tides & floods, and intrusion of brackish water to agricultural field*
- *Saline Groundwater table at shallow depth: Mostly in flat plains due to influence of sea water*
- *Lack of good quality irrigation water: Due to absence of any major irrigation project while the ground water is saline. Lack of suitable and efficient irrigation methods for conjunctive use of available water resources and want of good quality water resources with objective to increase crop water productivity*

- *Heavy rains in monsoon and meager rains afterwards (high precipitation is skewed to few months only and dry spell thereafter): Agriculture is entirely rain-fed*
- *Drainage congestion & water logging: Due to flat topography, shallow water table, heavy soil texture and high intensity of rain during monsoon periods*
- *High humid: Due to nearness to the seas*
- *Poor productivity: Due to lack of sufficient number of HYVs of different crops having resistance to adverse soil and water stress situations*
- *Poor mechanization in field: Due to lack of available choice related to equipment and other agricultural implements*
- *Marketing and processing of agricultural produce: Lack of access to stores and markets at sites, poor roads and transportation, and no means of processing unit.*
- *Poor animal health: Due to high temperature and humidity for prolonged period*
- *Weather adversities: The region very frequently suffers from cyclones, tropical storms, sea surges, climatic depression, floods, droughts, active wave action etc. related climatic hazard, particularly in the East coast region*
- *Fragile ecology: Highly fragile and vulnerable ecology may endanger inland areas, if not properly conserved.*
- *Climate change vulnerability: Sea level rise may submerge many areas with sea water with further degradation of land and water, may cause change in cropping pattern, many habitation may be displaced, and possibilities of more sever cyclone and storms.*
- *Very poor farming communities with poor knowledge and skill: Majority of the farming communities are marginal to small with very poor socio-economic status who are not aware of the improved technologies and also cannot afford the cost of technologies*
- *Lack of adequate coordination of research activities through a network at the national level*

3. Key potential strength of the coastal area

a) *Excess rainfall in wet season that goes waste into the sea*

Excess rainfall can be harvested to:

- Create irrigation resources for dry seasons and for multiple cropping
- Reduce the soil & water salinity build up
- Rain water harvested in farm can give a scope for agriculture- aquaculture farming system

b) *Heavy texture soil, GW at shallow depth & high humidity*

- There will be less loss of harvested rainwater.

c) *Ample supply of brackish water*

- A potential but underutilized resource, which can also be used for enhancing productivity of the coastal lands.

e) *Availability of technology for crop, soil and water management*

f) *Responsiveness of soil to improvement in crop yield*

g) *Agriculture and aquaculture are the livelihoods for majority of people, while animal husbandry remains the occupational livelihood for mainly the marginal and landless farmers*

h) *Active human resource availability*

- Younger, active and literate generation available for pursuing agriculture as primary occupation

4. Initiative by Central Soil Salinity Research Institute (CSSRI)

The vast deltaic region on the East Coast forms the rice-bowl of the country. Agriculture, agroforestry, silviculture and pisciculture are few of the major activities in this zone, but the productivity is very low due to a variety of constraints which warrants special attention. The degradation of the soil and water of coastal areas is caused due to phenomena like saline water flooding following cyclonic storms such as *aila, tsunami* waves and the presence of shallow brackish ground water table near the soil surface due to the influence of seas or saline water rivers as in the delta region of Ganga (Sundarbans), Mahanadi, Godavari, etc. major rivers. The degraded soil and water of the coastal region will be further endangered due to sea level rise following global warming. With proper scientific planning and management of the vast natural resource of the coastal region it is, thus, possible that the agricultural productivity of the degraded soil and water can be increased considerably.

Based on research on coastal saline soils, several technologies have been developed and tested at this research station as well as in the farmer's field by CSSRI, RRS, Canning Town (WB). The strategies for improving the farming conditions in costal salt affected areas have been focused primarily on two ways (1) developing salt tolerant crop varieties and (2) rainwater harvesting through different land shaping models. Rice is the major crops grown in both seasons (*kharif* and *rabi*) and therefore, high focus has been given on developing and dissemination of salt tolerant rice varieties since inception of this research station. Several rice varieties have been evolved by the CSSRI. Some of these rice varieties are *Mohan* (CSR 4), CSR 6, *Canning* 7, CST 7-1, *Sumati* (CSRC (S) 2-1-7), *Utpala* (CSRC (S) 11-5-0-2), *Bhutnath* (CSRC(S) 5-2-2-5), CSRC(S) 21-2-5-B-1-1, CSRC (S) 7-1-4 and *Amalmana*. These varieties have been evolved and released for the coastal salt affected areas and continuous efforts are being made for larger adoption.

Some of the successful research areas carried out on managing natural resources of coastal environment can broadly be summarized as (1) Control of soil salinity through mulching/cover crop, (2) Management of coastal acid sulphate and saline soil, (3) Nutrient management for coastal saline soils, (4) Managing rice fields against toxic gasses, (5) Efficient water management through micro-irrigation systems, (6) Managing arsenic contaminated water for irrigation, (7) Improved salt tolerant rice varieties and (8) Land shaping techniques and rainwater harvesting for enhancement of productivity.

The work on rain water storage in surface ponds at CSSRI was started during 1970-71 when three dugout ponds were excavated (CSSRI, 1971). The surface storage and rainfall water yield relationship as well as ground water table depth was computed. So far construction of rainwater harvesting structure on watershed scale was given importance to arid and semi arid region where rainfall was comparatively low. Information on hydrological impacts of rainwater harvesting structure in coastal ecosystem on farm level was relatively meager. During 1980, under the leadership of Dr. KVGK Rao one pond of 0.15 ha with a depth of 3 m for demonstration-cum investigation was excavated in a farmers' field of 0.8 ha in Sundarbans region for developing suitable methods to store rainwater and its use for irrigation in winter. About 1400 m^{-2} area was raised by about 15 to 20 cm with the dug out earth (CSSRI, 1981). The work on paddy-cum-fish farming/brackish water farming during summer fallow period were also started in coastal low land rice fields during 1982 (CSSRI, 1982). The sequential-cum-synchronous types of paddy-cum-fish culture involved land reshaping by digging 1m deep by 1m wide trench along the boundary or across the rice fields depending on its size and shape to facilitate fish growth and further use of the excavate soil to erect 0.5 m high and 1.5 m wide peripheral dyke. The dyke was used to grow vegetables thereon (Biswas *et al.*, 1991). An inlet-outlet sluice was fitted between the feeder canal and the plot to regulate the tidal water flow for brackish water farming during summer. During the first three months (April-June) sequential brackish water culture *Penaeus monodon* (tiger prawn) and *Liza parsia* (1:1 stocking ratio at a total stocking density of 75000 ha^{-1}) was cultivated in paddy plots by using highly saline tidal water (EC 12.5-23 dS m^{-1}), During *Kharif* season from two week after transplanting 20 cm deep water was retained in paddy plots which was utilized for synchronous culture of fresh water fishes (rohu, catla, mrigal, silver carp) and prawn juveniles at a total stocking density of 23500 ha^{-1}. Five different cropping patters rice, rice + fresh water fish, rice + brackish water fish, rice + fresh water fish + brackish water fish, rice+ fresh water fish + brackish water fish + vegetable were tested. The maximum yield was obtained when brackish water aquaculture was combined with fresh water fish-cum-*kharif* rice together with vegetables on the dykes and gave 39% additional net income over the traditional practice of mono cropping with rice. The system was continued for successive eight years from 1982-1989 and soil salinity was came down from 14-24.8 dS m^{-1} to 3.5-7.8 dS m^{-1} with the onset of monsoon rain and no trend of salt accumulation was observed over years in this study.

In coastal area the land shaping technique is a unique technology for addressing the key challenges like land degradation (salinity), drainage congestion and scarcity of fresh water for irrigation and in turn have the potential to enhancing production, productivity, income and employment. These techniques particularly farm pond and paddy-cum-fish are financially viable and attractive proposition for the coastal region. However, for larger adoption of these technologies need to address some key issues like socio-economic constraints, some of which can be addressed by research level (e.g., land configuration, soil quality) some other at policy level (e.g., financial incentives). Major constraints for adoption of land shaping techniques are marginal land holdings that too divided into several parcels, high initial investment, presence of acid sulphate soils near surface or at shallow depth at places, distance from residential village etc. Community based rainwater harvesting as well as common pool wasteland may be encouraged in this direction (Mandal *et al.*, 2013).

5. Issues and Future strategies

In coastal areas of Andhra Pradesh, many rice fields are being converted into brackish water fish farms due to high remuneration from aquaculture for more than a decade. They revert back to rice cultivation but are unable to grow a successful crop because of severe salinity in the pond soils (Singh, 2009[b]).

The development of successful saline agriculture will require a greater understanding of the potential of plant species to withstand ambient salinity and sodicity levels in soil and water, and also of the uses and markets for the agricultural products produced. In case salt-affected lands do not belong to individual farmers but to the state—a common property of the rural community used for animal grazing without any control or dusty playground used by the village youth—developing suitable combinations of plant species may be a promising option to restrict and reverse land degradation. The use of salt-affected land and saline water resources through crop diversification options should therefore be considered as an opportunity to shift from subsistence farming to income-generating ventures (Qadir *et al.*, 2008).

The Ganges delta is distributed over Bangladesh and a major part of West Bengal (India). At the extreme south, the delta is about 360 km wide along the Bay of Bengal, and in terms of area about 80,000 km^2 distributed over the two countries classifying Ganges delta into Moribund delta, Mature delta, Tidally active delta and Active delta. Throughout Pleistocene times, the site of active deltaic sedimentation has switched due either to geological factors combined with changes in the river hydrology, the latter particularly in the recent times owing mainly to human interventions, thereby affecting adversely the entire process of livelihood system including agriculture, aquaculture, and all related spheres by and large in the entire lower Ganges delta. Now, the Ganges merges with the Brahmaputra, and the site of active sedimentation lies to the east as the tidally dominated part (TDGD). With increasing population pressure and other anthropological factors along with trend of seawater rise vis-à-vis global warming and various other factors majority of the areas remain highly fragile in nature and ecologically unsustainable. Agricultural productivity including aquaculture, being the principal areas of occupation of the majority, are generally poor because of various constraints, which, along with ecological vulnerability, are responsible for abject poverty and uncertain livelihood of the local inhabitants in this ecosystem. There is need for a holistic look at the entire problem in order to seek for future road map for higher and sustainable productivity in agriculture and aquaculture and improved livelihood status of this contiguous area stretching over two countries with almost similar problems. It should be remembered that the future steps for improvement should be of mutual benefit to both the countries, more specifically the TDGD, acting as a sink of the entire river system originating thousands of miles upstream, with full regards to hydrology as well as the geo-political factors over the entire course of flow. Unfortunately, this has not happened in the past in full spirit making both countries suffer so far (Sen *et al.,* 2012).

Development of technologies by Scientists/researchers alone cannot solve the problem of farming communities unless the process of technology dissemination is complemented by desired policy initiatives. Very often the technologists failed to understand why despite being their technologies economically viable, farmers are reluctant to own that technologies. Is it because the farmers' behaviour is stubborn or irrational and they are afraid of any change? But the fact is farmers' have to operate their farming operation under host of socio-economic conditions that affects their decision to adopt new technologies. Socio-economic factors like input prices, market environment, fragmented and small/marginal land holdings, availability of own or hired human labour, labour wage rates, financial and credit needs, availability and capacity to absorb, risk preferences etc, all these factors affect the adoption behaviour towards new technologies. Resource poor farmers, particularly of coastal region are naturally risk averters and prefer to be safe than sorry. They tend to prefer a lower outcome that is relatively certain to the prospect of a higher return with a greater degree of uncertainty is attached. Farmers prefer stability of output even with a lower return rather than the high-cost-high-return technologies where the instability of output is much higher.

Existing market environment and marketing status of agro-products, particularly the un-processed commodities, availability of remunerative / reasonable prices are very crucial to change the cropping pattern towards high value crops and also crop diversification. Market prices are the key drivers to change the farm economy but we all are aware of the high price volatility in agri-marketing sector that adversely affect the up-scaling of these agro-technologies. Role of finance, credit needs and crop insurance are the major players to push the new technologies in farmers' field and in turn uplift the rural economy. It is important to understand the credit needs and credit absorption pattern in the rural areas for agri-enterprises development.

6. Conclusion

The complex problem of coastal areas involving the lives and livelihoods of millions of people, typical of this ecosystem, has not received adequate attention so far proportionate to the magnitude of diversity of the problems. There is a need to understand and resolve issues on large-scale technology dissemination covering the areas of input-supplies & management; market & marketing environment – the driver of change in cropping pattern and production; credit needs & absorption of the farmers, and the role financial institutions therein; finally to highlight the grassroots level experiences, success stories and lesson learned. This requires well-planned and strong multi-disciplinary approach in a systems mode. In addition, climate change is no longer a distant reality now and the impact of hazards due to climate is expected to be still more severe on coastal areas in future, particularly on its large population and agriculture. Research on adaptations in agriculture to the changing environment and scientific mitigation strategies are essential to safeguard livelihoods of millions thriving on coastal agriculture and maintain overall ecological balance.

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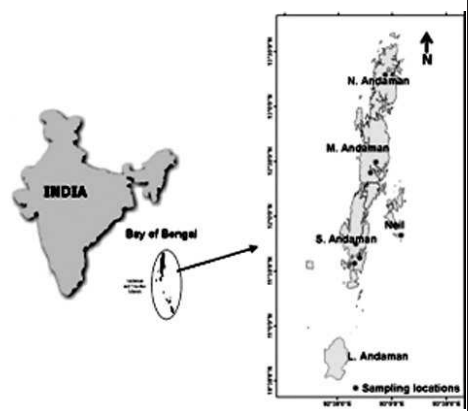
Managing soil and water for better livelihoods under island ecosystem – issues and technological options

A. Velmurugan, T. P. Swarnam and S. Dam Roy

Central Agricultural Research Institute, Port Blair - 744 101

1. Introduction

Land is one of the most important natural resources for sustenance of life which embodies soil, water, flora, fauna and involves the total ecosystem. Soil and water are two most important natural resources, the management of which had been associated with human civilization itself. But, the interest in soil and water management in recent times has been stimulated as a consequence of unsustainable land use and threatening impacts of climate change which seriously affects agro-ecosystem functions and its capacity to support human as well as other life forms. The problem assumes serious proportion when these resources are limited in supply and the human population overwhelmingly depends on them as a means of livelihood. The management of soil and water resources with appropriate technology is the key for providing livelihood and sustaining the economic activity in an island condition with limited land area, inadequate fresh water storage, intricate production system, and limited choice for crop combinations. Thus appropriate production technology for island conditions and its management strategy for field level adoption are very essential for sustainable livelihood security.



2. Island ecosystem of Andaman and Nicobar

Andaman and Nicobar group of Islands located in the Bay of Bengal are ecologically rich and strategically more important. The Island has undulating topography characterized by hills and longitudinal valley areas. It experiences typical hot and humid tropical climate. Both southwest and northeast monsoons bring heavy downpour from May to December. The average annual rainfall is 3100 mm with 154 rainy days of which maximum rainfall is received during southwest monsoon season. As these islands are situated close to the equator the evapo-transpiration is also very high due to intensive solar radiation received especially during dry months where it far exceeds the rainfall resulting in water deficit condition (Fig. 1).

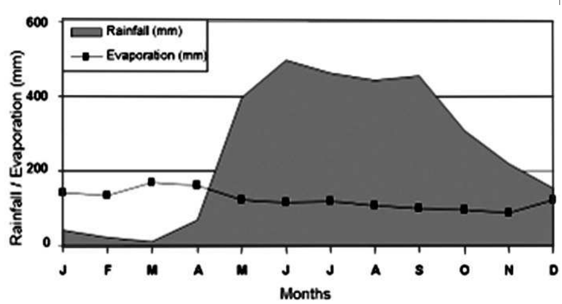
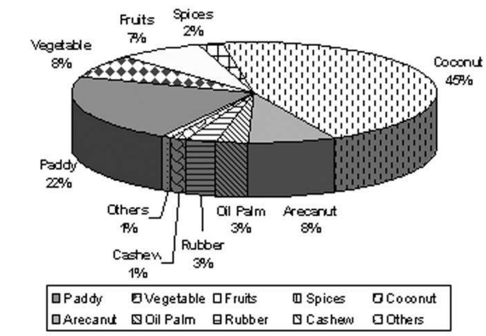


Fig. 1. Climatic parameters of A&N Islands

The relative humidity varies from 68 to 86% and the maximum and minimum temperature is 32 and 22 °C, respectively during different months. Due to the prevailing climate and favourable edaphic conditions the island is rich terrestrial and aquatic biodiversity most of which are very unique to these islands.

3. Area and Production of important crops

Out of the total geographical area of 8,249 sq. km forest accounts for more than 90% of the area and the land available for agricultural activities are about 50,000 ha. The present land utilization pattern of A&N Islands is given in Fig. 2.



* Area includes intercrops as well (Source: Statistical Handbook of A&N, 2011)

Fig. 2. Area under major crops in A & N Islands

The total area under major plantation crops is 69% of total cultivated area which includes area under intercrop as well. Coconut and arecanut alone accounts for 53% of area followed by oil palm and rubber. After tsunami not more than 10,000 ha area is under rice-vegetable system and 20% of the cultivated area is under annual crops. The pressure created on plantation areas by increasing population and tourism sector for safer sites is alarmingly rising. Simultaneously there is no scope for area increase either by converting forest land or area under other crops.

Over the years the area under plantation crops remained static till 2004 tsunami after which it decreased, while there is no significant increase in the productivity. The productivity of rice is low (2.2 t/ha) and vegetable production suffers from the contrasting problem of water shortage during dry season and damage due to heavy rain during monsoon season.

4. Physiography of the Island

The physiography of these islands has profound influence on the distribution pattern of different land use / cover apart from hydrological cycle and soil resources. The islands are generally divided into longitudinal hills, upland, mountain and coastal valley which can be seen in Fig. 3.

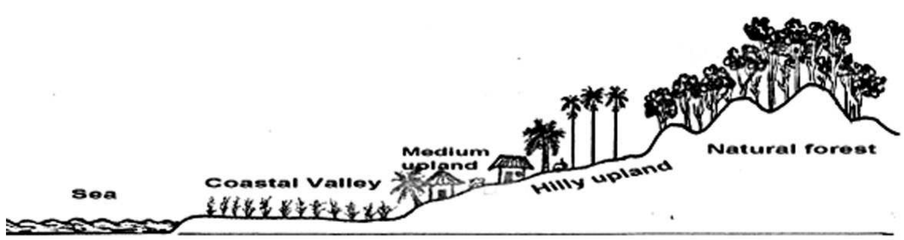


Fig. 3. Different physiography and land use in a typical cross of A&N Islands

The topography of the island is rolling with low range hills to narrow valleys at the foothills resulting in an undulating terrain ranging from steep slopes (>45°) to coastal plains (<10°). Except the Kalpong river in North Andaman, perennial streams of the status of river are absent in these Islands. Nearly 75 percent of the rainfall received in the islands is lost due to undulated terrains, steep slopes, porous soil stratum and its proximity to the sea. Thus, harvesting, storage and recycling of rain water is the only source of fresh water availability and forms the most important technological challenge for natural resource management in these islands. Apart from this, the coastal plains experiences water logging during rainy season and the situation gets worse when the peak rain fall coincides with the high tides. Thus, to provide sustainable livelihood under island conditions, proper management of water and soil resources in relation to climate and topography forms the basic strategy.

5. Issues

5.1 Soil fertility and erosion

Soil acidity is one of the most prevalent problems for crop production in Andaman Islands where 70% of the agricultural area is affected due to intensive weathering and leaching of soluble salts caused by existing hot, humid tropical climate. The soil fertility status of these islands shows that the soils are low to medium in available N, P and K (Fig. 4). Potassium is deficient due to leaching from the slopes as there is no external input into the soils (Ganeshamurthy et al. 2002). The productivity of acid soils is limited by the presence of toxic levels of Al^{3+} and Mn^{2+} and deficiency of nutrients such as P, Ca, Mg, Zn and Mo. Aluminium toxicity due to high exchangeable Al, reduced P uptake due to low available soil P and high soil P fixing capacity are the main factors affecting growth and yield of crop plants on acid soils. The analysis of surface soil samples from different land uses of Andaman Islands (Table 1) indicated that iron (Fe^{2+}) and manganese (Mn^{2+}) content are exceeding the respective critical limit indicating potential toxicity to plants. Besides Al^{3+} toxicity was also found in soils where pH is less than 5.5 (Swarnam and Velmurugan 2013).

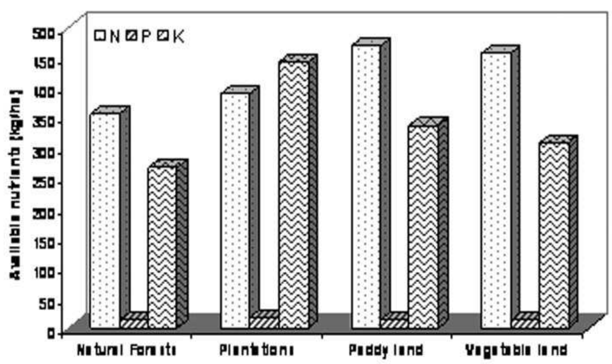


Fig. 4. NPK status of soils of different land use

Besides soil acidity the other major problem is the soil erosion due to heavy and intensive rainfall occurring in these Islands. The soil loss from vegetable field under no till conditions, coconut plantation, arecanut plantation, home garden and natural forest was found to be 3.8, 12.4, 10.6, 8.4 and 2.3 tonnes/ha, respectively (Pandey and Chaudhari 2010). As soil under island condition is limited in supply and most precious natural resource its conservation is very essential for sustainable agricultural production.

5.2 Water logging and moisture stress

The Islands face the twin problems of waterlogging especially in coastal plains and valley areas during monsoon season and water scarcity during dry season. These problems restrict crop diversification in plains and valley areas during rainy season where no crops other than rice can be grown from May to November. Though these islands receive more than 300 cm rainfall annually, water deficit during dry season is a major problem due to high evapotranspiration, seepage, gravitational flow and poor ground water storage requiring supplemental irrigation for successful crop production. This requires suitable water harvesting and storage structures at different physiographic locations.

5.3 Shrinking land resources

Due to the 2004 tsunami and sea level rise 11,000 ha of agricultural land and 9,100 ha of plantation area and 4,918 ha of forest area have been damaged in the territory affecting the livelihood of about 6,000 farmers and the total loss exclusively in agricultural sector is estimated to be in the tune of Rs. 321 crores. Sea water inundation of cultivated lands caused by tsunami has adversely affected various soil properties of A & N Islands (Chaudhuri et al 2006). The salinity level in soils taken after tsunami varied from 7.2 to 22.9 dSm^{-1}, besides higher concentration of Na^+ (51 -293 meq l^{-1}), Cl (41 -218 meq l^{-1}) and SO_4^{2-} (21 – 101 meq l^{-1}) (Raja *et al.* 2009).

5.4 Low productivity

In the Islands, the productivity of major crops like rice and coconut are much lower than the national average. Most of the plantation crops are grown with limited management and with less inputs resulting in lower productivity of these crops. Rice is grown with poor management where only limited amount of fertilizers are applied and no weeding is carried out because of lack of farm labours. In addition monocroppping without proper spacing is followed in majority of the plantation areas resulting in less diversification and employment opportunities.

6. Technological options

In Andaman and Nicobar Islands there is no scope for expansion of agricultural area into the forest land as there is a blanket ban on clearance of forest land for agriculture purpose. At the same time the land is called to produce more from the existing area to meet the diversified demand for agricultural produces. Thus, more emphasis on appropriate production technology is to be given as soil and water are the major limiting factors of productivity enhancement. In addition, marginal and degraded lands can be reclaimed to explore its suitability for cultivation in addition to phased conversion of existing plantation crops into high density plantations with suitable intercrops so as to provide sustainable livelihood to farming community of these islands.

6.1 Management of soil fertility

As majority of the cultivated area is under plantation crops in the hill slopes and valley where the soils are acidic, management of soil acidity provides additional income to farmers by improving crop productivity. In addition, improvement in soil condition may lead to crop diversification and intensification in these areas. The consumption of inorganic fertilizers in plantation is very low mainly due to the cost factor, heavy rain and fluctuating price trends of the produce. Some soil properties given in table 1 indicate Fe^{2+} and Mn^{2+} toxicity and Zn^{2+} deficiency at some locations (Table 3.1). Therefore, to maintain and improve soil fertility and to achieve sustainable production in coconut, arecanut and other plantation crops soil test based application of soil amendments, organic manures and micronutrient is of utmost importance.

Application of lime to acid soil receiving high rainfall is a costly proposition because of lack of its local availability and high transportation cost from mainland, besides, the existence of low input agriculture in these Islands. The experimental results indicated that coconut husk compost along with poultry manure or vermicompost can be a viable option for acid soil. The liming effect was observed for a period of 150 days which is good enough to provide favourable condition for crop growth especially for any seasonal crop.

Table 3.1: Organic nutrient and enrichments (Andaman & Nicobar Island)

Land use/ Location	pH	EC (dS m^{-1})	OC (%)	DTPA extractable micro Nutrients (ppm)				HWSB (ppm)
				Fe^{2+}	Mn^{2+}	Zn^{2+}	Cu^{2+}	
North Andaman								
Plantations	5.73	0.15	0.81	13.80	6.32	0.23	0.21	0.097
Paddy land	5.78	0.11	0.66	15.90	6.41	0.25	0.11	0.177
Vegetable	5.35	0.11	0.58	15.02	4.79	0.20	0.13	0.122
South Andaman								
Plantations	5.72	0.09	0.60	12.17	9.26	0.50	0.11	0.358
Paddy land	5.99	0.04	0.66	13.61	3.81	0.36	0.23	0.340
Vegetable	5.76	0.10	0.53	11.02	9.60	0.38	0.28	0.220
Car Nicobar								
Kitchen garden		0.82	0.71	3.57	1.15	0.45	0.16	0.27
Plantations		0.76	0.92	4.37	1.37	0.47	0.08	0.15
Critical limit				4.50	3.00	0.60	0.20	0.15 -0.5

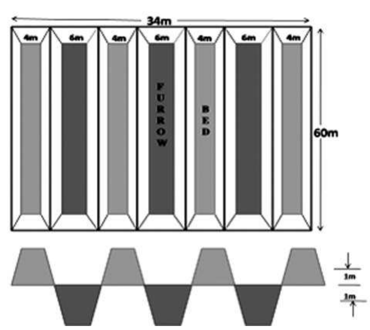
Potassium is a major limiting factor in arecanut growing areas. Other plantation crops are grown in fine to medium textured soils with slight to moderate acidity, high in organic carbon, moderate in available N & P but deficient in K and some of micronutrients. Thus application of vermicompost to coconut @ 25 kg/tree/year is recommended. Micronutrient @ 5kg/ha and rock phosphate @ 25 kg/ha can be mixed in the vermicompost tank 15-20dayhs before harvest so as to improve the crop availability for long period.

6.2 Land shaping methods for soil and water management

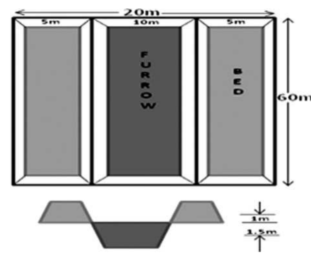
In coastal low land water logging during considerable part of the year is the major problem. In low lying valley it exceeds more than 1 metre during peak rainfall hours under island condition. In addition acid saline soils of coastal areas aggravate the problem and limit the crop production. The scope lies in different land shaping methods to restore agricultural production in these degraded lands. The methods are described below:

i) Broad Bed and Furrow System (BBF)

In this System beds of 4 - 5m width and furrows of 5 - 6m width with minimum 1m depth are made. Atleast 0.5 m slope is provided at both end of the furrow. Raised beds can be used for cultivation of vegetables. Paddy cultivation can be taken in furrows. In addition to paddy and vegetables fish can be integrated in furrows. This system provides the scope for insitu rainwater harvesting and enables the scope for second crop cultivation during dry seasons.

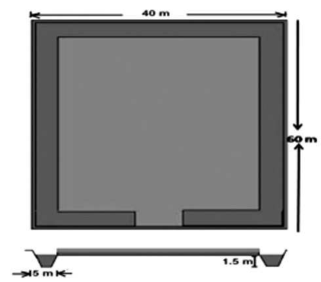


ii) Paired BBF



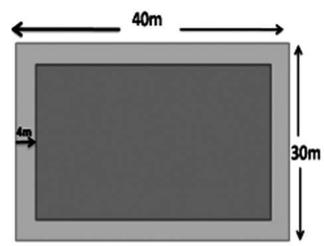
This system is a slight modification of BBF and is a boon for small land holders. In this System two beds of 6 m width and one furrow of 10m width with minimum of 1.5m depth are made. Raised beds are used for cultivation of vegetables. Deep water paddy cultivation is taken up in the furrow integrated with fish culture. Intensive vegetable cultivation is practised in the broad beds. This system also provides the scope for insitu rainwater harvesting and enables the scope for second crop cultivation during dry seasons.

iii) Paddy cum Fish System



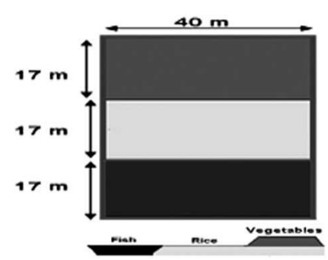
Paddy is the main crop along with fish is grown in the furrow of 5 m width and 1.5 m depth. Vegetables and fruits are grown all around the field in a raised bed using harvested water. This system is made by digging trenches of about 5m width and 1.5m depth around the field. This system also provides the scope for insitu rainwater harvesting and enables the scope for second crop cultivation during dry seasons.

iv) Farm pond



Farm pond is constructed to harvest rainwater during rainy seasons. The harvested water can be used during dry season for agricultural activities. Fish along with duck can be integrated in this approach. Addition of poultry shed enhances plankton growth in ponds which ultimately leads to enhanced fish growth as the droppings of the poultry serves as a source of organic manure to the pond. The depth of the pond should be atleast 2.5 m and round the year vegetable cultivation is taken up in the bund.

v) Three tier system



This System involves the shaping of low lying land into three equal portions (1/3rd each) as raised land, mid or original land and pond. Pond (2.5 m depth) is in the lower part of the sloppy land which can be used for harvesting rain water thus reducing water logging and for fish culture. Paddy cultivation in mid land along with vegetable cultivation in raised land (1 m height) is possible.

All the above systems perform better in preventing water logging in low lying areas and restoring agriculture in saline areas by efficient water management. If the interventions are made in a cluster approach then it is possible to provide a common drainage facility which will benefit the entire area and stability of the interventions made. Further there will be a gradual improvement in the degraded soil and water quality after intervention.

6.3 Water harvesting and crop diversification

All the land shaping interventions provides ample scope for crop diversification integrated with pisciculture due to the availability of water as well as better drainage in the beds. The water harvesting capacity and the area available for crop diversification is given in the following Table 3.2.

Table 3.2: Water harvesting capacity of land shaping Interventions (Andaman & Nicobar Island)

Interventions	Vol. of water harvested (m^3)	Raised bed area available for crop diversification (m^2)	Cropping intensity (%)
Broad Bed and Furrow system (BBF) (0.2ha)	1119	932	300
Paired BBF (0.2ha)	600	610	300
Paddy cum Fish System (0.24ha)	1200	1000	200
Multi tier System (0.2ha)	1080	1560	250
Farm Pond (0.2ha)	1000	600	200

Besides vegetable cultivation on the bed, fruits and fodder crops can be grown on the slopes of raised bed in addition to fish in the furrows. This is expected to support animal husbandry and improve the productivity of the dairy sector as the island faces acute shortage of fodder. Hence a diversified farming system approach which leads to enhanced farm income for the improvement of livelihood security of farmers can be achieved through land shaping coupled with water harvesting in the coastal low lands of island ecosystem.

6.4 Salt tolerant high yielding rice varieties

One of the main constraints for rice production in the tsunami affected and low lying coastal areas of these Islands is the salinity besides water logging. Salinity tolerant high yielding varieties can be a viable option for these areas. Rice varieties viz., CSR 36, CSR 23 and CARI-5 are suitable for these conditions which can give upto 4 ton /ha yield under normal management conditions and atleast 2.2 t/ha in a very limited management condition.

6.5 Fish culture

Fish culture is one of the most potential ventures in this island where the market demand is more for fresh water fishes due to demographic features. The land manipulation technique enhances effective land use, farm productivity and employment generation. However, adequate capacity building programmes are very essential to encourage the farmers to go for seed production of Indian Major Carps (IMC) and the significance of satellite nurseries were also emphasised to the farmers to meet the local demand for fish seeds in a self sustained manner.

7. Conclusions

The integration of crops raised with or without different land shaping interventions along with livestock, poultry, fishery, horticultural crops, agro forestry in addition to effective recycling of wastes will ensure increased farm income and sustainable livelihood security of these islands.

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Adaptation of Agriculture in the Indian Sundarbans

Soma Saha, Anish Chatterjee and A. Anurag Danda
World Wide Fund for Nature- India, New Delhi

1. Introduction

Climate change poses a serious threat to human survival, food security, natural resources, human health, economic activity and physical infrastructure. Though the multi-faceted impacts are felt at all levels, inhabitants of fragile ecosystems in developing countries are likely to be hardest hit.

Sundarbans delta, the only abode of the Royal Bengal Tiger, in the globe, with highest species diversity of mangrove along with human population of nearly 4.5 million (and 7.5 million in Bangladesh) is presently under threat due to relative sea level rise, changes in sea surface temperature, occurrence of cyclone events, and changes in the precipitation pattern.

2. Impact of climate change on Sundarbans:

The people of Sundarbans have observed the changes in weather events. In order to understand these changes, field interviews were conducted with the people of the Sundarbans. These perceptions were then validated from analysis of scientific weather data. The observations are summarized below to understand the situation.

Sundarbans is presently under the threat of severe coastal erosion due to relative sea level rise (Hazra et al, 2002). The analysis of 50 years of data from the Permanent Service for Mean Sea Level (PSMSL) from three of the four data stations in the Hugli estuary appears to show sea level increase of between +0.76mm/year and +5.22mm/ year at different locations in the eco-region. However, the tide gauge data of Sagar Island observatory for the period of 2002 – 2009 indicated a rise in the Relative Mean Sea Level (RMSL) at the rate of 12mm/ year during the decade (Hazra, 2010). Considering the record of past 25 years, the rate of relative sea level rise comes close to 8mm/ year, which is significantly higher than the rate of 3.14mm/ year observed during the previous decade (Hazra *et al.*, 2002).

In addition to relative sea level rise, global warming and subsequent thermal expansion of water, subsidence in the Sundarbans delta, compaction of silt and other local causes are also responsible for the exceptionally high rate of relative sea level rise in Indian part of Sundarbans (Danda *et al.*, 2011).

The eco-region is also experiencing rising average daily minimum temperature. A study of 80 years (1891 – 1970) temperature data reveals that the average daily minimum temperature has increased by 0.6°C and average daily temperature has increased by 0.1°C during this period. After 1970, increasing trend is well marked and more marked after 2000. An analysis of daily maximum, daily minimum, average daily and diurnal range of temperature data of Sagar Island of last 112 years (1891-2002) brings out some important features which are summarized in the following Table 4.1.

Table 4.1: Analysis of 112 years temperature data of Sagar Island, Sundarban, West Bengal

Period	Temperature in ° C			
	Average daily maximum	Average daily minimum	Diurnal range	Average daily
1891- 1930	29.658	22.935	6.723	26.296
1931- 1970	29.249	23.510	5.739	26.379
1971- 2002	29.471	23.660	5.811	26.545

From the above table it is clear that daily minimum temperature is rising faster than the daily maximum temperature resulting in a gradual decrease in diurnal range. This affects the primary productivity of the eco-region.

Surface air temperature of Bay of Bengal is rising at a rate of 0.019^{0}C per year along with rise in sea surface temperature at a rate of 0.0453^{0}C per year (Hazra, 2010). Increasing sea surface temperature is directly related with the increased frequency and severity of cyclonic storms and depressions in Bay of Bengal (Mishra, 2012).

Analysis of cyclonic events over the last 120 years indicate a 26 per cent increase in the frequency of high to very high intensity cyclones over this time period (Singh, 2007).

After having studied the scientific data regarding the changes in weather phenomena and ground truthing the information, one of the most vulnerable Islands was selected to undertake interventions towards adaptation.

3. WWF-India in Sundarbans

WWF-India is working in the Indian Sundarbans since the inception of Project Tiger in 1973 and is addressing climate vulnerability and adaptation issues since 2007 through small projects ensuring risk preparedness and enhancing adaptive capacity. Aiming to build a climate resilient Sundarbans that supports biodiversity, ecosystems services and sustainable development, WWF-India is demonstrating and mainstreaming adaptation approaches.

With the focus of reducing risk in terms of physical and livelihood security, WWF-India is engaging the local community through various outreach and demonstration activities. Mangrove regeneration, strengthening of embankments, early warning and effective disaster response are geared towards enhancing physical security of the vulnerable population whereas salt-tolerant paddy cultivation and pisciculture using specific fish species that can withstand salinity shock is aimed at reducing livelihood risks.

Mousuni is a small island, about 24 square kilometers with a population of about 20,000. This island comes under the jurisdiction of Namkhana Community Development Block of South 24 Parganas district, in the state of West Bengal. It has one Gram Panchayat namely Mousuni Gram Panchayat (last tier of the three-tier local self-government system). It has been further divided into four mouzas (revenue villages). It is one of the twelve southernmost islands in the Sundarbans region, which is highly vulnerable due to climatic events like cyclones, storms and tidal surges. The manifestation of impacts into accelerated coastline erosion and breach of embankment are very common and frequent in many parts of this island.

4. Interventions to achieve adaptation in agriculture

Almost 85 percent of the land in Mousuni, is under cultivation. Paddy (*Kharif* and *Rabi*) is the major source of livelihoods as well as food security for the local community. Paddy is mostly cultivated for subsistence and surplus, if any, is sold in neighbouring markets. However, changing weather patterns, frequent storms/cyclonic events and rising sea level has severely impacted the islanders. Periodic flooding of homestead and productive agricultural lands as well as inland water bodies has had a major impact on livelihoods of the community. Frequent flooding and incursion of saline water destroys houses, and renders agricultural land unproductive for at least next two years, resulting in sufferings of this agrarian community.

Since the last forty years after the "Green Revolution", farmers became dependent on high yielding paddy varieties (vulnerable to brackish water flooding), which require more chemical fertilizers and pesticides than traditional varieties. This led to elimination of most of the traditional paddy varieties (suitable to Sundarbans soil), grown by earlier generations.

To reduce agricultural vulnerability and increase crop resilience, traditional salt tolerant varieties were re-introduced by WWF-India. The interventions taken by WWF-India, so far are discussed below :

i. *Traditional salt tolerant paddy cultivation:* People are cultivating high yielding varieties (HYV) to harvest more from ever declining land holdings. As HYVs cannot withstand salinity shock, farmers are loosing their harvest in case of brackish water flooding and becoming vulnerable. To overcome this situation and reduce the crop loss, Talmugur, a traditional salt tolerant paddy variety has been re-introduced in this Island in kharif 2008. A lone farmer was able to harvest a crop despite brackish water flooding in 2009. The neighbouring farmers, who lost their crop in 2009, adopted Talmugur, after being convinced by the success of the lone farmer. Subsequently, in 2011, three more salt tolerant paddy varieties were re-introduced which showed better results. Till 2013, a total of six traditional salt tolerant paddy varieties are under cultivation. Measurement of salinity levels of soil and water were further advised by CSSRI, Canning, to empower the farmers to enable to select a particular salt tolerant paddy variety suitable to his land.

   Outcome: The farmers engaged in salt tolerant paddy cultivation reported assured harvest despite brackish water flooding. With minimal input costs, these varieties have reduced the cost of cultivation as well as reduced the chances of crop loss. The production of these traditional varieties, though a bit less (2416Kg/ha) than HYVs (3076Kg/ha), becomes significant in the area, as HYVs fail during brackish water flooding.

ii. *Pisciculture with saline resistant fish species:* Inland water bodies are mainly used for freshwater fish culture which is susceptible to brackish water flooding. This was experienced during cyclone Aila, when all fish stock of inland water bodies were destroyed due to flooding. This has prompted identification of fish species that can grow in fresh water as well as can withstand the shock of saline water ingress. Fish farmers with small water bodies, which are most vulnerable to frequent breach of embankment and loss of fish stocks, were identified for the demonstration project. Proper training and capacity building were provided to participants (as well as non participant fish-farmers). Identified fish species (Liza parsia, Liza tade, Mystus gulio and Scatophagus argus) are at an advanced stage of demonstration.

   Outcome: The fishermen are quite happy with the growth in fish stock, though harvesting is awaited.

iii. *Integrated Farming practices:* Prompted by the success of salt tolerant paddy and fish cultivation, from 2013, WWF-India has introduced Integrated farming systems, in collaboration with West Bengal University of Animal and Fishery Sciences (WBUAFS). Here we are facilitating duck farming along with fishery (to reduce the input cost of fish feed), vegetables and horticulture plants are being practised along the banks of small ponds. This is practised with the aim of enhancing the adaptive capacity of the small individual farmers in the island.

iv. *Climate Change Information and Adaptation Centre:* A Climate change information and adaptation centre has been established in Mousuni Island for information collection, collation, analysis and dissemination. Posters, charts and maps based on the information of this Island are displayed in the centre for dissemination of information to the local community. This centre is also serving as the nerve centre for the disaster response team(s) to operate at the time of crisis. The Centre, run by a managing committee (elected representatives of local community), gathers local information, disseminate knowledge (on preparedness, rescue, relief, adaptation measures) as well as generate awareness among the local community.

Outcome: State Forest Department, Agriculture Department, Panchayat and other NGOs (LWSI, CRS) are utilizing the platform of this centre for various purposes including training of community members (the centre has boarding and lodging facilities). The revenue earned is utilized for sustaining the centre.

5. Towards Adaptation

The terms 'adaptation' and 'coping' are interestingly confusing. Coping is a way of responding to an experienced impact with a shorter-term vision (for example, one/two season/s), and adaptation is the process of adjusting to change (both experienced and expected), which is longer term (for example, over a decade or longer). Coping is immediate, oriented towards survival. Adaptation strategies are "more proactive" in a sense as they are put into place to avoid turning natural hazards into disasters. The adaptation measures (traditional salt tolerant paddy varieties,fish cultivation and integrated farming systems) though planned, resource efficient, focused on finding alternatives and combines old and new knowledge (all the characteristics of adaptation), are oriented towards survival (characteristics of coping), at this point in time for the people in the island. We can claim this or justify these measures as adaptation only if these practices and results are sustained and only when these would provide longer-term livelihood security to the people.

The key is to being able to understand people's circumstances. It means bringing about a change in attitudes at the community level, which is a challenge and cannot be adjusted quickly. Not that coping is any less important. Only if the people can cope with the present situation can they avail the opportunity to adapt in the longer – term. Most adaptation strategies in the world, focus on coping with climate change effects. It is not clear exactly what changes the future holds, but projections generally agree that Indian Sundarbans (a part of the coastal ecosystem) will be exposed to changes such as higher temperatures, sea-level rise, more frequent and intense natural hazards and changing rainfall patterns. It is therefore necessary to think about how to adjust not only to these specific changes, but to the new uncertainty about our future climate. Climate change adaptation is the process of adjusting to new conditions, stresses and natural hazards resulting from a changing climate. The main problem is that most of us cannot visualise how to move from adaptation concept to practice, because there are few or at times no concrete examples to follow. Many countries are grappling with the question of how to adapt. They are uncertain about what adaptation implies exactly. Does it mean relocating entire communities living along riverbanks, in Indian Sundarbans? Does it mean building sea-walls as a defence against sea-level rise and storm surges? Or does it mean restructuring national institutions, policies and regulations on disaster risk reduction and natural resource management? Each of these approaches has financial, social, environmental and political implications, and following several approaches at once is usually financially and practically impossible. Deciding which strategy to select is a major question; how to actually design and implement it is a second major challenge. This is why we now talk about adaptation policies, plans and projects, which are supposed to facilitate the move towards adaptation on all levels – from the community to regional to the country levels. The goal of the adaptation process itself is to enhance people's resilience to climate change. Resilience is the ability of people to absorb shocks and quickly return to a prior state of well-being after a disturbance. Our efforts of saline resistant/tolerant fish and paddy cultivation are an endeavour to enhance their resilience, so that they receive competitive returns even after events of salt water inundation. The Climate Change Adaptation Centre, which disseminates information and knowledge related to climate change and adaptation measures and the infrastructure (of the centre) as a platform for utilisation by local government and other NGOs are proving to be extremely beneficial for maintaining the infrastructure, however it is too early to comment regarding its sustainability. These creative responses to climate variability and change have been designed to have a long-term positive impact. Moving from livelihood coping strategies based on risk aversion to a process of actually adjusting to a changed climate requires the right enabling environment to allow responses to take root and develop sustainably. Most people in the Indian Sundarbans are not well-adjusted to current climate variability. Hence, we can only claim that the people have adapted when the people are not only able to absorb shocks (allow people to become resilient) but also move beyond existing states of underdevelopment. From a practical perspective, this implies enhanced dialogue between actors on different levels. It means recognizing that transformation is necessary, as well as time and effort to rethink development trajectories in order for the transformation to take place. And it also means accepting that patience is needed for learning and shifts in attitudes. Adaptation can only happen at the local level if we really take the lessons and apply them in our policies, plans and projects as well as our attitudes and education systems. Then only we will make headway in reducing people's vulnerability to climate change, while also making gains in human well-being and the health of our ecosystems.

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Alternative options for better crop and income security in NAIP adopted villeges

S. Rahaman, A. K. Jana, U. Maity and N. J. Maitra

Ramkrishna Ashram Krishi Vigyan Kendra, Nimpith, South 24 Parganas

1. Introduction

The Sundarban falls under the Complex-Diverse-Risk prone (CDR) fragile agro-ecosystem situated between 20°2' to 22°6' North latitude and 88°25' to 89° East longitudes. It consists of 102 islands of which 54 numbers are inhabited and rest is protected forest, not open to public tapping. Although, agriculture is the mainstay of occupation for majority of the people, about 68% of the total cultivable lands is low lying, mostly mono-cropped and low yielding because of excessive rainfall resulting in water-logging due to impeded drainage system in monsoon. Again, scarcity of irrigation water accentuated by high salinity in soil during *summer*, inundation of brackish water in cultivable land and non availability of area specific technology for effective utilization of natural resources aggravates the problem to raise second crop in Sundarbans. The soil salinity particularly in *rabi-summer* season ranges from 2.0 to 8.0 mmhos/cm and soil fertility is medium. The climate of the region is sub-tropical humid where annual rainfall ranges from 1700-1800 mm and 80% of total downpour occurs during monsoon (June to September). The maximum and minimum temperatures hovers around 38°C and 15°C in the months of May and January respectively while maximum and minimum relative humidity has been found to be 90% and 60% in July and January respectively. More than 80% of the area in this region is occupied by a single crop of long duration traditional *kharif* paddy cultivated during June to December every year after which this land remains fallow after harvest of the *kharif* paddy due to late release of land, lack of irrigation and rise in soil salinity during *summer* months. During this season, most of the rural mass are forced to migrate elsewhere in search of their livelihood. Another constraint which is felt by the womenfolk of the region is the lack of fuel wood particularly during the rainy season. Hence, they venture deep into the forest to collect fuel wood with great risk on their lives. In this situation, through different interventions under National Agricultural Innovation Project (NAIP), Nimpith KVK tried to improve the farm profitability by intensification & diversification the crops with area specific technologies.

2. Different alternative options for augmentation of Agricultural production in NAIP adopted villages

2.1. Option I : Crop diversification through Sunflower cultivation:

Awareness of new varieties of oilseed crops under specific agro-climatic situation and better crop management practices can be achieved by the farmers which not only will increase the productivity of oilseed in a sustainable manner but also give a good economic return. In this regard, the scope of sunflower cultivation is better as the farmers adopt this crop very rapidly for their own consumption and also for using the thalamus as animal feed and stalk as fuel.

Through sunflower cultivation the rice fallows of Sundarbans can be effectively utilized. It has been found that through sunflower demonstration under NAIP it yielded 1.35 t/ha within a period of 3 months. The cost of cultivation was in the range of Rs.14980/- to Rs.15475/-per hectare. The net profit varies from Rs.15600/- to Rs.16000/- per hectare. On analyzing the cost of cultivation and the gross return it has been found that the crop gives a benefit cost ratio of 2.04.

Suitability with existing farming system in Sundarbans of west Bengal

Existing conditions	Before intervention	After intervention
Land situation	Low to medium	Low to medium
Soil type	Clay-loam	Clay-loam
Salinity	Below 3dS/m	Below 3dS/m
Irrigation opportunity	Less	Better utilization by incorporating less water demand crop
Cropping pattern	*Kharif* : Paddy *Rabi-summer* : Fallow	*Kharif*: Paddy *Rabi-summer* : Sunflower
Income	Av. Rs. 11250/- per ha	Av. Rs. 26750/- per ha
Creation of mandays	165 Numbers/ ha	315 Numbers/ha
Seasonal migration	More	Less

2.2. OptionII: Crop intensification through Cotton cultivation:

Due to late release of land after Kharif paddy including scarcity of irrigation water accentuated with soil salinity during *rabi*-summer season (3 to 5 dS/m), makes the agriculture ill developed and almost no crop is possible in that land situation during this season. Generally, the land remains fallow after *kharif* paddy and no income is generated during rest of the period. This mono cropped land gives a meager income to sustain the livelihood of the farming communities throughout the year. In this situation, most of the farmers have to migrate to city areas in search of livelihood. Besides, farm women used to venture into the deep forest with life threatening for collection of fuel wood to be utilized during rainy season. In this circumstance, through National Agricultural.


Before intervention


After intervention

Innovation Project (NAIP), RAKVK, Nimpith introduced cotton crop in the three island villages. As cotton is one of the deep rooted crop requiring less or no irrigation water and can withstand little bit of salinity, it grows well there providing countably good return against keeping the land fallow. The variety used as Surabhi having the duration of 155-165 days.

2.3. Suitability with existing farming system

The following tables give an idea about the extent of suitability of cultivating cotton in the Sundarbans in rabi-summer season. It is observed that earlier, only low land paddy was cultivated and the land remained fallow during rabi-summer. However, paddy-cotton sequence gave two times more income in rice fallow situation by utilization of residual moisture.

Before cotton cultivation

Type of land	*Kharif*			*Rabi*			Total profit/ Year (Rs/ha)
	Crop	Production (qt/ha)	Net income (Rs/ha)	Crop	Production (qt/ha)	Net income (Rs/ha)	
Low land	Paddy	22.75	13354.00	Fallow	–	–	13354.00

After cotton cultivation

Type of land	*Kharif*			*Rabi*			Total profit/ Year (Rs/ha)
	Crop	Production (qt/ha)	Net income (Rs/ha)	Crop	Production (qt/ha)	Net income (Rs/ha)	
Low land	Paddy	22.75	13354.00	Cotton	8.00	24000.00	37354.00

Before Intervention

After Intervention

2.4. Option III: Crop diversification through Sweet Potato cultivation:

Generally, the fallow lands are more prone to soil salinization process, as the open lands get dried quickly. When the surface soil becomes dried, the saline sub-surface water/ground water moves upward through the capillary pores of soil due to the force of surface tension. Finally the water vaporizes and the salt deposits on the surface of land. The peculiarity of this mechanism is that, immediate after harvesting of paddy, there is no salinity in the soil. With the rise of ambient temperature, the salinity also increases. In this situation, covering the soil by any means will check it from becoming dried and thereby protecting its salinity development by reducing the upward movement of saline water.

It was tested that sweet potato could tolerate soil salinity upto 2.5 dS/m and draught as well. Whatever the yield is, but covering the soil by the green herb of sweet potato vine for consecutive years, checks the salinity development and makes the land more congenial for other crop cultivation. Instead of keeping the land fallow after kharif paddy, if sweet potato is grown, it gives average production of 14 tons/ha equivalent to the gross and net income of Rs. 43,800/- and Rs. 16,368/- per hectare respectively with a BC ratio of 1.63. Besides, the leaves of sweet potato supply fodder, enough to feed 10 cattle during the period April – May when there is a dearth of green fodder for the animals.

2.5. Suitability with existing farming system:

In South 24 Parganas district of West Bengal there are different types of micro farming situations and KVK, Nimpith, since its inception, has given paramount thrust to select different types of micro situation specific cropping options for the district as a whole. Here, crops like sweet potato and cotton has been introduced in moderately degraded lowland saline soil having no option for irrigation and remains otherwise fallow after *kharif* paddy. It proved that both the crops fit well with the existing farming system in terms of productivity, profitability and sustainability point of view.

By implementing the technology of sweet potato cultivation over a period of 3 years it was observed that the salinity of the land is reduced to 1.32 dS/m from 2.43 dS/m in the rabi season and this indirectly helps to increase the productivity of subsequent *kharif* paddy. The cropping intensity in the study area covering 3 blocks, viz. Mathurapur-II, Kultali and Patharpratima was found to increase from 152% to 153% during this period through the adoption of sweet potato cultivation during the rabi season. Besides, an increase income to the tune of about 132% was also achieved which is described in the following Table 5.1.

Table 5.1: Economics of improved cropping system in Sundarbans of West Bengal

Sl. No.	Parameters	Before		After	
1.	Season	*Kharif*	*Rabi*	*Kharif*	*Rabi*
2.	Crop	Indigenous paddy	Fallow	Indigenous paddy	Sweet potato
3.	Productivity (q/ha)	22.75	-	23.50	132.00
4.	Net income (Rs./ha)	14674.00	-	15134.00	16368.00
5.	Man days/ha	135	-	135	65
6.	Av. salinity reduced over 3 yrs. (dS/m)	0.56	2.43	0.14	1.32
7.	Cropping intensity (%)	156	156.72		
8.	Increase in income (%)	Almost 132% over the traditional practice			

Before intervention

After intervention

2.6. Conclusion

Besides the NRM activities like land shaping & rain water harvesting, Ail cultivation, Desiltation etc. undertaken in the NAIP villages, different alternative options as mentioned above proved its economic viability and profit maximization potential in a sustainable manner not only for the adopted areas but for the district of south 24 parganas also as a whole. As the district suffers from a huge climatic hazards having direct and indirect effect on agricultural production system, more and more possibilities should be explored for the farmers of the district through which the objective for sustainable livelihood development can be achived.

Agriculture in Sundarbans

Subhas Chandra Acharyya
Ex- Joint Project Director,
Sundarban Development Board, Govt. of West Bengal

Sundarban region has a total effective area of 3.05 lakh ha cultivable land and according to 2011 census per capita land holding size has stood at 0.068 ha. This holding size is decreasing gradually with the increase of population in following years. The land type is mainly low lying having 61% and the percents of medium & upland are 26% & 11% respectively. Agriculture in this region depends on monsoon rains & basically monocropped. However micro irrigation potentials created through rain water harvesting and trapping of under ground water in some blocks of North 24 – Pgs, the area under a second crop stands around 30%. The agricultural system of the region is centered on two main cultivating seasons:

a) The *kharif* or monsoon season – the true monsoon period is between June – September. During this time *aman* paddy is the dominant crop and it is harvested during the period of post monsoon months in between November – December. In addition to that some high value vegetables like ladies finger, ridge gourd, bitter gourd, beans, snake gourd, etc are grown in uplands and *AILs* (field bundhs).

b) The *rabi* – summer season - this falls between November to June. During this period some *boro* paddy cultivation with stored water takes place. However the agricultural activities focus more on dry farming and less water consuming crops like winter vegetables, chilies, watermelon, summer vegetables, pulses like *khesari* & *moong* and oil seeds like sesame, mustard and sunflower.

Soils of this region are deep, fine textured, heavily elevated salinity during dry season through capillary action and in some pockets increasingly acidic sulphate build up disturbing the Ph level. Soil draining is generally inadequate and deep-water stagnation occurs in monsoon season. This limits the scope of introducing medium and high yielding varieties of paddy cultivars in most of the areas. To compensate the soil fertility, the farmers are used to apply chemical fertilizers and also without substituting organic substances. Granular pesticides are indiscriminately used to control the pests & diseases mainly for growing HYV paddy in *khariff* & *boro* seasons without considering the needs. This in turn declines the soil fertility and decreasing trend in productivity. On the other hand, rice fallow lands exposed to heavy precipitation at the onset of monsoon takes away the nutrient enriched surface soil with the runoff to the rivers for years together causing deterioration of soil health in general.

Lack of irrigation facility is the main constraint in increasing cropping intensity in Sundarbans and as such more than 70% of cultivable land remains fallow for 6-7 months after *aman* paddy harvest. This gives natural rise of soil salinity from the shallow underground aquifer as the land surface is exposed to the sun encouraging evaporation of surface moisture. Around 30% of the cultivable land could be brought under a second crop with supplementary irrigation and dry farming practices (Table 6.1). Another promising commercial venture is AIL [field bundh] cropping with high value vegetables during rainy season which covers the blocks of Joynagar-I&II, Mathurapur-I&II, Kultali and Pathar Prtaima under S24P. Cropping practices with SRI and no tilling cultivation with potato, pulses & other vegetables are also coming up.

Table 6.1: Area under Irrigation and under Multiple Cropping in Sundarbans of West Bengal

Area	Total Cultivable Area (ha)	Total *area under Irrigation (ha)	% to Total Cultivable Area	Total area Cultivable Multiple Cropping (ha) **	% to Total	Remarks Area
South 24 Parganas	243320	25591	10.52	68044	27.96	Irrigation through rainwater harvesting
North 24 Parganas	61514	18890	30.71	17996	29.20	Rainwater harvesting, Shallow & medium deep TW
Sundarbans	304834	44481	14.59	86010	28.21	

** Bureau of Applied Economics & Statistics- 2005-06*
*** Annual Reports of Dy. Director of Agriculture, GoWB, 2011*

Though the rice yield has increased in recent times that too remains below the state average of 4 mts/ha. The increase in yield rate is mainly due to bringing more areas under medium & HYV paddy cultivars and using chemical fertilizers & Pesticides in the khariff season. Setting up of regulated drainage structures for draining out excess rainwater from the catchments makes this increasing trend possible. The average yield rate of aman rice varies from 2-2.5 mts / ha. However progressive population growth, resulting in increase in the number of households and further fragmentation of holdings has effectively made agriculture unviable.

Rainwater is an important natural resource to the people of Sundarbans. Apart from agriculture, the supply of fresh water for domestic use, livestock rearing, fishery is dependent on surface rainwater harvesting through storage structures. The average annual rainfall in the area varies between 1600 -1800 mm. 85% of this rainfall occurs during four months of the monsoon i.e. from mid June to mid October. But more than 60% of this rainfall drains down to the rivers and of no use in cultivation. However limited efforts have been made by the individual households and the State departments to store the rainwater in ponds, canals, water bodies for the survival & intensifying livelihoods of the local people. Sundarban Affairs Department re-excavated around 411 km of derelict canals in Sundarbans (1981 – 85) for rejuvenating these water bodies for storing rain water mainly for providing irrigation to the nearby command areas during rabi & rabi-summer season to raise a low water consuming second crop. In addition to that this department has been working on excavation of new ponds in one portion of low-lying land owned by individual farmers through Rain Water Harvesting Project under Additional Central Assistance, 12th Finance Commission Grant & Rural Infrastructure Development Fund (RIDF) and could excavate 30,000 (app.) new ponds so far under this programme. Target of this programme is 50,000 schemes through which even number of holdings of marginal & sub-marginal farmers can be brought under composite farming system (e.g. agriculture, orchards, horticulture & vegetable cultivation, sweet water pisciculture, duckery, etc) absorbing additional employment and fetching high return. Recently work – programme for excavation of new ponds and re-excavation of existing ponds has been taken up under NREGA to create micro irrigation potentials.

In spite of these ventures, the agriculture in Sundarbans remains in a very subsistence level for its heavy dependence on monsoon rains. The changing pattern of monsoon season, as observed in past decade, has directly affected the cropping pattern and agricultural practices followed in this region for years together. Delayed and/or early onset of monsoon as well as delayed and/or early recession of the same seriously hamper the productivity and disturb the cropping cycle. Excessive downpour in a limited period, scattered rainfall, less & no rainfall at the critical stages of crop growth and heavy raining during harvesting time reduces yield as well as productivity.

Impacts of climate change on agricultural system in Sundarbans are likely to be very significant. The climate related factors guide the adaptation challenges and the existing pattern of agricultural practices may magnify the impacts of climate change related trends. The probable impacts of climate change on agriculture can be assessed as low yield due to change in monsoonal trend, change in temperature regime, jeopardizing cropping season, rise in salinity in the cultivable lands, shortage of irrigation and pests & disease outbreak, etc.

Though it is stated that 85% of the population in Sundarban Region depends on agriculture, but the data revealed from 2001 census depicts a very different picture. The absorbing capacity of work force in agriculture itself is lower than the national average. The following Table 6.2 will show the persons engaged in agriculture.

Table 6.2: Persons engaged in Agriculture for the year 2005-06 in Sundarban of west Bengal

Area	Total Population	Bargadars (% to total population)	Pattaholders (% to total population)	Small Farmers (% to total population)	Marginal Farmers (% to total population)	Agril. Labourers (% to total population)
South 24 Parganas (13 Blocks)	2795154	299088 (10.7)	149280 (5.34)	55188 (1.97)	230332 (8.24)	330083 (11.81)
North 24 Parganas (6 Blocks)	962202	48550 (5.05)	89906 (9.34)	17349 (1.80)	113540 (11.80)	121300 (12.60)
Sundarbans (19 Blocks)	3757356	347638 (9.25)	239186 (6.36)	72537 (1.930	343872 (9.15)	451383 (12.01)

Source: Bureau of Applied Economics and Statistics 2005-06

Sundarban region features a rainfed monocropped agricultural base and its existing cultivating sector is almost saturated and for that other sectors are absorbing the overspill though in a very limited scale. This may be substantiated with the following employment pattern based on the data published by BAE&S for the year 2005-06 (table 6.3). The active work force of this region gets limited day's employment in agricultural operations and after that they are to take up allied activities and seasonal migration for a gainful employment.

It is observed from the above that only 34.68% of total population is the workers and remaining 65.32 % are the non-workers which also involve the women and minor persons (Table 6.4). Out of the total workforce, a considerable portion belongs to marginal workers who are not getting enough employment all the year round. The following table has shown the distribution of total workers over main workers and marginal workers in this region. The policy makers should work out integrated planning for generating additional employment opportunity and to enhance farm income.

Table 6.3 : Distribution of population over different categories of workers for the year 2001 in Sundarbans of West Bengal

Area	Total Population	Total Workers (% to TP)	Cultivators (% to TW)	Agricultural Labourers (% to TW)	Household Workers (% to TW)	Other Workers (% to TW)
South 24 Parganas (13 Blocks)	2795154	968624 (34.65)	241276 (24.90)	349156 (36.05)	40658 (4.19)	337534 (34.85)
North 24 Parganas (6 Blocks)	962202	334345 (34.75)	65599 (19.62)	121300 (36.28)	22835 (6.83)	124561 (37.25)
Sundarbans (19 Blocks)	3757356	1302969 (34.68)	306875 (23.55)	470456 (36.11)	63493 (4.87)	462095 (35.46)

Source: Bureau of Applied Economics & Statistics 2005-06

Table 6.4: Distribution of Total Workers in Main & Marginal Workers in Sundarban of West Bengal

Area	Total Workers (% to total population)	Main Workers (% to total workers) workers)	Marginal Workers (% to total workers	Non-Workers (% to total population)
South 24 Parganas (13 Blocks)	968624 (34.65)	655815 (23.46)	312809 (11.19)	1826630 (65.35)
North 24 Parganas (6 Blocks)	334345 (34.75)	252332 (26.22)	81963 (8.53)	627907 (65.25)
Sundarbans (19 Blocks)	1302969 (34.68)	908147 (24.17)	394772 (10.51)	2454537 (6532)

Source: Bureau of Applied Economics & Statistics 2005-06

In setting up Sundarban Development Board, as a backward area development organization, Government stressed on increasing cropping intensity through multiple cropping (cropping intensity only 104 in 1979). Institutional finance had been provided for creating irrigation potentials through rain water harvesting, introducing dry farming technologies and improved agricultural practices both in *khariff* & *rabi* season's cultivation and development of communication infrastructure, etc. Some non-conventional crops like chillies, sunflower, cotton, *rabi* & summer vegetables pulses had been introduced and popularized in Sundarbans. Cropping intensity went up to 132 in 2002. The irrigated area stood at 14 -15% of the total cultivable land. This becomes stagnant for years together due to different administrative and economic reasons and as such the cropping intensity is not increasing to a desired level. As the cultivators being deprived of the remunerative prices for their produces and faced with adverse agro-climatic factors, they have turned their face from cultivating low water consuming crops and favour boro paddy cultivation with very little and confined irrigation base.

Sundarban Development Board could not prepare any comprehensive plan for integrated development of this economically as well as socially backward region. In recent ears the Board has been emphasizing on some popular programme for free distribution of agricultural inputs having no long-term effect on the sector as a whole. The agricultural programme undertaken by the Board during 2012 -13 are given below :

Rabi Season'as cultivation-

i) Distribution of Moong Seed – 20,000 kg to 5000 farmers @4 kg / bigha

ii) Distribution of Elephant–foot–yam (OL) seed – 300 MTs to 7500 farmers@ 40 kg /ph

iii) Distribution of mixed vegetable seeds to 8000 farmers

iv) Distribution of Sprayers to 9500 farmers

Khariff Season's Cultivation –

i) Distribution of Urea – 1750 MTs @ 50 kg/ farmer [35,000 farmers]

It is well known that the socio-economic and agro-climatic conditions of this region are very much different from other agricultural zones of West Bengal, which requires special area planning. The predominant sectors like agriculture and fisheries need long – term integrated planning for enhancement of farm income as well as to generate additional employment opportunity. The active work force of this region gets limited day's employment in agricultural operations and after that they are to take up allied activities and seasonal migration for a gainful employment. Now Sundarban has stood as a steady supplier of unskilled work force to Kolkata and its agglomerations that are deprived of minimum wage and are trapped in social exploitation net.

The agrarian economy of this region needs a radical change to overcome its stagnation phase. Farm income is to be enhanced through integrated farming system of small holdings. Work programmes towards diversification of crops, incorporation of allied activities in the farming system and reorganization of market structure for ensuring remunerative returns to the growers will be helpful in rejuvenating the agricultural sector. A comprehensive planning process with area specific approach is required to be worked out in long-term perspective. Eastern Green Revolution source should also be trapped for implementing capital – intensive projects with strong administrative good wills. Populistic and short – term approach will not be able to address the situation as well as to feed the ever increasing population of the region.

The research organizations, agriculture universities and some NGOs have done some exemplary works in introducing better farm management practices, and improved technologies in agriculture & allied sectors. Now the time has come to adopt cost-effective and eco-friendly technologies without deteriorating the critical natural resources. Land area is shrinking; productivity is not increasing as desired; farm income is not encouraging, on the contrary population is increasing by leaps and bounds. These organizations are to appreciate these challenges and to come out with appropriate strategies to overcome the stagnation in agriculture sector of Sundarban region.

Some important strategies

i) Reducing stagnation of water in paddy fields during *khariff* season through regulated drainage and raising the lands through land shaping for increasing productivity of land and on the other hand storing rain water for providing irrigation for *rabi* & *rabi* – summer cultivation. The technology has been termed as land shaping through excavation of new pond in a part of low lying land for rain water harvesting. The extent of implementation of this programme is growing in a lower scale as compared to the potential area that could be covered. More investment for this programme will create the opportunity for increasing productivity &

cropping intensity, taking up allied activities in small holdings, generating additional employment opportunity and income.

ii) Sundarban region has several kilometers of canal and water bodies which are de-linked from rivers mostly used as drainage and reservoirs for irrigation purposes. These are to be rejuvenated for smooth drainage and to enhance storing excess rain water for dry season farming. At least 25% of the cultivable area of this region is to be brought under irrigation and for that a time specific integrated plan is to be worked out.

iii) Programme on "Adaptation to Climate Change for Food Security" is to be propagated amongst the farming communities through which some salt tolerant rice varieties can be re-introduced in saline affected lands with high water stagnation.

iv) Large scale introduction of System of Rice Intensification (SRI) programme.

v) Popularizing the technology of minimum tillage in the crop production (tuber crop like potato) in rabi season availing post – monsoon soil moisture.

vi) Popularising Ail cropping (raised field bundhs) with high value vegetables in rainy season followed by oil seeds and hybrid vegetables in winter with limited irrigation.

vii) Sustainable farm management system with reduced reliance on chemical fertilizers & pesticides may be popularized and in substitute use of organic manures & bio-fertilizers and cultivation of leguminous crops and algae for Nitrogen fixation can be introduced in large scale.

viii) In view of higher temperature as induced by global warming, heat & salt tolerant and thermo-insensitive varieties of crops should be selected for this region.

ix) Introduction of agro – forestry based land use system that integrates agriculture, trees, animals & people in the same space resulting in improved soil quality, better water management, higher returns from holdings, fuel, timber & nutrition support base and improved standards of living.

x) Crop insurance for field & plantation crops is to be introduced to save the farmers from loss due to extreme weather events.

xi) Sustainable management practices for fisheries and other allied activities for preservation of ecology and natural habitat of the region.

xii) Development of marketing infrastructure and storage facilities for agricultural and marine products.

xiii) Investment to be made for building agricultural infrastructure facilitating drainage, irrigation, marketing, storing & processing , etc. so that the primary growers can avail the benefits for enhancing farm income and to generate additional employment opportunity.

xiv) As per report published by the Sundarban Affairs Department in 2012, total number of Rainwater Harvesting structures (new ponds) in a part (one fifth) of agricultural lands of individual farmers on a 90% subsidy stood at 33,327. An estimated area of 6,665 ha of land could be brought under multiple cropping. At the same time a total n. of 33327 farmers' families could introduce integrated farming systems including agriculture, horticulture,fisheries, etc., which generate additional income and employment opportunities.

xv) After 2012, the works under this project is almost abandoned. However, " Jal dharo, Jal bharo" project with MGNREGA fund has been implemented through Panchayats. The data are not readily available.

Adoption of improved rice variety in coastal region – experiences from India

S. K. Sarangi[1], D. Burman[1], S. Mandal[1], B. Maji[1]
B. K. Bandyopadhyay[1] and D. K. Sharma[2]

[1]*Central Soil Salinity Research Institute, Regional Research Station Canning Town, South 24 Parganas, West Bengal, Pin - 743 329, India*

[2]*Central Soil Salinity Research Institute, Karnal, Haryana, India*

1. Introduction

The coastal ecosystem stretching over a length of 8,129 km along the eastern and western fringe of the country covers an area of 10.78 Mha. Based on agro-ecological variations the entire coastal region of the country is divided into 5 agro-climatic zones by the Planning Commission, viz. Zone 3 – Lower Gangetic Plains (part of West Bengal), Zone 11 - East coast Plains and Hills (parts of Orissa, Andhra Pradesh, Tamil Nadu and Pondicherry), Zone 12 – West Coast Plains and Ghat Region (Kerala, Goa, parts of Tamil Nadu and Karnataka, Konkan region of Maharashtra), Zone 13 – Gujarat Planins and Hilly Region (South Gujarat) and Zone 15 – Island regions (Andaman, Nicobar and Lakshadweep). State-wise distribution of the coastal saline soils are shown in Table 7.1. Most of the coastal areas have problematic soils, such as saline, alkaline, acid sulphate, or marshy/waterlogged soils, situated in the low-lying areas mainly along the deltas. Depending upon the physiography and climate, characteristics of the soils vary widely, which have been summarized in Table 7.2. Most of the soils are heavy textured with salinity (EC) in the order of 0.5 dS m^{-1} in monsoon to as high as 50 dS m^{-1} in summer. Normally there is abundance of cations in soluble salts in the order: Na>Mg>Ca>K. Chloride is the predominant anion, whereas bicarbonate occurs in traces. In the acid sulphate soils in Kerala and Andaman & Nicobar Group of Islands sulphate is the dominant anion. Except in a few pockets in South and West Coast, where SAR in the soil solution occasionally exceeds 15, sodicity is not normally encountered in these soils. Soils are therefore slightly acidic to slightly alkaline in reaction. Besides, there are location-specific problems, like seawater intrusion along with severe cyclones in un-bunded low-lying areas all along the coastal areas particularly in the east, and impeded drainage for a majority of the areas, which are low-lying and dominated by heavy textured soil.

India has about half of its rice area under rainfed lowland situation having low production due to several constraints like drought, floods, pests, weeds and soil constraints. Most rainfed lowland rice farmers are poor and must cope with unstable yields and financial risks. They adapt their cropping practices to the complex risks, potentials, and problems they face. They typically grow traditional, photoperiod-sensitive cultivars and invest their labour instead of purchasing inputs. The problem is also compounded by natural disasters like cyclone, sea water intrusion, drought etc. that visit the coastal areas almost regularly. The recent incidence of *aila* in the *Sundarbans* on 25 May, 2009 has devastated the larger areas by washing the earthen embankments and flooding the villages for a prolonged period with saline sea water. The main cropping season *Kharif* was spoiled due to extreme soil salinity and lack of tolerant rice varieties. The subsequent *Rabi* season was also hampered the agriculture due to rise in soil and water salinity. Similarly on 12 October, 2013 cyclone *Phailin* affected the coastal districts of Odisha damaging agricultural crops, trees and livelihoods of millions of people were threatened. Thus coastal areas of India are prone to climatic hazards and natural disasters more than other agroclimatic regions.

Table 7. 1. Extent of coastal saline soils of India

States	Area in million hectares (Mha)
West Bengal	0.82
Gujarat	0.71
Orissa	0.40
Andhra Pradesh	0.28
Tamil Nadu	0.10
Karnataka	0.09
Maharashtra	0.06
Kerala	0.03
Goa	0.02
Andaman & Nicobar Islands	0.02
Pondicherry	0.001
Total	2.52
Area under magroves	0.57
Total	3.09 (or 3.1)

Table 7.2: Characteristics of salt affected soils in India

Soil class	Main characteristics	Distribution
Saline micaceous deltaic alluvium of humid regions	Neutral to slightly acid pH, high EC, preponderance of chlorides	Sundarban delta in West Bengal and parts of Mahanadi delta in Orissa
Saline humid and acid sulphate soils of humid tropical region	Acid pH, high EC, presence of humic (organic) horizon, preponderance of chlorides and sulphates	Malabar coast in Kerala
Salt affected deep black soils (vertisols)	Neutral to highly alkaline pH, high EC, preponderance of chlorides and sulphates with or without bicarbonates, montmorillonitic mineralogy	Parts of Gujarat, Andhra Pradesh and Karnataka
Medium to deep black soils of the deltaic and coastal semi-arid regions	Neutral pH, high EC, preponderance of chlorides and sulphates, montmorillonitic minerology	Saurashtra coast in Gujarat and deltas of Godavari and Krishna rivers in Andhra Pradesh
Saline marsh of the Rann of Kutch	Neutral to slightly alkaline pH, high EC, preponderance of chlorides and sulphates	Rann of Kutch in Gujarat

The coastal region is characterized by diverse eco-systems, having humid, sub-humid or arid climate. The annual rainfall is high in the coastal areas of Kerala, Andaman and Nicobar Islands and West Bengal (1750 – 3000 mm) to very low in Saurashtra (650 mm) in Gujarat. The rainfall is received mostly from south-west monsoon. The rainy season, which contributes 70-80% of annual rainfall, starts normally from the middle of June and ends in October. July and August are the wettest months. Besides, its annual distribution is unimodal or bimodal, causing severe waterlogging to extreme moisture stress in the soil during different times in a year. The typical maritime climate of mild and short winter, fairly high relative humidity, low sunshine hours (3-7 h/day) and high annual evapotranspiraton (1350 – 2150 mm) are important considerations influencing the cropping pattern and the method of cultivation. The area is characterized by three dominant seasons during the year. The summer season extends from middle of March to middle of June, the rainy season from middle of June to middle of October, and the winter season extends between end of November and end of February. Middle of October to November and from March to middle of April are pre-winter and pre-summer, respectively.

Table 7.3: Trends in area, production and yield of rice for major states in coastal India

States	Particulars	1990-94	1995-99	2000-04	2005-10	Mean
Andhra Pradesh	Area	2753	2685	2373	4087	2975
	Production	6487	6403	6405	12683	7995
	Yield	2365	2378	2695	3102	2635
Orissa	Area	4235	4223	4199	4404	4265
	Production	5556	4877	5136	6964	5633
	Yield	1311	1154	1220	1582	1317
West Bengal	Area	4819	4672	4391	5617	4875
	Production	8765	9033	9984	14400	10546
	Yield	1820	1934	2267	2566	2147
Tamil Nadu	Area	1859	1892	1616	1909	1819
	Production	5804	5724	4602	5585	5429
	Yield	3120	3016	2779	2930	2961
Kerala	Area	461	338	269	242	328
	Production	890	669	597	583	685
	Yield	1930	1984	2219	2419	2138
Karnataka	Area	1014	1052	1048	1473	1147
	Production	2190	2435	2376	4098	2775
	Yield	2158	2313	2264	2779	2379
Maharashtra	Area	1524	1460	1492	1521	1499
	Production	2269	2390	2226	2571	2364
	Yield	1489	1638	1492	1687	1577
Gujarat	Area	583	634	607	732	639
	Production	818	963	880	1376	1009
	Yield	1407	1518	1420	1882	1557
All India	Area	39354	40027	39391	43618	40598
	Production	68517	72122	73446	94349	77109
	Yield	1733	1801	1863	2163	1890

Area: in '000 ha; Production in '000 tons and Yield in kg ha^{-1}

Table 7.4: Characteristics of salt tolerant varieties of rice for coastal India

Variety	Salinity tolerance (dS m^{-1})	Plant Height (cm)	Duration (days)	Grain yield (t ha^{-1})	Photosensitivity
Upland (0-15 cm water)					
Canning 7	6-8	95-105	130	4.0-4.5	Insensitive
CSR 4 (Mohan)	6-8	95-100	125	3.5-4.0	Insensitive
CSR 36	4-6	95-100	130	3.0-3.5	Insensitive
CST 7-1	6-8	90-95	135	4.0-4.5	Insensitive
Medium land (15-30 cm water)					
CSR 1 (Damodar)	6-8	105-110	130	2.5-3.0	Sensitive
CSR 2 (Dasal)	6-8	105-110	130	2.5-3.5	Sensitive
CSR 3 (Getu)	6-8	105-110	130	2.5-3.0	Sensitive
CSR 6 (Nonasail)	6-8	110-115	120	2.5-3.0	Sensitive
Sumati	6-8	95-105	145	4.0-4.5	Sensitive
Utpala	6-8	90-100	145	4.0-4.5	Sensitive
Bhutnath	6-8	100-115	145	4.0-4.5	Sensitive
Low land (30-45 cm water)					
CSR 8 (Dadsail)	4-6	140-145	150	3.0-3.5	Sensitive
SR 26B	4-6	130-145	155	3.5-4.0	Sensitive
Sabita	4-6	130-145	160	3.5-4.0	Sensitive
Geetanjalle	4-6	160-170	145	4.0-4.5	Sensitive
Amalmana	4-6	130-145	145	5.0-5.5	Sensitive
Patnai 23	4-6	130-145	150	3.0-3.5	Sensitive
Namitadipti	4-6	130-145	155	4.0-4.5	Sensitive
Deep Water (>45 cm water level)					
NC 678	4-6	145-160	160	2.0-2.5	Sensitive
Asfal	2-4	130-140	165	2.0-2.5	Sensitive
Tilak kachari	2-4	160-165	165	2.0-2.5	Sensitive
Najani	2-4	130-140	165	2.0-2.5	Sensitive
Gavirsaru	2-4	123-130	165	2.0-2.5	Sensitive
CSRC (D) 7-0-4	4-6	130-135	160	2.5-3.0	Sensitive
CSRC (D) 13-16-9	4-6	140-145	160	2.5-3.0	Sensitive
CSRC (D) 12-8-12	4-6	145-150	160	2.5-3.0	Sensitive

Crop cultivation is the major land use pattern of the coastal areas. Nearly 80-90% of the cultivated land is used for agricultural crop production. The next important land use after agriculture is the fish cultivation in ponds and ditches. Nearly 70% of income of the farmers is generated from crop cultivation and the rest are from fisheries and other animal husbandry activities. Almost the entire crop area is monocropped with rice in the monsoon season, and more than 80% of the cultivated land remain fallow during rest of the period after monsoon season due to moderate to high soil salinity and lack of irrigation water. Wherever limited amount of water is available from ponds, drainage channels, shallow tube wells, etc. crops like rice, sunflower, chilli, watermelon, potato, tomato, rapeseed, maize etc. are grown in *rabi*/summer seasons. The analysis of statewise rice statistics (Table 7.3) reveal that the mean rice productivity is highest in the state of Tamil Nadu (2961 kg ha^{-1}) where as it is lowest in Orissa (1317 kg ha^{-1}). The productivity potential of some of the varieties released for coastal region (Table 7.4) are much higher than the existing productivity.

2. Adoption of Boro rice varieties

In the coastal areas salinity as well as scarcity of good quality of irrigation water are the major constraints for boro rice cultivation, therefore rice varieties which are salt tolerant and requires less irrigation water are preferred by the farmers. In order to find out suitable boro rice varieties on-farm trials were conducted at Sandeshkhali PS (Block Sandeshkhali II, village: Daudpur) in North 24 Pargana district and at Gosaba PS (Block Gosaba, Village: Pakhiralay South, Jatirampur, Dulki and Pakhiralay) in the district of South 24 Parganas. Considering the availability of land and water for irrigation six farmers each in Gosaba PS (South 24 Parganas District) and Sandeshkhali PS (North 24 Parganas District) were selected and trials were conducted at these sites. Eight numbers of improved rice (Boro) varieties including "Canning-7" as local check were evaluated and details of the varieties are given in Table 7.5.

Table 7.5: Details of rice varieties used for trials in 2011-2012 *Boro* (*Rabi*) season

Sl. No.	Variety	Height (cm)	Duration (days) (days)	Grain yield (tha^{-1})	Salinity tolerance ($dS\ m^{-1}$)
1	Canning 7	95-105	130	4.0-4.5	6.0-8.0
2	Boby	115-120	110	3.1-4.0	<6.0
3	Annada	95-100	115	3.5-4.5	6.0-8.0
4	Bidhan 2	100-110	125	4.5-5.0	6.0-8.0
5	CSR 4	95-100	125	3.5-4.0	6.0-8.0
6	Lalat	105-110	115	2.2-3.0	6.0-8.0
7	WGL 20471 (Lalminikit)	100-105	120	4.0-4.5	6.0-8.0
8	IET 7486 (Sadaminikit)	95-100	120	3.0-4.0	6.0-8.0

Monitoring of soil and water sample for salinity as well as for pH, NPK and Organic C were conducted on regular basis. Detail of the initial and periodical values of these parameters are given below [Table 7.6 & Fig.1(a) & (b)]. At Sandeshkhali the source of irrigation water was ground water at a depth of 360-380 feet, whereas at Gosaba the source was conserved rain water in the pond/ditches. Since the ground water at Gosaba is highly saline, farmers prefer to use the stored water of boro rice cultivation, ground water below 900 feet is suitable for drinking purpose, which is expensive for use as irrigation water. At both the locations, soil salinity increased with progress of the growing season, however, the buildup of soil salinity is higher at Gosaba than at Sandeshkhali. Similarly, the irrigation water salinity increased during the month of March over that in the month of February, however, at Gosaba, the irrigation water salinity remained almost constant after March, whereas at Sandeshkhali, it further increased during the month of April.

Table 7.6: Initial soil and water properties of the boro rice on-farm trials

Location	Initial soil and water properties (January 2012)							
	Soil		Water		Av. N kg ha^{-1}	Av P kg ha^{-1}	Av K kg ha^{-1}	% OC
	ECe ($dS\ m^{-1}$)	pH	EC ($dS\ m^{-1}$)	pH				
Sandeshkhali	3.98	5.60	1.87	8.19	221.67	18.95	449.93	0.68
Gosaba	5.36	5.91	2.51	8.67	184.8	20.62	468.1	0.65

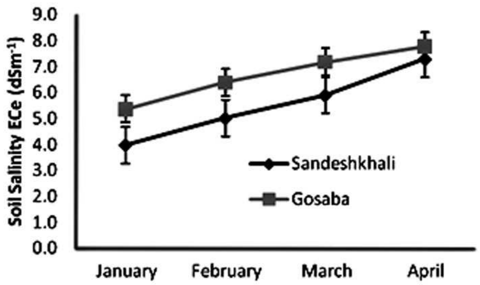


Fig. 1a. Changes in soil salinity during boro rice growing period

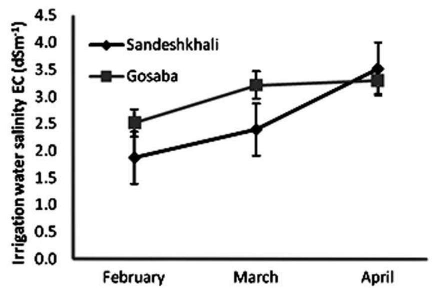


Fig. 1b. Changes in irrigation water salinity during boro rice growing period

3. Performance of boro rice varieties in on-farm trial during Boro 2012

At Sandeshkhali the highest grain yield of 3.98 t ha^{-1} (yield of Check var. was 3.48 t ha^{-1} which was significantly lower) was observed in case of Bidhan 2, which was at par with WGL 20471 (Lalminikit) and IET 7486 (Sadaminikit) producing grain yields of 3.81 and 3.80 t ha^{-1} respectively. The higher grain yield in these varieties were due to more numbers of effective tillers filled grains/panicle and 1000-seed weight (Table 7.7). Lowest grain yield of 2.94 t ha^{-1} was observed in case of variety Lalat.

Table 7.7: Agronomic data for boro rice varietal trial conducted at Sandeshkhali (North 24 Parganas)

Variety	Plant height (cm)	Total no. of tillers/ hill	No. of effective tillers/hill panicle	Length of panicle (cm)	No. of filled grain/ panicle	No. of unfilled grain/ (g)	Grain yield (tha^{-1})	1000-seed weight	Spikelet fertility (%)
Canning 7	92.00	19	14	20.73	111	23	3.48	20.89	82.70
WGL 20471	96.28	22	19	20.01	117	23	3.81	20.65	84.28
IET 7486	92.28	22	19	19.06	116	24	3.80	19.95	82.85
Bidhan 2	102.23	20	16	21.28	124	22	3.98	21.00	84.93
CSR 4	92.17	19	16	21.06	113	23	3.29	19.17	83.08
Annada	86.28	21	18	19.62	112	22	3.53	20.28	84.21
Lalat	99.61	18	15	20.34	110	24	2.94	20.95	82.70
Boby	102.45	19	16	20.95	108	25	3.13	19.95	81.20
SEd	1.53	0.73	0.98	0.66	3.21	0.95	0.10	0.62	–
CD (P=0.05)	3.10	1.48	1.98	1.34	6.53	1.92	0.20	1.26	–

When the data for the two locations were compared, it was observed that grain yield was higher for each of the tested varieties at Sandeshkhali than Gosaba, this may be due to less soil and water salinity at Sandeshkhali. At Gosaba the higher grain yield of 3.84 tha^{-1} (yield of Check var. was 2.91 tha^{-1} which was significantly lower) was recorded in case of variety Bidhan 2, which was superior over all other varieties (Table 7.8). The varieties WGL 20471 (Lalminikit) and IET 748 (Sadaminikit) produced grain yields of 3.45 and 3.39 tha^{-1} respectively, which were significantly lower than Bidhan-2. Significantly higher number of 122 grains/panicle was observed in case of variety Bidhan 2. The 1000-seed weight of Bidhan 2 (21 g) was at par with Annada and Lalat. Lowest grain yield of 2.88 tha^{-1} was observed in case of variety CSR4.

Table 7.8: Agronomic data for boro rice varietal trial conducted at Gosaba (South 24 Parganas)

Variety	Plant height (cm)	Total no. of tillers/ hill	No. of effective tillers/hill panicle	Length of panicle (cm)	No. of filled grain/ panicle	No. of unfilled grain/ (g)	Grain yield (t ha^{-1})	1000-seed weight	Spikelet fertility (%)
Canning 7	87.62	18	12	19.84	100	29	2.91	19.00	78.12
WGL 20471	91.67	21	18	19.00	112	24	3.45	19.17	82.35
IET 7486	89.11	21	18	18.45	110	26	3.39	19.00	80.74
Bidhan 2	99.00	19	16	20.67	122	24	3.84	21.00	84.02
CSR 4	92.23	18	15	20.45	98	29	2.88	18.78	76.37
Annada	85.45	21	18	18.89	110	23	3.36	19.95	83.33
Lalat	96.78	20	14	19.89	102	27	2.85	19.95	79.52
Boby	98.95	19	16	20.17	108	29	3.04	19.45	78.83
Sed	1.76	0.71	0.63	0.60	3.44	1.76	0.09	0.66	–
CD (P=0.05)	3.57	1.44	1.28	1.22	6.98	3.57	0.19	1.34	–

4. Participatory Varietal Selection (PVS)

During the maturity stage of the boro rice varieties, the farmers from different villages were invited to vote for two most and least preferred varieties out of the varieties tested. At Sandeshkhali total 33 farmers including 6 women farmers participated in the process. At Gosaba 23 farmers and 15 women farmers participated. The farmers were first described about the process. PVS process was conducted before harvest of the crops at the two sites (Table 7.9 & 10). It was observed at Sandeshkhali that the highest preference score of +16 was recorded in case of variety IET 4786 (Sadaminikit) followed by Bidhan 2 (+15). The two least preferred varieties were CSR 4 (-23) and Lalat (-13). Reasons for better preference of Bidhan 2 at Sandeshkhali PS as described by the farmers were salt tolerance, preferred grain type, expected more market price and acceptable (taller) plant height. For IET4786 the characteristics were expected higher market price, less shattering of grain, more weight. Reasons for lower preference of CSR 4 was less number of panicles and that for Lalat were long duration, grain type is not acceptable. Reasons for better

Table 7.9: Participatory Varietal Selection conducted at Sandeshkhali during April 2012

Variety	Count of Positive and Negative Votes								Preference Score*
	Male		Female		Breeders		Total		
	Positive votes	Negative votes	Positive votes	Negative votes	Positive votes	Negative votes	Positive votes	Negative votes	
Canning-7	3	2	4	0	2	0	9	2	+7
Boby	3	1	2	1	1	0	6	2	+4
Annada	0	8	1	3	0	2	1	13	–12
Bidhan-2	14	2	4	3	2	0	20	5	+15 (2)
CSR-4	0	15	1	7	0	2	1	24	–23 (1)
Latat	1	10	0	2	0	2	1	14	–13 (2)
Lalminikit (WGL20471)	6	4	2	1	0	0	8	5	+3
Sadaminikit (IET4786)	13	1	4	1	1	0	18	2	+16 (1)

Table 7.10: Participatory Varietal Selection conducted at Gosaba during April 2012

Variety	Count of Positive and Negative Votes								Preference Score*
	Male		Female		Breeders		Total		
	Positive votes	Negative votes	Positive votes	Negative votes	Positive votes	Negative votes	Positive votes	Negative votes	
CSR-4	1	5	0	7	0	1	1	13	-12 (-2)
Bidhan-2	23	4	16	0	2	1	41	5	+36(1)
Annada	10	4	2	6	1	0	13	10	+3
Boby	6	5	9	2	3	2	18	9	+9(2)
Canning-7	0	3	0	4	1	0	1	7	-6
Sadaminikit (IET 4786)	0	14	0	11	0	4	0	29	-29(-1)
Lalminikit (WGL 20471)	5	7	4	1	2	0	11	8	+3
Lalat	3	5	0	0	1	2	4	7	-3

preference of Bidhan 2 at Gosaba were more number of grains panicle^{-1}, long panicles, salt tolerant, acceptable maturity period and those for Boby were tall plants, long panicles, more grain yield. The reasons for lower preference of IET 4786 was less number of panicles and for CSR 4 the undesirable characteristics were long duration, cooking quality is not acceptable.

5. Adoption of *Kharif* (Aman) rice varieties

Rice is the principal crop during *kharif* season in the coastal areas of India. Since majority (around 85%) of the land is low-lying, therefore varieties which are generally tall and high yielding are preferred during this season. For medium and uplands varieties which are medium to short in height and high yielding are preferred. An on-farm trial was conducted in the districts of North and South 24 Parganas of West Bengal to find out suitable rice varieties for different land types and their adoption preference by farmers and farm women. Rice varieties tested at Sandeshkhali in North 24 Parganas district were Geetanjali, NC678, CSRC (D)-7-0-4, CSRC (D)-2-17-5, CSRC (D)-12-8-12, CSRC (D)-13-16-9 and Swarna *sub 1*. Ten varieties/ lines were selected for trials at Kheria Village in Basanti Block and at Dulki Village in Gosaba Block of South 24 Parganas District. The entries were Amal-Mana, Geetanjali, CSRC (D) 7-0-4, CSRC (D) 2-17-5, CSRC (D) 12-8-12, CSRC (D) 13-16-9,

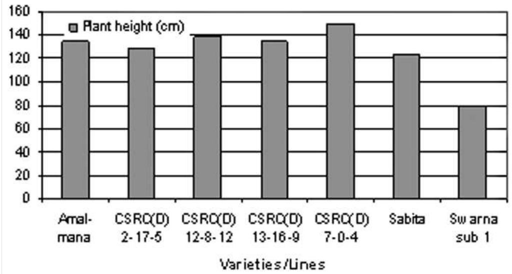
Table 7.11: Details of rice varieties used for trials in 2012 *Kharif* (Aman) season

Sl. No.	Variety	Height (cm)	Heading Duration (days)	Grain yield (t ha^{-1})	Salinity tolerance (dS m^{-1})
1	Amal-Mana	140	122	4.5	6.0-8.0
2	Geetanjali	140	122	3.9	6.0-8.0
3	CSRC (D) 7-0-4	159	133	3.7	4.0-6.0
4	CSRC (D) 2-17-5	173	133	3.1	4.0-6.0
5	CSRC (D) 12-8-12	145	129	3.7	4.0-6.0
6	CSRC (D) 13-16-9	169	133	3.0	4.0-6.0
7	Swarna *sub 1*	91	90	3.1	–
8	NC 678	151	127	2.4	4.0-6.0
9	Sabita	145	123	3.0	4.0-6.0
10	SR 26 B	146	129	2.4	4.0-6.0

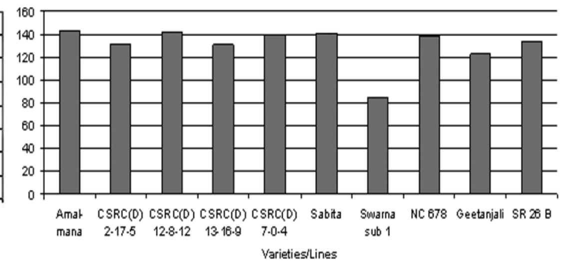
Swarna *sub 1*, NC 678, Sabita and SR 26 B (Table 7.11). The evaluation was done in RBD design with three replications.

6. Monitoring of growth parameters

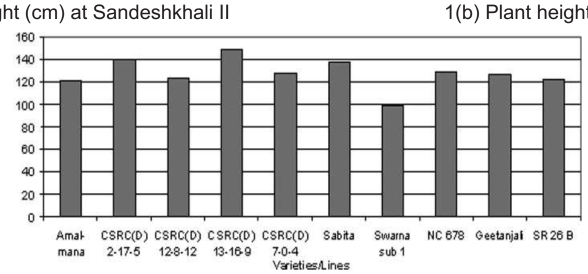
Two number of hills from each plot was collected at panicle initiation stage for the determination of plant height. The plant height is one of the important parameters for determining the suitability of the varieties to different land situations (Table 7.12, 7.13 & 7.14). Data presented in Fig 1. (plant height at PI stage) revealed that Swarna *Sub 1* had the lowest plant height at all the three locations studied, therefore it is suitable for medium land situation, where as the variety Amal-Mana recorded highest plant height at Basanti and the line CSRC(D) 13-16-9 was longest in plant height at Gosaba.



1(a) Plant height (cm) at Sandeshkhali II



1(b) Plant height (cm) at Basanti



1(b) Plant height (cm) at Gosaba

2. Plant height of different rice entries of three different location of study at PI stage

7. Yield and yield attributes of *kharif* rice varieties

At Sandeshkhali-II the water depth during the crop growing season was relatively low (<25 cm). Under this situation highest grain yield (4.15 tha^{-1}) was produced by Swarna *sub-1* followed by Amal-Mana (3.80 tha^{-1}) mainly due to higher number of panicles/hill (Table 7.12). At Gosaba, the water depth was medium (25-30 cm), where highest grain yield was produced by Amal-Mana (4.55 tha^{-1}) followed by Swarna *sub-1* (4.38 tha^{-1}) due to higher yield attribute like panicles/hill (Table 7.14). CSRC (D) 12-8-12 performed better among the varieties/lines tested at Basanti producing highest yield of 4.8 tha^{-1} followed by Amal-Mana (4.4 tha^{-1}) due to higher yield attributes like panicles/hill and grains/panicle (Table 7.13).

8. Participatory Varietal Selection of *kharif* rice varieties

In Participatory Varietal Selection (PVS) at Sandeshkhali II, Swarna *sub 1* and Amal-Mana emerged as the most preferred varieties of farmers because of traits like strong and taller plants, less lodging, less disease and pest incidence, more tillers, long panicle, and expected higher grain yield. Whereas CSRC(D)2-17-5 and Sabita were the least preferred varieties because of traits like less number of tillers, susceptible to lodging, less compact panicle, expected lower grain yield. At

Table 7.12: Agronomic data for *Kharif* (*Aman*) rice varieties evaluation trial conducted at Daudpur, Block- Sandeshkhali-II, Dist.- North 24 Parganas

Variety/ Line	Plant Ht (cm)	Total Till/ hill	Panicle/ hill	Length of Panicle (cm)	Grains / Panicle	Chaffs Panicle	Spikelet fertility (%)	1000 grain wt(g)	Yield (tha^{-1})	Duration (days)
Amal-Mana	141.50	11	11	21.39	122	7	87.83	27.0	3.80	145
Sabita	172.33	9	6	19.6	106	22	78.11	25.0	2.68	142
CSRC (D) 7-0-4	173.33	10	10	23.29	132	38	75.83	24.0	3.70	140
CSRC (D) 2-17-5	167.16	10	10	21.48	93	12	84.43	24.5	3.05	136
CSRC (D) 12-8-12	177.16	9	9	23.16	140	26	80.23	25.5	3.52	140
CSRC (D) 13-16-9	156.83	9	9	21.52	97	14	85.17	24.5	3.50	135
Swarna sub 1	95.21	11	11	19.11	113	10	90.37	24.0	4.15	134

Table 7.13: Agronomic data for *Kharif* (*Aman*) rice varieties evaluation trial conducted at at Kheria, Block-Basanti, Dist. South 24 Parganas

Variety/ Line	Plant Ht (cm)	Total Till/ hill	Panicle/ hill	Length of Panicle (cm)	Grains / Panicle	Chaffs Panicle	Spikelet fertility (%)	1000 grain wt(g)	Yield (tha^{-1})	Duration (days)
Amal-Mana	167.83	11	9	22.16	113	10	91.22	28.0	4.40	145
Geetanjali	138.33	10	9	19.91	78	13	86.70	27.0	3.82	142
CSRC (D) 7-0-4	128.16	8	7	20.66	117	17	85.37	27.5	3.70	140
CSRC (D) 2-17-5	152.33	8	8	20.37	92	15	84.17	28.0	3.60	136
CSRC (D) 12-8-12	135.83	12	10	20.91	121	25	82.87	26.0	4.80	140
CSRC (D) 13-16-9	146.16	9	7	23.94	112	7	94.27	28.5	3.50	135
Swarna sub 1	104.83	12	6	20.37	77	9	87.77	25.5	4.20	134
NC 678	140.83	9	6	23.42	115	16	88.36	29.0	3.50	145
Sabita	143.5	7	6	22.86	118	19	83.85	28.0	2.60	142
SR 26 B	138	13	8	22.05	100	12	86.21	24.0	3.60	140

Dulki Village (Gosaba), Amal-Mana and Swarna *sub 1* were the most preferred varieties of farmers due to traits like healthy plants, more no. of tillers, long panicle, medium height, expected higher grain yield. The least preferred varieties were Sabita and SR 26B due to traits like less number of tillers, short panicle length, less number of panicle and expected lower grain yield. At Gosaba and Basanti blocks tall varieties like Amal-Mana and CSRC(D) 12-8-12 were the preferred varieties since the water depth at Gosaba and Basanti were 25-30 and >30 cm respectively, these varieties performed better in terms of grain yield and chosen by the farmers.

Table 7.14: Agronomic data for *Kharif* (Aman) rice varieties evaluation trial conducted at at Dulki, Block- Gosaba, Dist. South 24 Parganas

Variety/ Line	Plant Ht (cm)	Total Till/ hill	Panicle/ hill	Length of Panicle (cm)	Grains / Panicle	Chaffs Panicle	Spikelet fertility (%)	1000 grain wt(g)	Yield (tha^{-1})	Duration (days)
Amal-Mana	138.66	10	10	22.14	120	10	92.62	29.0	4.55	144
Geetanjali	147.14	9	8	19.62	81	12	84.68	28.0	3.96	140
CSRC (D) 7-0-4	130.16	11	7	21.46	115	16	85.28	28.0	3.70	138
CSRC (D) 2-17-5	144.83	11	11	21.50	99	16	82.13	29.0	3.60	135
CSRC (D) 12-8-12	129.66	10	8	18.86	122	26	84.12	27.5	4.15	140
CSRC (D) 13-16-9	151.83	8	8	23.94	113	7	94.27	29.5	3.50	135
Swarna sub 1	106.83	13	11	20.37	107	9	87.67	27.0	4.38	134
NC 678	143.16	10	7	23.32	129	16	86.36	29.0	3.45	145
Sabita	128.00	9	6	22.66	118	19	82.65	28.5	3.15	142
SR 26 B	130.33	9	9	22.05	101	15	87.21	23.0	3.42	140

9. Comparison of average block yield with PVS yield

In the district of South 24 Parganas out of 30 blocks, 13 are salt affected (Joynagar I, Joynagar II, Kultali, Canning I, Canning II, Basanti, Gosaba, Mathurapur I, Mathurapur II, Patharprotima, Kakdwip, Namkhana and Sagar) and in the district of North 24 Parganas out of 22 blocks, 6 are salt affected (Haroa Hasnabad Hingalganj Minakhan Sandeshkhali I Sandeshkhali II). The average productivity of these blocks for aman and boro season rice is given in Fig. 3. The best PVS yields in the blocks of Basanti, Gosaba and Sandeshkhali II during aman season were 121.2, 113.6 and 65.3% higher than that of the respective block yields. During boro season the best PVS yields in the blocks of Gosaba and Sandeshkhali II were 82.9 and 39.2% higher than that of the respective block yields.

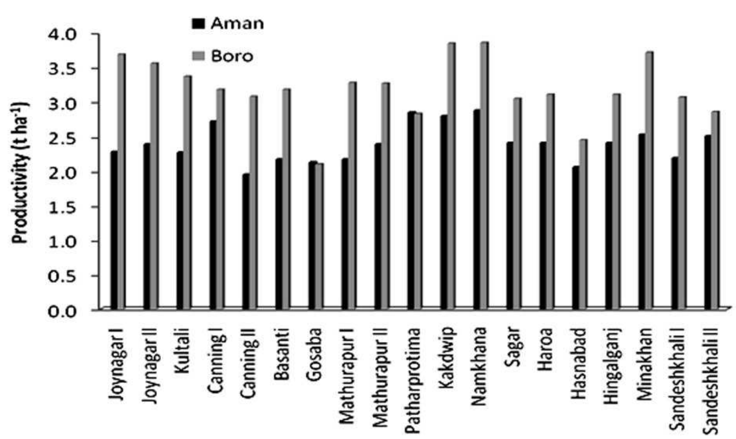


Fig. 3 Average productivity of Aman and Boro rice in salt affected blocks of South and North 24 Parganas districts of West Bengal

10. Epilogue

During *boro* (*rabi*/dry) season salinity is the main constraint for rice cultivation whereas during *aman* (*kharif*) season water depth was one of the important criteria for selection of suitable varieties. During boro season eight rice varieties/lines were tested under low (average 3.98 dS m^{-1}) and high salinity (average 5.36 dS m^{-1}) levels at North and South 24 Parganas districts of West Bengal respectively. Eight numbers of improved rice (Boro) varieties (Canning 7, Boby, Annada, Bidhan 2, CSR 4, Lalat, WGL 20471 and IET 7486) were evaluated. The rice variety 'Canning-7' was used as local check. At Sandeshkhali the highest grain yield of 3.98 t ha^{-1} (yield of Check var. was 3.48 t ha^{-1} which was significantly lower) was observed in case of Bidhan 2, which was at par with WGL 20471 (Lalminikit) and IET 748 (Sadaminikit) producing grain yields of 3.81 and 3.80 t ha^{-1} respectively. The higher grain yield in these varieties were due to more numbers of grains/panicle and 1000-seed weight. Lowest grain yield of 2.94 t ha^{-1} was observed in case of variety Lalat. At Gosaba the higher grain yield of 3.84 t ha^{-1} (yield of Check var. was 2.91 t ha^{-1} which was significantly lower) was recorded in case of variety Bidhan 2, which was superior over all other varieties. During *kharif* (rainy) season out of ten varieties/lines of rice (Amal-Mana, Geetanjali, CSRC(D) 7-0-4, CSRC(D)2-17-5, CSRC(D)12-8-12, CSRC(D)13-16-9, Swarna *sub1*, NC 678, Sabita and SR 26B), Swarna *sub1* (4.15 t ha^{-1}) performed best under medium land situation, Amal-Mana (4.55 t ha^{-1}) under low land situation and CSRC(D) 12-8-12 (4.80 t ha^{-1}) under semi-deep water situations in terms of grain yield. The same varieties were also selected under participatory varietal selection by the farmers and farm women of the nearby villages in South and North 24 Parganas district of West Bengal. When the best experimental yield were compared with the present block level yield it was found that this can be increased as high as 121.2, 113.6 and 65.3% in Basanti, Gosaba and Sandeshkhali II respectively during aman season and 82.9 and 39.2% in Gosaba and Sandeshkhali II respectively during *boro* season.

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Adoption of Improved Rice Varieties in Coastal Region of Bangladesh

M. R. Islam[1], M. A. Rahman[1], M. R. A. Sarker[1], N. Sharma[1] and G. B. Gregorio[2]

[1]*Plant Breeding Division, Bangladesh Rice Research Institute, Gazipur, Bangladesh*

[2]*Plant Breeding Genetics and Biotechnology Division, International Rice Research Institute, Philippines*

1. Coastal region in Bangladesh

About 1.0 million hectare of cultivable lands of the coastal areas of Bangladesh was affected by different levels of salinity (Islam *et al.*, 2013). According to the level of salinity this area was categorized into four *viz*. S_1 (EC < 4dS m^{-1}), S_2 (EC = 4-8 dS m^{-1}), S_3 (EC = 8-15 dS m^{-1}) and S_4 (EC > 15 dS m^{-1}). Among these categories S1- S3 were being used for rice cultivation in the wet season associated with high rainfall. On the other hand, brackish shrimp farming and salt cultivation were adopted in S_4 (Islam *et al.*, 2008). Soil salinity is one of the major constraints to rice production in coastal areas of Bangladesh. To reduce salinity, major engineering structure and expensive soil amendments are needed (Gregorio and Senadhira, 1993). However, these amendments require large investments. Thus tailoring rice plants to adapt under salt loading proved to be practical and effective. The soil and water were saline due to the inundation of coastal offshore by tidal saline water and dissolving rock and concentrated by evapo-transpiration. Three environmental constraints *i.e*. saline soil, saline surface and underground irrigation water and temperature (high and low) have made the environment very complex. The effect of these constraints is increasing day by day due to climate change.

Consequently, water stagnation of > 20-60 cm was prevailing in the rainfed lowland rice (RLR) ecosystem. Modern high yielding varieties of rice were not suitable for large parts of the coastal zone because the poor performance under water stagnation and high salinity in large areas. Moderately salt tolerant (EC = 8 dS m^{-1}) rice varieties viz. BR23, BRRI dhan40 and 41 had been observed to have limited adaptability in those areas due to short seedling height and sensitivity to water stagnation (Salam *et al.*, 2010). In fact, a large area remained fallow during dry season (November – April) due to high soil and water salinity. Few farmers cultivated short duration salt-sensitive rice varieties in this dry period with irrigation from shallow tube wells (Islam *et al.*, 2008).

Bangladesh Rice Research Institute (BRRI) and Bangladesh Institute of Nuclear Agriculture (BINA) released some rice varieties in collaboration with International Rice Research Institute (IRRI) through conventional and precision MABC breeding approach those could tolerate salt stress of 8-12 dS m^{-1} and possessed a large range of plant characters. Those varieties are tested in the farmer's field of different coastal districts of Bangladesh and observed their adoption in those areas.

2. Performance of the released varieties in the farmers' field of coastal region

Performance of released varieties in the farmers' field for T *Aman* and *Boro* season, 2009-2010

Three and five varieties suitable for saline prone coastal areas for wet and dry season respectively were evaluated in the salt affected coastal districts of Pirojpur, Khulna, Noakhali, Satkhira and Feni of Bangladesh. Thirty day-old seedlings were transplanted @ 2-3 seedlings with a spacing of 25 x 15 cm. The unit plot size was 5.4 m x 12 rows with two replications. Fertilizer dose was applied @ 80 (Wet) and 120 (dry):60:40 kg NPK/ha. Gypsum and $ZnSO_4$ was applied @ 40 and 10 kg/ha, respectively. N was applied in three splits. Total amount of P, K, Gypsum and $ZnSO_4$ was applied at final land preparation. Other cultural management was done as and when necessary.

The crop was harvested and monitored by active participation of farmers in wet season. The water salinity was varied from 0.1 to 2 dS m^{-1} in the experimental plots and 9-10 dS m^{-1} in the beside shrimp ponds. BRRI dhan40 was the highest yielded (4.4 and 5.0 tha^{-1}) variety followed by BRRI dhan41 (3.9 and 4.3 tha^{-1}) and BR23 (3.8 tha^{-1}) for both the locations (Table 8.1). The water salinity was monitored of the experimental plots and it was ranged from 0.2 to 15 dS m^{-1} in dry season. BRRI dhan47 was the highest average yielded (6.1 tha^{-1}) variety followed by BRRI dhan61 (6.0 tha^{-1}), BRRI dhan28-Saltol (5.4 tha^{-1}), BRRI dhan28 and CR dhan405 produced (5.1 tha^{-1}) the lowest (Table 8.2).

Table 8.1: Yield performance of released varieties in different locations of farmers field, Wet season, 2009-10

Sl. no	Designation	Duration (days)	Plant ht. (cm)	Yield (t ha^{-1})					
				Shyam	Kaliganj	Botia.	Nilganj	Tiakhali	Mean
1	BRRI dhan40	141	148	6.5	5.1	3.0	3.6	3.6	4.4
2	BRRI dhan41	143	140	5.1	4.8	2.6	3.5	3.6	3.9
3	BR23	151	132	4.9	4.9	2.7	3.3	3.4	3.8

Table 8.2: Yield performance of released varieties in different locations of farmers field, Dry season, 2009-10

Sl. no.	Designation	Duration (days)	Plant ht. (cm)	Yield (t ha^{-1})								
				Lon	Dhali	Sat	Bois	Raj	Dak	Chit	Hori	Mean
1	BR7105-4R-2 (BRRI dhan61)	150	105	6.7	6.8	7.0	3.8	6.9	3.5	6.7	6.4	6.0
2	Ir72046-B-R-4-3-2-1 (CR dhan405)	153	105	6.5	5.5	6.8	4.0	5.3	2.9	4.6	5.3	5.1
3	BRRI dhan 28-Saltol	146	110	7.0	6.3	5.7	2.8	7.1	2.9	4.4	6.6	5.4
4	BRRI dhan28	146	110	6.7	6.6	6.5	1.2	6.4	0.5	6.5	6.5	5.1
5	BRR I dhan47	150	110	6.8	6.8	7.3	3.7	6.9	3.2	7.0	7.0	6.1

Lon- Londonipara, Sonagazi; Dhali- Dhalia, Feni sadar; Sat- Satkhira sadar; Bois- Boishkhali, Shyamnagar; Raj- Rajbadh, Batiaghata; Dak- Parchalna, Dakope; Chit- Chitholia, Nazirpur; Hori- Horipagla, Nazirpur

Performance of released varieties in the farmers' field for wet and dry season, 2010-2011

Six and three varieties suitable for saline prone coastal areas for wet and dry season respectively were evaluated in the salt affected coastal districts of Pirojpur, Khulna, Noakhali, Satkhira and Feni of Bangladesh. Thirty day-old seedlings were transplanted @ 2-3 seedlings with a spacing of 25 x 15 cm. The unit plot size was 5.4 m x 12 rows with two replications. Fertilizer dose was applied @ 80 (Wet) and 120 (dry):60:40 kg NPK/ha. Gypsum and $ZnSO_4$ was applied @ 40 and 10 kg/ha, respectively. N will be applied in three splits. Total amount of P, K, Gypsum and $ZnSO_4$ was applied at final land preparation. Other cultural management will be done as and when necessary.

The water salinity was < 2 dS m^{-1} in the experimental plots and 9-10 dS m^{-1} in the beside shrimp ponds. BRRI dhan54 was shown the highest mean yield (6.1 tha^{-1}) followed by BRRI dhan53 (5.2 tha^{-1}), OM4498, BRRI dhan40, BR23 (5.0 tha^{-1}) and BRRI dhan41 (4.5 tha^{-1}) produced lowest yield (Table 8.3). OM4498 and BRRI dhan53 showed the lower duration but good harvest. The water salinity was monitored the experimental plots and it was ranged from 2 to 33 dS m^{-1} in dry season. BRRI dhan61 was shown the highest average yield (6.3 tha^{-1}) followed by BRRI dhan47 (6.2 tha^{-1}), IR72579-B-3-2-3-3 (5.0 tha^{-1}), and BRRI dhan28 produced (4.6 tha^{-1}) the lowest (Table 8.4).

Performance of released varieties in the farmers' field for wet and dry season, 2011-2012

3.1 Amtali, Barguna (Low saline area)

Experiments were conducted following randomized complete block design (RCB) with three replications using twelve and ten varieties in wet and dry season respectively in Amtali, Barguna.

Table 8.3: Yield performance of released varieties in different locations, Wet season, 2010-11

Sl. no.	Designation	Duration (days)	Plant ht. (cm)	Yield (t ha^{-1})						
				Sat	Deb	Paik	Naz	Sona	Noak	Mean
3	OM4498	115	102	5.2	5.4	—	4.3	4.6	5.1	5.0
7	BRRI dhan53	122	115	5.5	5.7	5.5	5.3	4.9	4.8	5.2
8	BRRI dhan54	135	105	6.8	6.7	5.8	5.9	5.3	6.6	6.1
7	BRRI dhan40	142	128	6.0	5.8	4.6	4.3	4.8	4.4	5.0
8	BRRI dhan41	146	123	4.6	5.0	4.3	4.2	4.7	4.6	4.5
9	BR23	154	106	5.7	5.8	4.8	3.1	4.4	5.4	5.0

Naz= Nazirpur; Sona= Sonagazi; Deb= Debhata; Noak= Noakhali; Paik= Paikgasa plot, Sat= Satkhira

Table 8.4: Yield performance of released varieties in different locations, Boro, 2010-11

Sl. no.	Designation	Plant ht. (cm)	Duration (days)	Yield (t ha^{-1})						
				Deb	Asha	Paik	Naz-T	Naz-C	Sona	Mean
1	Ir72579-B-3-2-3-3	102	148	5.7	2.5	1.6	5.7	6.5	7.9	5.0
2	BRRI dhan61	96	146	6.6	4.9	3.8	6.3	7.1	8.4	6.3
3	BRRI dhan28	111	142	5.8	1.5	0.0	6.5	6.0	7.6	4.6
4	BRRI dhan47	102	146	6.2	4.6	3.2	7.3	8.1	7.9	6.2

Naz (T)= Tarabunia, Nazirpur; Naz (C)= Chalitabaria, Nazirpur; Sona= Sonagazi; Deb= Debhata; Asha = Ashasuni; Paik = Paikgasa

Twenty-one (21) and 35 days old seedlings were transplanted in the field wet and dry seasons respectively and 2-3 seedlings per hill were transplanted. The spacing was 25 X 15 cm. Fertilizer dose was used: Urea-TSP-MoP-Gypsum-$ZnSO_4$ @ 152 (wet) and 220 (dry)-53 (wet) and 75 (dry) - 83 (wet) and 100 (dry)-61(wet) and 100 (dry) -10 kg per hectare. Urea was applied in three installments.. In T. Aman season, 152 kg urea kg per hectare was applied in three installments. Hand weeding was done when deemed necessary.

Finally eleven varieties were evaluated due to non-germination of BRRI dhan40 in Bazarkhali. In first set, the yield ranged from 1.54-4.30 tha^{-1}. BRRI dhan51 produced the highest yield (4.3 tha^{-1}) and local check Sadamota gave the lowest yield (1.5 tha^{-1}) (Table 8.5). Second set was severely damaged at seedbed due to submergence. BRRI dhan51, 52 and 54 performed better than others (> 4 tha^{-1}) although there was submergence stress. The yield of third set was found higher compare with the first set. BRRI dhan33 and BRRI dhan39 gave highest yield (3.46 tha^{-1}) and the lowest yield obtained again from Sadamota (1.80 tha^{-1}) (Table 8.5).

Significant differences observed among the varieties for yield (Table 8.7) in dry season. The yield ranged from 5.64-8.80 t ha^{-1}. BRRI hybrid dhan2 produced the highest yield (8.80 t ha^{-1}) followed by BRRI hybrid dhan3 (8.64 t ha^{-1}) and Alloran (8.15 t ha^{-1}). However, Alloran, BRRI dhan29 (7.47 t ha^{-1}) and BRRI dhan55 (7.58 t ha^{-1}) gave the statistically similar yield. The lowest yield was observed in BRRI dhan50 (5.64 t ha^{-1}). The yield was low due to salinity immediate after transplanting some plants damaged since they were salt sensitive variety.

3.2. Moderate saline area (Batiaghata, Khulna)

Experiments were conducted following randomized complete block design (RCB) with three replications using eleven and ten varieties in wet and dry season respectively in Batiaghata, Khulna. Twenty-five (25) and 35 days old seedlings were transplanted in the field in wet and dry seasons

Table 8.5: Yield and agronomic characteristics of 1st and 3rd), T Aman, 2011-12, Bazarkhali, Amatoli, Barguna (1st set- Date of sowing: 24 June, 2011; 3rd set 16 August 2011)

SL#	Genotype	Plant height (cm)		Sterility (%)	Growth duration (days)		Yield (tha^{-1})	
		1st set	3rd set		1st set	3rd set	1st set	3rd set
1	BRRI dhan33	126.3	77.7	22	117	111	2.60	3.46
2	BRRI dhan39	111.3	79.3	7	118	113	3.24	3.47
3	BRRI dhan41	151.0	98.7	20	153	112	2.79	3.34
4	BRRI dhan44	134.3	96.7	16	138	120	2.87	3.23
5	BRRI dhan51	109.3	60.3	12	140	134	4.30	2.26
6	BRRI dhan52	126.3	93.7	19	135	126	2.55	3.37
7	BRRI dhan53	118.3	86.7	8	118	122	2.75	3.15
8	BRRI dhan54	147.7	97.0	20	140	132	3.65	3.37
9	BINA dhan8	110.3	89.0	16	113	118	2.83	3.24
10	BRRI dhan30	132.3	88.3	20	137	124	3.69	3.02
11	Sadamota (ck)	161.0	117.3	19	168	133	1.54	1.80
	LSD (0.05)	5.11	5.87	5.63	0.89	0.29	0.95	0.53
	CV (%)	2.31	3.85	20.32	0.39	3.14	18.71	10.09

Table 8.6: Yield and agronomic characteristics of 12 varieties, T Aman, 2011-12, Bazarkhali, Amatoli, Barguna (2nd set- Date of sowing: 15 July, 2011)

Sl#	Genotype	Plant height (cm)		Duration (days)		Yield (tha^{-1})	
		RI	RII	RI	RII	RI	RII
1	BRRI dhan33	102	114	121	120	3.5	4.22
2	BRRI dhan39	104	–	121	–	3.77	–
3	BRRI dhan40	–	–	–	–	–	–
4	BRRI dhan41	123	–	140	–	3.32	–
5	BRRI dhan44	118	–	142	–	4.76	–
6	BRRI dhan51	80	81	140	142	4.13	4.00
7	BRRI dhan52	107	114	140	140	4.49	4.30
8	BRRI dhan53	114	–	127	–	3.90	–
9	BRRI dhan54	129	127	135	135	4.00	4.49
10	BINA dhan8	101	101	117	118	3.76	4.04
11	BRRI dhan30	104	110	142	142	3.70	3.14
12	Sadamota	137	–	161	–	2.42	–

Damaged due to submergence stress

Table 8.7: Yield and agronomic characteristics of 10 genotypes at Boro, 2011-12, Bazarkhali, Amtali, Barguna

Genotype	Plant height (cm)	Tiller no./hill	Duration (days)	Panicle no/hill	Filled grain	Unfilled grain	% Sterility	Yield (tha^{-1})
BRRI dhan28	101.0	15	148	12	106	19	15	6.41
BRRI dhan29	89.7	16	161	13	128	34	21	7.47
BRRI dhan47	96.7	13	152	11	98	21	17	6.81
BRRI dhan50	83.7	17	159	13	106	26	20	5.64
BRRI dhan53	105.0	13	150	11	88	15	15	6.5
BRRI dhan55	90.0	14	155	11	92	14	13	7.58
BRRI dhan45	91.7	12	144	10	84	26	24	5.82
Alloran	97.3	13	159	10	88	19	18	8.15
BRRI Hybrid dhan2	97.3	15	159	11	99	19	16	8.8
BRRI Hybrid dhan3	95.3	14	159	12	91	24	20	8.64
LSD (0.05)	3.33	1.91	3.5	2.17	13.50	–	–	0.50
CV (%)	2.05	7.82	2.57	11.08	8.03	–	–	3.44

respectively and 2-3 seedlings per hill were transplanted. The spacing was 25 X 15 cm. Fertilizer dose was; Urea-TSP-MoP-Gypsum-$ZnSO_4$ @ 152 (wet) and 220 (dry)-53 (wet) and 75 (dry) -83 (wet) and 100 (dry)-61(wet) and 100 (dry) -10 kg ha^{-1}. Urea was applied in three splits. Hand weeding was done when deemed necessary.

Significant difference observed among the varieties for yield performance in wet season it was ranged from 1.40 - 4.16 tha^{-1}. BRRI dhan52 (4.16 tha^{-1}) produced the highest yield followed by BR23

(4.1 tha^{-1}) and BRRI dhan41 (4.09 tha^{-1}). The lowest yield was observed in Saltol-Sub1 (IR84649-120-8-1-B) (1.40 tha^{-1}), Saltol+Sub2 (1.55 tha^{-1}) and BINA dhan8 (1.87 tha^{-1}) (Table 8.8). All early varieties (BRRI dhan53, BINA dhan8, IR84649-120-8-1-B, Saltol+Sub1) produced low yield due to damage by rat.

The yield ranged from 3.87 - 5.21 t ha^{-1}. BRRI hybrid dhan3 produced the highest yield (5.21 t ha^{-1}) followed by BRRI hybrid dhan2 (5.07 t ha^{-1}) and Alloran (4.76 t ha^{-1}). However, Alloran, BRRI dhan47 (4.54 t ha^{-1}) and BRRI dhan50 (4.56 tha^{-1}) gave the statistically similar yield (Table 8.9). The lowest yield was observed in BRRI dhan45 (3.87 t ha^{-1}). The yield in *boro* season was low in Batiaghata due to improper land preparation. Using spade did not properly puddle Land.

Table 8.8: Yield and agronomic characteristics of ten genotypes, T Aman, 2011-12 Batiaghata, Khulna

Sl #	Genotypes	Plant ht. (cm)	Duration (days)	Sterility (%)	Yield (tha^{-1})	Remarks
1	BR23	134.3	169	43	4.10	
2	BRRI dhan41	128.7	154	22	4.09	
3	BRRI dhan44	136.0	140	34	3.20	
4	BRRI dhan49	111.0	140	32	3.27	
5	BRRI dhan52	120.0	140	34	4.16	
6	BRRI dhan53	101.3	122	27	2.58	Rat Damage
7	BRRI dhan54	121.3	154	27	3.55	False smut
8	BINA dhan8	90.7	120	30	1.87	Rat Damage
9	IR84649-120-8-1-B)	98.3	120	27	1.40	Rat Damage
10	Saltol+Sub2	97.3	120	32	1.55	Rat Damage
11	Morichsail (ck)	163.0	169	13	2.71	
	LSD (0.05)	6.25	1.015	7.57	0.618	
	CV (%)	3.10	0.39	15.26	12.29	

Table 8.9: Yield and agronomic characteristics of 10 genotypes during Boro, 2011-12, Batiaghata, Khulna

Variety	Plant height (cm)	Duration (days)	Panicle no/hill	Yield (tha^{-1})
BRRI dhan28	88	145	22	4.39
BRRI dhan29	94	163	24	5.06
BRRI dhan45	90	145	22	3.87
BRRI dhan47	92	152	22	4.54
BRRI dhan50	81	155	22	4.56
BRRI dhan53	92	146	23	4.34
BRRI dhan55	84	153	23	3.98
Alloran	90	152	24	4.76
BRRI Hybrid dhan2	91	155	23	5.07
BRRI Hybrid dhan3	84	148	21	5.21
LSD (0.05)	7.11	2.74	2.36	0.829
CV (%)	4.67	1.06	6.10	10.56

3.3. High saline area (Kaliganj, Satkhira)

The experiment was conducted following randomized complete block design (RCB) with three replications using ten varieties at Sehara, Kaliganj, Satkhira. Seeding was done in the seedbed in two different dates (15 July and 30 July). Thirty six and 26 days old seedlings of 1st and 2nd set were transplanted with 2-3 seedlings per hill in the field. The spacing was 25 X 15 cm. Fertilizer dose used was; Urea-TSP-MoP-Gypsum-$ZnSO_4$ @ 152 (wet) and 220 (dry)-53 (wet) and 75 (dry) -83 (wet) and 100 (dry)-61(wet) and 100 (dry) -10 kg per hectare. Urea was applied in three installments. Hand weeding was done when deemed necessary.

Salinity level varied from 4.0-7.1 dS m^{-1} and 3.0-4.0 in gher-1 and gher-2 respectively throughout the growing season in wet season. In 1st set, most of the varieties like BRRI dhan44, BRRI dhan47, BRRI dhan52, BRRI dhan53 and BRRI dhan54 produced good yield of 4.23 tha^{-1}, 3.31 tha^{-1}, 3.72 tha^{-1}, 3.35 tha^{-1} and 3.29 tha^{-1} respectively (Table 8.10 and 8.11). Because the salinity level and water depth was low during transplanting therefore, seedling recovery was higher and no seedling damage. In 2nd set, seedling damage was higher due to high salinity (5.0 dS m^{-1}) and water depth was 13 cm. Consequently most of the varieties were not survived except the varieties (BRRI dhan47, BINA dhan8, BRRI dhan53 and BRRI dhan54), which have the salt tolerance at early seedling stage.

Performance of released varieties in the farmers' field for T *Aman* season, 2012-2013

4.1. Low saline area (Amtali), Barguna

Three sets of experiment were conducted following randomized complete block design (RCB) with three and two replications using twelve varieties including one local check (Sadamota) at Bazarkhali, Amtoli, Barguna. Seeding was done in three different dates (24 June, 15 July and 07 August 2012). Twenty one, 29 and 23 days old seedlings were transplanted using 2-3 seedlings per hill. The spacing was 20 X 15 cm. Fertilizer dose used was; Urea-TSP-MoP-Gypsum-$ZnSO_4$ @ 152 (wet) and 220 (dry)-53 (wet) and 75 (dry) -83 (wet) and 100 (dry)-61(wet) and 100 (dry) -10 kg per hectare. Urea was applied in three splits. Hand weeding was done when deemed necessary. The

Table 8.10: Yield and agronomic characteristics of ten genotypes, (1st set), Kaliganj, Satkhira, T Aman, 2011-12

Sl No	Genotype	Plant Height (cm)	Duration (days)	Yield (tha^{-1})	PAcp
1	BRRI dhan23	128	150	3.4	6
2	*BRRI dhan40	-	-	-	9
3	BRRI dhan41	120.0	145	2.36	5
4	BRRI dhan44	118.3	136	4.23	5
5	BRRI dhan47	90.3	115	3.31	5
6	BRRI dhan52	111.3	144	3.72	6
7	BRRI dhan53	95.0	127	3.35	6
8	BRRI dhan54	108.7	124	3.29	5
9	BINA dhan8	88.0	116	2.75	6
10	IR8465-311-5-1-1-3	81.0	138	2.20	7

PAcp= Overall phenotypic acceptability, where score one (1) indicating higher tolerance and nine indicating most sensitivity.* damaged due to water stagnation

Table 8.11: Yield and agronomic characteristics of ten genotypes, (2nd set), Kaliganj, Satkhira, T Aman, 2011-12

Sl No	Genotype	Plant height (cm)	Duration (days)	Yield (tha^{-1})
1	BRRI dhan23	–	–	–
2	BRRI dhan40	–	–	–
3	BRRI dhan41	–	–	–
4	BRRI dhan44	–	–	–
5	*BRRI dhan47	92.0	115	1.47
6	BRRI dhan52	–	–	–
7	*BRRI dhan53	95.3	125	0.61
8	*BRRI dhan54	110.7	124	0.43
9	*BINA dhan8	87.0	115	1.94
10	IR8465-311-5-1-1-3	–	–	–

*The adaptable varieties, - Damaged due to high salinity

water salinity was monitored weekly for whole crop growth period, and it ranged from 0.14 to 0.98 ds m^{-1} so no more significant salinity effect was observed.

The yield of 1st and 2nd sets was found higher compared with the 3rd set. In 1st and 2nd sets, most of the varieties produced similar yield except BR11-Saltol, BRRI dhan54 and local check Sadamota, gave higher yield in 2nd set than 1st set. From this finding, it indicates that the optimum time of seeding for this area is 1st July to mid July. In first set, the yield ranged from 3.5-5.6 tha^{-1}. BRRI dhan52 produced the highest yield (5.6 tha^{-1}) and local check Sadamota gave the lowest yield (3.5 tha^{-1}) (Table 8.12). In 2nd set, the yield ranged from 4.2-5.8 tha^{-1}. BR11-Saltol produced the highest yield (5.8 tha^{-1}) and BRRI dhan33, BRRI dhan57 and local check Sadamota gave the lowest yield (4.2 tha^{-1}) (Table 8.13). BRRI dhan53 and BRRI dhan54 gave highest yield (4.0 tha^{-1}) and the lowest yield obtained from Sadamota (2.5 tha^{-1}) in 3rd set (Table 8.14).

Table 8.12: Yield and agronomic characteristics of 11 genotypes, T. Aman 2012-13, Amtoli, Barguna (1st set)

Sl#	Variety	Duration (days)	Plant height (cm)	Yield (tha^{-1})
1	BR23	156	132.7	5.1
2	BRRI dhan33	–	–	–
3	BR11-Saltol	139	125.3	5.5
4	BRRI dhan41	153	134.0	5.5
5	BRRI dhan44	138	121.0	5.4
6	BRRI dhan51	146	100.0	4.8
7	BRRI dhan52	144	122.3	5.6
8	BRRI dhan53	–	–	–
9	BRRI dhan54	142	132.3	5.1
10	BINA dhan8	–	–	–
11	BRRI dhan57	–	–	–
12	Sadamota (local ck.)	165	152.7a	3.5
	LSD (0.05)	1.7	2.1	0.9

-Rat damage due to earliness

Table 8.13: Yield and agronomic characteristics of 11 genotypes T. Aman 2012-13, Amtoli, Barguna (2nd set)

Sl#	Variety	Duration (days)	Plant height (cm)	Yield (tha^{-1})
1	BR23	143	125.0	5.5
2	BRRI dhan33	110	103.7	4.2
3	BR11-Saltol	129	105.0	5.8
4	BRRI dhan41	128	141.0	5.3
5	BRRI dhan44	127	113.7	5.0
6	BRRI dhan51	136	89.0	5.3
7	BRRI dhan52	129	113.0	5.3
8	BRRI dhan53	124	107.7	4.7
9	BRRI dhan54	126	119.3	5.6
10	BINA dhan8	130	95.3	4.8
11	BRRI dhan57	105	79.7	4.2
12	Sadamota (local ck.)	148	148.0	4.2
	LSD (0.05)	1.5	4.7	0.6
	CV (%)	0.7	2.5	7.5

Table 8.14: Yield and agronomic characteristics of 11 genotypes with local check (Sadamota), T. Aman 2012-13, Bazarkhali, Amtoli, Barguna (3rd set)

Sl#	Variety	Duration (days)	Plant height (cm)	Yield (tha^{-1})
1	BR23	119d	111.0	3.7
2	BRRI dhan33	112e	92.0	3.9
3	BR11-Saltol	131a	93.5	3.4
4	BRRI dhan41	–	–	–
5	BRRI dhan44	125b	108.5	3.5
6	BRRI dhan51	131a	78.5	3.6
7	BRRI dhan52	126b	97.5	3.3
8	BRRI dhan53	123c	106.5	4.0
9	BRRI dhan54	112	105.0	4.0
10	BINA dhan8	126	93.0	3.9
11	BRRI dhan57	105	81.5	2.8
12	Sadamota (local ck.)	125	123.5	2.5
	LSD (0.05)	1.8	2	0.8
	CV (%)	0.7	1.9	10.8

Germination problem

4.2. Moderate saline area (Batiaghata, Khulna)

Two sets of experiment were conducted following randomized complete block design (RCB) with three replications using twelve varieties including local check (Kumri) at Batiaghata, Khulna. Seeding was done in three dates (24 June, 15 July and 6 August, 2012). The 3rd set of experiment was damaged due to heavy rainfall immediate after sowing. Twenty one day old seedlings were transplanted (15 July and 6 August 2012) with 2-3 seedlings per hill. The spacing was 20 X 20 cm.

Urea was applied in three installments. First splits was applied 7-10 days after transplanting, second installment was applied when 4-5 tillers emerged and third installment was top-dressed 5-7 days before panicle initiation. In T. *Aman* season, 152 kg urea per hectare was applied in three installments. Farmers practice/ BRRI recommended dose was used: Urea-TSP-MoP-Gypsum-$ZnSO_4$ @ 152-53-83-61-10 kg per hectare. Hand weeding was done when deemed necessary. Insect pest managements were performed in the growing season as and when necessary.

Highly significant variation was observed among the varieties for yield in both sets. The yield ranged from 2.8-4.3 tha^{-1} in 1st set and 2.4-6.0 tha^{-1} in 2nd set. BR11-Saltol (4.3 tha^{-1}) produced the highest yield followed by BRRI dhan54 & BRRI dhan52 (4.1 tha^{-1}), and BRRI dhan28-Saltol (2.8 tha^{-1}) produced the lowest yield in 1st set (Table 8.15). The highest yield was observed in BRRI dhan52 (6.0 tha^{-1}) followed by BR11-Saltol (5.8 tha^{-1}), BRRI dhan53 & BRRI dhan54 (4.3 tha^{-1}) and the lowest in local check Kumri (2.4 tha^{-1}) in 2nd set (Table 8.16).

4.3. High saline area (Kaliganj, Satkhira)

Three sets of experiment were conducted following randomized complete block design (RCB) with two replications using ten varieties/ lines at Sehara, Kaliganj, Satkhira. Seeding was done in three different dates (01 July, 16 July and 31 July). Transplanting was done 03 September 2012 (1st and 2nd set) and 16 September 2012 (3rd set). Sixty four, 49 and 47 days old seedlings of 1st, 2nd and 3rd sets were transplanted during Transplanted Aman season 2012-13. BRRI recommended fertilizer dose was used (Urea-TSP-MoP-Gypsum-$ZnSO_4$ @ 152-53-83-61-10 kg ha^{-1}). Hand weeding was done when deemed necessary. Insect pest managements were performed in the growing season as and when necessary. Water salinity level varied from 2.1-6.3 dS m^{-1} throughout the growing season.

Table 8.15: Yield and agronomic characteristics of 11 genotypes, T. *Aman*, 2012-13, Batiaghata, Khulna (1st set)

Sl#	Variety	Duration (days)	Plant height (cm)	Yield (tha^{-1})
1	BR23	161b	123.3b	3.9abc
2	BRRI dhan41	149c	119.0c	3.0fg
3	BRRI dhan44	130f	112.3e	3.6b-f
4	BRRI dhan49	132ef	98.3h	3.7a-d
5	BRRI dhan52	134d	117.7cd	4.1abc
6	BRRI dhan53	120g	111.3ef	3.7a-e
7	BRRI dhan54	133de	121.0bc	4.1ab
8	BRRI dhan57	108i	106.3g	3.1efg
9	BINA dhan8	131ef	108.0fg	3.1d-g
10	BR11-Saltol	131ef	114.3de	4.3a
11	BRRI dhan28-Saltol	117h	100.0h	2.8g
12	Kumri (local ck.)	172a	163.0a	3.5c-f
	LSD (0.05)	2.3	3.5	0.6
	CV (%)	1.0	1.7	10.4

Table 8.16: Yield and agronomic characteristics of 11 genotypes, T. *Aman* 2012-13, Batiaghata, Khulna (2nd set)

Sl#	Variety	Duration (days)	Plant height (cm)	Yield (tha^{-1})
1	BR23	143b	130.0c	3.9bcd
2	BRRI dhan41	138c	122.0d	3.2d-f
3	BRRI dhan44	130e	141.7b	4.2bc
4	BRRI dhan49	131e	105.7g	4.3bc
5	BRRI dhan52	120g	118.7e	6.0a
6	BRRI dhan53	115h	111.0f	4.3b
7	BRRI dhan54	131e	122.7d	4.3b
8	BRRI dhan57	102i	112.3f	3.4c-e
9	BINA dhan8	122f	106.3g	3.8b-e
10	BR11-Saltol	135d	118.0e	5.8.a
11	BRRI dhan28-Saltol	115h	98.0h	2.9ef
12	Kumri (local ck.)	166a	167.7a	2.4f
	LSD (0.05)	12.0	2.7	0.9
	CV (%)	0.9	1.3	13.5

Table 8.17: Yield and agronomic characteristics of 10 genotypes, Kaliganj, Satkhira, T. *Aman* 2012-13 (3rd set)

Sl#	Variety	Duration (days)	Plant height (cm)	Yield (tha^{-1})
1	BR11-Saltol	125a	90.0b	2.7c
2	BRRI dhan28-Saltol	113d	74.0e	2.8c
3	BRRI dhan41	–	–	–
4	BRRI dhan44	–	–	–
5	BRRI dhan47	119e	93.0a	3.4b
6	BRRI dhan52	121b	94.0a	4.0a
7	BRRI dhan53	109e	78.5d	2.7c
8	BRRI dhan54	115d	85.5c	2.3d
9	BINA dhan8	122b	81.0d	2.3d
10	BR8371-4R-2	122b	84.0c	2.8c
	LSD (0.05)	1.8	2.8	0.2
	CV (%)	0.6	1.4	3.2

1st and 2nd sets were completely submerged from 6-10 September 2012 immediate after transplanting and varietal recovery was very low except BRRI dhan52. Finally no data was collected from 1st and 2nd sets. In 3rd set, all the varieties established but BRRI dhan41 and BRRI dhan44 were completely damaged by flood. Highly significant variation was observed among the varieties for yield performance. The yield ranged from 2.3-4.0 t ha^{-1}. BRRI dhan52 (4.0 tha^{-1}) produced the highest yield followed by BRRI dhan47 (3.4 tha^{-1}), BRRI dhan28-Saltol and BR8371-4R-2 (2.8 t/ha) and the lowest in BRRI dhan54 & BINA dhan8 (2.3 tha^{-1}) (Table 8.17). Sterility was comparatively lower for all genotypes in this polder and ranged from 9.7-30.9%. The highest sterility (%) was observed in BRRI dhan54 (30.9%) and lowest in BRRI dhan52 (9.7%).

5. Summary of improved varieties for coastal areas:

Recently a good number of improved varieties for coastal areas of Bangladesh have been recommended for cultivation after more focused and collaborative research in the different coastal districts of Bangladesh. The experiments were executed with active participations of farmers, DAE and NGO personnel. After four years evaluation of different varieties suitable for coastal region the following varieties were suggested for cultivation in different salt affected areas. In the Fig. 1,2,3 some successful cultivation of different varieties in salt affected coastal areas of Bangladesh are shown.

For wet season: BRRI dhan44**,** BRRI dhan47, BRRI dhan52, BRRI dhan54, BINA dhan8 were recommended for high salt affected areas with flash flood prone areas. BRRI dhan44, BRRI dhan49, BRRI dhan52, BRRI dhan54, BR11-Saltol were recommended for moderately salt affected areas. BRRI dhan44, BRRI dhan52, BRRI dhan53, BRRI dhan54, BR11-Saltol were recommended for less salt affected areas.

For dry season: BRRI dhan47, BINA dhan8, BRRI dhan61 and BINA dhan10 were recommended for medium to high salt affected areas. BRRI dhan28, BRRI dhan50, BRRI dhan55, BRRI dhan58, BRRI dhan47 and BRRI dhan61 were recommended for low saline affected areas.

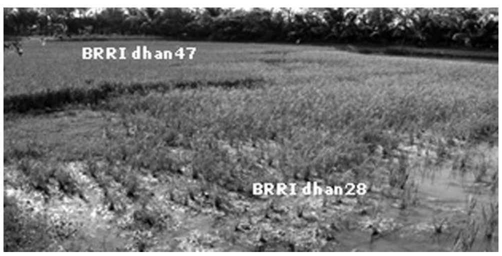

Fig.1. Successful cultivation of BRRI dhan47 in farmers brackish shrimp pond in Ashashuni, Satkhira, Bangladesh

Fig.2. Successful cultivation of BINA dhan8 in farmers field where salt farming is normal practice, Chittagong, Bangladesh

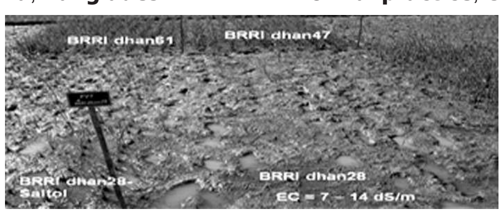

Fig.3. Successful cultivation of BRRI dhan61 in farmers field in Ashashuni, Satkhira, Bangladesh

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Climate Change Impacts and Adaptation Initiatives for Agriculture in Coastal Areas

B. K. Bandyopadhyay
Emeritus Scientist (ICAR)
Central Soil Salinity Research Institute Regional Research Station
Canning Town - 743 329

1. Introduction

Agriculture –which feed the entire human population– is under great threat due to climate change. Of late many agricultural systems are nearing crisis point even without climate change. More and more chemical fertilizers are now needed to produce per kg of food grain. This is particularly true in developing countries where the farm land is being over exploited to feed the rapidly growing population. Water is becoming scarce in many regions and climate change could be an additional stress. The climate change will result in higher average temperatures, changing rainfall patterns, rising of sea levels, more and more intense & extreme weather events such as droughts, floods, and hurricanes, etc. There will be lot of uncertainties about the location and magnitude of these changes and it poses a major threat to agricultural systems. Developing countries like India are particularly vulnerable to climate change because their economies are closely linked to agriculture and a large proportion of their population (mainly the poor farming community) depends directly on agriculture and natural ecosystems for their livelihoods. These people are poor in economic status, education and technical know-how to combat the adverse impact of climate change. Thus, climate change will act as 'risk multiplier' for the poorest countries of the world and will affect their sustainable development more compared to the developed countries.

Since the last few decades the average surface temperatures of the earth has risen appreciably as a result of continued emissions of green house gases. These changes are resulting in erratic weather patterns and the impacts are already being manifested in many parts of the world, particularly in tropical regions. These phenomena have serious implications on bio- diversity as well as economics and livelihood patterns of the people. According to the Fourth Assessment Report of the Inter Governmental Panel on Climate Change (IPCC) average global temperatures are likely to increase further by 1-6.4° C by 2100. The probable consequences of global warming include changes in temperature regime, rainfall pattern, agricultural yields, sea level rise, extreme weather events, melting of glaciers/ ice, changes in ecosystem function, forest fires, wildlife conservation, shifts in species distribution, possible extension of sub-tropical deserts,[13] etc. Of late some of these impacts are being felt with greater frequency in the Indian subcontinent e.g. extreme weather events such as cyclones on India's eastern coast and droughts in the western states of Rajasthan and Gujarat. Serious health related problems are also being attributed to climate impacts like outbreaks of vector borne diseases like malaria.

2. Coastal Region of Sundarban - A brief

Sundarbans is the world's largest mangrove ecosystem and has been declared as World heritage site by UNESCO in 1987. It is lying in the Ganga-Bramhaputra-Meghna delta region, overlapping the boundaries of India and Bangladesh. The sea level rise in this area will lead to increase salinity of land & water, higher tidal surges, permanent submergence of land masses with saline water and low agricultural yield increasing the vulnerability of communities and having an untold impact on the ecosystem and biodiversity of the area. There will be increased scarcity of freshwater and increase in the drainage congestion in the area. It is estimated that 10 cm sea level rise (SLR) will inundate 15% of Sundarbans, 25 cm SLR will inundate 40%, 45 cm SLR will inundate 75%, 60 cm SLR will inundate 100% and 100 cm SLR will destroy the whole Sundarbans in Bangladesh[33][37]. The delta in the Indian part covers an area of 9,630 sq. km of which the mangrove forest covers 4110 sq. km (total forest cover of India plus Bangladesh is about10,000 sq.km) and 1700 sq. km is occupied by water bodies. The area is consisting of main land and 102 low lying delta islands of which 52 are inhabited. The islands and its ecosystems are highly vulnerable to changes in climate. Recent research based on satellite imagery has revealed that sea level is rising in Sunderbans at an average rate of 3.14 mm a year. In the past two decades four islands (Bedford, Lohachara, Kabasgadi and Suparibhanga) have been submerged and 6000 families rendered homeless[34][38]. Shore erosion is a normal phenomenon in an active delta but takes place very gradually. However, in the recent years some islands of Sundarbans region are facing acute problem of accelerated coastline erosion as well as periodic flooding of homestead and productive agricultural lands. The mangrove tree species *Sundari* (*Heriteria fumes*), the main economic species in the Sundarbans and from which the name of Sundarbans has probably been derived, is being gradually replaced by less valuable Goran (*Ceriops decandra*) and Gewa (*Excoecaria agallocha*). The loss of the Sundarbans wetlands due to sea level rise would reduce breeding ground for many estuarine fish, and consequently their population and production.

3. Causes of global warming

Global warming is the rise in the average temperature of earth's atmosphere and oceans. Earth and ocean's temperature depends on the balance between energy entering and leaving the earth's system. When incoming energy from the sun is absorbed by the earth system, the earth warms up. When the sun's energy is reflected back into space, earth avoids warming. When energy is released back into space, earth cools. The factors causing changes in earth's energy balance [35] are:

(i) Changes in the greenhouse gas content of atmosphere, which affects the amount of heat retained by the earth
(ii) Variations in the sun's energy reaching the earth
(iii) Changes in the reflectivity of the earth's atmosphere and surface

Since the early 20th century, the earth's mean surface temperature has increased (Fig. 1) by about 0.8 °C (1.4 °F) of which about two-thirds of the increase occurring since 1980. [1] [2]

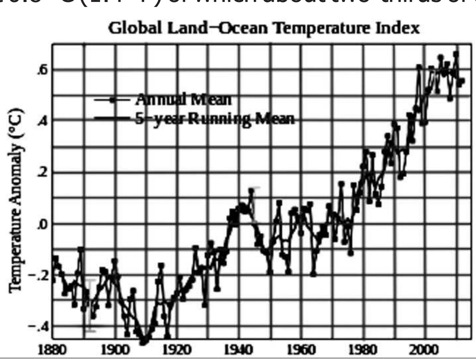

Fig. 1. Global mean land-ocean temperature changes from 1880–2012, relative to the 1951–1980 mean. The black line is the annual mean and the red line is the 5-year running mean. The green bars show uncertainty estimates (Source: NASA GISS)

It has been reported [35] that solar activity has been relatively constant, aside from the 11-year cycle, since the mid-20th century and therefore, does not explain the recent warming of the earth. Changes in the shape of the earth's orbit as well as the tilt and position of the earth's axis affect temperature on relatively long timescales (tens of thousands of years), and therefore cannot explain the recent warming. Similarly, changes in the reflectivity of the earth's atmosphere and surface were not significant to explain recent global warming [35].

Scientists are certain that Global warming is primarily caused by increasing concentrations of greenhouse gases (CO_2, CH_4 and N_2O) produced by human activities such as the burning of fossil fuels, deforestation, industrial production, agricultural activities, etc.. [3][4][5][6] . Fig.2. shows the contribution of different sectors to global warming .These findings are recognized by the national science academies of all major industrialized nations.[7]

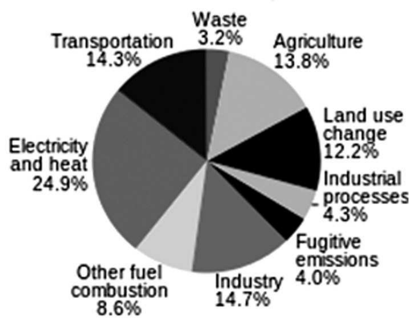

Fig 2. Annual worldwide green house gas emissions in 2005 by different sectors (Source: www.wikipidia: Global warming)

Carbon-di-oxide comes from the combustion of fossil fuels in cars, factories and electricity production and is most responsible for global warming. The content of carbon-di oxide in the atmosphere is increasing rapidly in the recent years (Fig.3). The major contributors of carbon-di oxide are the developed countries and USA in particular (Fig.4). The developed world's emissions had contributed most to the *stock* of GHGs in the atmosphere and the *per-capita emissions* (i.e., emissions per head of population) are still much low in developing countries. The emissions from the developing countries will now increase to meet their development needs.

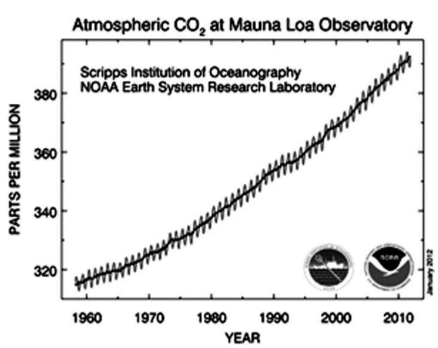

Fig. 3. Increase in atmospheric carbon dioxide over the year 1960-210 (Source: www.epa.gov/climatechange/science/causes.html)

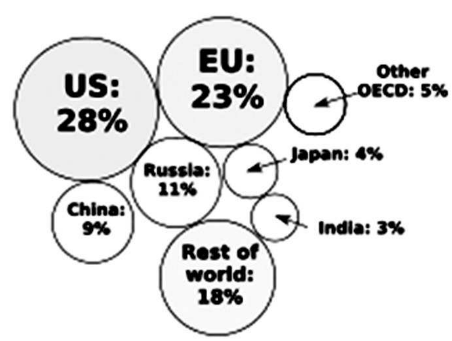

Fig. 4. Share of global cumulative energy-related carbon dioxide emission between 1890-2007 (Source: www.wikipidia: Global warming)

Besides CO_2 the other GHGs contributors include methane (Ch_4) released from agricultural activities and from the digestive systems of grazing animals (ruminants), nitrous oxide (N_2O) from fertilizers used in agriculture, gases used for refrigeration (chlorofluorocarbons) and industrial processes, and the loss of forests that would otherwise store CO_2. Water vapour (H_2O) is the most abundant greenhouse gas (GHG), however because it spends just a short time in the atmosphere so it is not considered as an important GHG. The practices like, conversion of forests, grass and pasture lands into crop lands result in significant releases of greenhouse gases. The Intergovernmental Panel on Climate Change (IPCC) estimated that 31% of total emissions of green house gases in 2004 came from agriculture and forestry.

Different greenhouse gases have different heat-trapping abilities. The other GHGs can trap more heat than CO_2. A molecule of methane (CH_4) produces more than 20 times the warming of a molecule of CO_2. Nitrous oxide (N_2O) is 300 times more powerful than CO_2. Other gases, such as chlorofluorocarbons (its use has been banned by many countries as it degrades the ozone layer) have heat-trapping potential thousands of times greater than CO_2. But because their concentrations are much lower than CO_2, none of these gases adds as much heat to the atmosphere as CO_2 does.

In order to understand the effects of all the gases together the greenhouse gases are considered in terms of the equivalent heat absorption capacity compared to CO_2. Since 1990, yearly emissions of GHGs have gone up by about 6 billion metric tons of "carbon dioxide equivalent" worldwide, a more than 20 percent increase.[36] USA and other developed countries are the major contributor (Fig. 4) to global carbon footprint (the amount of greenhouse gases released to the atmosphere by human activities such as, the burning of fossil fuels for energy, deforestation, industry, agriculture, etc. by a country is called its carbon footprint) rather than the developing countries.

Climate models projections were summarized in the 2007 in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). IPCC has projected that during the 21st century the global surface temperature is likely to rise a further by 1.1 to 2.9 °C (2 to 5.2 °F) for their lowest emissions scenario and by 2.4 to 6.4 °C (4.3 to 11.5 °F) for their highest.[8] The ranges of these estimates arise from the use of models which are differing in sensitivity to greenhouse gas concentrations.[9][10] The heat absorbed by the earth is not uniformly distributed throughout. The ocean is the main heat absorber and its heat content is much larger than any other store of heat energy in the land and air. Fig.5. shows the earth's heat balance over the two periods 1961 to 2003 and 1993 to 2003. Ocean accounts for more than 90% of the possible increase in heat content of the earth system during these periods. It has been established that the amount of glaciers/ ice in different parts of the globe is on decrease due to global warming. Thus, the global warming will result in sea level rise both due to increase in temperature of ocean and melting of glaciers/ ice.

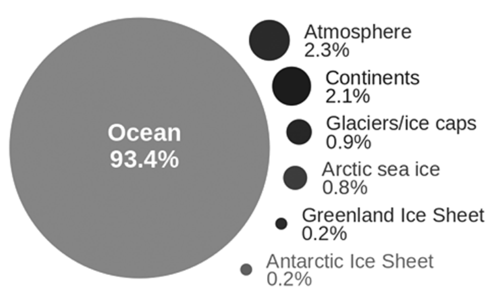

Fig.5. (source[27]). Global distribution of absorbed warming

4. Effect of Climate Change

The climate change and associated impacts [11] will vary from region to region around the globe.[12] Warming is expected to be strongest in the Arctic and will be associated with the continuing retreat of glaciers and permafrost sea ice. Other likely effects of the warming include a more frequent occurrence of extreme weather events including heat waves, droughts, heavy intensity rainfall, ocean acidification (due to dissolution of CO_2) and species extinctions due to shifting temperature regimes. This may result in great threat to food security (due to decreasing crop, fish and meat yields) of human being and the loss of habitat due to inundation.[14][15] Fragile ecosystems such as that of Sundarbans might have already been critically threaten even before significant climate change impacts manifest themselves.

Higher temperatures will challenge many agricultural systems. Plants are sensitive to high temperatures during critical stages such as flowering and seed development. Often combined with drought, high temperatures can mean disaster to crop yield. Increased carbon dioxide levels in atmosphere also have implications on crop plants, although impacts are complex and need further research. Climate change impacts may not be all negative everywhere. Some agricultural systems, mainly at higher latitudes and higher altitudes, may benefit at least in the short term from higher temperatures. Some dry areas may get more rainfall. But the most vulnerable will be the many millions of people who survive on rain-fed agriculture in Asia and Africa. Millions of people who make up the world's small-scale fishing communities and those who make their livelihoods in low-lying regions like the Indo-Gangetic plains will also be highly vulnerable.

Fishing communities are equally vulnerable. The aquaculture production will be under great challenge due to increased water temperatures, increased sea water acidity, extreme weather events, environmental hazards, harmful algal bloom, sea level rise, changes in phytoplankton-zooplankton population and sea currents. The impacts of these on marine ecosystems, particularly coral reefs, could be devastating.

Many pests and diseases of crops, animals and humans are sensitive to climate and temperature changes. The future changes may come in many unpredictable ways. Some, will become prevalent in areas where they were previously unknown. There is usually low immunity to a disease and poor knowledge about the pest or disease management in areas where they have not occurred before.

Natural ecosystems are equally at risk from climate change, a fundamental challenge of climate change is its rapid pace. The natural environment is not static, and ecosystems have evolved and adapted to gradually changing environmental conditions throughout history. The plants and animals that cannot quickly adapt to new conditions or relocate to new areas will become extinct. This will destabilizing vital ecosystems and will also erodes the genetic base for future crops & livestock. The impact of climate change on different sectors may be summarized as follows:

5. Mitigation Strategies to Climate Change

IPCC defines mitigation as activities that reduce greenhouse gas (GHG) emissions, or enhance the capacity of carbon sinks to absorb GHGs from the atmosphere. Climate change mitigation, in actual term, generally involves the human (anthropogenic) activities to reduce the emissions of greenhouse gases. Studies indicate that there is a substantial potential for future reductions in emissions of GHGs by a combination of emission-reducing activities such as energy conservation, increased energy efficiency gadgets, and satisfying more of society's power demands with renewable energy and/or nuclear energy sources. Climate change mitigation also includes acts to enhance natural sinks, such as reforestation, increased carbon sequestration in soil through appropriate management of agriculture, etc.

In order to limit global warming it is necessary to adopt policies that will limit greenhouse gas emissions by human activities. This will be more and more difficult with each year delay in taking appropriate mitigation measures as the volume of GHGs in atmosphere are on increase. More drastic measures will be required in later years to stabilize a desired atmospheric concentration of greenhouse gases. Most countries are now parties to the United Nations Framework Convention on Climate Change (UNFCCC),[16] whose ultimate objective is to prevent dangerous anthropogenic climate change activities.[17] The UNFCCC have adopted a range of policies designed to reduce greenhouse gas emissions[18][19][20][21] and to assist in adaptation to global warming.[18][21][22][23] The parties to the UNFCCC have agreed that emergent actions are to be taken to reduce the emission of GHGs[24] and that future global warming should be limited to below 2.0 °C (3.6 °F) relative to the pre-industrial level.[24] Reports published in 2011 by the United Nations Environment Programme[25] and the International Energy Agency[26] indicates that efforts taken in the early part of 21st century to reduce emission of GHGs may be inadequate to meet the UNFCCC's 2 °C target.

Average global temperatures are rising, and will continue to rise over the coming decades, limited mitigation measures taken may not show any visible impact, because of stocks of greenhouse gases already accumulated in the atmosphere. The rising temperatures are already having measureable impacts, on glaciers & ice caps, sea levels and rainfall patterns, and these impacts will also increase over the next decades. The ultimate temperature rise will depend on mitigation measures put in place to limit emissions of GHGs over the coming years. At this point of time, average temperatures are 0.7°C above pre-industrial levels; scenarios published by IPCC predict that temperature will rise up to 4.5°C or higher by 2080 depending on a range of factors and pathways that human development may take. Many believe that a rise of 2.0°C is the threshold beyond which impacts are likely to be severe, and dangerous to environmental systems.

Agricultural and land use practices also have a major role to play in mitigation measures. According to IPCC forestry, for example, accounted for some 17% of greenhouse gas emissions in 2004. But if deforestation can be halted, reforestation initiated, and existing forests are managed more sustainably by communities, forests could become part of the solution instead of part of the problem. Agriculture contributes about 14% of GHGs emission. But if soils can be better managed it can store more carbon. Agro-forestry is also an underutilized mitigation option in agriculture, it can store more carbon in trees, while improving the soil quality and storage of carbon in soil too. Use of bio-fuels can also be a good mitigation method. They have potential for reducing greenhouse gas emissions by replacing fossil fuels; but their production has its own environmental costs, and may compete with that of food and feed production. Ways and means should be developed to allow production of bio-fuels in an environmentally sustainable way that also benefits the poor farmers.

The results of mitigation efforts, in terms of reduced emissions and retained carbon and corresponding slowing of temperature rise, may not be evident for decades. But many of the options that relate agriculture and natural resources management will have immediate development benefits towards, the productivity of the natural resource or system. These are undoubtedly the win–win opportunities that the world should not miss. Whatever mitigation efforts may be taken, climate change is already happening, and temperatures will continue to rise during the coming years. It is not known exactly what adverse impact will happen and where, but the adverse impacts will intensify. The recent changes in global trends such as population growth, urbanization, increasing demands for water, over-exploitation of ecosystems, etc. will also have great adverse impact on climate change. If we really want meaningful mitigation we must re-look into the present trend in land use pattern & agricultural practices, energy generation and industrial activities within the global system as a whole.

6. Adaptations to Climate Change

The adaptation to climate change will depends on the ability or capacity of a system (human and natural) to adjust to climate change effects (climate variability and extremes) to (i) moderate potential damages, (ii) take advantage of opportunities and (iii) to cope up with the consequences. Unmitigated climate change (i.e., future climate change without efforts to limit greenhouse gas emissions) would, in the long term, be likely to exceed the capacity of naturally managed and human systems for adjustment/adaptation. Adaptations to climate change not just a local but might require trans-boundary partnership programme and regional and international co-operations.

There are already good numbers of technologies for adapting the climate change. Some will contribute to mitigation of climate change itself, some others will contribute for drought- heat- salt- and flood-tolerant improved crop varieties, new ways to irrigate crops and better ways to manage soils, etc. But many of those technologies lack implementation due to poor communication/transfer of technologies to the ground level users. In livestock sector, among many other options, livestock keepers can choose high yielding & high feed efficient adapted breeds and alternative feeds that do not depend on crops. This will reduce their vulnerability. There are many innovations to improve the sustainability of fisheries, forests and water supplies. The commitment of policy makers, efficient communication systems to ground level users, training & education (capacity building) of inhabitants, effective targeting and adequate resources could be sufficient to override the negative impacts of climate change. It will bring huge benefits to poor and vulnerable communities, immediately and in the future; in terms of improved food, livelihood and environmental security. The different adaptation strategies may be summarized in the following pages.

6.1. Crop management for changing climate adaptation

Developing crop varieties for changing climate- Climate change adaptations need attention on several traits in crop varieties, such as salinity, submergence, drought and heat tolerance, and high yielding. Farmers will like to have their crops/varieties performing well in difficult environments, but also to produce very high yields when conditions are more favourable. Breeding for vigorous root systems, for example, allows plants to capture scarce water. Molecular biology has opened up new horizons for crop breeding, and will become increasingly important. Identification and selection of useful genes using molecular markers has become routine in plant breeding laboratories. The use of biotechnology to genetically improve crops is still controversial, but the pressures on the world's agricultural systems may hasten its acceptance, with all the appropriate bio-safety precautions. Again, breeders can develop new varieties having genetic diversity to tolerate climate uncertainty, and other variables such as resistance to pests and diseases. Among the world's most naturally hardy food crops are barley, cassava, millet and sorghum, which are widely grown in dry climates. These and other naturally tolerant crops contain a wealth of useful genes for plant breeders for developing drought and other stress tolerant crops.

Rice for coastal region- The rising sea levels and flooding of coastal farmlands presents a real risk for coastal farmers. Rice is the only cereal crop that can withstand submergence/long waterlogging of land, but most varieties die if fully submerged for more than 3 days. IRRI researchers and its collaborators have recently identified a rice gene called Sub1A, which allows plants to survive under completely submerged condition for up to 2 weeks. The submergence tolerant trait has been transferred into a popular rice varieties like Swarna sub1, IR68 Sub 1, Swarna Mausri sub 1, etc. and the improved version is giving high yields while protecting against flooding. Similarly, attempts are being made by IRRI and its collaborators to develop varieties with both submergence tolerance and salt tolerance traits (saline water submergence of crops is expected in coastal areas as a result of sea level rise) with inclusion of both sub 1 and salt tol. genes, and already some promising lines have been developed. Floating agriculture and hydroponics may also be important adaptation techniques for coastal areas for deep and long submergence of land.

Adjusting crop sowing time- Global reports indicate loss of crop production in the scale of 10-40% by 2100 AD. Greater losses are expected in Rabi season, every 1°C increase in temperature will reduce wheat production by 4-5 million tons. The loss can be reduced to 1-2 million tons if farmers can judiciously change their time of planting/sowing in accordance to the changing pattern of climate.

Managing pests and diseases- Changing climate will change the pattern and intensity of attack of pests and diseases to crops and livestock. Temperature, humidity, rainfall and other weather parameters influence pest and disease spread through different mechanisms. Higher temperatures speed up the lifecycle of some insect pests and their vectors thus, the pest populations will grow faster. Similar impacts will be on disease vector insects which will increase the spread of some diseases. Anticipation of pest and disease outbreaks, and integrated pest and disease management (IPDM) where outbreaks occur, are the fundamentals behind managing changing pests and disease infestation pattern in future and participatory learning of IPDM is necessary. The farmers need to understand the relationships between crops, pests and diseases, and the changing climate so that they can adapt their own systems and build resilience.

Index insurance- Index insurance is insurance that is linked to an index, such as rainfall, temperature or crop yields, rather than actual loss. This approach solves some of the problems that limit access to traditional crop insurance. Unlike with traditional crop insurance, the insurance company does not need to visit farmers' fields to assess losses and determine payouts; instead it uses data from rain gauges and other installations near the farmer's field. There are now several examples of index insurance in use around the world, including India.

6.2. Water management for changing climate

Agriculture in developing countries mostly uses the traditional technologies for irrigation. Agriculture consumes about 70–90% of total use of water. With growing populations, competitive demands from other sectors it is predicted that there will be huge shortage of fresh water due to climate change. High quantity water will not be available for agriculture in future and at the same time it will not be sustainable too. Alternative improved technologies must be used to produce more food with less water to feed the growing population. The technologies to be adapted should have high water use efficiency both under rain-fed and irrigated conditions. Water harvesting, precision irrigation and multiple use of water are just some of many other options for eking out limited water supplies. Low quality water can be managed and used in conjunction/mixing with good quality water and tolerant crops/ varieties are to be selected. Improved water management on watershed basis should be adapted considering other multiple users. Appropriate policy governance and institutional system are to be developed in each country for efficient management of water on watershed basis.

Improving watershed management- Improved management of water on watershed basis requires not only actions by individual farmers but collective efforts to improve stewardship of this scarce resource. Approaches should be made to empower the local and rural institutions in small scale and to be replicated on a large scale. For efficient use of water integrated water management approach is a very useful option. ICRISAT has successfully promoted an integrated approach for watershed management in India and other Asian countries and is now beginning to transfer the innovation to Eastern Africa. IWMI and CPWF have also developed improved water management techniques on watershed basis.

On farm water storage options- Water storage from groundwater, through soil moisture, small tanks/large reservoirs is going to be increasingly important for rural communities dealing with water scarcity, for increasingly erratic precipitation patterns and shorter rainy seasons, etc. Multi-purpose reservoirs offer a particularly valuable adaptation option. IWMI and CPWF have achieved encouraging success in different countries by adapting small reservoir technology. The small farm reservoirs (farm pond/furrows) technology developed by Central Soil Salinity Research Institute, Regional Research Station, Canning Town, West Bengal for Ganges delta (Sundarbans) and other coastal areas of India for harvesting rainwater in farm pond/deep furrows and its multiple uses turned out to be very successful[30][31] The technology has been implemented to large number of farmers' field in Ganges delta and Andaman Islands under NAIP (GEF) funded programme. With the use of these technologies the income of farm families increased by several times and there was increase in green cover of land (due to increased cropping intensity) by 2-3 hundred percent. The technologies have been economically and environmentally sustainable.

Using wastewater- Wastewater is already used for food production in many resource-poor countries when other water sources are less assured while there is high demand for food. Research at Central Soil Salinity Research Institute, Karnal, India has shown that wastewater can be an asset instead of a problem. Untreated waste water can be used successfully for irrigation of agro-forestry and other non-edible crops. Irrigation with untreated, partly treated or diluted wastewater has environmental and health risks, but farmers use it because it is a reliable source (often the only source) throughout the year, and often contains plant nutrients which reduces or eliminates the need for fertilizer. Technologies need to be further developed for use of waste water even for edible crops without any health risk.

6.3. Soil management for climate change adaptation

Even without climate change, deterioration of soil quality is one of the main challenges to future agriculture. This is largely due to over exploitation of soil resource for higher production, unsustainable crop & fertilizer management, imbalance fertilizer application and no/or little application of organic manures/ crop residues to soil. In each country there should be a policy for soil quality management and land use according to land zonation for sustainability of production. The present practices mines soils of their nutrients without adequate replenishment. This is leading to severe degradation of soil and consequently, increasing vulnerability of farming communities to climate change.

Improving soil organic matter- Appropriate soil management will be conserving/ improving soil quality and will reduce vulnerability of farming systems in the face of climate change. Organic manure is a critical input which improves soil fertility, soil structure, water-holding capacity, soil aeration condition and, in short, all the vital physical, chemical and microbiological functions in soil. Ways to improve the soil organic matter include addition of compost, crop residues, green manure, animal manure, intercropping, alley cropping (a method of cropping in which rows of a crop are sown between the rows of hedges or nitrogen-fixing trees, the roots of which enrich the soil), agro-forestry and growing cover crops especially the legume cover crops. This is perhaps the best win–win opportunity for agriculture. More organic matter in the soil means, better microbiological health of soil, better availability of nutrients, less loss of nutrients, less carbon dioxide in the atmosphere (due to increased carbon sequestration in soil) and in the long run higher yield, better adaption and mitigation to climate change, and better environment.

Application of micro dose of fertilizer- Under this system small quantities of inorganic fertilizers are applied in a hole near sowing/planting points, the practice is called 'micro-dosing'. Many farmers in drought ridden African countries are practicing this method and getting higher yield with less fertilizers. This increases the fertilizer use efficiency, reduces cost of cultivation and environmental pollution.

Fertigation- Fertigation is a technique of applying fertilizers in low concentration along with irrigation water. Application of fertilizers in low concentration with irrigation water will increase their efficiency and reduce losses. This will reduce environmental pollution by reducing release of N_2O (due to use of less fertilizers) in atmosphere. The loss of fertilizers will be further reduced when used with improved irrigation technologies like, drip or sprinkler.

Foliar application of fertilizer- Foliar application of fertilizers is a technique of feeding plants by applying liquid fertilizer in low concentration directly to their leaves. Application of fertilizers through foliar sprays, particularly the nitrogen fertilizers, will increase its efficiency and will reduce its losses and, less release of N_2O in the atmosphere.

Use of Bio-fertilizers- Bifertilizers contain living microorganisms. Biofertilizers when applied to seed, plant surfaces, or soil, the microbes colonizes in the rhizosphere or in the interior of the plant and promotes growth by increasing the supply or availability of nutrients to the host plant or release of growth promoting substances. Bio-fertilizers can perform multifarious functions. Some add nitrogen to soil through the processes of nitrogen fixation, some solubilizes native soil phosphorus (phosphate-solublizing bacteria), and some other stimulates plant growth through the synthesis of growth-promoting substances. Bio-fertilizers can reduce the use of chemical fertilizers and pesticides. The microorganisms in bio-fertilizers restore the soil's natural nutrient cycle, build soil organic matter and improve soil quality/soil health. Through the use of bio-fertilizers, healthy plants can be grown, while improving the sustainability and environmental quality.

Bio-fertilizers provide eco-friendly organic agro-input and are more cost-effective than chemical fertilizers. Bio-fertilizers such as Rhizobium, Azotobacter, Azospirillum and Blue green algae (BGA) have been in use for a long time. Rhizobium inoculation is used for leguminous crops. Azotobacter can be used with crops like wheat, maize, mustard, cotton, potato and other vegetable crops. Azospirillum inoculation is recommended mainly for sorghum, millets, maize, sugarcane and wheat. Blue green algae belonging to a general filamentous cyanobacteria genus (Nostoc or Anabaena or Tolypothrix or Aulosira), fix atmospheric nitrogen and are used as inoculant for paddy crop grown both under upland and low-land conditions. Anabaena in association with water fern Azolla contributes nitrogen up to 60 kg/ha/season and also enriches soils with organic matter. Applied chemical P fertilizers are immobilized in the soil, immediately and less than 20 percent of added P fertilizer is absorbed by plants. Application of phosphate-solubilizing bacteria will increase solubility/availability of natural P in soil and will reduce the application of P-fertilizers on one the hand, and environmental pollution resulting from both production and application of chemical P fertilizer, on the other hand.

Use of vermicompost- Vermicompost is a product (organic manure) developed through composting of undecomposed organic residues or waste using various worms, usually earthworms to create a heterogeneous mixture of decomposed organic materials (crop residues, vegetable residues, food wastes, etc.) within a short time compared to natural decomposition. Vermicompost contains both water-soluble and water insoluble nutrients and is an excellent, nutrient-rich organic manure and soil conditioner. Vermi-composting of organic materials reduces greenhouse gas emissions, such as methane and nitrous oxide, compared to natural decomposition. This process of producing vermicompost is called vermicomposting. The earthworm species most often used for composting is the Red wiggler (Eisenia fetida or Eisenia andrei).

Green manure- Green manure is the cover crops grown on land and later on mixed with soil by pulverization, usually at its flowering stage. Green manuring is a great way of adding nutrients and organic matter to soil, and increasing carbon sequestration in soil. Green manures can also be grown as a part of crop rotation during the growing season. There are two types of green manure crops: Legumes and Non-legumes. Legumes are plants whose roots work with the bacteria (Rhizobium) in the soil to fix nitrogen from atmosphere, called Nitrogen fixation. Some legumous green manure crops are: Sesbania, Alfalfa, clover, soybeans, etc. Non-legumes are all other green manures like Ryegrass, Buckwheat, Oats, etc.

Livestock systems for the future- Along with the climate change, there will be negative impacts on livestock-based production systems and availability of fodder. On the other hand the demand for animal products will increase with the increasing population. Strategies to be taken to increase the productivity of local breeds through cross breeding with high yielding breeds/ appropriate genetic engineering instead of importing high yielding exotic breeds since, the local breeds are often tolerant to temperature extremes and can remain productive even under high stress conditions. The new breeds should have high feed efficiency so that they can produce high yield with less feed. Researches should also be undertaken to develop new types of fodder which can withstand multiple high stress conditions.

6.4. Aquaculture management for climate change adaptation

Fishing and aquaculture provide food and livelihoods for many millions of resource-poor people, and may become even more important for global food security as the climate changes and other sources of food are becoming more uncertain. Productivity of many capture fisheries have declined sharply in recent decades or have already collapsed due to overfishing. Pollution mismanagement of freshwater and industrial/urban development in coastal also pose serious threats. Adaptive strategies must address these problems, as well as of those to be added by changing climate. Aquaculture, offers some good opportunities to adapt to climate change. By focusing on herbivorous species of fish, aquaculture can provide food with a low carbon footprint. Fish are highly efficient for converting grain to protein. Cattle require around 7 kg of grain to produce 1 kg gain in live weight but herbivorous fish, such as Talapia or carp, need less than 2 kg. Ironically, it requires less water to grow fish than meat as the water is mostly recycled and fish do not consume water. Climate change could open up new opportunities for aquaculture as the sea encroaches on coastal lands. More dams, reservoir/ponds may need to be constructed in future to buffer changing rainfall patterns. The urban waste also will demand more innovative disposal. All these opens new vistas for fish cultivation. Cage and Pen Culture may also be an important technique for adaptation, specifically for coastal areas. Small-scale aquaculture also holds promise as an option for diversifying livelihoods. More and more strains of fishes are to be developed that are tolerant both under saline and non-saline conditions and are self breeders at their habitat. For example, Tilapia is one of the most widely farmed fish species in the world. Research has shown that there are some strains in Talapia which have tolerance to saline environments. World Fish is trying to develop more salt tolerant Talapia.

6.5. Conservation of forests for climate change adaptation

Billions of people have livelihoods that are intricately linked with the forest ecosystems and their unique biodiversity. Forests provide food & nutritional supplements, fuel, timber and medicinal products not only to forest dwellers, but also outside forests. Sustainable management and conservation of existing forests are very important due to the indispensable role of forests in reducing the vulnerability of the globe to climate change. Reforestation, wherever possible, should be undertaken as an effective step towards climate change mitigation.

Mangrove ecosystems are unique for coastal areas. Mangrove plants stabilize the coastal soils and protect it from erosion through its intricate root system. The plants are highly salt tolerant and the ecosystem is well adjusted with the coastal tidal floods. Mangroves not only provide effective protection to the coastal zone but also protect the in-country habitations against cyclones, sea surges, Tsunami waves, etc. Mangroves are important habitat for breeding and growth of fries of many fish species including shrimp. Massive mangrove reforestation programme should be undertaken in all the coastal areas, particularly in the delta areas, as an important step for climate change adaptation and safety of the coastal areas. It has been found[33] that presently 3 species of mangroves viz. *Heritiera fomes*, *Sonnerata apetala* and *Avicennia officinalis* are most suitable for mangrove afforestation in the coastal zone of Subdarbans.

Agro-forestry-Agro-forestry system of cultivation is very important in view of the rapid decline in forest areas, particularly, in the developing countries. Agro-forestry systems serve the function of both adaptation and mitigation objectives. Tree-based systems have some obvious advantages for maintaining production during wetter and drier years. Trees are less susceptible than annual crops to weather variability and extremes like droughts or floods. Research is needed to introduce salinity tolerant tree species in agro-forestry system, particularly for coastal area. Work at Central Soil Salinity Research Institute (CSSRI), Regional Research Station, Canning Town has shown that Agro-forestry of cultivation can be successfully introduced in the coastal low lands too.[39] Tree-based systems can deliver products such as fruits, fodder, fuel wood and timber. At the same time, they store significant amounts of carbon, in trees and soil. By adding trees to their farming systems, farmers can assure their livelihood against weather variability and uncertainty, improving their in soil quality, and contributing to mitigation of future climate change.

7. Livelihood change and capacity building for climate change adaptation

The coastal farmers are now on the cross road for transition of their livelihood patterns as the impact of climate change is already being felt in fragile ecosystems like the Sundarbans. People should re-look into their livelihood options in the event of future sea level rise and other climate change impacts. They should look for system approach that includes both farming and non-farming activities, sustainable natural resource management and livelihood as a whole. They need to change paradigms of their livelihood portfolios among agriculture, aquaculture, animal husbandry, poultry, forestry/agro-forestry, small scale business, cottage industries or integration of all those or few of them, depending on the situation, to build resilient in livelihoods under changing climate and reduce the risk. But the choices must be made by the people whose livelihoods are in transition. However, the population pressure on farming profession in coastal areas should be reduced to make it economically viable in the event of climate change impact on agriculture in coastal areas. For example, the farming is over-populated in the coastal areas of Sundarbans and the small fragmented land holdings of farmers are becoming economically non-viable. The population pressure on farming should be reduced by providing alternate livelihood options to the people and consolidation of landholdings or by contact farming.

Capacity building of human resources- The capacity/knowledge building of human resources is very important for both climate change adaptation and mitigation efforts. The Capacity building should cover various aspects of livelihood viz. economical, biophysical, socio-cultural, marketing and environmental nature. Children should be included in the programme through modification of school curriculum to introduce science-based concepts on climate change vulnerability and to work for their adaptation and mitigation. Many changes are to be made in the coming years, at all levels of society, to reduce greenhouse gas emissions. The farming communities should be trained for appropriate management of soils and trees to capitalize on their carbon storage potential. Carbon sequestration in soil and plant is the main contribution that agriculture can offer to the world's mitigation efforts.

8. Conclusion

It is clear that anthropogenic activities are primarily responsible for recent climate change. The development activities undertaken by different countries of the world contribute to the emission of greenhouse gases in the atmosphere resulting in increased heat absorption by the earth system and increase in global temperature. We are now at a crossroad to decide between development and conservation of climate or a balance between the two. The decisions we make now may prove to be the most important decision humankind ever collectively takes. The two groups viz. (i) the world's poor, and (ii) the future generations that stand to be the most loser if the wrong decisions are made. Ironically, these two groups are least responsible for climate change and have the least/ no role in decision-making.

Climate change will have serious negative impacts on agricultural systems. Agriculture is already under severe strain from over-exploitation, climate change and multiple other stresses. Agriculture is also contributing negatively to the climate change. Many of the world's most vulnerable people depend directly on agriculture for their food and livelihoods and the economics of many countries, particularly the developing countries, are highly dependent on agriculture. The climate is changing and the agricultural systems must also to be changed if we are to avoid catastrophe. Farming, fishing and forest communities will need to adapt their livelihood in system approach in future, while mitigation efforts must be undertaken to reduce the contribution of agriculture to the climate change. This can be done through reducing emission of greenhouse gases from agricultural fields and increasing carbon sequestration in soil and plant. The changes required to do these, will be many and diverse. They will happen at the local level, tailored to local circumstances and to be managed by the communities themselves. The mitigation measures to be undertaken should have immediate benefits for the communities, as well as long-term benefits for future generations. The mitigation measures must be based on sound science, enriched by continuous research and enabled by effective policy at all levels.

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Financing rain water harvesting in 24 Parganas in West Bengal

Sandip Ghosh

Retired Chief General Manger
National Bank for Agriculture and Rural Development

1. Introduction

Land area in the South of 24 Pargana North and South districts in West Bengal meets the Bay of Bengal and is important ecologically due to the famous Mangrove forest known by the name Sundarbans. This area has several delta formations and the soil as well as ground water of this area has salinity problem due to sea water intrusion. Ecologically this area had been the home for several species of Halophytes which have been destroyed by human beings for settlement and livelihoods purposes and the problem begins here. Salinity is needed for the Halophytes but definitely it is detrimental for field crops and some plantation and horticultural species which have to be grown by millions of people who have settled in these lands for generations. Efforts have to be made by the dwellers of this area as well as society for making these areas habitable for the millions who live here. A World Bank supported programme was launched in early eighties for overall development of the region and creation of water harvesting structures on individual holding, involving subsidy and bank loan was a component in this programme; but due to several reasons , this aspect of the programme did not achieve the desired results. Lot of efforts have been made through Government supported institutions and Non Government Organizations since independence and good infrastructure has been created in many blocks , yet lot remains to be done. More over this part of the world faces frequent natural disasters which often destroy the infrastructures created like earthen dykes, hutments bridges dugout farm ponds and agricultural fields. New projects and programmes involving people and investments of manageable quantum is required on a continuous basis for bringing about sustainable development of these areas. This paper indicates about various guidelines and schemes introduced by the RBI and NABARD in the recent past which can be made use of for bringing about people centric sustainable development in these salt affected areas.

2. Population affected by coastal salinity in 24 Parganas

Block wise total number of house holds and population in the thirty salinity affected blocks is presented in Annexure I. More than eleven lakh families and above fifty nine lakh population are affected by salinity problem . Majority of these people are engaged in different types of services and labour work for their livelihood. The land holding details for both the districts show a large number of small and marginal holdings in these areas as may be seen from the table below:

Table 10.1: Land holding details of 24 Parganas districts of West Bengal

Holding Size (ha)	No of Holdings	% to total holdings	Area in ha	% area to total
<= 1.00	447759	80.70	174024	47
>=1.00 - <= 2.00	80843	14.60	120144	33
>2.00	26314	4.70	75431	20
Total	554916	100	369599	100

The data presented above has been reproduced from PLP(NABARD2012-2017). Similar data for 24 Pargana South for the yearly PLP9NABARD) for 2012-13 indicate that the district has 362 thousand farmers out of which 325 thousand belong to the category of small and marginal This statistical information alone does not reveal the actual picture as total holding of individual farmers are also not located at one place but are scattered into several parcels which makes farm management and development initiative very much difficult. The data in Table 1 show that out of the total numbers of holdings , more than 95% belong to small and marginal farmers and out of the total area covered under individual land holding 80% belong to small and marginal farmers. The data is for the districts but the situation is terrible for the salt affected blocks which are mostly mono cropped as irrigation facility is absent or negligible. Due to salinity and proximity to sea ground water use is very limited; moreover in some parts Arsenic problem has created scarcity for safe drinking water. In order to mitigate this problem surface water storage for farming is the only solution but it needs land which again is a scarce commodity and creates enormous social problem when land is demanded for any common development purpose. The technology to be adopted: Regarding technology the scientific papers presented by research institutes will deal in greater detail , here the technology which had been financed in the past and which can be taken up for development through bank loan is being discussed. In early eighties NABARD sanctioned land development project to the then PLDB(now known as ARDB)and other banks in 24 Parganas which involved digging farm pond in one third area of individual holding and using the excavated earth for raising the level of the remaining land area. It may be noted that the entire area in question is having elevation between 5 to 10 m above MSL and thus is prone to inundation. This technology is simple , can be adopted easily by the farmers and helps in storing rain water which is salt free and can be used for growing crops in post monsoon period. This also supplies safe drinking water to the people and the livestock. Trees can also be raised along the banks of the pond which will supply fuel wood which again is a scarce resource in this area. Bankable schemes can be prepared including different components as indicated below:

1. Digging of pond with land shaping and land levelling.
2. Loan for crop production (along with insurance coverage).
3. Provision for low cost drip , manually operated water lifting pumps.
4. Roof water harvesting and storage in plastic tanks with bleaching powder etc. for drinking.

This paper can not suggest a model project but such projects can be developed and financed by different financing institutions.

Banking institutions in 24 Parganas(North and South)

As per the data presented in PLP(NANARD for 24Pargana South), as on 31st March 2011, in the rural areas of the district, there were 198 commercial bank branches of 16 banks 63 branches of RRB (Regional Rural Bank), 8 branches of District Central Cooperative Bank and 2 branches of Cooperative Agricultural and Rural Development Bank. The cooperative institutions operated through Primary Cooperative Agricultural Societies which numbered 260 in the entire district; but probably this institution is having maximum potential but minimum output due to several reasons. One major problem is ownership ; PACS should have been the institution by the farmers , of the farmers and managed by the farmers themselves but it has never functioned that way in reality. Democratic ways were paper documents only which led to malfunctioning and ultimately many has to be closed. If any fruitful outcome is to be gained through proper end use of bank credit , then these institutions must be strengthened.

As per the data presented in NABARD PLP(2012-2017) for the 24 Pargana North, 122 rural branches of 23 commercial banks ,43 rural branches of RRB , two rural branches of District Central Cooperative Bank and two semi urban and one urban bank branch of Cooperative Agriculture &Rural Development Bank are serving the rural population. The number of PACS is 432 in this district, however it is not known how many are in the salt affected blocks and how many are in operation.

Policy and Development initiatives of RBI and NABARD:

RBI has broad based the guidelines for priority sector lending giving greater emphasis to agriculture lending. Some important aspects are financing to PACS ,Farmer Service Societies, LAMPS by banks to be treated as direct lending to farmers. Producer Companies set up exclusively by small and marginal farmers can be given loans up to Rs 5 crores which will be covered under indirect financing to agriculture under priority sector. NABARD has created facility for direct loaning to cooperaitve banks and PACS. Kissan Credit Card has been redesigned to make it Smart Card-cum-debit card since April 2012 by NABARD. Lot of emphasis has been given in the past by RBI and NABARD for creation of grass root level institution for credit delivery as well as dissemination of improved technology among the farmers; these initiatives are continuing and further improved. To name some of these, SHG formation, formation of Farmers clubs, making of producer companies, revival of PACS and cooperative credit institutions. Through initiatives taken by NABARD, GOI and RBI computerisation and core banking has been started in cooperative banks so that they are able to cater to the needs of the farmers in a faster and better way. NABARD provide grant assistance for creation and running of farmers clubs. In several states as well as in West Bengal farmers clubs have formed federations and are able to access finance for value addition and better marketing of their produce. NABARD assistance can also be availed for making Producer Companies and such institutions can avail finance for production, processing and marketing. NABARD provide assistance for formation of Joint Liability Groups if such groups are able to access bank loan is a sustainable manner at least for three years. Group activity is most important in areas like 24 Parganas where population density is very high. The transaction cost both at bank branch level as well as at farmer level can be reduced to a huge extent through group initiative. For example if ten farmers having land holding in a patch , form a group for making a farm pond and for having a pump set with pipeline for irrigation purpose and jointly take the responsibility of maintaining the asset and repayment of loan then such groups can be extended bank finance as a group. As per the details furnished in PLP , more than thirty NGO institutions were associated with NABARD for various social engineering work in both these districts for better credit dispensation among the rural population.

Action to be initiated:

Rural Infrastructure Fund: As directed by GOI, NABARD has created a fund called Rural Infrastructure Development fund (RIDF) which is used for financing all kinds of development projects formulated and implemented by the respective State Governments. If local area institutions pursue with the Government, then development projects for making of protection dykes, large dugout farm ponds, lift irrigation infrastructure can be created in the salt affected areas under this fund. Formation of JLG: Large number of JLG can be made in these areas for extending finance for dug out ponds, extending crop loans, loan for water lifting devices etc. NGOs can initiate action in association with the local area banks. Primary cooperative agricultural societies: PACS can formulate area specific schemes and if such institutions have a reasonably viable balance sheet, they can also form projects availing assistance from NABARD.

UPNRM in NABARD: Umbrella Programme for Natural Resource Management is a fund created in NABARD where all projects related to NRM are financed to any institution on a project lending approach. Climate Change Adaptation: An international fund has been created for Climate Change Adaptation which is being managed through a board. NABARD has been recognised as National Implementing Entity (NIE) in India by the Climate Change Adaptation Fund Board (AFB). Ministry of Environment and Forests GOI is the designated authority for transmission of project proposals to AFB. Interested institutions/Organizations can approach local offices of NABARD for further details and can formulate projects for sustainable development of these salt affected areas.

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Recommendations of the Workshop

Presentation by invited speakers and discussions were held in Technical Session I on several issues on large-scale technology dissemination covering the areas of input-supplies & management; market & marketing environment – the driver of change in cropping pattern and production; credit needs & absorption of the farmers, and the role financial institutions therein; finally to highlight the grassroots level experiences, success stories and lesson learned. After that the Technical Session II was devoted for detail discussion on how to scale-up these evolved technologies to other/many areas. Dr D K Sharma, Director CSSRI, Karnal, Chaired the session and following are the key recommendations emerged –

1. Since the current NAIP project is going to end by next year, initiative should be taken for up-scaling of these technologies in collaboration with other departments/agencies like State Govt., KVKs, NABARD, Nationalised Banks and other development agencies including NGOs. Linking the farmers with the funding agencies, ongoing Govt. scheme/programme like MGNREGA, BGREI etc for up-scaling these land-shaping techniques in the coastal region across the states.
2. ICAR have large number of KVKs and many of these are working in the coastal region. Cooperation can be sought to Zonal Project Directorate (ZPD) to reach to these KVKs and finally to the farmers for dissemination of these technologies.
3. NAIP has generated many success stories from the grassroots level experiences. These stories should be documented properly and due attention is needed for its wide publicity through mass media.
4. Agricultural marketing department has made several initiatives such as establishment of Krishak Bazaar in every blocks to facilitate the remunerative prices to the farm produces. It was requested to establish such Bazaars in the blocks where the NAIP work was under progress. Transportation facilities/linkages needed to be developed exclusively for of agro-produce to nearby markets.
5. Establishment of Farmers' Club may be encouraged with the help and cooperation of NABARD that may enhance the farmers' capability to adopt new technologies. Formation of such club may be helpful to the farmers like custom hiring of farm implements and other inputs can be obtained in bulk after formation of such club which otherwise may be difficult to afford by the individual farmers.
6. Non-availability of salt resistant crop varieties in bulk quantity is one of the key problems restricting the variety dissemination. Seed village concept can be adopted for multiplication of seeds at villages. However, due attention to the farmers' choice, preferences and demand for the seed should be assessed through small-scale demonstration in some selected areas before taking up large scale seed production of particular seed.

7. The on going NAIP has highlighted the profitability and popularity of ail cultivation system among the coastal farmers. This concept and system may be popularized to other farmers in the region also.
8. Issues have been raised on the banking credit system, KCC. In many cases the title of the land is not clear and therefore the actual farmers are devoid of taking the advantage of the credit system, Due consideration is needed to evolve some kind of alternative arrangement to sort out the issues.
9. Trading with agricultural commodities should be regulated and people having valid license/registered trader should be allowed for procurement. Once several high value crops like watermelon, chillies and tomato were grown in the Sundarbans region with large volume. However currently production of these commodities has declined greatly primarily due to inadequate marketing system and also other production related constraints (pest, disease attack). Currently betel vine have been most popular cash crop in some pockets of the region and that primarily driven by market.
10. Around 3,76,000 farm households are there in Sundarban and scattered to a large area. Along with KVKs other Govt. dept., SAUs should be brought together for upscaling of these technologies. Also taking advantage out of the ongoing programme like IWMP or ATMA scheme can be explored on. West Bengal has very strong panchayat system. Possibilities can be explored to disseminate such techniques to farmers field through the panchayat system and simultaneously, establishment of small-scale processing or value addition to the agro-products can be thought of after pertaining training to the rural youth.
11. Conflict between man and nature is one of the root cause of land degradation and low land productivity in the region. Conservation and management of forestry should be given due consideration.
12. Initial cost of land shaping is quite high and naturally un-affordable to the farmers. But the incremental return to the investments is quite encouraging. Proper economic analysis may be carried out by applying financial analysis tools like Internal Rate of Return (IRR), Net Present Value (NPV), Benefit-Cost Ratio and Pay Back period for attracting funds from the financial institutions.
13. E-agriculture like use of mobile technology can be a good option to disseminate the knowledge and technical guidance to the farmers. Expert help and cooperation can be sought from technical personnel from KVKs, SAUs and other research institutes.
14. Due attention is needed to increase the irrigated areas in Sundarbans region and various land shaping techniques are quite suitable for this purpose.

CENTRAL SOIL SALINITY RESEARCH INSTITUTE
REGIONAL RESEARCH STATION
Canning Town - 743 329, South 24 Parganas, West Bengal, India