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Soil and Water Management Options for Enhancing Agricultural Productivity of Coastal Area of West Bengal

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The coastal region of West Bengal primarily falls under the geomorphic sub-units of as *lower alluvial plain, deltaic flood plains, marshy/ inundated area, coastal sand dunes, coastal plains*, etc. Most of the coastal lands are low-lying (average 2-3 m above MSL) and many have elevation below the high tide mark of tidal rivers thus, they get easily submerged with rain/sea water. Taxonomically majority of these soils are in the order of *Entisols* and *Inceptisols*. The soils have *Hyperthermic* temperature and *Aquic* moisture regime. The soils are usually heavy textured varying from clay to silty loam. The economy of coastal areas of West Bengal is mainly dependent on agriculture (agriculture, fisheries, forestry, etc.) which influences the livelihoods of millions of rural households in the region. The agriculture in the coastal region is, as a whole, complex, diverse and risk prone. The cropping pattern is predominantly mono-cropped with low yield, growing traditional rice in almost 98% of the area in monsoon season as no other crops is possible during the period (*Kharif*) due to submergence of agricultural fields. But, the overall productivity of rice in the in the area is low, ranging between 2.2-2.6 t ha^{-1}. However, there lies plenty of scope of crop diversification towards high value fruits & vegetable crops by adopting suitable soil, water and crop management practices. The excess rain water in *Kharif* season (monsoon) goes waste into the sea as runoff water can be stored in farm with suitable land shaping for use as irrigation resource for growing multiple crops and integrated crop-fish cultivation. Several types of land shaping models has been suggested to meet the farmers' choice and land situation. The rainwater harvesting in the farm through appropriate land shaping also reduces salinity build up in soil and drainage congestion thus, making the land suitable for diversified crop cultivation.

(***Key words:*** *Coastal saline soil, Land shaping, Rainwater harvesting, Crop management, Integrated crop-fish cultivation)*

The coastal region of West Bengal lies between 87° - 25'E and 89°E latitude and 21° - 30'N and 23° -15'N longitude, spreading over mostly 3 districts viz. East Medinipur, South 24-Parganas and North 24-Parganas and covering an extensive area of land along the Bay of Bengal coast. The major part of the coastal area in West Bengal falls within the boundary of the districts of North 24 Parganas and South 24 Parganas, popularly known as Sundarbans. The total coastal areas under coastal agro-ecology in West Bengal is 14,152 sq km. The region belongs to the broad geographic unit Alluvial and deltaic plains of West Bengal. Under this region geomorphic sub-units such as lower alluvial plain, deltaic flood plains, marshy/inundated area, coastal sand dunes, coastal plains, etc. predominate. Most of the coastal lands are low-lying (average 2-3 m above MSL) and many have elevation below the high tide mark thus, they get easily submerged with rain/ sea water. In the Sundarbans region, the river Hugli (the Ganges) with its tributary systems meander severely in its confluence with the Bay of Bengal and are divided into number of branches, enclosing and intersecting the delta into large numbers island besides, the main land. The Bay of Bengal through the network of these rivers spreads its long arms, which are the chief sources of brackish water. The tides carry saline water and the tidal floods have, thus, great influence on the formation and development of coastal soils of the state. Most of the areas have very low elevations (average being 2-3 m above MSL) and a few areas are even below the sea level. In many cases, particularly in the Sundarbans region, the height of tide is above the mean elevation of the lands.

The soils of the coastal areas of West Bengal have developed on alluvium and taxonomically majority of these soils are under the order of Entisols and Inceptisols. The soils have Hyperthermic temperature and Aquic moisture regime. The soils are usually heavy textured varying from clay to silty loam. However, light textured soil i.e. sandy-to-sandy loam soils are found at places. The soils are generally neutral in reaction but highly acidic (pH 4.00) acid sulphate soils are found at places in the

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Sundarban region. The soils are low to medium in available N content, variable in available P content and high in available K content (Bandyopadhyay *et al.*, 1985; Bandyopadhyay, 1990; Maji and Bandyopadhyay, 1991; Bandyopadhyay *et al.*, 2008). Major portion of applied N fertilizer is lost through volatilization (Sen and Bandyopadhyay, 1987). Integrated nutrient management has been found to be very effective for increase in fertilizer use efficiency and sustainable yield of crops on coastal saline soils.

The acid sulphate soils are highly deficient available P. For improving crop yield on the acid sulphate soils the application of lime and higher dose of phosphorus and green manuring are highly beneficial (Bandyopadhyay and Maji, 1999, Burman *et al.*, 2007). Half dose of lime was as beneficial as full dose. High K status in soil is due to presence of K containing elliptic materials and K containing salts like KCl and K_2SO_4. Under highly acidic condition, Fe and Al are present in toxic level. These soils are generally rich in almost all micronutrients except Zn at places.

Most of the coastal areas of West Bengal are affected by salinity. The salinity development in the soils is primarily attributed to tidal flooding, frequent inundation of saline water from sea or river, drainage congestion and upward capillary movement of saline water from brackish ground water located at shallow depth (usually within 1m depth, throughout the year). The salts are dominated by Cl^- and $SO_4^=$ of Na, Mg, Ca and K. In general saline soils of West Bengal are low in fertility status. They are low in available N content, low to medium in available P content and high in available K content.

Except Zn and Cu, other micro-nutrients in the soils are generally high in status. The profile characteristics of soils from different coastal districts of West Bengal are given in Table 1.

Hydrology of Coastal areas of West Bengal

The coastal areas of the West Bengal is located in the Gangetic delta region and is a part of Bengal basin. Due to new-tectonic movement during 16th to 18th century the Bengal basin had tilted easterly along a hinge zone starting from Sagar (Sundarban) going north of Malda (North of West Bengal) and curving towards Dhaka (Bangladesh). As a result of this, the flow of Ganges river started coursing through the river Padma in Bangladesh leaving Hugli the erstwhile course as a more tidal channel. During 16th - 18th century innumerable distributaries were

Table 1. *Characteristics of some pedons of the coastal districts of of West Bengal West Bengal*

Horizon	Depth (cm)	Texture	Clay (%)	pH (1:2)	ECe (dSm^{-1})	SAR	ESP	CEC (c mol (p+) kg^{-1})	Base sat. (%)	Org. C (%)
Pedon: Bayarmari, P.S. Sandeshkhali, district North 24 Parganas :										
Ap	0-15	cl	38	4.6	7.2	8.5	13.4	12.0	65.0	1.09
Bwg1	15-50	cl	35	4.3	3.7	6.4	13.0	13.3	65.0	1.00
Bwg2	50-100	c	55	4.2	4.7	7.0	13.2	17.6	69.0	2.23
Bwg3	100-125	sic	55	4.1	9.9	9.2	12.9	16.2	68.0	2.26
Bwg4	125-150+	sic	52	5.4	18.9	12.1	15.0	15.6	69.0	1.68
Pedon: Bhagankhali, P.S. Basanti, district South 24 Parganas:										
Ap	0-19	sil	26	7.4	7.2	10.0	9.0	10.4	64.1	0.37
Ag	19-169	sil	26	7.9	5.5	8.7	7.6	9.7	65.1	1.08
Bwg1	169-209	sic	46	7.5	5.9	8.0	6.8	13.5	73.9	1.14
Bwg2	209-244	sic	50	7.5	6.0	9.4	6.0	14.5	62.0	0.64
Bwg3	244-281	sic	46	6.4	2.8	9.2	5.7	13.7	61.8	0.73
Pedon: Dariberia, P.S. Tamluk, district Medinipur										
Ap	0-12	c	45.2	6.5	6.0	8.8	13.3	0.90	13.5	76.0
BA	12-30	sic	48.8	6.5	4.3	10.2	10.7	0.62	15.3	78.1
Bwg1	30-54	sic	43.2	6.4	5.9	10.0	12.4	0.63	11.1	79.1
Bwg2	54-90	sic	53.2	6.3	8.1	9.8	14.6	0.41	16.0	82.9
Bwg3	90-110	cl	34.2	6.5	10.0	11.1	13.7	0.40	9.8	80.0
Bwg4	110-150	sicl	37.9	6.7	10.4	11.0	13.0	0.60	11.6	84.0

(Source: Bandyopadhyay *et al.*, 2003)

generated from Ganges which formed huge network of creeks and channels within Sundarban delta of India and most of them act as brackish water channels. The water salinity of rivers/estuaries/ creeks has been increased.

The Central Ground Water Board, Eastern Region has studied the hydrology of the coastal areas of West Bengal in details (www.cgwber.nic.in/ westbengal.htm). Ground water occurs in porous alluvial formation both under water table and confined conditions. The yield of the aquifer is about 150m3 hr-1. Fresh ground water bearing aquifer is occurring at varying depth ranges within 180 - 360 mbgl with the drilled depth of 600 mbgl. The fresh groups of aquifers are sandwiched between saline/ brackish aquifer. The top saline / brackish aquifer lies within the depth span of 20 m - 180 m with max depth of 320 mbgl in the extreme south. The shallow fresh water aquifers occur in dunes in Dihga- Ramnagar area of East Medimipur down to depth of 9 mbgl and in levee deposit within 50 mbgl in Baruipur - Sonarpur - Bhangar - Canning tract in Sough 24 Parganas district.

The important chemical types of ground water are Ca-Mg-HCO_3 type for low mineralized water in North 24 Parganas and East Medinipur districts and Na-HCO_3 type in South 24 Parganas and Ca-Mg-Cl in some isolated patches in delta region. Owing to the sub-marine and estuarine environment in which sediments are deposited and also owing to saline water intrusion as a result of proximity to the sea and tidal influence, in East Medinipur and South 24 Pargans, Cl content is in general high in upper aquifer in Subarnarekha Basin 8-100m, in Haldia area and Kasai basin 40-115 m, and in South 24 Pargans 20-15 m depth range very high with specific conductance. However, aquifers at deeper depth 115 - 300 m in Digha, 125-300 m in Haldia area and 170-350 m in South 24 Parganas district are relatively fresh and Cl content is within permissible limit. The salinity in ground water in East Medinipur and South 24 Pargans is high (> 3 dsm^{-1} at 25°c). The iron content in ground water in all the districts of coastal West Bengal is at high level (< 1.0 mg l^{-1}). The arsenic contamination problem in ground water has been reported in some coastal regions of West Bengal.

Current Status of Agriculture in Coastal areas of West Bengal

The economy of coastal areas of West Bengal is mainly dependent on agriculture (agriculture, fisheries, forestry, etc.) which influences the livelihoods of millions of rural households in the region. Nearly 20% of the Net State Domestic Product (NSDP) is accounted by this primary sector in these coastal districts. Out of which agriculture contributed 16% of NSDP in East Medinipur, 12% in North 24 Parganas and 15% in South 24 Parganas (Table 2). Agriculture's contribution to districts NSDP indicated a declining trend over the period 2002-03 and 2006-07. This indicated that the young generations are shifting towards other livelihood options than the agricultural sector alone as those are more effective to pull the income. The low producing agriculture sector of the coastal region alone can no longer fulfill the requirements of their livelihood needs. However, agriculture sector remain to be most important sector because this sector supports the livelihood of large number of active workers.

The employment pattern in the rural areas of the coastal region of West Bengal shows that the availability of labour force is less than demand during the pick planting (July-August) and harvesting (November- December) periods of *Kharif* rice which the major crop of the region. In the remaining periods there is huge surplus labour force who are to depended on non-agriculture based livelihood options available in nearby cities and towns. Thus there is huge migration of workers to nearby cities and towns during the lean periods of agricultural activities. If the agricultural activities are intensified through scientific soil, water and crop management the agriculture dependent livelihoods

Table 2. *Estimates of Net State Domestic Product (NSDP) of Coastal districts of West Bengal*

(at 1999-00 constant prices)

Particulars	East Medinipur		24 Parganas(N)		24 Parganas (S)	
	2002-03	2006-07	2002-03	2006-07	2002-03	2006-07
Agriculture	23.9	15.7	15.3	11.5	17.7	14.6
Forestry	0.9	0.8	0.5	0.5	1.2	1.3
Fisheries	10.6	8	3.3	4.5	7.6	6.8
Per Capita Income (Rs)	19166	28061	18034	23108	16621	18892

Note: NSDP in %

and employments in the coastal areas can be improved substantially thus curtailing the migration of labour forces to the cities and towns to a great extent.

The agriculture in the coastal region is, as a whole, complex, diverse and risk prone. The cropping pattern is predominantly mono-cropped with low yield, growing traditional rice in almost 98% of the area in monsoon season as no other crops is possible during the period due to submergence of agricultural fields. The crop production in monsoon season suffers from various adversities like heavy and intensive rain resulting deep-water logging, periodical inundation by high tides, poor surface and subsurface drainage, frequent cyclonic storms and floods. Land utilization pattern in coastal districts indicated that, at district level, in East Medinipur district nearly 73% of reported area is under cultivation (Net Sown Area) followed by 67% in North 24 Parganas and only 39% in South 24 Parganas. The cultivable land in all these districts are highly fragmented and more than 85% of operational holdings are categorized as marginal (<1 ha) and nearly 10% of the holdings are of small categories (1-2 ha). While implementing land and water management technologies the size of operational holdings should be kept into mind. Most of lands (about 80-90%) in the region remain follow in the other season because high soil and water salinity, and lack of good quality irrigation water.

Though the coastal areas are dominated by the mono-cropping with rice, However, the overall productivity of rice in the in the area is low, ranging between 2.2-2.6 t ha^{-1}. Among the rice productivity under different season, the productivity of boro rice (3 t ha^{-1}) is relatively higher than *Aman* (2 t ha^{-1}) and Aus rice (2.2-2.6 t ha^{-1}). Majority of the rice are grown as *Aman* paddy (80% in South 24 Parganas and 62% in East Medinipur & North 24 Parganas). The productivity of rice exclusively in coastal salt affected areas are over poor, sometime below 2 t ha^{-1} during *Kharif* (*Aman* paddy) season and the scope for paddy cultivation in *Rabi* season is severely restricted due to scarcity of good quality of irrigation water.

Though the coastal areas of West Bengal is mostly mono-cropped with rice, but there lies plenty of opportunities of crop diversification towards high value fruits & vegetable crops by adopting suitable soil, water and crop management practices.

(a) Water management

Expansion of irrigated area and availability of quality irrigation is the most challenging task in the coastal areas of West Bengal to increase the crop production and productivity. Among various sources of irrigations shallow tube well (STW) and rain water harvested in Govt. Canals, ponds, ditches and depression are the most important sources. The coastal districts receive plenty of rainfall during *Kharif* season in much excess of the evapo-transpiration demand during the season. The excess water goes waste into the sea as run off can be harvested in suitable structures in the farm to create potential irrigation resource. The cropping intensities in the area during dry seasons can be increased substantially with this irrigation resource provide the crops that requires less water (Ambast *et al.*, 1998) are selected. The water balance study at CSSRI, RRS, Canning Town has shown that about 450 mm of rainfall in the monsoon season would be excess after meeting the evapo-transpiration losses. The excess rainwater can be stored in dug out farm pond, which can be simultaneously used for dual purposes of fresh water pisci-culture and as irrigation resource.

b) Land management

Major coastal areas of the country face the problem of salinity, water logging, drainage congestion and presence of brackish ground water table very near to the surface. Many of these problems can be substantially reduced by adopting suitable Land shaping, some of them are described below. The basic purpose of these land shaping is to create different land types (high, medium and low) for multiple & diversified crops in different seasons, harvesting rain water, to reduce drainage congestion of some land area in the farm and providing scope for crop/paddy-fish simultaneous cultivation for higher farm income and employment generation. The selection of a technology will depend on situation of the land, the soil characteristics, land holding capacity and above all the choice of the farmer. Covering the soil surface with mulches (rice straw, farm waste, etc.) or canopy cover (field crops, green maturing corps etc.) or even ploughing up of soil will reduce the soil salinity build up in soil in dry months.

(i) *Farm pond (FP)*

Soil dug out for making farm pond on 1/5th of farm area) is used for rainwater harvesting and fish cultivation throughout the vear. The remaining field

is made into high, medium and low (original land) land. The high land is used for vegetable cultivation throughout the year. The medium and low land are used for cultivation of paddy (or paddy-cum-fish) in *Kharif* and low water requiring field/vegetable crops (or paddy in small area) in *Rabi* with harvested rain water. This technology offers a scope for multiple crop cultivation on rain fed mono-cropped coastal region and generates higher employment and farm income (CSSRI, 2008).

(ii) *Deep furrow and high ridges*

Half of the farm area is shaped into alternate deep furrow and high ridges. The furrows are used for rainwater harvesting and fish cultivation in *Kharif*. Ridges are used for vegetable cultivation throughout the year. The remaining land is used for paddy-cum-fish cultivation in *Kharif* and low water requiring field/vegetable crops in *Rabi*/ summer. The furrows provide better drainage and protect the crops from damages due to occasional heavy rains following *Rabi*/summer due to climatic disturbances. The rain water stored in furrows keep the root zone soil relatively saturated with fresh water during the initial dry months after *Kharif*, thus reduces upward capillary flow of brackish water from shallow subsurface layer and thereby reducing the salinity build up in soil.

(iii) *Shallow furrow and medium ridges*

Half of the farm area is shaped into alternate shallow furrow and high ridges with excavated soil at an interval of 3.0m. The furrows are used for rain water harvesting and fish cultivation under paddy-cum fish in Kharif. Ridges are used for fruit crop/vegetable cultivation throughout the year. The remaining land is used for cultivation of paddy-cum-fish in *Kharif* and low water requiring field/vegetable crops in *Rabi*/summer.

(iv) *Paddy-cum-fish (PCF)*

Channels are dug around the field for Paddy-cum fish cultivation and rainwater harvesting in *Kharif*. Raised lands are (bunds of channels) used for vegetable cultivation throughout the year. In *Rabi* and summer seasons the land is used for cultivation of low water requiring field/vegetable crops and paddy (small area) with harvested rain water in channels.

(v) *PCF* (Kharif) + *Brackishwater fish* (Rabi)

Same as Paddy-cum-fish (b) above. Except that brackishwater fish is cultivated in Rabi and summer instead of field/vegetable crops.

c) Crop management

The cropping system in the coastal areas is predominantly rice based mono-cropping. A change in cropping system for higher production and income from agriculture in the coastal region integrated farming activities covering agriculture, horticulture, fisheries, animal husbandry and forestry/agro-forestry is the need of the hour. Research focus needs to be re-oriented towards integrated rice based cropping system, which should be compatible with the available land and water resources. Special stress is to be given on simultaneous development of both agriculture and fishery. (Prain 1994) as was also opined by others (Natarajan and Ghosh, 1980, Sinha, 1981, Srivastava *et. al.*, 2004, Pandey *et al.*, 2005). Halwart and Gupta (2004) also pointed out that the most viable option for increasing agricultural production in the rain fed coastal areas of the country is the integrated agriculture-aquaculture farming system. Besides the fresh water fisheries brackish water fisheries have great potentiality on account of large resources of both surface and subsurface brackish water in the coastal region. Brackish water fisheries can produce prawns in addition to other brackish water fishes and can give much higher income. Composite fish culture instead of monoculture needed to be followed in inland fresh water fisheries for higher income.

There is a great scope not only for the field crops but also for a wide variety of other crops. Suitable salt tolerant varieties of *Rabi* field crops like, sunflower, cotton, groundnut, etc. and vegetable crops like cucurbits, tomato, brinjal, knolkhol, sweet potato, leafy vegetables, flowers, fruit/plantation crops like, coconut, areca nut, sputa, guava, cashew, and spices like, turmeric, black cumin, coriander, fennel & fenugreek are high value commercial crops etc. are to be developed and introduced in coastal salt affected areas for higher yield. The crop varieties to be developed should have the characteristics of salt tolerance, high yield, and short duration and low water requiring.

Development of agro-forestry, has significant productive as well as protective functions in the coastal areas. Salinity and water logging resistant trees are to be introduced for meeting the local requirement (Burman *et al.*, 2007b). A forestation not only supplies timber, fuel, fodder and variety of other products but also has a moderating influence against floods and erosion and help to maintain soil quality and ecology. Agro-forestry plants along the

coast might also check the menace of felling of trees in the adjoining forest areas by the poor rural people of coastal areas to meet their requirement of timber and fuel. Some of the promising agro-forestry plants in the area are: *Casuarinas, Eucalyptus, Akashmoni, Sunddari, Pasur* (Burman *et al.*, 2007b). Besides the agro-forestry the tropical rain forests/mangrove forest occupying along the sea coast are to be conserved and their area needs to be augmented, for the protection of coastal area. Mangroves colonies stabilize the saline silted lands/wetlands adjoining the coastal line and are also valuable repositories of biodiversity. They play a vital role in protection of the shoreline against erosion caused by wave action and cyclones.

REFERENCES

Anonymous. (1988). Integrated Coastal Area Management and Agriculture, Forestry and Fisheries. *FAO guidelines. Food and Agricultural Organization*, Rome. 33 p.

Ambast, S.K., Sen, H.S. and Tyagi, N.K. (1998). *Rainwater management for multiple crops in rainfed humid Sunderban delta (W.B).* Bulletin No. 2/98, Central soil Salinity Research Institute, Karnal. 69 p.

Ayyappan, S. and Jena, J.K. (2004). Indian fisheries and aquaculture: present status and future prospects. *Journal of the Indian Society of Coastal Agricultural Research* **22**(1&2): 19-27.

Bandyopadhyay, B.K., Bandyopadhyay, A.K.and Bhagava,G.P. (1985). Charecterization of soil potassium and quality intensity relationship of potassium in some coastal soils. *Journal of the Indian Society of Soil Science* **33**: 548-554.

Bandyopadhyay, B.K. (1990). Fertility of salt affected soils in India - An over view. *Journal of the Indian Society of Coastal Agricultural Research* **8**: 61-78.

Bandyopadhyay, B.K. and Maji, B. (1999). Lime and phosphate requirement of coastal acid saline soils for rice cultivation. *Journal of the Indian Society of Coastal Agricultural Research* **17**: 96-100.

Bandyopadhyay, B.K., Sen, H.S., Maji, B. and Yadav, J.S.P. (2001). Saline and alkali soils of their management. *Indian Society of Coastal Agricultural Research* Monograph Series 1. pp 1-72.

Bandyopadhyay, B.K. and Rao, D.L.N. (2001). Integrated nutrient management in saline soils. *Journal of the Indian Society of Coastal Agricultural Research* **19**: 35-58.

Bandopadhyay, B.K., Ghorai, D., Majumder, A. and Sen, H.S. (2003). Nitrogen management for coastal saline soil of West Bengal- An integrated approach. *Journal of the Indian Society of Coastal Agricultural Research* **21**: 1-7.

Bandyopadhyay, B. K., Maji, B., Sen, H. S. and Tyagi, N. K. (2003). *Coastal soils of West Bengal their nature, distribution and characteristics.* Technical Bulletin 1/2003, Central Soil Salinity Research Institute, Regional Research Station, Canning Town, India, 62 p.

Bandyopadhyay, B.K., Burman, D., Majumder, A., Prasad, P.R.K., Dawood, M. Sheik and Mahata, K.R. (2006) Integrated nutrient management for coastal salt affected soils of India under rice-based cropping system. *Journal of the Indian Society of Coastal Agricultural Research* **24**(1): 130-134.

Bandyopadhyay, B.K. and Burman, D. and Pal, D. (2008). Management of soil fertility for sustaining crop productivity in coastal agro-ecosystem in India. *Journal of the Indian Society of Coastal Agricultural Research* **26**(2): 102-110.

Burman, D., Bandyopadhyay, B.K. and Mahanta, K.K. (2007 a) Management of acid sulphate soil of coastal Sundarbans region: Observations under on-farm trials. Presented in 'International Symposium on management of coastal ecosystem: Technological advancement and livelihood security' held in Kolkata, India from October 27-30, 2007. Organized by *Indian Society of Coastal Agricultural Research, Abs.* No. p 62.

Burman, D., Bandyopadhyay, B.K. and Bal, A.R. (2007 b). Identification of suitable agro-forestry tree species for alternate-farming in the low-lying coastal salt affected soils vis-à-vis effect of land shaping. Presented in 'International Symposium on Management of coastal ecosystem: Technological advancement and livelihood security' held in Kolkata, India from October 27-30, 2007. Organized by *Indian Society of Coastal Agricultural Research, Abs No.* 1, p18.

Biswas, C.R., Bandyopadhyay, A.K., Chattopadhyay, A.K., Chattopadhyay, G.N., Ghosh, A. and Chakraborty, P.K. (1988). *Rice-Fish multi cropping in coastal salin areas.* Published by Central Soil Salinity Research Institute, Regional Research Station, Canning Town, India.

CSSRI (2007). Annual Report 2007, Central Soil Salinity Research Institute, Karnal, India.

CSSRI (2008). *Strategies for Sustainable Management of Degraded Coastal* Land and Water for Enhancing Livelihood Security of Farming Communities. *NAIP* Project Documentation, Published by Central Soil Salinity Research Institute, Regional Research Station, Canning Town, India.

Edwards, P. (2000). Aquaculture, poverty impacts and livelihoods. *Natural Resource Perspectives* **68**: 1-4.

Govt. of India (1981). Report on development of coastal areas affected by soil salinity. Planning Commission, New Delhi. pp 1-138.

Ghosh, S.P. (1999). Horticulture production, marketing and export-smell of success. *Indian Farming.* **49**(7): 23-28.

Ghosh, A., Chattopadhyay, G.N. and Chakraborty, P.K. (1985). Brackish water paddy-cum-fish culture in coastal West Bengal. *Indian Farming.* **35**(2): 29-35

Halwart and Gupta, M.V. 2004). Culture of fish in rice fields. FAO and World Fish Centre. p 83.

Maji, B. and Bandyopadhyay, B.K. (1991). Micro nutrient research in coastal salt affected soils. *Journal of the Indian Society of Coastal Agricultural Research* **9**: 219-223.

Maji, B. Panwar, N. R. and Biswas, A. K. (2004). Ecology and soil health of coastal ecosystem. *Journal of the Indian Society of Coastal Agricultural Research* **22**: 35-42.

Natarajan, A.V. and Ghosh, A. (1980). *The status of paddy and fish culture in India. Bulletin Central Inland Fish Research Institute* Barrackpore, **32**: p 11.

Prain, Gordon D. (1994). Local knowledge and global science: The need for partnership in plant genetic resources research. In: *Local Knowledge, Global Sciences and Plant Genetic Resources: Towardsa partnership*, Godon D. Prain and Bagalanon (eds.), Proceedings International Workshop on Genetic Resources, UPWARD, Los Banos, Laguna.

Pandey, P.K. Panda, S.N. and Pholane, L.P. (2005). Economic evaluation of rain water harvesting in on-farm reservoirs for the integrated farming system - a sustainable approach for small farmers. *Environment and Ecology* **3**(3): 671-675.

Sen, H.S. and Bandyopadhyay, B.K. (1987). Volatilization loss of nitrogen from submerged rice soil. *Soil Science* **143**: 34-39.

Sen, H.S., Bandyopadhyay, B.K., Maji, B., Bal, A.R. and Yadav, J.S.P. (2000). Management of coastal agro-ecosystem. In "*Natural Resource Management for Agricultural Production in India*" J.S.P. Yadav and G.B. Singh (eds,), Published by the General Sec. "*Int. Conf. on Managing Natural Resources for Sustainable Agricultural production in 21st Century*" and the Indian Society of Soil Science, New Delhi, 14-18 Feb., 2000. pp 925-1022.

Sinha, V.R.P. (1981). Integrated synergic approach to aquaculture. In: *Resource Management and Optimization.* New York, USA, **4**: 331-342.

Srivastava, R.C., Singhandhupe, R.B. and Mahanty, R.K. (2004). Integrated farming approach for runoff recycling system in humid plateau areas of eastern India. *Agricultural Water Management* **64**(3): 197-212.

Tripathi, S., Chakraborty,A., Bandopadhyay, B.K. and Chakraborty, K. (2007). Effect of integrated application of manures and fertilizer on soil microbial, bio-chmical properties and yields of crops in a salt- affected coastal soil of India. Presented in 'International Symposium on management of coastal ecosystem: 'Technological advancement and livelihood security' held in Kolkata, India from October 27-30, 2007. Organized by *Indian Society of Coastal Agricultural Research*, Abs. No. 1, p 58.

Yadav, J.S.P. (1994). Constraints and potentials of coastal agriculture in India. *Journal of the Indian Society of Coastal Agricultural Research* **12**(1 & 2), 1-14.

Yadav, J.S.P. (1999). Research and development for coastal agriculture: The key issues. *Journal of the Indian Society of Coastal Agricultural Research* **17**(1 & 2), 19-28.