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Farming Systems Options to Adapt with Climate Change in South Western Bangladesh

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ABSTRACT

The major constraints of agricultural production in the south western coastal areas of Bangladesh are soil and water salinity of varying degrees, lack of fresh water for irrigation, slow soil drying pattern which are being augmented further due to climate change, requires suitable options of farming systems and component technologies. The major constraints and potentials of agricultural production systems in medium and high saline soils, farmers' needs and preferences were identified using participatory rural appraisal tools and based on that a number of integrated and component agricultural technologies were listed, validated and identified for scaling out to adapt with the changing climatic situation. The validated technologies were – integrated rice-fish for *gher* and vegetables on the levee, salt tolerant rice, pulse and oilseed crops and seasonal fruits and vegetables.The integration of salt tolerant high yielding rice varieties and tilapia in *ghers* with vegetables on the levee increased the gross return (93%) and gross margin (121%) remarkably compared to existing system of cultivating local varieties of rice and mixed species of fishes. The salt tolerant rice varieties, BRRI dhan47 and BRRI dhan53 produced grain yield of 4.00 and 4.65 t ha^{-1}, respectively, in medium saline soils where the popular variety BRRI dhan28 was damaged. Watermelon yielded 3.3 to 5.4 t ha^{-1} in the fields where soil salinity was recorded 13.8 to 17.3 dS m^{-1} at maturity in April. Community-based approaches are needed for larger scale dissemination of the validated and identified technologies.

Keywords: Adaptation options, Climate change, Farming systems, Coastal saline area

INTRODUCTION

Since Bangladesh achieved independence in 1971, food production has increased three-fold, the population growth rate has declined from around 2.9% per annum in 1974 to 1.4% in 2006 and the country is now largely food secure (MoF, 2007; BBS, 1975; BBS, 2007). Despite these successes, more than 50 million of our people still live in poverty in respect to nutritional intake of 2122 kcal or less (MoEF, 2008). The climate change is one of the threats to the poverty as Bangladesh is one of the most climate vulnerable countries in the world. It experiences frequent natural disasters, which cause loss of life, damage to infrastructure and economic assets, and adversely impact lives and livelihoods, especially of poor people living in remote or ecologically fragile parts of the country, such as river islands and cyclone-prone coastal belts (Huq *et al*., 2006; IPCC, 2007). Moreover, the geographical location and geo-morphological conditions of Bangladesh have made the country one of the most vulnerable ones to climate change, particularly to sea level rise (SLR) (FAO, 2011). In the recent years, Sidr in 2007 and Aila in 2009 (MOEF, 2008) is a great examples that the country is experienced from severe tropical cyclones. The south western part, also known as the Ganges tidal plain, comprises the semi-active delta and is crisscrossed by numerous channels and creeks are more vulnerable as its topography is very low and flat.

Climatic vagaries always take a heavy toll on the livelihoods of the coastal farmers. Such changes are becoming either frequent or coming with greater intensities causing loss of lives and properties, crops and rural infrastructures. The recent scenario of global climate change is not limited to a geographical boundary rather there are clear indications of changes in air temperatures and magnitude and distribution of annual rainfall in Bangladesh. Reduced flows in the major river systems resulted in moving soil salinity front northward turning more normal soils into saline soils (Haque, 2006; Rahman and Ahsan, 2001). Though these changes are natural but have been augmented by the unscrupulous human interventions through usage of more fossil fuels in the wake of increased industrialization, withdrawal of trans boundary river water and other alikes. Impacts of these climatic changes are resulting in increased pauperization of the costal farmers. Therefore, livelihoods of the coastal farmers must have to be improved with various adaptation and coping mechanisms in order to be able to cope up with the dire consequences of these climatic changes (Gwambene, 2007).

Cropping intensity in the coastal areas is far below those achieved elsewhere in the country (Petersen and Shireen, 2001). The major constraints of agricultural production in these areas are soil and water salinity of varying degrees, lack of sweet water for irrigation, slow soil drying pattern, unavailability of salt tolerant crops, varieties and technologies, lack of exposure to modern agricultural technologies of the coastal farmers and a host of socioeconomic vulnerabilities. New cropping practices and new rice varieties might be one of the adaptation options to withstand higher salinity and higher temperatures and be grown and harvested during the non-cyclonic period (Ali, 1999). The Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI) and Bangladesh Fisheries Research Institute (BFRI) under the umbrella of the National Agricultural Research Systems (NARS) developed a number of technologies suitable for the coastal saline area (BRRI, 2011; BARI, 2011; BFRI, 2005, BFRI, 2012). BRRI has developed salt tolerant rice varieties. Similarly BARI has developed pulse, oilseed and vegetables varieties and BFRI has recommended rice-fish culture suited to the area.However, these technologies not yet validated in the tropical cyclone, Aila and Sidr affected area of the southern part of the country where varying levels of salinity and water stagnation exists involving community in a holistic approach. Moreover, techniques for dibbled Aus rice innovated by the farmers of the south eastern part may be one of the adaptation option for the south western part of Bangladesh. Therefore, initiative has been taken in hand aiming to identify and available the suitable farming system technologies for enhancing capacity of the farmers to adapt to the impacts of climate change.

MATERIALS AND METHODS

Study Sites

Several studies were conducted in Parchalna and Laxmikhola villages under Dacope Upazila of Khulna district during 2009 to 2011. The former village is considered as medium saline area as the salt water intrusion was not occurred during Aila. On the other hand, the later one is considered as a high saline area where salt water intrusion occurred during Aila. Both the villages are mainly characterized by tidal water logging in wet season which represent the Khulna district in general which is a food deficit, located in the south-west of the country. The maximum annual mean temperature of the district is 35.5^0C and the minimum is 12.5^0C, mean annual rainfall is 1710 mm. The textures of the soils are mainly clayey and loamy. The study area is remarkably characterized by *gher* (land surrounded by bund mainly for shrimp and prawn cultivation) system. *Gher* is introduced more than two decades ago which is a source of earning foreign currency but decreases the crop production and creates higher salinity in the soils which results the ecosystem more vulnerable. The major agricultural production practices reported by the farmers are as follows:

i) Single crop of transplanted Aman rice with traditional variety like Morichsail, Nonakuchi, Sadamota etc, which cover about 60% area. The rest of the part is dominated by the higher yielding rice variety, BR23.

ii) Rice-fish culture with local rice varieties of Aman rice and mixed species of fishes is practiced by some farmers. They release larger number of fishes in the paddies resulting in highly sub optimal system productivity. This practice covered about 20-30% areas in Dacope upazila of Khulna district. Vegetables cultivation on the dike of the *gher is* lacking.

Technology Targeting and Testing

Farmers' need assessment for agricultural technologies was done jointly by the researchers, extension workers and other stakeholders through participatory rural appraisal (PRA) in the study area. About 60 farmers participated in a meeting held in the premises of a farmer's house. The day-long meeting concluded for listing of the farmers' needs. Technologies suited to the needs were collected from the National Agricultural Research Systems (NARS) and innovated by the local farmers of coastal areas. The collected technologies were –i) quality seed of rice, fish for *gher* and vegetables for levee, ii) salt tolerant rice varieties and advance lines, iii) dibbled Aus rice, iv) pulse (mung bean and cowpea) and oil seed (sesame) crop varieties, v) seasonal fruits and vegetables such as water melon, musk melon and okra. Listed technological options were shared with the farmers and were selected potential ones through a series of dialogues with the farmer groups. The farmers group opted for testing and validating of one or two of those technologies of their choices. Brief descriptions of the tested technologies are as follows:

Integrated Rice-fish and Vegetables Production in Gher

Quality seeds of modern variety of monsoon rice (transplanted Aman), BR23 with quality fingerlings of mono sex tilapia were compared with existing practices of integrated local variety of rice with mixed species of fish, in six farmer's *gher* where soil salinity reached a peak to > 30 dS m^{-1} during March-April. During mid July, fingerlings were released in the inner side canal of the *gher* which were connected with the rice crop during mid August. Thirty day old seedlings were transplanted with 2 to 3 seedlings per hill maintaining 20 cm x 20 cm of plant spacing. Rice was harvested at maturity in mid December. On the levee of those *ghers*, monsoon (summer) and winter vegetables such as bitter gourd, yard long bean, bottle gourd, Indian spinach, spinach, tomato, turnip, eggplant, country bean, cabbage etc. were grown.

Modern Rice Varieties for Wet and Dry Season

The widely adopted dry season rice (Boro) variety, BRRI dhan28, and salt tolerant variety, BRRI dhan47 were demonstrated in six farmer's field of Parchalna village in 2009-10. Thirty five day old seedlings were transplanted on 3-9 January. From land preparation (1-5 January) to first week of March, irrigation was done with canal water with salinity up to 4 dS m^{-1}. Later on irrigation was done with pond water with salinity of 1-3 dS m^{-1}. Irrigation was stopped at hard dough stage. At maturity, crops were harvested during 14-20 April.

Some high yielding varieties of transplanted Aman rice bred for tidal saline and non-saline area were demonstrated in 6 farmer's fields each in both the study villages. The varieties included BRRI dhan41, BRRI dhan44 and BRRI dhan46 along with the existing variety, BR23. The varieties were grown under farmer's crop management practices followed for BR23. The varieties were evaluated at maturity by 30 farmers, both male and female of the community and preference ranking was done considering characteristics they preferred.

Thirteen entries along with BRRI dhan28, BRRI dhan28-*Saltol* and BRRI dhan47 were tested in Mother Trial system in Boro season at both the study villages through community approach in 2009-10. In 2010-11, seven entries were tested in Laxmikhola. The trial was conducted with the direct supervision of the plant breeder. Forty five days-old seedlings were transplanted at the rate of 2-3 seedlings $hill^{-1}$ with a spacing of 25 cm x 15 cm. The unit plot size was 5.4 m x 12 rows with two replications. The crop was irrigated with surface water stored in the canal of which salinity reached at peak to 4 dS m^{-1} during first week of April. Other crop management practices were followed as per BRRI (2011) recommendation.

Dibbled Pre-Monsoon Rice (Aus)

The Aus varieties, BRRI dhan27, BRRI dhan47, BRRI dhan48 along with BRRI dhan28 were dibbled in six farmer's fields. Seeds were sown on 8 to14 May and emerged by 25 to 28 May.

Dry Season (Rabi) Crops

BARI released crop varieties, BARI mug6 (mungbean), BARI til3 (sesame) and BARI til4 and BARI felon1 (cowpea) and BARI dheros1 (lady's finger) were tried in different gradient of soil salinity whereas imported seeds were used in case of water melon and musk melon. Crops were sown at the moisture of field capacity after harvest of *T. Aman*. Soil salinity of the crop fields were monitored at different growth stages.

RESULTS AND DISCUSSION

Integrated Rice-fish and Vegetables Production in Gher

In *gher*, the existing local varieties of *T. Aman* rice produced 0.98 t ha^{-1} grain yield and the fish and prawn yielded o.35 t ha^{-1} (Table 1). The adoption of BR23 replacing local *T. Aman* rice varieties increased grain yield more than 2 t ha^{-1}. The use of quality seed of the same rice variety increased the grain yield further by 0.74 t ha^{-1} (Table 1). The fish yield was recorded similar in the existing system of mixed species of carps and mono sex tilapia without supplemental feeding. The adoption of quality rice seed and mono sex tilapia increased the variable cost (22%) over the existing practice which was further increased for cultivating different summer and winter vegetables (34%) on the levee of the *gher*. The price of quality rice and vegetables seed mainly increased the variable cost. The package of rice-fish culture in *ghers* and vegetables on its levee increased the gross return (93%) and gross margin (121%) remarkably compared to the existing system (Tables 2 and 3). The higher gross return and gross margin was directly related to the extra income from vegetables and more income from higher rice yield (Tables 3 and 4).

Table 1. Agronomic productivity of different integrated rice-fish farming in *ghers*, Dacope, 2010

Farming system options	Yield (t ha^{-1})		
	Rice	Fish	Vegetables
T. Aman (LV) + Mixed carp species and prawn (check)	0.98 ± 0.27	0.35 ± 0.04	-
T. Aman (MV) + Mono sex tilapia	3.31 ± 0.61	0.32 ± 0.03	-
T. Aman (MV with quality seed) + Mono sex tilapia	4.05 ± 0.55	0.34 ± 0.05	1.06 ± 0.31

1. LV = local variety, MV = modern variety, Figures followed by ± are standard deviation

Table 2. Variable cost of different integrated rice-fish farming in *ghers*, Dacope, 2010

Farming system options	Variable cost (Tk. ha^{-1})			
	Rice	Fish	Vegetables	Total
T. Aman (LV) + Mixed carp species and prawn (check)	14635	14103	-	28738
T. Aman (MV) + Mono sex tilapia	21042	14013	-	35055
T. Aman (MV with quality seed) + Mono sex tilapia	23827	14388	6533	44748

Table 3. Gross return of different integrated rice-fish farming in *ghers*, Dacope, 2010

Farming system options	Gross return (Tk. ha^{-1})			
	Rice	Fish	Vegetables	Total
T. Aman (LV) + Mixed carp species and prawn (check)	17290	48906	-	66196
T. Aman (MV) + Mono sex tilapia	57979	41712	-	99691
T. Aman (MV with quality seed) + Mono sex tilapia	70457	41273	15882	127612

Price of outputs (Tk kg^{-1}): paddy = @ 17.5, Fish (Tk kg^{-1}) = Tilapia @ 60, mixed species @ 100, prawn @ 500

Table 4. Gross margin of different integrated rice-fish farming in *ghers*, Dacope, 2010

Farming system options	Gross margin (Tk. ha^{-1})			
	Rice	Fish	Vegetables	Total
T. Aman (LV) + Mixed carp species and prawn (check)	2655	34803	-	37458
T. Aman (MV) + Mono sex tilapia	36937	27699	-	64636
T. Aman (MV with quality seed) + Mono sex tilapia	46630	26885	9349	82864

Modern Rice Varieties

Boro rice was affected by different degrees of soil salinity at different stages. On an average, BRRI dhan28 yielded 2.43 t ha^{-1} resulted negative gross margins (Table 5). In contrast, BRRI dhan47 produced 32% higher grain yield and thus achieved higher gross margin of more than three folds compared to BRRI dhan28 in 2009-2010. On the other hand, in another trial conducted in 2010-2011 with the varieties, BRRI dhan47 and BRRI dhan53 along with BRRI dhan28. In this study, BRRI dhan28 was fully damaged affected by soil salinity whereas BRRI dhan47 and BRRI dhan53 produced grain yield of 4.00 and 4.65 t ha^{-1}, respectively. Soil salinity presented in Table 6 indicates that the crops mostly affected by salinity from middle February to onward. BRRI dhan47 is recommended for the saline soils up to 6 dS m^{-1} (BRRI, 2011). But the crop was affected by higher soil salinity during heading to grain filling stages. That higher salinity affect might be avoid or reduced by transplanting Boro rice earlier which is possible by replacing long duration local varieties of preceding Aman rice by shorter duration rice.

Among the tested Aman varieties, BRRI dhan44 produced 1.5 t ha^{-1} higher grain yields than all other varieties in medium saline soils whereas BRRI dhan41 and BRRI dhan46 yielded similarly (Table 7). However, those varieties produced 0.32 and 0.37 t ha^{-1} additional yield compared to existing BR23. The variation of rice yield was not for salinity effect as the rice fields were flashed with rain water. From the results it is revealed that under the proper rain water flashed field in Aman season both normal and salt tolerant varieties can be grown. In high saline area where the water stagnation was for longer period during crop growth stages, all the tested varieties yielded similarly (Table 8). In preference ranking of rice variety, community of both the situation of salinity considered the factors of grain yield, tolerance to lodging and stagnant water, sterility and panicle appearance along with grain size (Table 8). BRRI dhan41 and BRRI dhan44 were preferred against the existing BR23 by the farmers of medium and high saline soils, respectively. However, the lodging tendency is considered as an issue for BRRI dhan41, particularly for *gher*. Farmers had some reservation for BRRI dhan44 for further testing in different land types before large scale dissemination. The soil salinity of the study fields recorded during Boro season was 4.3 dS m^{-1} at transplanting and 14.5 dS m^{-1} at hard dough stage in Parchalna whereas the corresponding values were 10.5 and 31.1 dS m^{-1} in Laxmikhola, respectively. Thus the villages were considered as medium and extreme saline soils, respectively. In the extreme saline condition in Laxmikhola, IR72579-B-3-2-3-8 produced the highest grain yield (2.1 t ha^{-1}) followed by IR72579-B-3-2-3-3 (1.8 t ha^{-1}) and IR76393-2B-7-1-1-3-1(1.7 t ha^{-1}) (Table 9). They performed better than BRRI dhan47 in terms of salt tolerance and shattering tendency which is reported a problem in BRRI dhan47 and were found similar in growth duration. On the other hand those advanced lines yielded similarly in medium saline soils of Parchalna. BRRI dhan47 and BRRI dhan53 preferred by the farmers in terms of grain yield, less sterility and grain quality in 2010-11.

Table 5. Agro-economic productivity of Boro rice after *T. Aman* rice, Parchalna, Dacope, 2009-10

Variety	Grain yield (t ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})
BRRI dhan28	2.43	39638	36450	- 3188
BRRI dhan47	3.21	38065	48075	10019

Table 6. Soil salinity of Boro rice fields at different dates, Parchalna, Dacope, 2009-10

Farmer (F)	Soil salinity (dS m^{-1})						
	01 Jan.	17 Jan.	2 Feb.	17 Feb.	02 Mar.	17 Mar.	4 Apr.
F1	4.3	5.4	6.1	8.7	12.7	14.5	23.3
F2	5.8	5.1	6.0	9.3	14.0	29.75	-
F3	6.8	8.0	6.2	6.1	5.8	14.5	14.7
F4	5.5	5.9	5.2	9.0	6.9	20.4	-

Table 7. Performance and preference of *T. Aman* varieties in medium saline area, 2010

Variety	Grain yield ($t\ ha^{-1}$)	Preference ranking						
		Yield	Lodging	Tolerance to stagnant water	Sterility	Grain size	Total score	Preference rank
BR23	3.69	7	10	9	7	8	41	2
BRRI dhan41	4.01	8	8	9	7	9	41	2
BRRI dhan44	5.62	10	8	9	8	8	43	1
BRRI dhan46	4.05	8	8	7	7	8	38	3

Table 8. Performance and preference of *T. Aman* varieties in high saline area, 2010

Variety	Grain yield ($t\ ha^{-1}$)	Preference ranking						
		Yield	Lodging	Tolerance to stagnant water	Sterility	Grain size	Total score	Preference rank
BR23	4.23	8	10	9	7	8	42	1
BRRI dhan41	4.14	9	7	9	8	9	42	1
BRRI dhan44	4.11	8	8	8	8	8	40	2
BRRI dhan46	4.14	8	8	7	7	8	38	3

Dibbled Aus Rice

The plant population at 7 days after emergence (DAE) in different fields of Aus rice ranged 20.4 to 22.2 m^{-2}. The emerged plant of all varieties damaged in five farmer's fields within 20 DAE affected by high soil salinity (> 18 $dS\ m^{-1}$) except one field where four varieties were demonstrated and soil salinity of that field was recorded as 14.4 $dS\ m^{-1}$. The field had proper bund resulting stored rain water which helped to flush the salt to down. The varieties, BRRI dhan27, BRRI dhan28, BRRI dhan47 and BRRI dhan48 were matured by 5 to 12 September and yielded 3.95, 3.92, 3.80 and 3.89 $t\ ha^{-1}$, respectively. The results indicated the needs of further investigation.

Table 9. Performance of PVS genotypes under medium and extreme saline condition, Boro season, Dacope, 2009-2010

Designation	Yield (t ha^{-1})	
	Laxmikhola	Parchalna
IR78800-4R-6	--	3.1
IR72593-B-13-3-3-1	--	2.9
IR72593-B-18-2-2-2	1.5	2.8
IR72579-B-3-2-3-3	1.8	3.1
IR72579-B-3-2-3-8	2.1	3.4
IR76393-2B-7-1-1-3-1	1.7	2.8
BR7105-4R-2	1.3	--
BR7084-4R-1	--	--
BR7102-4R-1	--	2.8
IR59418-7B-27-3	--	1.8
IR75395-2B-B-19-2-1-2	--	--
IR72046- B-R-4-3-2-1	--	1.5
IR72046- B-R-6-1-1-1	1.6	--
BRRI dhan28-*Saltol*	0.7	2.8
BRRI dhan28	--	--
BRR I dhan47	0.6	3.2

- Damaged due to salinity

Non Rice Crops in Rabi Season

Watermelon yielded 3.3-5.4 t ha^{-1} in the fields where soil salinity was recorded 6.6 to 7.9 dS m^{-1} at seeding in February and 13.8 to 17.3 dS m^{-1} at maturity in April (Table 10). On the other hand, muskmelon produced fruit yield of 3.7 t ha^{-1} at salinity of 6.6 dS m^{-1} at seeding and reached up to 17.3 dS m^{-1} at maturity in May. Although the yield of watermelon and musk melon was not encouraging, it showed the possibility to grow the crop in rabi season after 22 years of brackish water shrimp farming. Other agronomic options might me explored to enhance the productivity of those crops. Watermelon, cowpea, mungbean, okra and sesame failed to establish in some cases where soil salinity recorded 13.6 dS m^{-1} at seeding during 15 February to 25 March and the soil salinity rose up to 45.8 dS m^{-1} in May.

Farmers' community selected potential cropping systems according to their preference for medium and higher saline soils. The technologies, integrated rice-fish and vegetables in *ghers*, preferred varieties of rice in Aman and Boro seasons could be scaled out. The *rabi* crops cultivation in saline soils need further improvement exploring improved agronomic practices in the saline environment.

Table 10. Date of seeding, damage, harvest, yield of *rabi* crops and salinity of crop fields of medium and high saline area, Dacope, 2009-2010

Date of Seeding	Date of harvest/ damage	Soil salinity ($dS\ m^{-1}$)		Yield ($kg\ ha^{-1}$)/damage				
		At seeding	At damage/ harvest	Water melon	Sesame	Okra	Mungbean	Musk melon
Parchalna (medium saline area)								
28 Feb-2 Mar.	2-28 Apr	7.90	13.75	3292	492	4117	D	-
22 Feb- 15 Mar.	20-31 Mar	13.60	32.75	D	D	D	D	D
Laxmikhola (high saline area)								
4-6 Mar	10-20 May	6.60	17.30	5352	D	D	D	3705
15 Feb-25 Mar	15-30 March	16.65	45.80	D	D	D	D	D

DS = Date of seeding, DH = Date of harvest, DD = date of damage, D = Damaged affected by soil salinity

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