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Coping strategies adopted by the rice farmers in the coastal area of Bangladesh

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ABSTRACT

The present study describes the changes from a rice-based cropping system to a shrimp-based cropping system in the coastal area of Bangladesh and their impact on soil environment. The coping strategies of local farmers against increases in salinity are also analyzed. Two main cropping systems, the shrimp-boro rice cropping system and the aman rice-boro rice cropping system, are the main systems that are practiced by local farmers in the study village. Soil samples were collected from the plots of these cropping systems and chemical analysis was done. It was found that the salinity level rose from a level of 4.5 ds/m in 2010 to a level of 6.5 ds/m in 2012 with changes in the availability of nutrients in the soil. As a coping strategy against this increasing salinity, the local farmers switched rice varieties from year to year, and they did not cultivate a single variety alone but a combination of varieties. However, although the local farmers have established this shrimp-boro rice cropping system with a combination of modern rice varieties, it is hypothesized that if they continue this cropping system for a long time then the livelihood of the farmers will be unstable in the future.

INTRODUCTION

The shrimp- and rice-based cropping systems are common practice in coastal Bangladesh. Traditional bheri/gher aquaculture used to be practiced in the coastal areas of Bangladesh to raise shrimp and other fishes with the monsoon season aman rice long before the introduction of current shrimp culture practices. During the last two decades, shrimp aquaculture created new cropping system in the coastal area of Bangladesh. This aquaculture has extended inland and converted rice fields into shrimp farms and has thus changed the rice based cropping system to one that is shrimp-based. Therefore, a new cropping system: shrimp in the monsoon season with boro rice in the winter season has recently emerged to replace the aman rice-boro rice cropping system (Rahman et al. 2013a).

From the 1980s to the present, shrimp cultivation has created a substantial economic and social transformation in those coastal areas where it has been adopted (DoF 2010). Furthermore, in recent years, shrimp has become a significant foreign exchange earner for Bangladesh (DoF 2010). However, shrimp farming has been the subject of criticism since it can damage the local ecology by increasing the salinity of the water and soil, changing the composition of the soil and bringing about rapid changes in land use and land cover (Haque 2004). There are also claims that it has led to the disintegration of the economic and social conditions of coastal rural communities (Ali 2006).

Rice is the staple food of the people of Bangladesh. Local farmers in the coastal area have established a new cropping system that includes both rice and shrimp farming in the same field with a yearly rotation. As rice is a staple food for the local farmers, they cannot give up farming rice. The problem is that the shrimp farming requires saline water to be kept for at least seven months in the field.This prolonged inundation of rice-cum-shrimp fields with saline water has caused the salinity level of the soil of this shrimp-boro rice cropping system to increase, which could change the yield of the rice varieties that the local farmers cultivate (Rahman et al. 2013b). The local farmers are also very concerned about this increase. They try to cope with

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this problem as they select their rice varieties in the current ecological situation. There has been little attention paid as to how the local farmers adapt to these changes in salinity with their own technologies, therefore the present study aims to discover the perception of the farmers of the coastal area of Bangladesh concerning the salinity problem and the coping strategies they adopt against this salinity when they decide which rice varieties to cultivate.

METHODOLOGY

Research Site

The study was conducted in a village named Shuktia, which belongs to Tala upazila (an upazila is a local administrative unit under the district) under Satkhira district in southwestern Bangladesh (Figure 1). The local farmers cultivate the same field for rice production (using irrigation) in the winter season and for shrimp production in the summer and rainy seasons, using saline water from the nearest river, the Dolua.

There were 227 households in the study village, of which 174 were engaged in rice and shrimp farming. The survey was performed in two stages. First, all the households in the village were identified and basic information was recorded through personal interviews with all the heads of households. Second, a detailed survey of 65 randomly selected farmers out of these 174 was conducted. The sample farmers operated with land areas of 0.02-0.2 ha, 0.2-1.0 ha, 1.0-3.0 ha, and >3.0 ha, hereafter referred to as marginal, small, medium, and large farmers, respectively. The fieldwork was carried out from August-September 2010 and again in January 2013.

Soil Sample Collection and Chemical Analysis

Soil samples were collected at six different plots: four plots where the shrimp-boro rice cropping system is practiced and two plots where the aman rice-boro rice cropping system is used. Soil samples were collected at a depth of 15 cm in five different locations in each plot. Soil samples were collected from each plot every month from February 2010 to September 2012. All the samples were then taken to the Soil Resource Development Institute (SRDI), Bangladesh, to measure the salinity level, soil pH, organic matter content (OM%), total nitrogen (TN), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), boron (B)and zinc (Zn).

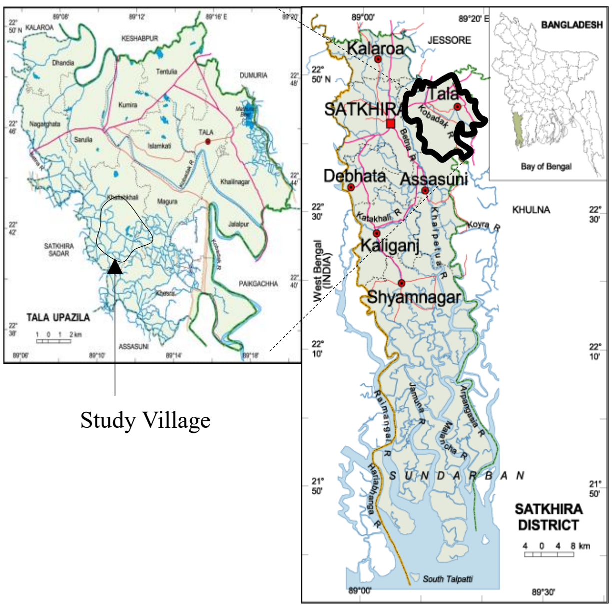

Figure 1. Location of the study area.

Matrix Ranking

A PRA (Participatory Rural Appraisal) tool named Matrix Ranking was used to discover the local farmers' judgments, choices and decisions when selecting their rice varieties for cultivation. In 2010, the farmers used to cultivate five rice varieties. The matrix ranking was done by focusing on eight criteria that the farmers considered when judging each variety. The criteria include: i) higher yield, ii) high market value, iii) salt tolerance, iv) high seed price, v) boiled rice keeping quality, vi) taste, vii) straw value, and viii) cold tolerance. Five farmers from different household categories were selected to give a score for each criterion for every rice variety. The range was 0-10. The matrix ranking procedure was carried out following instructions given by DAE (2000). After obtaining the score from the farmers selected, the principle component analysis was done using the statistical software XLSTAT 2009. In 2013, it was observed that the local farmers started to cultivate five varieties in the boro season, of which three varieties differed from those in 2010. The matrix ranking was also performed on this occasion in the same way as for 2010.

Collection of Yield Component Data of Rice Varieties

The yield components of different rice varieties were collected from farmers' rice fields in 2013 during the harvesting of the boro rice. For each rice variety, three farmers' fields were randomly chosen. The sample plants were taken from the 1 square meter sample plots from five locations in each field. Four locations were at the four corners and one at the centre. From each 1 sq. m. area, five plants were taken for a yield component analysis (Matsushima, 1979). The fresh weight of the samples was taken after harvesting and the yield was measured by dry weight after the rice had been sun-dried. The gross yield of all the rice plants in 1 sq. m. area was found from the average weight of the sample plots. The mean comparison of yield components among the rice varieties was carried out using Tukey's b-test using the software SPSS 17.

RESULTS AND DISCUSSION

Shrimp and rice cropping systems in the study area

Shrimp farming in the study village is not a recent practice. It has been widely adopted since its introduction around 15 years ago. Before the activity of shrimp farming in the village, local farmers used to cultivate only rice. At that time, rice was grown in two times in a year. The locally called boro rice was cultivated from the month of December/January to April/May, and a second rice, aman rice, was cultivated from August/September to November/December. The aman rice-boro rice cropping system was the single dominant regime in the village before the introduction of shrimp aquaculture. This system was maintained in both the medium highland and medium lowland areas. After the introduction of shrimp aquaculture in the village under study, the cropping systems changed in the medium lowland areas to the shrimp-boro rice rotating pattern (with shrimp aquaculture replacing aman rice). The medium highland areas continued to be cultivated under the double rice cropping system. The medium highland areas are very suitable for the aman rice-boro rice cropping system and are a common cropping system in other regions of Bangladesh after the introduction of irrigated HYV rice cultivation during the dry season. However, the local farmers consider that the medium highland area in the study area is not suitable for shrimp cultivation because the land cannot retain sufficient water for shrimp farming. Accordingly, shrimp aquaculture is not practiced by the local farmers, particularly in the medium highland area.

Irrigation Status of the Study Area

Boro rice cultivation in the study area is extremely dependent on underground irrigation water. The local farmers have developed a strong irrigation system from the beginning of the history of boro rice cultivation. Almost all of the farmers (who were maintaining boro rice-based cropping patterns) were using ground water to irrigate their rice fields during boro rice cultivation. There were more than 100 irrigation devices named low lift pumps (locally called boring) which were sparsely located in the entire boro-rice cultivated area of the study village. The results from the household survey revealed that all of the farmers who were cultivating the boro rice, were using irrigated water driven either by their own irrigation device or after hiring such a device from others (Field survey, 2010-2013).

The Impact of Shrimp-Boro Rice Cropping System on Soil Salinity and Fertility Levels from 2010 to 2012

Different soil parameters in the shrimp-boro rice cropping system for the period 2010–2012 are presented in Table 1. The OM content (OM%) and the Ca level did not significantly change from 2010 to 2012. However, the salinity level was recorded as 4.45 ± 1.27 ds/m in the year 2010, which had significantly ($P < 0.05$) increased to 6.45 ± 1.34 ds/m by the year 2012. Similarly, the pH level and the K content of the soil also increased significantly over the 2010–2012 study period. The Mg and S levels also increased significantly between 2010 and 2012. However, the TN, P, B and Zn content of the soil decreased significantly ($P < 0.05$).

Table 1. Comparative soil fertility status in the shrimp-boro rice cropping system in the study area for the years 2010, 2011 and 2012

Parameters	2010			2011			2012		
	Range	Average	Index value	Range	Average	Index value	Range	Average	Index value
pH	7.7–8.3	7.9^b	..	7.9–8.4	8.3^a	..	8.2–8.6	8.4^a	..
OM (%)	2.17–3.40	2.57^a	0.545	1.98–2.96	2.40^a	0.500	2.43–2.94	2.72^a	0.500
Total N (%)	0.10–0.18	0.14^a	0.250	0.09–0.12	0.10^b	0.250	0.12–0.15	0.13^a	0.250
P (µg/g soil)	10.97–13.55	12.18^a	0.409	10.20–14.58	11.69^b	0.354	8.77–11.30	10.17^c	0.250
K (µm/100 g soil)	0.48–0.67	0.57^c	1.000	0.62–0.77	0.71^b	1.000	0.86–1.30	1.06^a	1.000
Ca (µm/100 g soil)	23.88–27.88	26.19^a	1.000	18.38–30.47	23.62^a	1.000	22.06–35.47	27.62^a	1.000
Mg (µm/100 g soil)	3.07–8.14	4.12^c	1.000	5.30–8.11	6.74^b	1.000	6.37–8.55	7.77^a	1.000
S (µg/g soil)	53.15–196.09	67.80^c	1.000	32.52–150.09	74.22^b	0.833	30.52–120.16	98.35^a	0.861
B (µg/g soil)	1.34–2.04	1.66^a	1.000	1.04–1.60	1.35^b	1.000	0.63–0.98	0.80^c	0.944
Zn (µg/g soil)	0.55–1.94	1.11^a	0.477	0.39–0.92	0.56^b	0.271	0.42–0.69	0.57^b	0.250
Salinity (ds/m)	2.8–6.9	4.5^c	0.432	3.2–7.5	5.5^b	0.500	4.5–8.0	6.5^a	0.500

Source: Field survey 2010–2012.
Note: Average values with different superscript letters (a, b, c) within a row are significantly different at the 95% level of significance.

Rice Varieties Cultivated by Local Farmers

The local farmers of the study village used to cultivate different rice varieties according to their needs and in response to environmental changes, particularly, to salinity and soil nutrients. The farmers changed their rice varieties from year to year with the changes in the salinity level of the land of the shrimp¬-boro rice cropping system. The data has revealed that in the year 2010 the local farmers used to cultivate five varieties, namely BRRI dhan28, Hira, Manik-2, 45 and Tia in the boro season. However, interviews with local farmers and field observation have revealed that by 2013 some of the rice varieties had been changed by the farmers, but some are still being cultivated. For instance, while keeping BRRI dhan28 and Tia, the local farmers replaced Hira-2, Manik and 45 with three other varieties viz. Jholok, Mongol and Jamaibabu (Table 2). These changes might be due to the salt-tolerance capacity of the new rice varieties.

Table 2: Rice varieties cultivated in the boro season by local farmers in the years 2010 and 2013

Cultivated rice varieties					
2010			2013		
Name	No. of households	Percent of households	Name	No. of households	Percent of households
BRRI Dhan28	146	87	BRRI dhan28	148	85
Hira	130	77	Jholok	121	70
Manik-2	80	47	Mongol	90	52
45	82	49	Jamaibabu	116	67
Tia	129	77	Tia	145	83

Source: Field survey 2010 and 2013

From Table 2, it can be said that 87% of the local farmers used to cultivate the BRRI dhan28 rice variety. After BRRI dhan28, the farmers' choice was to cultivate Hira and Tia. However, in 2013 it was found that BRRI dhan28 was still being cultivated by most farmers (85%), and another variety named Tia has also been becoming increasingly popular since 2010.

Farmers' Preferences to Choose the Rice Varieties

In the study area, the farmer chose different rice varieties to cultivate in their shrimp-cum-rice farmland. It has been found that all the varieties were not cultivated every year. Rather, some varieties were changed from year to year. A PRA tool named 'matrix ranking' was used to find out the preferences of the farmers when selecting their rice varieties. The data were collected in 2010 and again in 2013. It was found in 2010 that BRRI dhan28, Hira-2 and Tia got the highest average score among the local farmers according to the performances of these rice varieties, but by 2013 some varieties had changed, although BRRI dhan28 was still being cultivated mainly because of its high market value, its boiled rice keeping quality, taste and straw value. Next to BRRI dhan28, Tia was the farmers' preference. As the salinity level increased, some other rice varieties named Mongol and Jamaibabu began to be cultivated because of their better salt-tolerant capacity. Considering all the scores given by the farmers against each criterion for each variety, Principal Component Analysis (PCA) was done using the statistical software XLSTAT-2009.

The score scatter diagram was prepared for both 2010 and 2013 considering the eight parameters for these rice varieties. The score scatter diagram is presented in Figures 2 and 3 for 2010 and 2013, respectively. Figure 2 shows that the farmers were not confined to cultivating a single rice variety. Rather, they chose different varieties because each variety is superior regarding certain criteria than the other varieties. Considering higher yield, variety 45 was superior to the others, whereas for rice keeping quality, market value, straw value and taste, the BRRI dhan28 was the most preferable one. On the other hand, for salt tolerance and cold tolerance, farmers chose varieties Hira-2 and Tia.

Figure 3 shows the score scatter diagram for 2013.The local farmers had changed some of the rice varieties they used to cultivate in 2010, but some rice varieties were still being cultivated. From Figure 3, it is observed that for higher yields, farmers selected the varieties named Tia and Jholok, but for market value, taste, rice keeping quality and straw value, they were still cultivating BRRI dhan28, which they used to cultivate in 2010. It was also found that for salt tolerance and cold tolerance the Mongol and Jamaibabu varieties were superior to the others.

From the above results, it can be said that the understanding of farmers regarding their selection of different rice varieties was the same. Truly speaking, all the above-mentioned data were collected entirely based on farmer's traditional and practical knowledge and experience over the years. The results, analysis and interpretation are also grounded on the same foundation, and this is not exactly natural science-based, but one thing is quite obvious that the farmers understand their situation very clearly. This understanding is focused when selecting their rice varieties and they give similar scores against each particular criterion for each variety. Some varieties they selected for a higher yield while some were selected for a better market value, taste or rice keeping quality, and some were selected to cope with the salinity. Some changes in the selection of the varieties were observed over the years 2010 and 2013, but definitely farmers' understanding when selecting their rice varieties was found to be the same.

Yield Components of Different Rice Varieties

The data for the yield and yield components of different rice varieties have been presented in Table 3. It was found that the Jamaibabu variety grew to a significantly greater height than the four other varieties although the number of tillers was found to be significantly lower than that for the other varieties. The highest panicle number per hill was found for the BRRI dhan28 and Jholok varieties and the lowest one was found for Jamaibabu. These differences were found to be significant at the 0.01% level of significance. The highest grain number per panicle was found in the Jamaibabu variety but the same variety achieved the significantly lowest 1000-grain weight. It has also been observed that the variety named Jholok achieved the highest yield per hill as it has got the highest 1000-grain weight, whereas the significantly lowest yield per hill was found for the Jamaibabu variety. This might be due to the lowest 1000-grain weight for this variety.

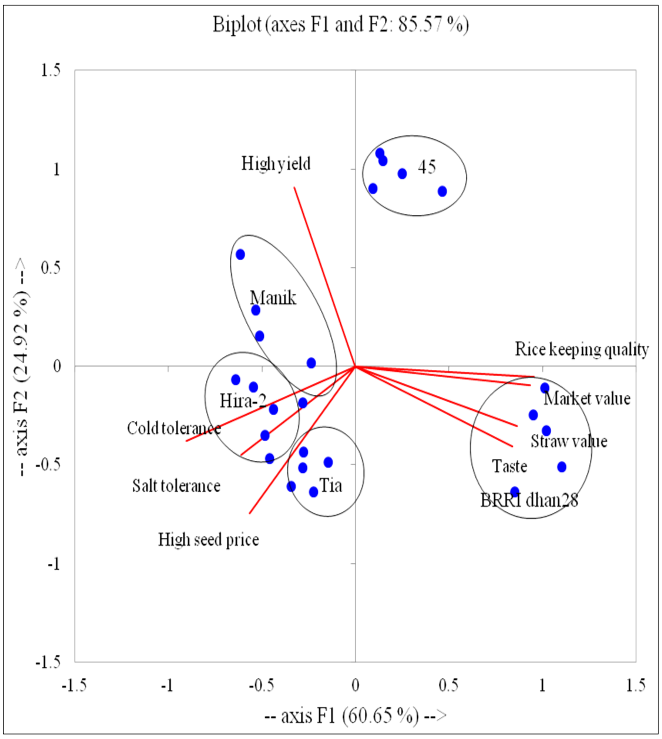

Figure 2. Score scatter diagram of PCA using eight parameters for different rice varieties in the year 2010

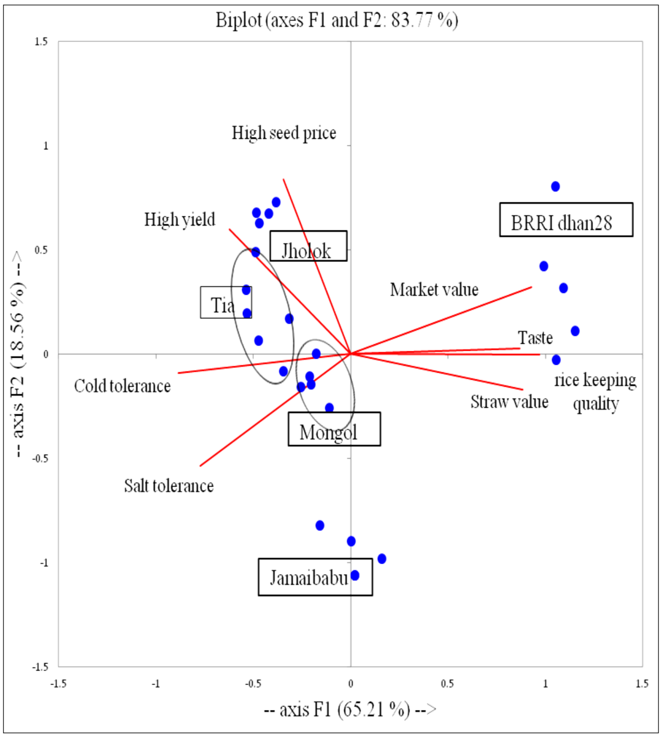

Figure 3. Score scatter diagram of PCA using eight parameters for different rice varieties in the year 2013

Table 3. Yield and yield components of different rice varieties in the year 2013

Varieties	Plant height (cm)	No. of Tillers/hill	Panicle no./hill	Grain no./panicle	1000 grain wt (g)	Yield/hill (g)
BRRIdhan 28	102^{c}	13^{a}	12^{a}	103^{d}	22^{c}	26.4^{b}
Jholok	105^{bc}	13^{a}	12^{a}	112^{c}	24^{a}	33.1^{a}
Jamaibabu	123^{a}	9^{b}	8^{c}	141^{a}	17^{d}	20.4^{c}
Mongol	105^{bc}	12^{a}	10^{b}	123^{b}	23^{b}	28.5^{b}
Tia	106^{b}	12^{a}	10^{b}	120^{b}	23^{b}	28.2^{b}

Source: Field Survey, 2013
Note: Average values with different superscript letters (a, b, c) within a row are significantly different at the 95% level of significance.

The yield data collected through the interviews with local farmers revealed that, according to the farmers, the highest yield was obtained from the Jholok variety. The yield data collected from the rice field revealed the same. From this result, we can understand that the farmers' logical understanding of the ecological situation is very good, and they know very well why and what they are selecting in order to fulfill their needs and meet their demands regarding the varieties they require for their rice cultivation.

CONCLUSION

The coping strategies developed by the local farmers of any community are based on their experience and local wisdom. In the present study, such coping strategies were found among the local farmers of a coastal community in southwestern Bangladesh. Due to the high salinity levels, it is difficult to cultivate any high yielding rice variety (HYV) in rice fields where shrimp is also cultivated in the same field on a rotational basis (Karim et al., 1990). However, it was mentioned in the results and discussion that the existing soil salinity level of the shrimp-boro rice cropping system was found to be 6.5 dS/m, which can be classified as moderately saline soil (SRDI 1985). The farmers of the study area were very much concerned about the existing ecological and economic situation and they are trying to adjust to the situation. Therefore, it was possible to grow some of the salt-tolerant varieties the farmers chose. In this study, it was found that the local farmers used to cultivate not just one single variety of rice but a combination of varieties. Some varieties were cultivated to cope against salinity but these varieties might not be so tasty to satisfy the farmers. Therefore, they cultivated some other varieties, which would certainly meet their demands. Thus, the farmers chose and selected rice varieties not only to cope with soil salinity, but they also emphasized on other consideration like taste, market value, the quality of the rice, and so on.

The findings of the present research illustrate that the introduction of shrimp farming has changed the system of land use in the study area and therefore the cropping systems have changed from being aman rice-boro rice to shrimp-boro rice based. The results reveal that the shrimp-boro rice rotating cropping system was much more profitable than the previous rice cropping system (Rahman et al., 2013c), but the three-years data from the soils of the shrimp-boro rice cropping system indicate that the salinity level of the soil has increased and the status of the available soil nutrient levels has also changed (Rahman et al., 2013b). The local farmers were concerned about these changes and they have adapted to these environmental changes, particularly with regard to salinity and the deterioration of the fertility of the soil, by changing rice varieties.

However, it is hypothesized that if this shrimp-boro rice cropping system is continued for a long period of time, the salinity level of the soil of this cropping system will reach a level at which the boro rice might not be grown in future. The system may eventually be transformed into a shrimp monoculture. This year-round shrimp monoculture might create an unstable livelihood for the small farmers in the study area by worsening the quality of their crop fields and this shrimp-boro rice cropping system will then be judged to be hampering the sustainability of small farmers' livelihoods. Therefore, the following recommendations can be considered with a view to sustaining the livelihoods of the small farmers who are practicing the shrimp-boro rice cropping system.

- The boro rice should be continued for the sake of the farmers' own consumption as it is the staple food of the locality.
- Shrimps should not be farmed every year. Rather, it should be cultivated every alternate year to maintain the low salinity level for boro rice growing. Therefore, this cropping system will act as a safety-net and a sustainable livelihood system for small farmers in the coastal area of Bangladesh.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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