Journal of Agricultural Science; Vol. 5, No. 11; 2013
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Effect of Shrimp-Based Cropping Systems on Salinity and Soil Fertility in a Coastal Area of Bangladesh: A Village-Level Study

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Received: July 25, 2013 Accepted: August 26, 2013 Online Published: October 15, 2013

doi:10.5539/jas.v5n11p1 URL: http://dx.doi.org/10.5539/jas.v5n11p1

Abstract

The present study analysed soil salinity and some essential soil nutrients for rice plant as affected by a shrimp-based cropping system in a coastal area of Bangladesh. The study was conducted in a village located in Satkhira district. Two main cropping systems, the shrimp-*boro* rice cropping system and the *aman* rice-*boro* rice cropping system, are mainly practised by local farmers in the study village. Soil and water samples were collected from the plots of these cropping systems and chemical analysis was done to measure the salinity level of the soil and water as well as to find out the nutrient status of the soil. The data was also collected for economic analysis and estimated rice and shrimp yield from the local farmers. The results revealed that the soil salinity level of the shrimp-*boro rice* cropping system was higher than that of *aman* rice-*boro* over the consecutive years of 2010, 2011 and 2012. The soil was found to be moderately saline. The organic matter content, potassium, calcium, magnesium and sulphur levels of the soil in the shrimp-*boro* rice system were increased, while the total nitrogen, phosphorus, boron and zinc availability decreased. It was also found that the yield of *boro* rice was 4,950 kg/ha whereas the *aman* rice yield was 3,020 kg/ha and that for shrimp the yield was calculated as 268 kg/ha for one growing season (six months). The total income from *boro* rice, *aman* rice and shrimp was calculated as 127,760 Tk, 87,118 Tk and 149,476 Tk, respectively. The paper concludes that although some nutrient elements were available in adequate amounts, salinity kept these nutrients from being taken up by the rice plants since salinity changes the osmotic pressure of the soil solution system. This may ultimately lead to a reduction in rice yield and threaten the sustainability of the local shrimp-*boro* rice cropping system.

Keywords: shrimp farming, rice cultivation, salinity level, soil nutrients

1. Introduction

Traditional *gher* aquaculture had been practised in the coastal areas of Bangladesh to grow shrimp and fish since long before the introduction of current shrimp culture practises (DDP, 1985). *Gher* is a modified rice field with high dikes to keep water inside to cultivate shrimp/prawns. In the early 1960s, the government constructed a large number of embankments to protect agricultural land from tidal waves and saline water intrusion in the coastal areas. However, due to poor drainage systems in the protected area, it became water-logged in the rainy season, causing problems for rice cultivation. However, since the 1970s, strong international market demand and high prices for shrimp have encouraged farmers to resume shrimp farming in the polders within embanked areas. These two factors together provided a catalyst to accelerate shrimp farming (Karim, 1986). From 1979 to 1980, slightly more than 20 000 ha were placed under shrimp production (Ahmed, 1988), an area that had increased to *c*. 240 000 ha by the 2008-2009 period (DoF, 2010).

Shrimp farming in Bangladesh is characterised by small-scale operations, marginal management, the irregular application of feed and fertilisers and an average production of 146 kg ha^{-1} $year^{-1}$ (Alam, Pokrant, Yakupitiyage & Phillips, 2007). In the south-western coastal areas (i.e. the greater Khulna region), brackish-water shrimp farming occurs in the dry season (December-July), followed by transplanted *aman* rice in the rainy season from July to December. In some areas, shrimp farming is characterised by monoculture. In the south-eastern coastal areas (i.e. Cox's Bazaar region), shrimp are grown from May to November, and for the rest of the year the farmland is used for salt production. In some parts of the south-eastern tidal area, rice alternates with shrimp and fish farming (ESCAP, 1988). Another form of the shrimp-rice cropping pattern has been observed by Rahman, Ando & Takeda (2013) in the south-western part of coastal Bangladesh, which includes shrimp farming in the rainy season (May-November) and rice cultivation (locally called *boro* rice) in the winter season (December-April).

Whichever shrimp farming system is used, saline water is generally used to cultivate shrimp for at least 7 months, and this prolonged inundation of the field by saline water increases the salinity level of the soil (Dwivedi & Kandrika, 2005; Chowdhury, Shivakoti, & Salequzzaman, 2006). The salinisation of agricultural lands near shrimp growing fields due to the seepage of saline water has become a major environmental issue in the region (Jayanthi, Muralidhar, & Ramachandran, 2007). That the salinity of soil influences the growth of rice is general knowledge among local farmers. Within the study area, shrimp and rice are cultivated in the same field in a rotation, and therefore shrimp farming can affect soil fertility. Therefore, the present study aimed to determine the effect of shrimp-based cropping systems on the salinity and fertility of agricultural soils in the south-western coastal region of Bangladesh.

2. Materials and Methods

2.1 Study Area

A village named Shuktia was selected as the research site. The village belongs to Tala Upazila (*Upazila* is a local administrative unit under the district) and is located *c*. 23 km south-east of the Satkhira district headquarter. Satkhira is a coastal district of Bangladesh situated in the south-western part of the country. Agro-ecologically, the study village is located in the Ganges Tidal Floodplain area (Brammer, 1988) and situated between 22°32′ and 22°50′ north latitude and 89°05′ and 89°20′ east longitude (Figure 1). A river named *Dolua* passes by the side of the village and the local farmers extract saline water from this river for shrimp farming. The research area was selected based on a recommendation from the Agricultural Extension Officer of Tala Upazila.

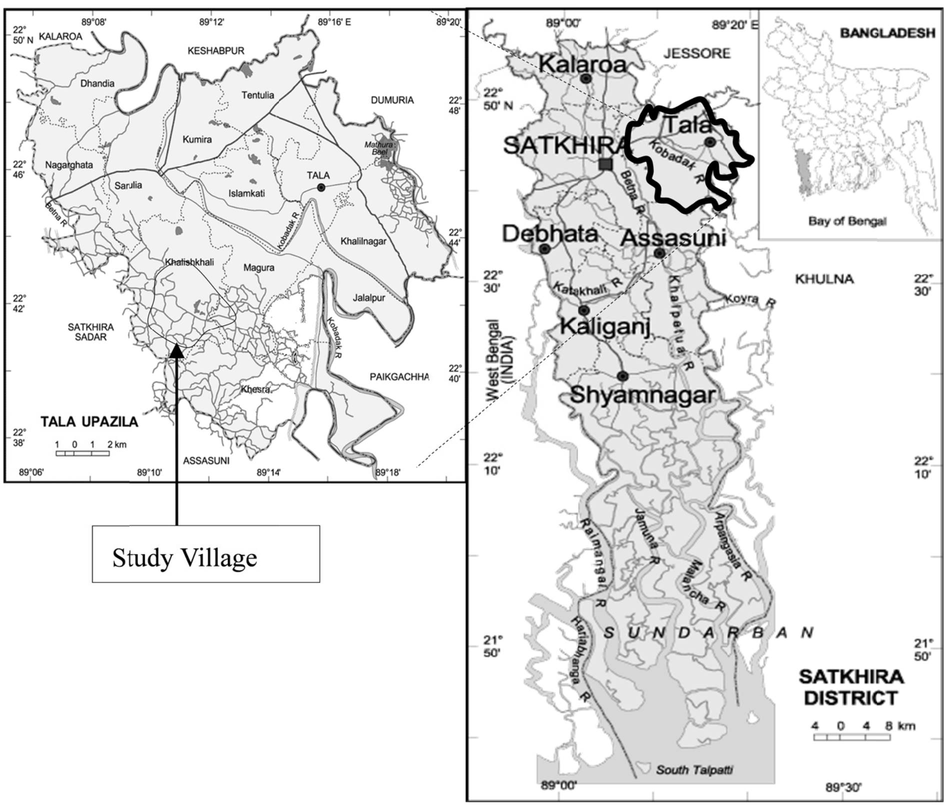

Figure 1. Location of the study area

Rice and shrimp production are important for both consumption and the income of local people at the research site. The field for cultivating rice in the winter season relies on groundwater irrigation, whereas shrimp are raised in the summer and rainy season using saline water from the nearby *Dolua*. Another reason for selecting the study site for this research is the availability of access. A finely constructed road exists from the village to district Satkhira and access to the capital city of Dhaka is available, although it requires *c*. 12 h by bus from the village to Dhaka.

2.2 Soil Sample Collection and Chemical Analysis

Soil samples were collected at six different plots: four plots where the shrimp-*boro* rice cropping system was practised, and two plots where the cropping system was *aman* rice-*boro* rice . 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. Transparent polythene bags were used to preserve the samples and each bag was labelled. The soil samples were dried under shade at room temperature (25ºC) for 2 weeks and then ground. The ground samples were then sieved through a 20-mesh sieve to make the samples suitable for chemical analysis (Hesse, 1971; Jones & Case, 1990; Petersen, 2002). The ground and labelled samples were then sent to the laboratory of the Soil Resource Development Institute (SRDI), Bangladesh, and kept at room temperature until the completion of chemical analysis. Soil salinity was measured as electrical conductivity (EC-dS/m) using a conductivity meter (Rhoades, 1982), and soil pH was measured using a glass electrode pH meter (McLean, 1982) with soil water ratios of 1:1 and 1:2.5 for both tests, respectively. Organic matter (OM) and total nitrogen (TN) were measured using wet oxidation and the micro-Kjeldahl method, respectively (Bremner & Mulvaney, 1982; Nelson & Sommers, 1982). Available soil phosphorus (P) was analysed using the Olsen method (Olsen & Sommers, 1982) and exchangeable potassium (K), calcium (Ca) and magnesium (Mg) were analysed using the ammonium acetate extraction method (Barker & Surh, 1982). Available sulphur (S), boron (B) and zinc (Zn) were analysed by 0.15% $CaCl_2$ extraction (Page, Millar, & Keeney, 1982), diethylenetriaminepentaacetic acid (DPTA) extraction (Lindsay & Norvell, 1978) and the MCP extraction method (Page et al., 1982), respectively. In the rice fields, the farmers used to apply chemical fertilizers namely urea, triple super phosphate, muriate of potash and zinc sulphate at a rate of 250, 70, 35 and 7 kg/ha, respectively for *boro* rice and 145, 70, 35 and 7 kg/ha, respectively for *aman* rice. On the other hand, during shrimp cultivation the local farmers applied calcium carbonate and triple super phosphate at 35 kg/ha and the rice polish as the only feedstuff at 860 kg/ha.

2.3 Water Sample Collection and Analysis

Water samples were collected from the same plots as the soil samples. Surface water samples were collected from February 2010 to September 2012; however, groundwater was collected from the same sample plots only in the months of December, January, February and March of the consecutive years 2010, 2011 and 2012. The water samples were analysed only for salinity (EC-dS/m) using a conductivity meter at the Humboldt Soil Testing Laboratory, Bangladesh Agricultural University, Bangladesh.

2.4 Data Analysis

All the collected data were analysed with SPSS 17.0 and Microsoft Office Excel 2007. The least significant difference (LSD) test and Tukey's-b test were conducted to compare the mean value of soil chemical elements. The soil quality index value was calculated using equation 1 to compare soil fertility status between the shrimp-*boro* rice cropping system and the *aman* rice-*boro* rice cropping system. This concept was adopted from Chowdhury, Khairun, Salequzzaman & Rahman (2011).

$$QI=\sum S_n/n*h \tag{1}$$

Where QI = quality index, S = Suitability score (Table 1), n = 1, 2, 3… nth data, N = total number of data and h = highest score value (e.g. 4 for soil fertility).

Table 1. Suitability ranges for soil fertility status by soil chemical analysis

Range/ Fertility status	EC (dS/m)	OM%	TN%	P	K	Ca	Mg	S	B	Zn
Very high (4)	>16.0	>5.0	>0.45	>30.0	>0.375	>7.5	>1.875	>45.0	>0.75	>2.25
High (3)	8.1-16.0	3.1-5.5	0.361-0.450	24.1-30.0	0.30-0.375	6.1-7.5	1.51-1.875	36.1-45.0	0.61-0.75	1.81-2.25
Medium (2)	4.1-8.0	1.1-3.0	0.181-0.360	12.1-24.0	0.151-0.30	3.1-6.0	0.751-1.5	18.1-36.0	0.31-0.6	0.91-1.8
Low (1)	2.0-4.0	<1.00	<0.180	<12.0	<0.15	<3.0	<0.75	<18.0	<0.3	<0.90

Adopted from SRDI (2003), BARC (2005) and Chowdhury et al. (2011).

3. Results

3.1 Salinity Level and Soil Fertility Status Between the Cropping Systems

The salinity and the soil fertility status of both the shrimp-*boro* rice cropping system and the *aman* rice-*boro* rice cropping system are summarised in Table 2. No significant differences ($P < 0.05$) were observed in soil pH, TN, Mg or S between the two cropping systems. The soils of both the shrimp and rice fields were found to be moderately alkaline. The salinity level was significantly ($P < 0.05$) higher (5.46 ± 1.56 dS/m) in the shrimp-*boro* rice cropping system than in the *aman* rice-*boro* rice cropping system (3.43 ± 0.84 dS/m). Similarly, the OM%, P, K, Ca and B content of the soil in the shrimp-*boro* rice cropping system were significantly higher than that of the *aman* rice-*boro* rice cropping system. However, a significantly higher Zn content (0.99 ± 0.28 µg/g soil) was found in the *aman* rice-*boro* rice cropping system compared with that of the shrimp-*boro* rice cropping system (0.75 ± 0.36 µg/g soil).

Table 2. Comparative soil fertility status and salinity level of the two cropping system plots in the study area (n=6)

Parameters	Shrimp-*boro* rice				Aman rice-*boro* rice			
	Range	Average	SD	Index value	Range	Average	SD	Index value
pH	7.7-8.6	8.2	±0.2	..	7.5-8.5	8.1	±0.3	..
OM (%)	1.98-3.40	2.55^a	±0.33	0.520	1.35-2.57	1.78^b	±0.31	0.500
Total N (%)	0.09-0.18	0.13^a	±0.02	0.250	0.08-0.20	0.12^a	±0.03	0.250
P (µg/g soil)	8.77-14.28	11.43^a	±1.21	0.343	4.92-12.55	8.17^b	±2.06	0.257
K (meq/100 g soil)	0.48-1.30	0.76^a	±0.22	1.000	0.39-0.59	0.50^b	±0.05	1.000
Ca (meq/100 g soil)	18.38-35.47	25.63^a	±4.09	1.000	14.95-25.14	20.00^b	±3.25	1.000
Mg (meq/100 g soil)	3.07-8.55	6.13^a	±1.81	1.000	3.08-8.55	5.52^a	±1.64	1.000
S (µg/g soil)	30.52-196.09	80.71^a	±41.20	0.937	43.56-150.95	93.38^a	±24.09	0.992
B (µg/g soil)	0.63-2.04	1.31^a	±0.39	0.984	0.62-1.55	1.01^b	±0.26	0.945
Zn (µg/g soil)	0.39-1.94	0.75^b	±0.36	0.335	0.54-1.52	0.99^a	±0.28	0.414
Salinity (EC-dS/m)	2.80-8.00	5.5^a	±1.56	0.445	2.18-5.49	3.4^b	±0.84	0.313

Source: Field survey 2010-2012.

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

3.2 Changes in Salinity Level and Soil Fertility Status During 2010-2012

Different soil parameters in the shrimp-*boro* rice cropping system for the period 2010-2012 are presented in Table 3. 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 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 all decreased significantly ($P < 0.05$).

3.3 Changing rate of Salinity Level and Fertility Status Between 2010 and 2012

The rates of change in salinity and other soil nutrients over the period from 2010 to 2012 are shown in Figure 2. These changes were calculated for the shrimp-*boro* rice cropping system only. An average 22% increase in salinity occurred from 2010 to 2012. OM%, K, calcium (Ca), Mg and S also increased at average rates of 6%, 86%, 5%, 89% and 45%, respectively. In contrast, decreases of 7%, 17%, 52% and 50% were observed for TN%, P, B and Zn, respectively, over the 2010-2012 study period.

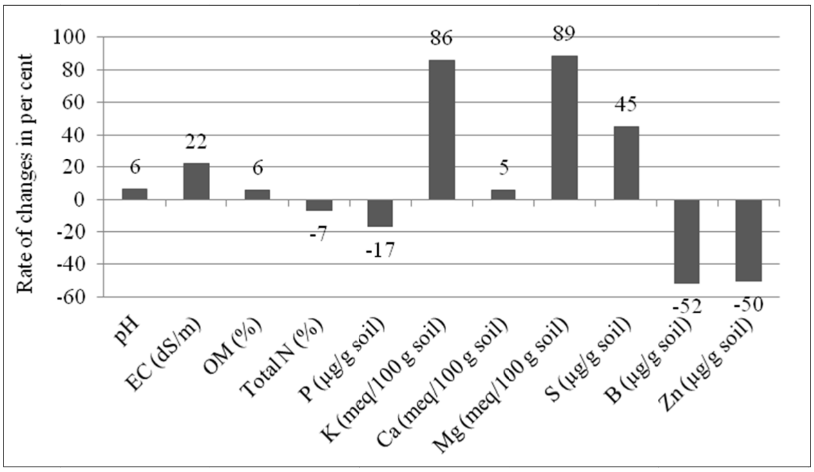

Figure 2. Soil salinity and nutrient element rates of change between the years 2010 and 2012

Table 3. 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 (meq/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 (meq/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 (meq/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) within a row are significantly different at the 95% level of significance.

3.4 Water Salinity

Monthly fluctuations in field water salinity of the shrimp-*boro* rice cropping system from February 2010 to September 2012 are shown in Figure 3. Field water salinity remained high during the months from May to August in all 3 years (2010-2012) with a range from 16.7 ds/m to 50.9 ds/m. Beginning in September, salinity began to decrease due to the onset of monsoon rainfall that diluted the saline water in the field. The farmers usually irrigate their fields from the month of December to March. Therefore, groundwater salinity was only estimated for those months. Average groundwater salinity was also measured, which was found to be 2.09 ds/m in 2010, but it increased to 2.68 ds/m in 2011 and 2.84 ds/m in 2012.

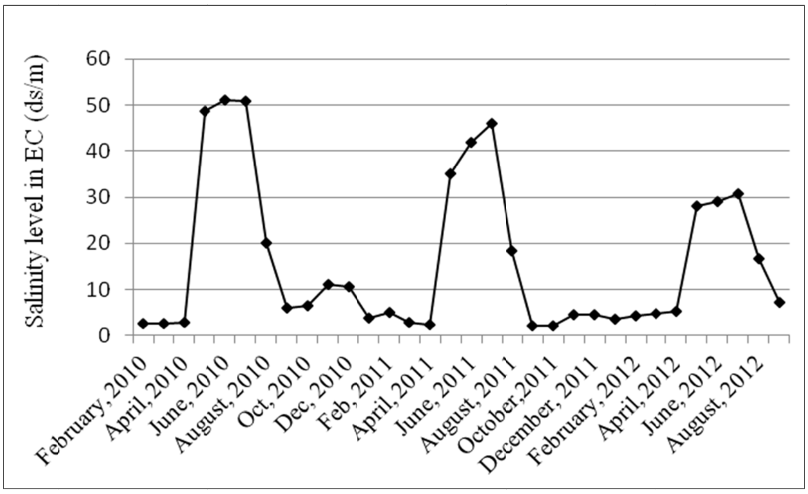

Figure 3. Monthly fluctuation of field water salinity in the shrimp-*boro* rice cropping system

3.5 Yield and Economic Return from Rice and Shrimp

The cost, income and yield of *aman* rice, *boro* rice and shrimp are presented in the Table 4. It was found that the total cost of production was calculated to be higher (average 54,411 taka/ha) in *boro* rice cultivation than for *aman* rice cultivation, where the average cost was 45,737 taka/ha. Table 4 also shows that the grain yield is higher in *boro* rice (4,950 kg/ha) than *aman* rice (3,020 kg/ha). The higher yield of *boro* rice is a common phenomenon in the study area; similar to other rice-growing areas of Bangladesh. However, because of higher yielding in *boro* rice and the nearly same price of one kilogram rice of *boro* and *aman*, the total income from *boro* rice was calculated as higher than that from *aman* rice. The benefit cost ratio for one hectare of *boro* rice production was calculated as 2.37, whereas it was only 1.90 for *aman* rice production. In case of shrimp the total cost of production for one hectare of land is 43,853 taka which is less than the estimated cost of both *aman* and *boro* rice. The average yield from one hectare of shrimp culture was about 268 kg for one growing season (six months) in the study area. It was also calculated that the average total income from one hectare of shrimp cultivation was 149,476 taka and the average benefit cost ratio was 3.67, which is much higher than that of *boro* and *aman* rice crops.

Table 4. Cost, income and yield from one hectare of rice and shrimp in the study area

Items	*Aman* rice	*Boro* rice	Shrimp
Total cost (Tk/ha)	45,737	54,411	43,853
Total income (Tk/ha)	87,118	128,760	149,476
Yield (kg/ha)	3020	4950	268
Benefit cost ratio	1.90	2.37	3.67

Source: Field Survey, 2012.

1 USD= 82 Tk.

4. Discussion

Soil pH is the most important factor in the nutrient availability of soils. In most cases, a pH range of 6.0-7.5 is optimum for the adequate availability of nutrients in the soils (BARC, 2005) of Bangladesh. In the present study area, the soil was alkaline (pH > 7.0) in the plots of both cropping systems (Table 2). This pH is suitable for shrimp aquaculture but not for rice production (SRDI, 2003). During the period from 2010 to 2012, very little variation in soil pH occurred in the study area. According to Soil Resource Development Bangladesh (SRDI, 1985), soil OM content of at least 2.5% is the indication of a good agricultural soil. This research revealed that the OM was significantly higher (2.55%) in the shrimp-*boro* rice cropping system than in the *aman* rice-*boro* system. The high OM of the surface soil may be due to decayed feedstuff and rice straw in the shrimp-*boro* rice cropping system. However, no significant changes in OM% were observed over the 2010-2012 study period.

The index value for N (0.250) indicated a poor status. This poor N status might be attributable to the high volatilisation of ammonium to nitrate, which is affected by salinity of the soil (Jurinak & Wagenet, 1981). The index value for P was not satisfactory at only 0.343 for the shrimp-*boro* rice cropping system and 0.257 for the *aman* rice-*boro* rice cropping system. The status of P declined from 0.409 in 2010 to 0.354 in 2011 and 0.250 in 2012 (Table 3). However, significantly higher levels of K were found in the plots of the shrimp-*boro* rice cropping system compared with those of the *aman* rice-*boro* rice cropping system, and the index value for K content was very good in both of the cropping systems (the index value was 1.00 for both). On the basis of the results, soil pH was significantly increased from 2010 to 2011 and 2012 from 7.9 to 8.4 and the calcium content was also high, therefore, at this high pH the soil P would be fixed with Ca and formed a complex resulting lower P availability (Sharpley, Meisinger, Power, & Suarez, 1992).

Differences in the availability of Ca, Mg and S in the soils of both cropping systems were found to be insignificant (Table 2). The index value of these mineral nutrients was within optimum ranges in both of the cropping systems. The presence of higher levels of K, Ca, Mg and S in the study area soils was caused naturally. According to Chowdhury et al. (2011), naturally saline water contains various dissolved solids composed mainly of carbonates, bicarbonates, chlorides, sulphates, phosphates, silica, Ca, Mg, sodium, and K. In addition to the saline water, the chemicals (Calcium carbonate and triple super phosphate) and the feedstuff (rice polish) were applied for shrimp cultivation; consist of a higher amount of K, Ca, Mg and S (Hashim, Aminuddin, & Siva, 1996) and some other chemical fertilizers were also applied in each rice growing season. These would be the cause of increasing levels of K, Ca, Mg and S in the soils of both study area cropping systems.

Among the micronutrients, both cropping systems had desirable B contents in their soils (an index value of 0.984 for the shrimp-*boro* rice system and 0.945 for the *aman* rice-*boro* rice cropping system), though significantly higher amount of B was found in case of shrimp-*boro* rice system. In the study area farmers did not apply any B fertilizers to cultivate the rice in any of the two systems. In *aman* rice-*boro* rice system rice is cultivated two times in a year while in shrimp- *boro* rice system it is cultivated in one time, therefore the B is upatken by the rice plants more in *aman* rice-*boro* rice sytem. This could be a cause why B was found decreased under *aman* rice- *boro* rice cropping system. In case of Zn the index value indicated a poor status in both cropping systems, though; significantly higher amount of Zn was found in *aman* rice-*boro* rice system than shrimp-*boro* rice system. The high pH condition and high Ca concentration in the saline soils are responsible for the low availability of the Zn. In saline soils, the domination of exchange sites by sodium ions causes zinc ions to be lost by leaching under submerged condition with a high concentration of sodium (Alloway, 2003). This might be the cause of higher amount of Zn under *aman* rice- *boro* rice system over the shrimp-*boro* rice system.

Considering the changes of nutrient elements from 2010 to 2012, we can estimate that some of the nutrients, e.g. P, B and Zn have been decreased significantly. According to BARC (2005), B and Zn availability were reduced in the soil with a high pH and high salinity. We have also found that the pH level and salinity level both were increased from 2010 to 2012, therefore the B and Zn availability in the soil has decreased. On the other hand, the increase of K, Ca, Mg and S from 2010 to 2012, as discussed before, was caused naturally with the intrusion of saline water as well as application of chemical fertilizers and shrimp feedstuffs.

The SRDI (1985) has categorised the soils of Bangladesh into five categories based on salinity levels (electrical conductivity as dS/m): non-saline soil (<2.0 dS/m), slightly saline soil (2.1-4.0 dS/m), moderately saline soil (4.1-8.0 dS/m), strongly saline soil (8.1-16.0 dS/m) and very strongly saline soil (>16.0 dS/m). According to the results of our research, the soil of the shrimp-*boro* rice cropping system can be categorised as moderately saline soil with an electrical conductivity of 5.46 dS/m (Table 2), while the soil of *aman* rice-*boro* rice cropping system can be categorised as slightly saline soil with an electrical conductivity of 3.43 dS/m. The soil salinity of the shrimp-*boro* rice cropping system could be harmful to rice production. At this salinity, rice yield could be reduced by more than 24% because as stated in Maas and Hoffman (1977), beyond a salinity of 3.0 dS/m, rice yield can be decreased by 12% with every 1.0 dS/m increase in electrical conductivity.

The present study identified a salinity problem in the study area, which increased over the period from 2010 to 2012. Soil salinisation from shrimp farming was reported by Azad, Jensen, and Linn (2009), as an environmental problem related to shrimp farming in Bangladesh due to the long-term inundation of saline water in shrimp farmland every year. The shrimp farmers keep water salinity levels high in shrimp farmland from April to November (Figure 3). This saline inundation also causes the seepage of saline water into the adjacent rice fields, causing problems in rice production (Wahab, 2003; Ali, 2006). Several studies have shown that salinity reduces N and P uptake (Pessarakli, 1991; Al-Rawahy, Stroehlein, & Pessarakli, 1992; Sharpley et al., 1992). K uptake is also impaired by salinity, and experiments have shown that application of additional K in highly saline soils is not effective in improving the K uptake (Marschner, 1995). However, the effects of N and P application saline soils have not been reported. Saline soils do not support plants, especially rice growth, since salinity reduces the uptake of nutrients in adequate amounts due to a higher osmotic pressure in the plant soil system (Bhumbla, 1977) despite adequate nutrient levels being available in the soil. Therefore, the rice production is under threat in the shrimp-*boro* rice cropping system in the study area due to the creation of salinity problems.

5. Conclusions

Shrimp cultivation in the coastal area of Bangladesh has been an economically profitable enterprise since its establishment. Therefore, the area of the shrimp farms has also expanded extensively and many rice fields have been converted into shrimp farms in the inland regions of coastal areas, where both shrimp and rice are now cultivated alternately in the same field in a year. The prolonged retention of saline water for shrimp cultivation has increased the salinity level of soils. This increase in salinity causes changes in the availability of essential soil nutrients. Our findings revealed that due to increases in soil salinity the availability of some nutrient elements increased while the availability of others decreased significantly. Although some nutrients were present in adequate amounts, they could not be taken up by rice plants due to the altered osmotic pressure of the soil system under increased salinity. However, though at present the boro rice yield of the study area is not lower than the average to other parts of Bangladesh, the changes in nutrient availability and uptake might significantly reduce the yield of rice in future in the coastal area of Bangladesh, generally cultivated just after the shrimp cultivation.

Acknowledgement

The authors would like to express their heartfelt thanks to the "Promoting the Study of Sustainable Humanosphere in South-East Asia" Project, Kyoto University, for its financial support to this study. The authors are also grateful to SRDI and BAU soil testing laboratory, Bangladesh, for the conducting the chemical analysis of soil samples.

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