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Impact of salinity on rice production in the south-west region of Bangladesh

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ABSTRACT

This study tries to quantify the impact of salinity on rice production in the south-west region of Bangladesh. *Khorip* is the dominant crop season in the region. The average production of rice during *khorip* season is 4,232 kg ha^{-1} in low saline areas, whereas, it is 3,760 kg ha^{-1} and 2,663 kg ha^{-1} for moderate and high saline areas, respectively. The Cobb-Douglas production function estimation results find that salinity has a negative and statistically significant influence on rice yield. This study also finds that salinity intrusion negatively influences farm profitability as well as farm performance. If the salinity of high saline area can be reduced to the threshold level, farmers will gain about 685 US\$ ha^{-1} from increased rice yield. Salinity level needs to be controlled for realizing the benefits from an increase in production. Drainage, fresh water management for irrigation in time of dry season and spreading salt tolerant rice varieties in saline prone area are the controlling measures against salinity intrusion. Land zoning, property rights, tax for external costs associated with shrimp farming in the coastal areas of the country may be some command and control approaches to address the salinity problem. These will ultimately increase farm profitability in the saline affected areas.

KEYWORDS

Farm performance;
Production function;
Salinity;
South-west region of Bangladesh.

INTRODUCTION

Agricultural production usually depends on agricultural inputs, such as, land, labor, capital (machinery and pesticides), seeds, management practices, soil characters and climate variables. In addition, salinity level also influences agricultural production in coastal areas. The coastal agricultural land of Bangladesh is otherwise very fertile for growing rice. However, salinity is a soil hazard which deteriorates the soil health and fertility status of the soil in the coastal areas. Such deterioration results in low agricultural production, low income and consequently reduces farm labor employment in the south-west region of Bangladesh[6]. Salinity intrusion is a growing concern for the south-west region of Bangladesh. It affects cultivation pattern in the region. Salinity ingress causes an increase in soil salinity, especially when the farmers irrigate their land with slightly saline surface water at the beginning of the low flow period. The higher rates of capillary action from an increased rate of topsoil aridity would accentuate the salinity problem. Shrimp farming is an important and commonly practiced venture in the region now-a-day. The farmers are becoming more interested in shrimp farming instead of crop production due its short term benefits. The inundation of agricultural land to create shrimp ponds has reduced the availability of land for homestead crop, fruit cultivation and livestock rearing in the region.

The soil salinity classes are measured by different level of EC (dSm^{-1}). Crop productivity decreases with the increase in this EC level. Richards[8] and Kaddah[11] state that, the salt tolerance level of rice ranges from 6 to 10 dSm^{-1}. The study of Thiruchelvam and Pathmarajah[16] shows that exceeding rice threshold EC level (in dSm^{-1}) in salinity reduces yield by a significant percentage. Datta and Jong[7] find a considerable decrease in paddy and wheat yield for an increase in salinity level. In the division of Barisal and Khulna, about 70 percent of the land is affected by different level of salinity, which reduces agricultural productivity[9]. The people of the south-west region of Bangladesh largely depend on agriculture, especially on rice cultivation. The currently cultivated rice varieties in the region are not fit for survival with the increased soil salinity. Salinity intrusion adversely affects coastal agriculture of Bangladesh through limiting fresh water availability. The salt content of soil and water varies spatially, seasonally, and according to land elevation. The salinity level in flooded water and soil is several times lower in the wet season compared to dry season[24]. According to Sarwar and Khan[5], both water and soil salinity along the coast increase with the rise in sea level. Haque[17] shows that fertility status of saline soils range from low to very low in respect to organic matter content, nitrogen, phosphorus and micronutrients like zinc and copper. Ali[1] states that salinity ingress has a negative impact on rice ecosystem and increased soil salinity depletes soil Ca, K, Mg, and organic C content. Moormann and Breemen[3] demonstrate that crop yield decreased by 50 percent when soil salinity level (EC values) reaches to 6-10 dSm^{-1}. Under the said circumstances, this study attempts to quantify the effect of salinity on rice production in the south-west region of Bangladesh.

MATERIALS AND METHODS

Study area

This study randomly selected three study sites namely: *Kathaltola* of *Dumuria upazila*, *Hogladanga* of *Batiaghata upazila*, and *Parchalna* of *Dacope upazila* in the south-west region of Bangladesh. These three sites represent low saline, moderately saline and high saline areas having 2-8 dSm^{-1}, 9-16 dSm^{-1}, and 16^{+} dSm^{-1} EC value, respectively. In *Kathaltola* of *Dumuria upazila*, the EC value is under the threshold level[25] for rice production; whereas, in *Hogladanga* of *Batiaghata upazila*, it is above the tolerance level for rice production; and in *Parchalna* of *Dacope upazila*, the soil salinity is extremely high which severely affects rice production. Approximately 65, 57 and 66 percent households of the low, moderate and high saline study sites, respectively depend on agriculture[2].

Study method

This study uses both the secondary and primary data to address the study objective. The database of concerned *upazila* statistics office, Soil Resource Development Institute (SRDI), published books, journals and reports are the main secondary information sources of this study. A stratified random sampling procedure is used to select primary survey responders in the study sites. Occupation and land ownership are the main strata. A total of 90 samples are selected for this study taking 30 from each of the three study sites. Primary data has been collected on rice production, cropping pattern, input use, cost and return from rice cultivation of the largest plot of land from each respondent through using a structured questionnaire in time of *khorip* season. It is the dominant crop season in these three study sites.

TABLE 1 : Area of cultivable land and soil salinity of the study area

Upazila	Total area (ha)	Cultivated area (ha)	Saline area (ha)	Saline land (%)
Dumuria	44,797	34,878	30,611	68
Batiaghata	23,622	17,340	16,380	69
Dacope	28,557	22,757	22,760	80

N.B.: 'ha' refers to 'Hectare' which is used for land measurement; Source: SRDI (2010)[21]

In order to assess the salinity-induced effects on rice yields, a Cobb-Douglas form of production function is estimated (equation 1).

$$Ln(Y) = \alpha_0 + \alpha_1 Ln(L) + \alpha_2 Ln(S) + \alpha_3 Ln(F) + \alpha_4 Ln(M) + \alpha_5 D_1 + \alpha_6 D_2 \quad (1)$$

Here, Y is yield of rice (kg ha^{-1}), S is seed used (kg ha^{-1}), F is fertilized used (kg ha^{-1}) and M represents cost of machinery (includes cost of chemicals and machinery use) in US\$ ha^{-1} (1 US\$ = 73 Bangladeshi Taka at the time of survey). D_i refers to dummy variables for different soil salinity classes. Considering low saline region as a reference, this study uses two dummies: D_1 for moderately saline region and D_2 for highly saline region.

This study attempts to estimate the change in production for a change in salinity level. The rice yield data is analyzed per soil salinity class to assess the damages caused by salinity intrusion in terms of the rice yield and earnings of the farmer. To assess the performance of the farmers engaged in rice cultivation in the study sites, a liner functional form (equation 2) is estimated to express the relationship of the farmers' performance with different saline affected land, cropping pattern and land size as explanatory measures.

$$P = \beta_0 + \beta_1 LS + \beta_2 CP + \beta_3 D_1 + \beta_4 D_2 + u \qquad (2)$$

Here, P = Performance of the farmers, LS = Land size (in hectare), and CP = Cropping pattern. Equation 2 also includes the salinity related dummies (D_1 and D_2) of equation 1 as explanatory variables. This study considers profit-sales ratio as the performance measuring indicator (P), where, profit is defined as net return (sales – cost of production in the same piece of land). Sales value per hectare is calculated through multiplying rice yield in kg ha^{-1} and market price of rice in US\$ kg^{-1}. The cropping pattern (CP) is expressed by the times of cultivation of a land in the same year. The CP value ranges from 1-3 for single, double and triple crops per year in the same piece of land.

RESULTS AND DISCUSSION

The salinity intrusion is an alarming phenomenon for the south-west region of Bangladesh. Bangladesh has a coastline of 710 km along the Bay of Bengal which is being influenced directly or indirectly by tidal water, salinity intrusion and cyclone/storm surge. Parvez[15] states that a higher level salinity persists in the coastal districts of Bangladesh, namely, Khulna, Satkhira, Patuakhali, Bagerhat, Cox's Bazar, Barguna, Bhola, Noakhali, Chittagong and Laxmipur. Among these ten districts, Khulna is the worst affected by salinity[15]. According to Faiz et al.[18] as cited in Haider et al.[12], approximately one-fifth of the total area of Bangladesh, which lies around the northern part of the Bay of Bengal ($20^0$252 to $23^0 20^2$ N latitude and $88^0$352 to $92^0 24^2$ E longitude) is seriously affected by saline water intrusion. According to the salinity survey, about 1.02 million hectares areas of Bangladesh (i.e. 70 percent of total cultivated land in the southern coastal areas) is affected by various degrees of salinity[19]. The highly saline prone area extends over one-fourth of the total salinity affected areas in the coastal region where salinity has encroached upon 3 percent more lands to 1.056 million hectares in 2009 from 1.02 million hectares in the beginning of the decade[20]. The salinity in the coastal areas increases at the time of cultivating *boro* rice during the dry season. Salinity remains high during November-May season and reaches to peak in April-May. It declines as monsoon comes, allowing farmers in the region to grow transplanted *aman* rice (in time of *Khorip* season). The salinity of the coastal areas of Bangladesh is higher than the other areas of the country. Salinity in the coastal region greatly hampers the agricultural production in this region, specially it hampers the rice production.

Salinity in the study area

The spatial variations in salinity level are found in the study area. The soil salinity of the south-west region of Bangladesh is increasing over the time period. According the SRDI database, more than two-third land of the three study sites *i.e. Dumuria*, *Batiaghata* and *Dacope* is saline affected (TABLE 1). Saline soil contains soluble salts in concentration that interfere with the growth of most crop plants.

The level of salinity in the study sites varies significantly. *Dacope* is the highly saline area having up to 22.18 dSm^{-1} EC value of soil in some places. About 40 percent of the cultivated land in this *upazila* is highly saline affected, having more than 16 dSm^{-1} EC level (Figure 1). In *Dumuria* and *Batiaghata*, the area coverage under higher salinity level is comparatively lower. The people of *Dumuria* and *Batiaghata* are facing comparatively less constraints in rice production from salinity perspective. About one-third land in these two *upazilas* is under the threshold level of salinity (8 dSm^{-1}). The moderate level salinity (8-16 dSm^{-1}) covers 29, 30 and 44 percent land of *Dumuria*, *Batiaghata* and *Dacope*, respectively.

Rice production in the study area

Salinity affects the physiological process of the plants which ultimately affects crop production. Transplanted *aman* rice is the dominant crop in the study sites in *khorip* season. The field survey findings indicate that the rice yield is very low in the highly saline affected areas of *Dacope upazila*. The average yield is moderate in moderately saline *Batiaghata upazila* and it is the highest in the low saline *Dumuria upazila* (TABLE 2).

TABLE 2 : Average yield and production in the study area

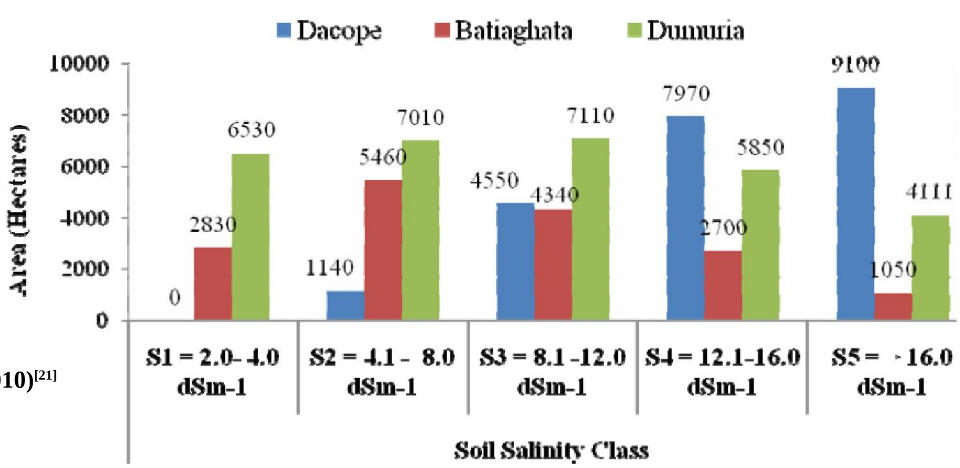
	Dumuria Upazila		Batiaghata Upazila		Dacope Upazila	
	Kathaltola (1.70 dSm^{-1})		Hogladanga (12.80 dSm^{-1})		Parchalna (22.18 dSm^{-1})	
Variable Name	**Mean**	**CV (%)**	**Mean**	**CV (%)**	**Mean**	**CV (%)**
Yield (Kg ha^{-1})	4232	12.89	3760	11.58	2663	28.51
Fertilizer (Kg ha^{-1})	139	33.77	162	40.56	295	38.45
Seed (Kg ha^{-1})	147	17.45	160	24.44	131	50.87
Labor (No ha^{-1})	133	16.86	130	7.78	143	14.96
Machinery (US$ ha^{-1})	52	13.86	62	16.57	66	24.86

N.B : $Coefficient\ of\ variation\ (CV)\% = \frac{standard\ deviation}{mean}\ x\ 100$; **Source: Author's compilation based on field survey (2011) and SRDI (2010)[21]**

Rice is cultivated during dry season in the study sites through similar process. This study attempts to find out the responses of salinity on rice production. It assumes that salinity build-up directly influences crop yields. A Cobb-Douglas form of production function (equation 1) is used in this study to establish the relationship between salinity and rice production.

Since fertilizer application has a direct effect on salinity, it is considered separately instead of adding into capital. The Cobb-Douglas production function includes two types of explanatory variables: labor, seed, fertilizer and capital are yield increasing variables, whereas, soil salinity is a yield decreasing variable. The estimated R^2 of the production function indicates that 85 percent of the total variation of rice yield is explained by the considered explanatory variables. The regression coefficients of the explanatory variables have expected signs. Moreover, the coefficients of all but labor of the considered explanatory variables are statistically significant (TABLE 3).

The negative production elasticity of soil salinity (α_5 and α_6) indicates the decline in rice yield for an increase in the soil salinity of the study sites. The coefficient of D_1 (α_5 = -0.19) indicates that holding other things con-



Source: SRDI (2010)[21]

Figure 1 : Spatial variation of salinity level in the study area

TABLE 3: Production function estimation

Source	SS	df	MS	Number of observation =	90
Model	5.383	6	0.897	F(6,83) =	80.76
				Prob > F =	0
Residual	0.922	83	0.011	R-squared =	0.85
Total	6.306	89	0.071	Adjusted R-squared =	0.84

Ln (Y): Yield	Symbol	Coefficient	Std. Error	t	P>t
Intercept	α_0	1.601	0.409	3.92	0.000
Ln (L): Labor	α_1	0.065	0.102	0.63	0.527
Ln (S): Seed	α_2	0.295**	0.057	5.15	0.000
Ln (F): Fertilizer	α_3	0.089*	0.042	2.11	0.038
Ln (M): Machinery	α_4	0.212*	0.084	2.54	0.013
D_1 for moderately saline region	α_5	-0.188**	0.031	-6.19	0.000
D_2 for highly saline region	α_6	-0.552**	0.047	-11.81	0.000

N.B: ** and * represent 1% and 5% level of significance; Source: Author's calculation

TABLE 4 : Performance and farming indicator

Indicators	Kathaltola (Low saline area)		Hogladanga (Moderate saline area)		Parchalna (High saline area)	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
Profit (US$ ha^{-1})	1057	14.14	792	17.28	372	29.69
Sales (US$ ha^{-1})	1344	11.08	1225	12.78	857	24.65
Performance	0.78	5.57	0.64	8.17	0.43	14.55
Land size (ha)	0.72	58.62	0.89	106.82	0.87	64.91
Cropping Pattern	2.37	20.72	1.70	31.47	1.07	23.79

N.B: Performance = Profit-sales ratio; $Coefficient\ of\ variation\ (CV)\% = \frac{standard\ deviation}{mean}\ x\ 100$**; Source: Author's calculation**

TABLE 5 : Performance estimation

Source	SS	df	MS	Number of observation =	90
Model	1.913	4	0.478	F(4,85) =	169.93
				Prob > F =	0
Residual	0.239	85	0.003	R-squared =	0.89
Total	2.152	85	0 .024	Adjusted R-squared =	0.88

(P): Performance	Symbol	Coefficient	Std. Err.	t	P>t
Intercept	β_0	0.815	0.032	25.46	0.000
(LS): Land size	β_1	0.014*	0.009	1.66	0.100
(CP): Cropping pattern	β_2	-0.017	0.013	-1.29	0.199
D_1 for moderately saline region	β_3	-0.157***	0.017	-9.41	0.000
D_2 for highly saline region	β_4	-0.379***	0.023	-16.79	0.000

N.B.: Dependent Variable: Performance; * and * represent 1% and 10% level of significance; Source: Author's calculation**

stant, rice yield in the moderate saline area is 17% [=1-exp(-0.19)] lower than the yield in the low saline area. Similarly, the coefficient of D_2 (α_6 = -0.55) indicates that holding other things constant, rice yield in the high saline area is 42% [=1-exp(-0.55)] lower than the yield in the low saline area. Soil salinity that comes from the shallow saline water use in dry season declines the rice production[10]. Higher degree of salinity which arises from poor land and water management and expansion of the agricultural frontier into marginal dry lands results lower production[4]. The present study shows that high, medium and low soil salinity generate low, medium and high rice production. The study of Dixit and Chen[14] shows 40 percent and 46 percent reduction in number of grains at medium and high salinity levels in comparison with the low salinity level. Salinity causes a yield reduction by affecting the number and weight of grains[13].

Performance analysis

Salinity has negative influence on the farm performance. The profit-sales ratio is used in this study to measure farm performance. Higher productivity might be associated with higher net return or profit per hectare. The rice production per hectare is lower in the highly saline area and vice-versa. Thus, profit per *hectare* is higher in low saline site compared to moderate and high saline study sites (TABLE 4). Land size and cropping pattern of the respondents of the three places are also different.

Land size, cropping pattern and soil salinity influence the farm performance. The estimated R^2 of model 4 (TABLE 5) indicates that 89 percent of the total variation in performance is explained by the variation in soil salinity level, land size and cropping pattern. The estimated regression coefficient of salinity level clearly indicates inverse relationship between salinity level and farm performance and this relationship is statistically significant (TABLE 5). More specifically, the coefficient of D_1 and D_2 (β_3 = -0.16 & β_4 = -0.38) indicate statistically significant inverse relationship between salinity and farm performance. Land size has statistically significant positive influence on farm performance. Cropping pattern is inversely related with the farm performance, though it is not statistically significant.

The study results shows that compared to the low saline area, profit-sales ratio of moderate and high saline areas are 16 percent and 38 percent lower, respectively. The farmers increase the use of fertilizer and other production inputs to cope with the salinity in the high saline areas, which incurs higher production cost. Lower production per hectare along with higher production cost in the highly saline affected areas reduces the performance (profit-sales ratio) as compared to the low saline areas. Thanh et al.[22] estimate that the salinity costs of shrimp farming in Vietnam in the form of lost paddy production, dam construction cost and delayed cost of planting is US$ 0.15 per hectare in the Mekong delta. Increased salinity of soil has negative economic impacts including a reduction in grazing land and reduced crop productivity[23].

CONCLUSION

The salinity of the coastal areas of Bangladesh is higher than the other areas of the country. The study results confirm the research hypothesis *i.e.* an increase in the soil salinity decreases rice production and net returns from rice production in the study sites. The statistically significant negative relationship between soil salinity and rice production questions the economic viability of cultivating rice in the highly saline areas. A higher soil saline affected region induces decreasing returns in rice cultivation, which reduces productive capacity of crop-land thereby decreasing agricultural profitability and farm performance. Soil salinity needs to be controlled for realizing the benefits from an increase in rice production. The possibility of rain water harvesting and storing to fulfill the demand of fresh water for irrigation during dry season may be explored. Soil salinity needs to be controlled by the farmers through proper efforts, such as, drainage, water management, organic manure application and management of the physical factors of soil. The currently cultivated rice varieties are not much salt tolerant. Therefore, R&D effort for innovating and spreading salt tolerant rice varieties for the high saline areas needs to be explored. The government needs to device clear policies regarding land zoning, property right, payment for external costs associated with shrimp farming in the coastal areas of the country to properly handle the human induced salinity intrusion. Moreover, implementation and coordination of the concerned policies attracts special attention for making the agricultural production system in the coastal regions sustainable.

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