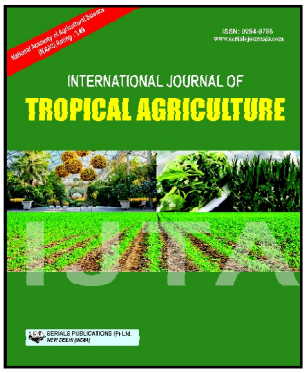

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People's perception on impact of salinity on trees and agricultural crops in the coastal area of Bangladesh

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Abstract: Salinity intrusion with gradual increasing rate results in declining the species growth and survival rate in the coastal areas of Bangladesh. This study explores people's perception on impacts of salinity on tree species and agricultural crops in the coastal zone of Bangladesh. Multistage Random Sampling techniques were used with a semi-structured questionnaire to collect information from 120 respondents. It was found that the people have recognized salinity as a problem and the construction of shrimp enclosures as the main reason for the increasing level of salinity. The study showed that people's responseto the reduction of tree species and agricultural crops was 25% and 58% respectively during the last forty years. Both tree species (*Mangifera indica*, *Artocarpus heterophyllus*, *Cocos nucifera*, *Phoenix sylvestris*, *Syzygium cumini* etc.) and agricultural crops (*Oryza sativa*, *Corchorus capsularis*, *Curcuma domestica*, *Zingiber officinale*, *Capsicum annuum* etc.) were found to be reduced. Whereas respondents identified that some salt-tolerant species (*Eucalyptus camaldulensis*, *Azadirachta indica*, *Acacia nilotica*, *Feronia limonia* and *Excoecaria agallocha)* have increased in the study area. The study revealed that less productivity, less fertility, soil erosion and soil and water salinity were the major problems in the region.

Keywords: Agricultural crops, Coastal area of Bangladesh, Salinity intrusion, Tree species, Perception

INTRODUCTION

Bangladesh is a densely populated country in the world with a huge population with an annual growth rate of 1.37 [1]. The total area of Bangladesh is 147,570 km^2 in which the coastal region covers an area of about 47,201 km^2 extending along the Bay of Bengal. This region now covers 19 coastal districts constitute 20% of the area and 28% of the population of the country are in proximity to, the Bay of Bengal [2,3].

Coastal areas around the globe, especially in the low-lying developing countries are suffering from salinity intrusion [4]. Varying degrees of soil salinity is affecting the cultivated areas in the coastal zone of Bangladesh. About 8,142 km^2 (5.5% of the country) land is being salt affected and it is increasing at the rate of 146 km^2 per year mostly over the last four decades[5,6]. SRDI [7] reported that from 1973 to 2009 about 0.223 million ha (26.7%) new land is affected by various degrees of salinity. Mahmuduzzaman et al. [8] also reported that in the last 35 years, salinity had been increased around 26 percent in this country.

A substantial amount of reduction in vegetation in the salt-affected areas occurs due to the severe effect of salinity on the bio-environment [9]. Tree growth becomes non-conducive as a result of soil salinity[10]. Increased salinity hinders growth and survivability of trees of the homesteads which are the main source of fruit and timber production of this region. Normal growth and crop production rate are being restricted by the unfavorable environment and hydrological situation caused by salinity throughout the year [11]. The production of crops in a saline zone in the coastal regions differs considerably from a non-saline zone. In the recent past, normal production of crop becomes very risky due to further saline water intrusion. Crop production, crop yields, cropping intensity and the livelihood quality of people have reduced in a greater extent than other parts of the country [12]. It is reported that due to the sea level rise by 0.3 m in coastal regions of Bangladesh, a net reduction of 0.5 million MT of rice production would take place [13].

Shrimp cultivation plays an important role to promote soil salinity particularly in southwestern coastal areas [6]. There are saline soils in the coastal and offshore lands of Khulna, Barisal, Patuakhali, Noakhali and Chittagong district. This study focuses particularly on Paikgachha upazila of Khulna district in the context of salinity. Uddin et al.[14] have reported that high range of salinity intrusion has reduced about 75% of indigenous rice varieties in Paikgachha. At the same time, crop diversity index value as well as plant diversity index value has been reduced respectively from 2.77 to 0.69 and from 3.40 to 2.53[14]. On the contrary, dominancy of salt-tolerant species has increased in this region.

The study was carried out to explore the people's perception on impact of salinity on trees and agricultural crops in a coastal zone of Bangladesh.

MATERIALS AND METHODS

General information of the study area

The Paikgachha upazila in Khulna district of Bangladesh was selected purposively (Fig. 1), as it is one of the most salinity affected areas. Paikgachha upazila, with an area of 411.19 sq. km, is bounded by Tala and Dumuria upazilas on the north, Koyra upazila on the south, Batiaghata and Dacope upazilas on the east, Tala and Assasuni upazilas on the west. Paikgachha upazila lies between 22° 28' and 22° 43' North latitude and 89° 09' and 89° 23' East longitude in Khulna district of Bangladesh. The annual average temperature of this area is 26.3 °C (79.3 °F) and monthly means varying between 12.4 °C (54.3 °F) in January and 34.3 °C (93.7 °F) in May. The annual average rainfall of this area is 1,809.4 millimeters (71.24 in). Approximately 87% of the annual average rainfall occurs between May and October [15,12]. The main rivers of that area are Kobadak, Shibsa and Vadra, while Haria, Deluchi, Harrakhali, Narai, Gangkhali, Katakhai and Karulia are small rivers. The river's water intrusion affected both the trees and crops species in this area. According to BBS [12], the soil pH value of high and medium highland areas of Paikgachha upazila ranged from 5.0-6.8. The lower, medium and a higher level of soil salinity was 2dS/m, 8.04 dS/m and 16 dS/m respectively.

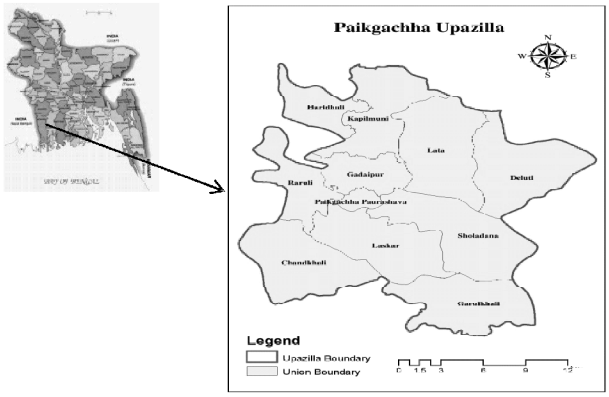

Figure 1: Map of the study area

Data collection and analysis

Field studies were carried out from July 2016 to November 2016. The study was conducted through Multistage Random Sampling techniques using a semi-structured questionnaire. Paikgachha upazila was selected as the primary sampling unit. Out of 11 unions of Paikgachha 6 were randomly picked up as the second sampling unit. From each selected union 2 villages were randomly selected as the third sampling unit. Finally, 120 respondents were selected as the ultimate sampling unit. The respondents were asked to provide information on their land use pattern, their perception on salinity level, the practice of tree species and agricultural crops in their different land use pattern and the major problems of their lands. The uncertainties were overcome by following some strategies i.e. about specific species appearance in several years the respondents who seem to provide confusing information were cross-checked by the key person of the surveyed family, neighbor and also from the key member of the society. People's information in the study area was supported by the reference of scientific journal sources. Four institutions named (1) Social Forestry Plantation Center, Paikgachha, Khulna (2) Department of Agriculture extension, Paikgachha, Khulna (3) Bangladesh Fisheries Research Institute, Brackishwater station, Paikgachha, Khulna (4) Soil Resource Development Institute (SRDI), Regional Office, Khulna also provided forest, agriculture, soil and water related data. The survey data were processed and analyzed with the Microsoft Excel version 2016 and statistical package SPSS version 23. ANOVA (tested one of the groups differs from the other groups) and LSD tests (tested which group differs) were carried out to understand the differences and relationship between variables.

RESULTS AND DISCUSSION

Land use pattern and salinity level of the study area

At present most of the lands in Paikgachha upazila are used for shrimp culture, although 40 years ago the major portion of the lands was used for agricultural purposes. According to respondents, the land was used 45% for shrimp pond, 37% for agricultural land, 9% for homestead area, 6% for urban area and 3% for fallow land (Fig. 2). Majority of the respondents had given their opinion that the salinity level in their locality has increased in the last 30 years. A significant proportion of respondents (66%) reported that salinity level at their locality is very high. But a considerable portion (28%) of the respondents reported that salinity level at their locality is medium, whereas very few respondents (6%) said that salinity level is low in their locality. The respondents from mostly salinity affected areas perceived that saline water needed for shrimp cultivation is drawn from adjacent rivers which started in-between 1983 to1987. This results in the extreme level of salinity intrusion in the study area. The respondents mentioned that high salinity shows negative relationship with the average salinity of land use pattern in case of species growth and survival rate whereas the sequencing of the opinions mentioned medium and low salinity show positive relationship. Table 1also shows that 3.5% and 26.7% of the salt affected area have increased during the last 9 and 36 years respectively [7]. The level of soil salinity during 2000 and 2009 in Paikgachha upazila have also presented in Table 2 [6,7].

Table 1
Extent of soil salinity during last four decades (1973-2009) in coastal areas

Salinity class															
Salt affected area (000'ha)			*S1 2.0-4.0 dS/m*			*S2 4.1-8.0 dS/m*			*S3 +S4 8.1-16.0 dS/m*			*S5 >16.0 dS/m*		
1973	2000	2009	1973	2000	2009	1973	2000	2009	1973	2000	2009	1973	2000	2009
833.45	1020.75	1056.19	287.37	289.76	328.39	426.43	307.20	274.21	79.75	336.58	351.68	39.90	87.14	101.91

S3 = 8.1-12.0 dS/m ; S4= 12.1-16.0 dS/m

Source: SRDI (2010)

Table 2
Soil salinity class in Paikgacha upazila during 2000 and 2009

Year	*Salinity Class and Area (ha)*				
	S_1 *2.0-4.0dS/m*	S_2 *4.1-8.0dS/m*	S_3 *8.1-12.0dS/m*	S_4 *12.1-16.0dS/m*	S_5 *>16.0dS/m*
2000	1,650	5,260	11,160	7,660	5,210
2009	2,230	3,030	6,930	8,920	8,810

Source: SRDI (2003), SRDI (2010)

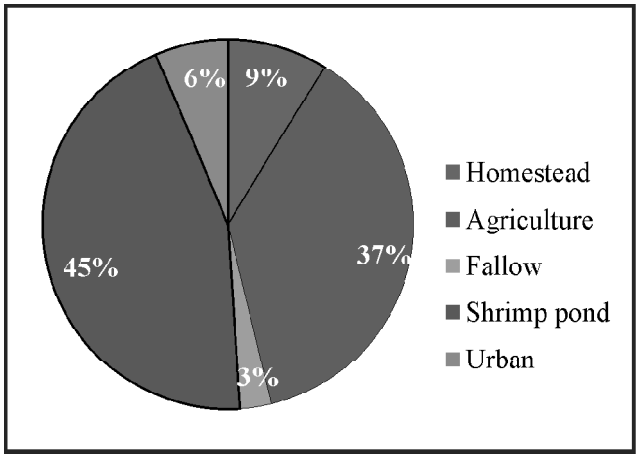

Figure 2: Land use pattern of the study area

Reduction of major tree species

According to most of the respondents (64%), the number and growth of tree species are being decreased day by day due to high salinity. In general, the respondents had recognized that salinity exerts negative effect on the growth of tree species.The major land uses of Paikgachha upazila were rural settlements with homestead vegetation called homestead forest that covers mainly in the high and medium highland areas. No natural forest was identified in the upazila. Respondents mentioned that on an average of 28%, 23% and 21% tree species were practiced in the years of 1976, 1996 and 2016 respectively presented in Fig. 3. So, the reduction of people's response to practicing tree species on an average was found 18% from 1976 to 1996, whereas it was 9% from 1996 to 2016. In total, during the last 40 years 25% of the people's opinion has reduced on practicing tree species.

From Table 3 it could be seen that the tree species in the study area have been reduced at varying rate, which is significantly different for different years ($F=3.32$; d.f.=2,159 respectively; $P<0.05$). Multiple comparisons with Least Significant Difference (LSD) test shows that within the study area the people's opinion on practicing tree species in 1976 has significant difference with 1996 ($P<0.05$) and highly significant difference with 2016 ($P<0.01$) (Table 4).

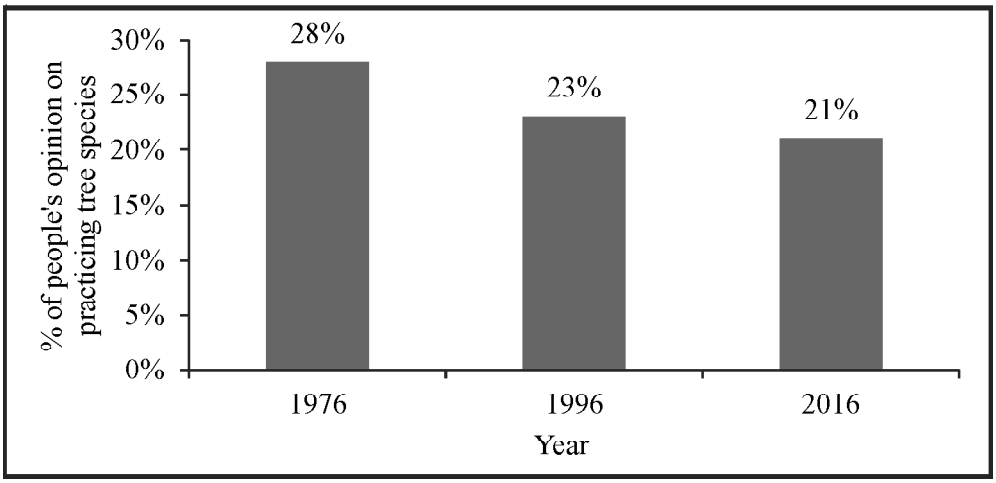

Figure 3: People's perception on forty years status of tree species

Table 3
Analysis of Variance (ANOVA) for status of tree species

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	1.67	2	0.83	3.32	0.03
Within Groups	39.89	159	0.25		
Total	41.56	161			

Table 4
Multiple Comparisons (LSD)for status of tree species

(I) Year	*(J) Year*	*Mean Difference (I-J)*	*Std. Error*	*Sig.*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
1976	1996	0.17*	0.08	0.03	0.01	0.33
	2016	0.23*	0.08	0.01	0.07	0.39
1996	1976	-0.17*	0.08	0.03	-0.33	-0.01
	2016	0.05	0.08	0.48	-0.10	0.21
2016	1976	-0.23*	0.08	0.01	-0.39	-0.07
	1996	-0.05	0.08	0.48	-0.21	0.10

* The mean difference is significant at the 0.05 level.

Table 5 represents the appearance of most observed tree species in the year of 1976, 1996 and 2016 respectively. Respondents opined that some tree species of 1996 and 2016 are disappearing at a higher rate due to high salinity. They mentioned that the most disappearing tree species was found *Terminalia bellirica*, *Terminalia chebula*, *Areca catechu*, *Borassus flabellifer*, *Diospyros peregrine*, *Phoenix sylvestris*, *Syzygium aqueum*, *Cocos nucifera*, *Terminalia catappa, Syzygium cumini* etc. On the other hand, forty years ago, the most observed tree species were *Mangifera indica*, *Artocarpus heterophyllus*, *Cocos nucifera*, *Phoenix sylvestris*,

Syzygium cumini, *Borassus flabellifer*, *Areca catechu* etc.

The reduction in the growth rate of tree species also contributes in the overall reduction of vegetation coverage. In a similar way, the vegetation coverage is reducing due to increasing soil salinity in different countries (China, Pakistan, Indonesia, Vietnam, Thailand, Australia, etc.) as discussed by FAO [10].

Table 5
People's opinion about the most observed tree species

Sr no.	*1976*	*1996*	*2016*
1	*Mangifera indica* (80%)	*Mangifera indica* (44%)	*Mangifera indica* (44%)
2	*Artocarpus heterophyllus* (76%)	*Artocarpus heterophyllus* (41%)	*Artocarpus heterophyllus* (41%)
3	*Cocos nucifera* (73%)	*Cocos nucifera* (56%)	*Cocos nucifera* (56%)
4	*Phoenix sylvestris* (72%)	*Phoenix syllvestris* (57%)	*Phoenix syllvestris* (57%)
5	*Syzygium cumini*(70%)	*Syzygium cumini*(35%)	*Syzygium cumini*(26%)
6	*Borassus flabellifer* (67%)	*Borassus flabellifer* (48%)	*Borassus flabellifer* (17%)
7	*Areca catechu* (66%)	*Areca catechu* (30%)	*Areca catechu* (14%)
8	*Syzygium aqueum* (50%)	*Syzygium aqueum* (28%)	*Syzygium aqueum* (16%)
9	*Tamarindus indica* (48%)	*Tamarindus indica* (42%)	*Tamarindus indica* (36%)
10	*Psidium guajava* (43%)	*Psidium guajava* (35%)	*Psidium guajava* (25%)
11	*Ziziphus mauritiana* (42%)	*Ziziphus mauritiana* (39%)	*Ziziphus mauritiana* (24%)
12	*Terminalia arjuna* (26%)	*Terminalia arjuna* (12%)	*Terminalia arjuna* (18%)
13	*Manilkara zapota* (30%)	*Manilkara zapota* (32%)	*Manilkara zapota* (17%)
14	*Excoecaria agallocha* (21%)	*Excoecaria agallocha* (37%)	*Excoecaria agallocha* (51%)
15	*Pithecellobium dulce* (21%)	*Pithecellobium dulce* (35%)	*Pithecellobium dulce* (44%)
16	*Avicennia officinalis* (20%)	*Avicennia officinalis* (35%)	*Avicennia officinalis* (49%)
17	*Terminalia bellirica* (19%)	*Terminalia bellirica*(5%)	*Terminalia bellirica*(1%)
18	*Albizia procera* (32%)	*Albizia procera* (19%)	*Albizia procera* (21%)
19	*Terminalia chebula* (18%)	*Terminalia chebula* (6%)	*Terminalia chebula* (1%)
20	*Sonneratia apetala* (17%)	*Sonneratia apetala* (31%)	*Sonneratia apetala* (50%)

Note: Parenthesis indicates the percentage of the respondents

Dutta and Iftekhar [9] reported that *Artocarpus heterophyllus*, *Mangifera indica*, *Ziziphus mauritiana*, *Tamarindus indica*, *Borassus flabellifer*, *Syzygium cumini*, *Psidium guajava*, *Spondias pinnata*, *Achras zapota*, *Bombax ceiba*, *Cassia siamea and Albizia procera* disappeared at higher rate in salt-affected areas of coastal Bangladesh.

Improvement of some species survival

The respondents reported that the number of species in the study area has decreased. But at the same time, the respondents (82%) also reported some species has increased in that area. These species have ranked in the following order: *Eucalyptus camaldulensis* > *Azadirachta indica* >*Acacia nilotica*>*Feronia limonia* > *Excoecaria agallocha* >*Sonneratia apetala* >*Albizia lebbeck* >*Acacia catechu* >*Avicennia officinalis* > *Sonneratia casualaris*>*Thespesia populnea*>*Citrus limon* >*Pithecellobium dulce*>*Swietenia macrophylla.*

Plants vary in response to soil salinity. Salt tolerant plants are better able to adjust internally to

the osmotic effects of high salt concentrations than salt-sensitive plants[7]. Even when vegetation coverage is reducing at such rapid rate, some species are growing well in saline condition [9].

Reduction of agricultural crops

Respondents reported that due to the degradation of soil properties for continuous saline water inundation, the production of agricultural crops has greatly been decreased in the study area. The agricultural area has been reduced faster than it was predicted a decade ago.

Respondents mentioned that in the years of 1976, 1996 and 2016 the practice of agricultural crops on an average was 65%, 35% and 27% respectively shown in Fig. 4. So, on average,the practice of agricultural crops was reduced by 46% from 1976 to 1996, whereas it was 23% from 1996 to 2016. In total, during the last 40 years 58% of practicing agricultural crops reduced in the study area.

Day by day, the practice of agriculture crops within the study area have been reduced due to the severe effect of salinity, that is considerably different for different years ($F=4.33$; d.f.= 2,75 respectively; $P<0.05$) (Table 6). Multiple comparisons with LSD test shows that within the study area the people's opinion on practicing agriculture crops in 1976 has highly significant difference from 1996 and 2016 ($P<0.01$). But people's opinion on practicing agricultural crops of 1996 has significant difference with 2016 ($P<0.05$) (Table 7).

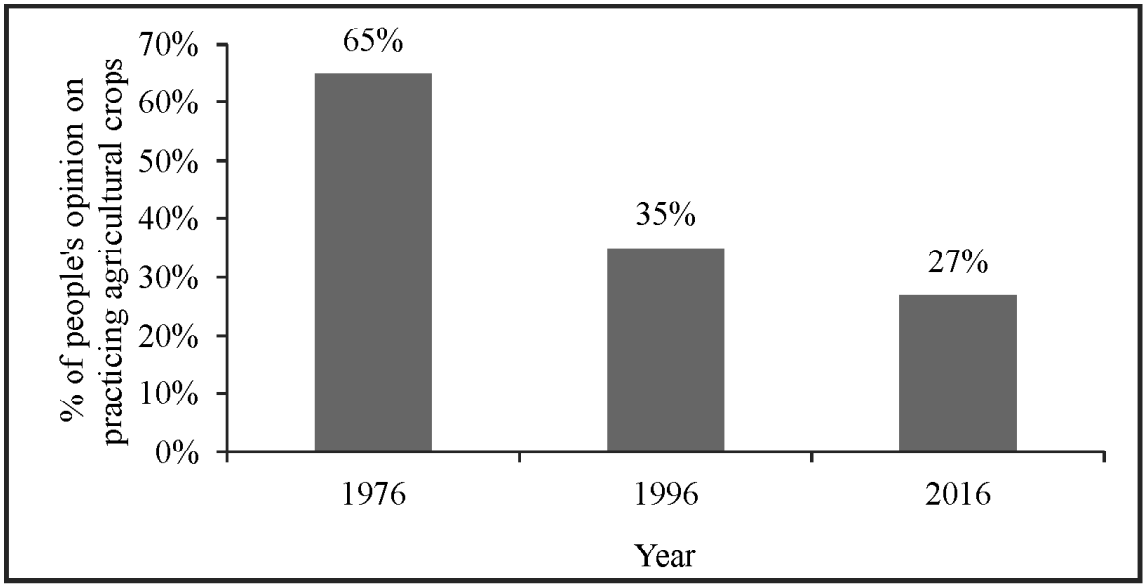

Figure 4: People's perception on forty years status of agricultural crops

Table 6
Analysis of Variance (ANOVA) for status of agricultural crops

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	2.65	2	1.32	4.33	0.014
Within Groups	82.81	75	0.30		
Total	85.47	77			

Table 7
Multiple Comparisons (LSD)for status of agricultural crops

(I) Year	(J) Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1976	1996	0.62*	0.08	0.00	0.46	0.79
	2016	0.84*	0.08	0.00	0.67	1.01
1996	1976	-0.62*	0.08	0.00	-0.79	-0.46
	2016	0.21*	0.08	0.02	0.04	0.38
2016	1976	-0.84*	0.08	0.00	-1.01	-0.67
	1996	-0.21*	0.08	0.02	-0.38	-0.04

* The mean difference is significant at the 0.05 level.

Table 8 represents the appearance of most observed agricultural crops in the year of 1976, 1996 and 2016 respectively. The respondents'opinion showed that these crops are disappearing due to the high salinity level. According to people's observation, the most disappearing agricultural crops were found *Citrullus vulgaris*, *Saccharum officinarum*, *Vigna mungo*, *Zea mays*, *Cicer arietinum*, *Curcuma domestica*, *Lathyrus sativus*, *Capsicum annuum*, *Cucumis sativus, Vigna radiata* etc.

Table 8
People's opinion on the most observed agricultural crops

Sr no.	1976	1996	2016
1	*Oryza sativa* (95%)	*Oryza sativa* (50%)	*Oryza sativa* (41%)
2	*Corchorus capsularis* (75%)	*Corchorus capsularis* (38%)	*Corchorus capsularis* (33%)
3	*Curcuma domestica*(74%)	*Curcuma domestica* (44%)	*Curcuma domestica*(43%)
4	*Zingiber officinale* (74%)	*Zingiber officinale* (33%)	*Zingiber officinale* (23%)
5	*Capsicum annuum* (73%)	*Capsicum annuum* (52%)	*Capsicum annuum* (40%)
6	*Allium cepa* (72%)	*Allium cepa* (50%)	*Allium cepa* (42%)
7	*Allium sativum* (70%)	*Allium sativum* (50%)	*Allium sativum* (42%)
8	*Brassica campestris* (67%)	*Brassica campestris*(44%)	*Brassica campestris*(38%)
9	*Citrullus vulgaris* (64%)	*Citrullus vulgaris* (16%)	*Citrullus vulgaris* (8%)
10	*Zea mays* (62%)	*Zea mays* (25%)	*Zea mays* (16%)
11	*Daucus carota* (61%)	*Daucus carota* (27%)	*Daucus carota* (24%)
12	*Vigna mungo* (60%)	*Vigna mungo* (24%)	*Vigna mungo* (14%)
13	*Lathyrus sativus* (60%)	*Lathyrus sativus* (26%)	*Lathyrus sativus* (17%)
14	*Saccharum officinarum* (59%)	*Saccharum officinarum* (25%)	*Saccharum officinarum* (12%)
15	*Lens culinaris* (58%)	*Lens culinaris* (35%)	*Lens culinaris* (25%)

Note: Parenthesis indicates the percentage of the respondents

Increase in salinity intrusion and increase in soil and water salinity will have serious negative impacts on agriculture [16]. It has also been described that in Bangladesh, rice production may fall by 10% and wheat by 30% by 2050 [17]. People's opinion showed the reduction of crop production was found about 37% during 15 years due to salinity in the salt-affected zones of coastal Bangladesh [9].

Impact of salinity on the land use of the study area

Clay to loamy soils was found to be most suitable for the construction of ponds for shrimp culture. When people started to draw saline water from adjacent rivers, the shrimp culture was established to give them more economic benefit. Considering shrimp cultivation, it requires less labor, less capital as well as less time to produce thus people are interested in it. The study showed 62% of respondents were not interested in shrimp culture, but due to the presence of saltwater in the outer area; they have nothing else to do. Only 21% of respondents were interested in shrimp culture and 17% of respondents gave their opinion for both shrimp culture and agricultural practice. With the recent outbreak of virus people are not much interested in this practice. Intensive farming makes the shrimps highly susceptible to diseases. Ponds were being constructed for shrimp culture where freshwater wetlands and rice growing areas still exist. Not only agricultural land but also their dwelling place was affected by saltwater. It was observed that

Table 9
Summary on problems of lands due to salinity intrusion in Paikgachha upazila

Problems/issues	*% of respondents*	*Possible impacts*	*Study areas*
Less productivity	80	• Less tree species and agricultural crops • Less livestock • Fewer fisheries productivity (except shrimp)	Lata, Soladana, Kapilmuni, Paurashava
Less fertility	75	• More chemical fertilizer (Urea, TSP, Potash, Earwax, lime etc.) • More insecticide	Lata, Soladana, Paurashava, Kapilmuni, Gadaipur, Garaikhali
Soil erosion	70	• Loss of organic matter and nutrients • Reduce in soil fertility • About 1.5 feet dirt in summer season	Lata, Soladana, Kapilmuni, Paurashava
Soil and water salinity	60	• High salinity in drought season (March-April) • Decrease in freshwater availability and shortage of irrigation water • Negative effect on crop production and homestead	Lata, Soladana, Paurashava, Kapilmuni, Gadaipur, Garaikhali
Waterlogging	50	• Inadequate drainage • Pollution hazards • Water borne disease	Lata, Soladana, Kapilmuni
Desertification	45	• High probability of desertification within few decades • Injured by cyclone, tidal surge, flood etc.	Lata, Soladana, Paurashava

some people have taken shrimp culture as a traditional source of income. Shrimp ponds have reduced the opportunities for other traditional dry season activities, such as grazing of cattle and homestead gardening. Long-term water logging reduces soil stability for plant production. Soil erosion was found to be a major problem in the study area. This condition may also hamper the suitability of living condition for their future generation. In the study area, such as Garuikhali, Gadaipur and more than half portion of Kapilmuni union were included under the freshwater zone. The people of these areas were economically and environmentally stable than other salinity affected regions. They improved their economic condition by the enhancement of agricultural crops, nursery, freshwater fish, domestic animals as well as generating other employment.

Majority of the people (80%) thought that the productivity of species including trees, crops, fishes and livestock have been reduced in their locality/ village. Less fertility, soil erosion, soil and water salinity, waterlogging and desertification were found to be as the major problems in the study area due to salinity that have been perceived by 75%, 70%, 60%, 50% and 45% of the respondents respectively. The summary on the problems of lands due to salinity intrusion in Paikgachha upazila, have presented in Table 9.

CONCLUSION

In the study area, both the tree species and agricultural crops are reducing at an alarming rate due to species depletion resulting from salinity intrusion. Salinity intrusion proved to be critical for the species richness and evenness visible in Paikgachha, while a few numbers of species identified as salt tolerant have increased. Most of the plants are sensitive to salinity because of its higher presence in both soil and surface water. Higher salinity acting as one of the major natural hazards has created pressure on the farmers by reducing their income source and food security. Salinity intrusion gives high yielding shrimp culture but it exerts negative impacts on tree growth, agricultural production and also to the environment. So, salt-tolerant species as identified by the respondents are recommended to be planted after proper trial to arrest further depletion of plant species.

RECOMMENDATIONS

Salinity intrusion affects the production of tree species and agricultural crops. So, necessary steps should be taken to reduce unguarded shrimp culture. Home stead and roadside plantation of tree species are essential in the study area. The loan should be given to the farmer to increase agricultural production. More research may be conducted to find out the survival of tree and crop species in high salinity area by salt tolerant experiment.

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