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PERCEPTION OF LOCAL PEOPLE ABOUT THE CAUSES OF SALINITY AND ITS IMPACTS ON CROP PRODUCTION IN THE CONTEXT OF THE SOUTHERN REGION OF BANGLADESH

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ABSTRACT

While Bangladesh's northern region frequently experiences flash floods, the country's southern coastal regions are susceptible to salinity intrusion. Approximately two-thirds of the region's arable land, as well as surface water and shallow aquifers, are affected by varying salinity levels. Polders were constructed to prevent saline intrusion; however, they have not performed as well as expected in recent years. The purpose of this study was to investigate how the local population perceived the sources of salinity and its impact on crop productivity. The research objectives were addressed through a mixed-methods investigation that included both qualitative and quantitative surveys of 200 homes in three selected polders. It was discovered that the type of rice produced was unrelated to household characteristics or saline level. However, it was discovered that the production of saline-tolerant rice cultivars was linked to both educational attainment and various forms of employment. Regional disparities in the adoption of saline-tolerant cultivars were also discovered by the study; for example, people in Dacope and Rupsha were found to be growing more saline-tolerant cultivars than people in Batiaghata. Given that coastal regions have distinct geomorphological features, more research on regional variations on the relationship between salinity and crop yield should yield more information.

Keywords: Bangladesh, Crop production, Khulna, Perception, Rice, Salinity

Different regions of Bangladesh are subject to distinct climatic and environmental challenges. The northern areas are predominantly affected by flash floods and droughts, whereas the southern regions, located adjacent to the Bay of Bengal, are particularly susceptible to salinity intrusion, tidal surges, and waterlogging. In numerous coastal areas, surface water in rivers often exhibits elevated salinity levels, and shallow aquifers are substantially affected by this salinity (Government of Bangladesh, 2022, 2024). The prolonged retention of saline water results in seepage into ponds, rice (*Oryza sativa* L.) fields, and other water bodies, disrupting the natural processes of nitrogen fixation and mineralization, which ultimately leads to a reduction in soil fertility (Baten *et al.*, 2015, Fahim and Arefin, 2024). Recent studies indicate that saline conditions in coastal areas affect approximately 30% of Bangladesh's total cultivable land (Soil Resource Development Institute (SRDI), 2023). Moreover, the coastal belt of Bangladesh is recognized as one of the most dynamic deltas on a global scale, with millions of tons of silt being transported through the Ganges and Brahmaputra Rivers daily. This continuous sediment flow is instrumental in the ongoing formation and alteration of the landscape (Edwin *et al.*, 2020; Dasgupta *et al.*, 2015). This phenomenon is particularly pronounced in the southwestern coastal region, where tidal fluctuations and river sedimentation are critical factors in shaping the environment.

It was reported that since 1973, salinity levels had been increasing, spreading from the coastline to the mainland further north, causing genuine concern among the general public, as well as policymakers

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and professionals (SRDI, 2010). Karim *et al*. (1990) found that more than half of the cultivable lands in coastal Bangladesh were affected by salinity during the early 1990s. SRDI (2010) also observed that 63% of the total cultivable lands were affected by varying degrees of salinity, negatively impacting 1.056 million hectares of arable land out of 2.86 million hectares of coastal and offshore lands.

Recent studies have highlighted various environmental and socioeconomic impacts of salinity. The intrusion of salinity, driven by both natural and anthropogenic factors, is escalating at an alarming rate, affecting approximately 53% of coastal land. This phenomenon has led to declining soil productivity, reduced crop yields, and significant environmental degradation and ecological impacts in the coastal zones of Bangladesh (Islam *et al*., 2021; Rahman *et al*., 2020). Consequently, many residents in these areas have transitioned their livelihoods from traditional crop farming to alternative occupations such as shrimp farming, prawn collection, and shop-keeping. Furthermore, the increasing salinity has led to a scarcity of drinking water resources (Khan *et al*., 2022).

Therefore, the south-central coastal areas, including districts such as Satkhira, Khulna, and Patuakhali, experience significant difficulties in crop production, with more pronounced effects during the dry seasons (Mainuddin *et al*., 2020). One of the primary obstacles faced in these regions is the accumulation of salt in the soil, especially later in the dry season, which has multiple negative effects on crops. These effects include reduced water uptake by plant roots, leading to osmotic stress and ion toxicity (Mainuddin *et al*., 2020). Consequently, crop yields are substantially reduced (Bhuyan *et al*., 2023).

According to a study by the Bangladesh Soil Resource Development Institute (SRDI), the area affected by salinity in Bangladesh has increased by 26% over the past 40 years. In 2009, about 1.056 million hectares of arable land in 19 coastal districts were affected, compared to 0.833 million hectares in 1973. Currently, Bangladesh has 2.86 million hectares of coastal and offshore arable land (The Business Standard, 2022).

Under such circumstances, initiatives have been taken to develop saline-tolerant rice in Bangladesh. There are several varieties of saline-tolerant rice in Bangladesh. Official statistics have revealed that rice production in the climate-vulnerable district of Satkhira has increased due to the introduction of salt-tolerant varieties. For example, in 2018, BRRI-67 was cultivated on 119 hectares, which expanded to 5,216 hectares by 2022. Similarly, the breeding area for Binadhan-10 has expanded from 778 hectares in 2017 to over 2,000 hectares currently (The Business Standard, 2022).

The primary objective of this study was to investigate people's perceptions of the causes of salinity and its impact on crop production in the coastal region of Bangladesh. The specific objectives were as follows: (a) Examine local perceptions: To investigate how the local population perceives the sources of salinity and its effects on agricultural productivity in the southern coastal regions of Bangladesh. (b) Assess crop productivity: To analyze the impact of salinity on crop production, particularly focusing on the cultivation of saline-tolerant rice varieties among different households. (c) Evaluate demographic influences: To explore the relationship between household characteristics, educational attainment, and employment diversity with the adoption of saline-tolerant rice cultivars in various regions.

METHODOLOGY

Research design

A concurrent mixed-methodological approach, combining both quantitative and qualitative techniques, has been employed in this study. Within the domain of the quantitative part, a generalized linear model (GLM) was followed to analyze the survey data (Fischer & Kauffmann, 2022).

Moreover, the study explored the people's perception about the causes of salinity and its impacts on crop production. Understanding perceptions can help identify potential conflicts and synergies among different user groups, thereby aiding in the development of frameworks that promote inclusive and participatory decision-making. For this, the insight of the Perceptual Process Model was considered, which outlines how people interpret sensory information to make sense of the environment. This model typically includes stages such as attention, perception, and interpretation. Moreover, insights of Sharma and Sahni (2023) influenced the authors to explore how local knowledge and perceptions influence water management decisions in coastal Bangladesh (Sharma & Sahni, 2023) as Tesfahunegn *et al*. (2016) observed that farmers' perception plays a key role in appropriate adaptation and mitigation strategies for land use and agricultural practice such

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as crop rotation.

Study area

The study was conducted in three sub-districts—Rupsha (Jabusa Beel, Location 1), Batiaghata (Location 2), and Dacope (Location 3)—of Khulna District in Bangladesh. There are three polders: P-30, P-31, and Jabusa Beel. A polder is a low-lying tract of land enclosed by a built construction that forms an artificial hydrological unit. It represents the geographic location of the study area (Fig.1).

Sampling strategy and size

A mixed sampling technique was used to determine the appropriate number of households for qualitative and quantitative data collection (Dang *et al.*, 2014). The sample size was determined using the following standard formula to detect change over time (Magnani, 1997):

$$n = deff\left[\frac{(Z_\alpha+Z_\beta)^2\ X\ \left(P_1(1-P_1)+P_2(1-P_2)\right)}{(P_2-P_1)^2}\right]$$

where

n required minimum sample size per survey round

deff design effect (1.2, the minimum used expected design effect for cluster surveys)

Zα 1.645 (95% confidence level, one-tailed test), this Z-score corresponds to the degree of confidence with which it is desired to be able to conclude that an observed change of size (P2 – P1) would not have occurred by chance

Zβ 0.845 (80% power, one-tailed test), this Z-score corresponds to the degree of confidence with which it is desired to be certain of detecting a change of size (P2 – P1)

P1 expected prevalence for the first survey or for the control area

P2 expected prevalence for follow-up survey;

(P2 – P1) the size of the magnitude of change it is desired to measure (minimum detectable difference)

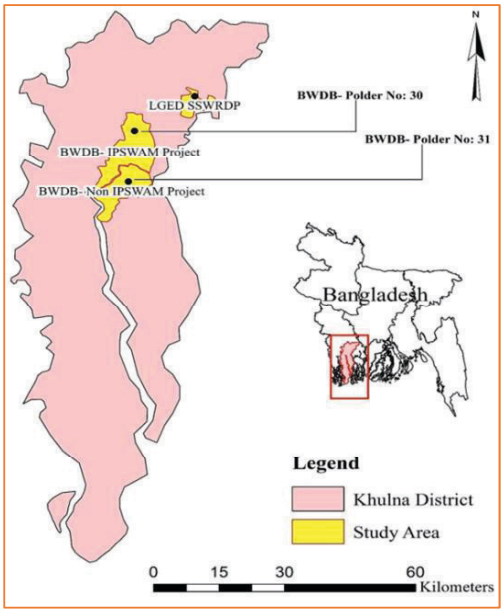


Fig. 1. Study areas

The study assumed that approximately 50% of people suffer from crop productivity loss due to salinity. Considering management and environmental conditions, this study also assumed that the change of improvement is slow and there is a minimum of 10% change or detectable differences in a five-year intervention attributable to polder management interventions. Stata command was used to calculate the sample size. The used parameter values were: P1 = 0.5 (proportion at the starting time), P2 = 0.4 (proportion over a certain period, which could be due to the upgradation of interventions or technologies), power = 80%, and alpha = 0.05 (two-sided).

Since this is one sample, no control communities were investigated; therefore, one sample command [sampsi 0.5 0.4, p (0.8) onesam] was used. It provided a sample size of 194 households. The calculated sample size was rounded to the nearest hundredth, and 200 households were finally surveyed. The sample size was further subdivided across three sub-districts. When dividing the sample size across sub-districts, the design effect was not considered, as all three sub-districts are interconnected and have similar geographical conditions.

The selection of sampling techniques for this study was thoughtfully guided by the insightful recommendations of Dang *et al.* (2014), ensuring a robust and methodical approach. In the first stage, the Khulna district was selected purposively based on its proximity to the Bay of Bengal and the available literature on the vulnerability of Bangladesh's coastal belt. In the second stage, three polders were selected from Khulna, one each from the Batiaghata, Dacope, and Rupsha sub-districts. Three different types of polders were chosen to ensure variety in governance and management structure.

The Local Government Engineering Department (LGED) operates polders, which are unique in their mix of rural and urban settings. The Jabusa Beel

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Table 1. Demographic information of polder and salinity in the study area

Polder and its management	Village	Union	Upazilla	Area of upazilla (ha)	Total saline area (ha) (Percentage of total area)	>12.0 dS/m (Percentage of total area)
SP12027: Local Government Engineering Department : Small-Scale Water Resources Development (LGED SSWRD)	Jabusa	Naihati	Rupsha	12,025	6770 (56%)	680 (6%)
Polder 30: Bangladesh Water Development Board: Integrated Participatory Sustainable	Fultala Daotala	Batiaghata Gangarampur	Batiaghata	23,622	16380 (69%)	3750 (16%)
Polder 31: Water Management (BWDB IPSWAM) BWDB non-IPSWAM	Baroikhali Kaminibasi	Pankhali Tildanag	Dacope	28,557	22790 (80%)	17070 (60%)

Source: SRDI (2010)

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sub-project (sub-project no. SP12027), located in the Rupsha subdistrict, was selected. It is located in the northern part of the southwestern region of Bangladesh, characterized by low salinity (Table 1). Another polder (no. 30) was chosen from the Bangladesh Water Development Board (BWDB) Integrated Participatory Sustainable Water Management (IPSWAM) project, which is located in the Batiaghata subdistrict towards the south of the Rupsha subdistrict. The polder is affected by medium salinity (Table 1). The third one was polder no. 31 and was selected from BWDB-managed general polders (non-IPSWAM polder). This polder was from Dacope subdistrict, which is adjacent to the Sundarban and the Bay of Bengal representing medium to high salinity (Table 1). The sample design with this mix of geographical variations, different governance regimes, and salinity are shown in Table 1.

Data collection and analysis

Household level data were collected from five Union Parishads-the lowest administrative tiers consisting of several villages in Bangladesh. One Union Parishad was taken from Rupsha sub-districts and two Union Parishads were chosen from Batiaghata sub-district and the rest two Union Parishads were selected form Dacope sub-district representing polder no. 30 and 31, respectively. After that, five villages, one from each union, were selected. A total of 40 households from each village resulting in a total of 200 households were randomly selected for conducting the survey. As random selection of respondents for qualitative research may not be as productive as respondents from specialized field (Marshall, 1996), this study has considered only the vulnerable households. Sample design represents the study area and ensures different socio-political and geographical variations. The questionnaire prepared for the research used nominal ranking substantially for quantifying the responses of the households. Quantitative tools (statistical tests) were applied for analyzing the inputs from the households.

A GLM was applied for both categorical and continuous responses. GLM extend ordinary regression models to encompass non-normal response distributions and modeling functions of the mean. Three components specify a GLM: (i) a random component identifies the response variable Y and its probability distribution, (ii) a systematic component specifies different explanatory variables used in a linear predictor function and (iii) a link function specifies the function of E(Y) that the model equates to the systematic component.

RESULTS AND DISCUSSION

Causes of salinity

People from different upazillas shared diverse experiences about the causes of increased salinity. Residents from Batiaghata recognized excessive groundwater extraction and storm surges as the significant reasons for salinity in the region. People from Rupsha ranked unauthorized cutting of the embankment and mismanagement of sluicegates as its major causes; in contrast, reduced upstream flow and shrimp cultivation were among the causes of salinity in Dacope, as perceived by the residents. Overall, community responses indicated approval

of the presence of salinity across the study area. The causes of increased salinity in the region are shown in Fig. 2 where it is evident that reduction of upstream flow, shrimp cultivation and flood or storm surge triggered salinity in the region.

The previous studies support the findings. Salinity in Bangladesh is driven by natural factors, such as saline water intrusion from the Bay of Bengal during the dry season (Mitra *et al*., 2020), and rising sea levels due to climate change (World Bank, 2018). Human activities, including shrimp farming and groundwater irrigation, further exacerbate soil salinization (Hossain *et al*., 2021; Rahman *et al*., 2019).

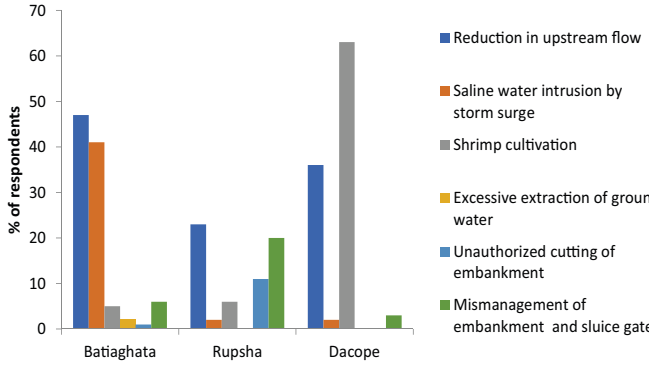


Fig. 2. Causes of increased salinity in Khulna (as reported by the respondents)

Salinity and crop cultivation

Although water from the deep tube well was free from salinity, the shallow tube well (STW) experienced salinity. Amon crop cultivation did not have any issues with salinity; however, in the cultivation of aus and boro crops, 53% and 41% of the households, respectively, reported the existence of salinity in STW water. Salinity in STW was not severe in Rupsha for both Aus and Boro crops, but it was substantial in Batiaghata. Although salinity in surface water inside the polder was the lowest in Batiaghata, at least a quarter of the households experienced salinity in surface water during either the aus or boro season (as shown in Table 2).

The survey also showed that less than one-fifth of the respondent households cultivated saline-tolerant varieties of crops. Considering the cultivation of saline-tolerant varieties as an outcome variable for adaptation techniques or coping strategies against salinity, this research conducted bivariate

Table 2. Salinity, effects of salinity and other factors in the study area

Salinity issues and actions	n/N	Percent (%)	Batiaghata (N = 80) %	Dacope (N=80) %	Rupsha (N=40) %
Salinity in shallow tube-well during aus crop	105/200	53	85	45	2
Salinity in shallow tube-well during boro crop	82/200	41	80	22	0
Salinity in shallow tube-well during aus or boro crop	107/200	54	85	47	2
Salinity in surface water inside the polder* during aus crop	53/200	26	10	36	40
Salinity in surface water inside the polder during boro crop	51/200	25	9	36	37
Salinity in surface water inside the polder during aus/boro crop	55/200	28	12	36	40
Salinity caused no effect/impact on livelihood	26/200	13	23	4	13
Salinity caused crop productivity loss	108/200	54	48	61	53
Salinity caused fish production loss	37/200	19	12	12	42
Adaptation by cultivated saline-tolerant variety of rice	35/200	17	9	24	22
Salinity reduction measures undertaken by agency/organization/department	31/200	15	33	3	8

*: Canal, pond and field inside the dam

Since half of the respondents reported crop production losses due to salinity, this study used this as an outcome variable for analysis to identify salinity and associated factors affecting crop production. Independent covariates chosen for this analysis were household characteristics (i.e., education of respondents, household size, occupation, land ownership, household's reported income, and respondents' evaluation of whether the survey households belonged to the poor or ultra-poor category). They reported the presence of salinity in various water sources (shallow tube water and surface water within the polder) for different rice varieties (i.e., Aus, Amon, and Boro). Bivariate regression analysis revealed that none of the controlling factors, including household characteristics and the presence of salinity, were significantly associated with crop production loss (Table 3). The research did not proceed with multivariate analysis because the bivariate analysis revealed no significant association among the factors.

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analysis. Accordingly, it showed that an increased level of education was positively associated with the cultivation of saline-tolerant varieties of rice (coeff: 0.267; p=0.017) and was statistically significant. Analysis also showed that heads of the households with more than one occupation or multiple earning sources were more involved with saline tolerant variety compared to heads of households with single occupation. Households from ultra-poor and poor section of the society, as classified in this research, rarely practiced cultivation of saline tolerant variety of crops (coeff: -1.050; p=0.010). Other variables such as household size, land ownership, principal occupation farmer or cultivator, monthly income were not found associated with the adaptation techniques addressing salinity.

Saline-tolerant crop cultivation was also associated with the region. Households in Dacope and Rupsha cultivated a saline-tolerant variety more often compared to households in Batiaghata. Beside, households that experienced salinity inside the polder during farming of Aus or Boro used saline tolerant variety more (coeff: 2.420; p=0.000) compared to the household who did not recognize existence of salinity inside the polder (Table 3).

The study also compared households' perceptions of salinity-induced crop production losses and the cultivation of saline-tolerant varieties in Dacope and Rupsha with those in Batiaghata. Bivariate analysis revealed that the cultivation of saline-tolerant rice varieties is significant in Dacope (coeff. 1.178, p = 0.013) and Rupsha (coeff. 1.108, p = 0.043). It also revealed regional variations in crop production losses due to salinity and the cultivation of saline-tolerant varieties (Table 3).

This research further compared crop production per hectare for those reported to have crop loss due to salinity (Table 4). Accordingly, it was found that

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Table 3. Salinity and associated factors of productivity loss in the study area

Characteristics	Outcome: Salinity-induced crop production loss		Outcome: Cultivated saline-tolerant variety			
	Bi-variate		Bi-variate		Multivariate	
	Coefficient	*p-value*	Coefficient	*p-value*	Coefficient	*p-value*
Education – continuous	0.043	*0.572*	0.267	*0.017*	0.235	*0.098*
Household size – continuous	–0.119	*0.229*	–0.060	*0.645*	-	-
Land ownership: 5-categories continuous (landless and onward)	0.014	*0.898*	0.251	*0.063*	-	-
Occupation (>1)	0.470	*0.132*	1.701	*0.007*	1.568	*0.031*
Main occupation – farmer/cultivator	0.244	*0.416*	0.853	*0.059*	-	-
Income – continuous	0.00002	*0.199*	0.00001	*0.437*	-	-
Respondents report – poor or ultra-poor (4th and 5th quintile)	0.411	*0.150*	–1.050	*0.010*	–0.139	*0.801*
Location (Ref: Batiaghata)						
Dacope	0.558	*0.082*	1.178	*0.013*	–1.205	*0.132*
Rupsha	0.200	*0.606*	1.108	*0.043*	–0.936	*0.261*
Salinity in shallow tube-well water during aus crop	–0.056	*0.842*	–0.191	*0.609*	-	-
Salinity in shallow tube-well water during boro crop	–0.524	*0.071*	–0.829	*0.047*	-	-
Salinity in shallow tube-well water during aus or boro crop	–0.063	*0.824*	–0.101	*0.787*	-	-
Salinity in surface water inside polder during aus crop	–0.373	*0.246*	2.325	*0.000*	-	-
Salinity in surface water inside polder during boro crop	–0.374	*0.250*	2.592	*0.000*	-	-
Salinity in Surface water inside polder during aus or boro crop	–0.063	*0.824*	2.420	*0.000*	1.948	*0.000*
Cultivated saline-tolerant variety of rice	0.441	*0.249*	-	-	-	-
Salinity caused crop productivity loss	-	-	0.441	*0.249*	-	-
Salinity reduction measures undertaken by agency/organization/department	–0.420	*0.285*	–2.022	*0.051*	-	-

farmers who reported crop loss due to salinity had a mean crop production of 2.49 metric tons/ha (2,490 kg/ha). This production was higher compared to the mean production of 1.741 MT/ha (1741 kg/ha) by the households not reporting crop loss due to salinity.

Present conditions of soil salinity and its impact on crop production

Soil salinity is a significant challenge for agriculture and livelihoods in coastal areas of Bangladesh. The following table 5 shows that after one decade of our study, the impact of salinity in the study areas has not decreased accordingly. This highlights the persistent challenges faced by farmers in these regions. Ongoing salinity issues continue to affect crop production, and the need for effective adaptation strategies remains critical. The data suggests a lack of significant changes in salinity levels, emphasizing the importance of further research and intervention efforts to address agricultural resilience in the context of salinity-affected areas.

In Dacop sub-district, approximately 30% of land is affected by salinity levels up to 12 dS/m (Hossain *et al*., 2023a). Traditional rice varieties, which thrive below 3 dS/m, yield only 2.5 tons per hectare, compared to the national average of 3.2 tons (Rahman *et al*., 2023b). This has led to a 25% income decline for farmers, forcing them to grow lower-yielding salt-tolerant crops. Average annual rainfall has dropped from 1,600 mm to 1,200 mm over the last two decades, worsening salinity issues. In Rupsha sub-district, around 35% of farmland is affected by salinity levels reaching 14 dS/m, resulting in an average yield of 2.3 tons per hectare and a 30% income decrease for farmers (Rahman *et al.,* 2023c). In Batiaghata, 28% of agricultural land suffers from salinity levels up to 11 dS/m (Hossain *et al*., 2023b), with traditional rice producing about 2.7 tons per hectare. Farmers have reported a 20% income decline, and rainfall has decreased from 1,700 mm to 1,400 mm in the past 20 years, aggravating the salinity problem and limiting freshwater for irrigation (Rahman *et al*., 2023a)

Impact of salinity on community livelihoods and adaptation interventions

It is noteworthy that 13% of surveyed households report that salinity has not significantly impacted their lives. On the other hand, more than half of the respondents have observed a decline in crop production attributed to salinity. Furthermore, approximately 20% of participants indicated that

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Table 4. Crop productivity of the respondents reported to have crop loss due to salinity in the study area

Covariates	N	Value
Crop yield	163 out of 200 households cultivated crops*	2.145 MT/ha (2,145 kg/ha)
Salinity caused crop productivity loss	108/200	
Crop yield among households that reported to have caused crop productivity loss due to salinity (mean)	108/200	2.49 MT/ha (2,490 kg/ha)
Crop yield among households that did not report crop productivity loss due to salinity (mean)	92/200	1.741 MT/ha (1,741 kg/ha)

*Households that did not cultivate crops inserted the value of 0

Table 5. Soil salinity and its impact on crop production

Sub-district	Soil salinity level	Traditional Thrive-level	Affecting agri-land	Average-yield	National average yield	Farmers' income decline	Rainfall decreased in the last 20 years
Dacop	12dS/m	Below 3dS/m	30%	2.5 tons/ha	3.2 tons/ha	25%	1200 mm from 1600 mm
Rupsha	14dS/m	Below 3dS/m	35%	2.3 tons/ha	3.2 tons/ha	30%	1400 mm from 1800 mm
Batiaghata	11dS/m	Below 3dS/m	28%	2.7 tons/ha	3.2 tons/ha	20%	1400 mm from 1700 mm

Source: Authors' compilation from literature in 2023.

they have also experienced repercussions in fish production. Gaining a comprehensive understanding of these effects is essential for collaboratively pursuing effective solutions.

Residents in Dacope are facing a pressing crisis due to a significant shortage of fresh water, which is essential for both drinking and agricultural purposes. This lack of accessible potable water poses significant challenges, particularly for local farmers who rely on freshwater supplies for irrigation. Agriculture is not just a source of food; it plays a crucial role in the community's economic stability and sustenance. The ongoing water crisis hampers their ability to cultivate a variety of crops, leading to decreased agricultural output and threatening food security for families. Interestingly, while the community struggles with fresh water scarcity, there has been a noteworthy increase in the production of *bagda*, or salt water shrimp. This species of shrimp has become a lucrative alternative, as it thrives in saline waters. The shrimp farming industry can offer economic opportunities and livelihoods for some residents. However, reliance on shrimp production also raises questions about long-term sustainability, potential environmental impacts, and the overall balance of the local ecosystem. The broader effects of rising salinity levels are evident throughout the region. Across all three areas of Dacope, communities are reporting decreased production of traditional crops, which are essential for local nutrition and livelihood. This decline poses a risk not only to individual farmers but also to community food systems as a whole. Additionally, the health and growth rates of trees are also negatively impacted, with a decrease observed in the strength and vitality of local forests. Trees can provide numerous benefits, including habitat for biodiversity, protection against erosion, and resources such as timber and fruits. Understanding community perceptions regarding adaptation to salinity is crucial for addressing these challenges. Figures 3 and 4 provide a visual representation of how residents view the impact of salinity on their livelihoods and the actions they are willing to take. The data indicate a growing awareness of the issues at hand, with around one-third of respondents having implemented adaptation strategies in response to the salinity crisis. These strategies may involve diversifying crops to more salt-tolerant varieties, modifying irrigation methods, investing in water conservation techniques, or exploring alternative livelihood options, such as aquaculture. The response to salinity illustrates the resilience and resourcefulness of the Dacope community. However, it also highlights the urgent need for support systems, such as access to education on sustainable farming practices, investment in infrastructure for freshwater supply, and initiatives focused on ecosystem restoration. By fostering collaboration between local

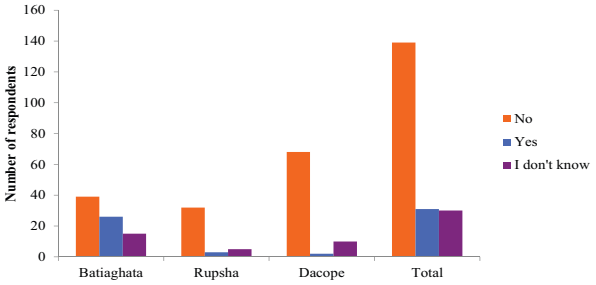


Fig. 3. Community perceptions on adaptation to salinity

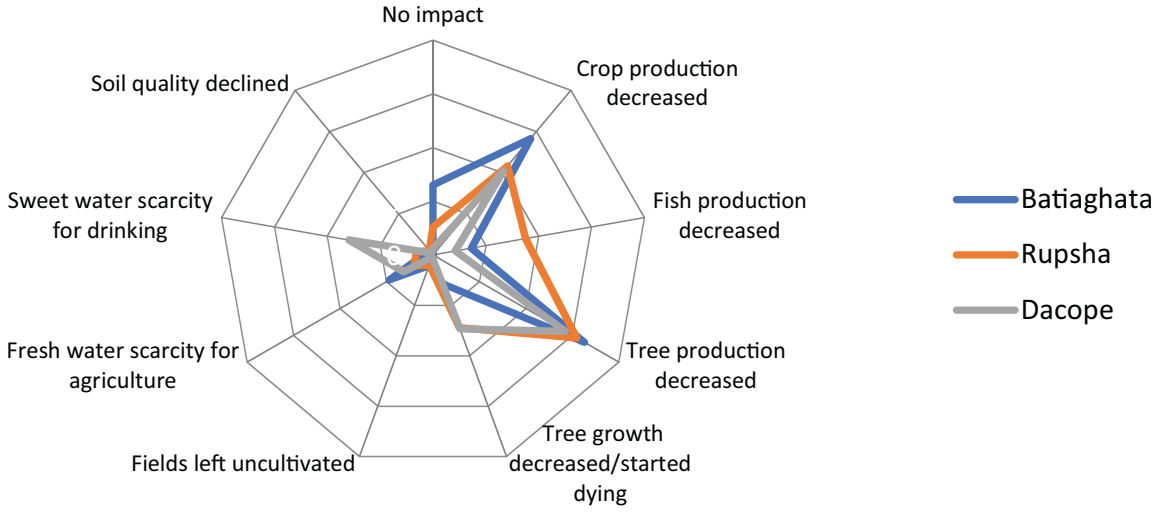


Fig. 4. Impact of salinity on community livelihood

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farmers, government entities, and environmental organizations, the community has the potential to develop more comprehensive strategies to combat the adverse effects of salinity while working toward ensuring food security and improving living conditions. Ultimately, the situation in Dacope calls attention to the interconnectedness of environmental issues, community livelihoods, and economic opportunities. Addressing the challenges of water scarcity and salinity will require not only local action but also broader policy support and environmental stewardship to create a more sustainable future for the residents.

Argument and findings

Unmanaged saline intrusion, combined with the influence of powerful farmers, in controlling the level of saline water in beel areas for shrimp farming, leads to a decrease in the yield of rice and other crops. The embankment for flood control has provided double benefits to the community: it has restricted the intrusion of saline water from the river Rupsha and Narayankhali Khal and, hence, secured rice cultivation, and besides, the improvement in the drainage system has helped in the removal of waterlogging and, thereby, increased agricultural yield. The prevention of saline water intrusion also improved social and environmental conditions.

The three locations (Jabusa beel of Rupsa, Location 1, Botiaghata of Khulna, Location-2 Dacope of Khulna, Location 3) showed conformity in terms of income, education and other socioeconomic indicators. This study also aligns with the findings of an earlier study conducted by the Asia Foundation (2012); for instance, Location-2 (Batiaghata) is closer to the Bay of Bengal than Rupsha (location-1) and as such, it is likely to have higher salinity, which may result in a higher rate of adaptation practices. Nonetheless, the residents of Rupsha were more active in action than those of Batiaghata. This phenomenon probably is an effect of at least two causal factors: management and governance issues, as well as the development interventions and people's orientation. The former explains the longstanding conflicts among the polder management committee, i.e. the Water Management Cooperative Association (WMCA). The presence of conflict has reduced effective control of the WMCA to protect the effectiveness of polders to resist the intrusion of saline water. It was found that a small number of residents in Rupsha contribute to worsening salinity conditions by deliberately cutting embankments to bring saline water inside the polder for their own benefit. This practice exacerbates the salinity issue, particularly during the dry season. In contrast, Batiaghata experiences fewer problems with illegal embankment breaches, largely due to the effective governance of the Water Management Association (WMA). Additionally, development programs facilitated by various local and international organizations are more abundant in Batiaghata. As a result, the infrastructure and polders in Batiaghata are better managed when compared to those in Rupsha, leading to a community that feels capable of handling disaster adaptation as a routine matter; thus, the residents believe that no further actions are necessary.

Due to prolonged monsoon, crop cultivation is affected, which has a long-term impact. However, the residents do not recognize the issue seriously. Residents of Dacope face severe problems of salinity for at least six months. For that period people have to resort to alternative source for drinking water. They rely on fresh water ponds, pond-sand filters and a few canals that contain less salt in water. However, the overall level of adaptive behavior to address salinity in terms of collection of drinking water from saline free sources, like cultivation of saline tolerant rice variety is low in the selected locations. The main reason behind may be their low level of awareness about the impacts. Government and non-government extension agencies are not sufficiently communicating the information to the communities. Hence, community people are also not very aware. An earlier study by the Asia Foundation (2012) also found a similar response, i.e., the level of knowledge among respondents about various aspects of the government or other agencies' implemented programs in their areas was found to be low. The coastal communities are not scared of cyclones and tidal surges because of the availability of cyclone shelters and polder embankments, and hence, do not consider that these events may have serious long-term consequences.

Preparatory activities for cyclone management in coastal areas have expanded significantly, with thousands of volunteers actively engaged alongside residents, who have taken steps to enhance their disaster preparedness. A system of auto-adjustment to such disasters has already been established in Bangladesh's coastal regions, allowing for timely responses when needed. Yet, a small segment of the population often fails to respond promptly, even while aware of the severe consequences, primarily due to homesickness and concerns for safety.

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Similar findings have been reported in previous studies (Rahman & Hossain, 2020; Islam *et al*., 2019). Residents in the study area have identified a decrease in upstream water flow as a key factor contributing to rising salinity levels, with additional causes varying by locality. In exploring the reasons for increased salinity, Hasan *et al*. (2021) categorized them into three broad categories: natural, socioeconomic, and political factors. It is important to note that there are subtle differences between scientific evidence and residents' perceptions regarding these causes (Hasan *et al*., 2021). Furthermore, poor management of Water Management Cooperative Associations (WMCA), exacerbated by local conflicts, has been shown to indirectly heighten salinity risks in the region (Hasan *et al*., 2021). Residents of Batiaghata have witnessed seawater intrusion during two significant cyclones, Sidr in 2007 and Aila in 2009, and have expressed that under typical conditions, salinity levels remain within acceptable limits.

Soil salinity poses a significant challenge for agriculture and livelihoods in the coastal areas of Bangladesh. A decade into the study, salinity levels remain high, continuing to impact crop production and farmers' income. In Dacop, about 30% of land has salinity levels reaching 12 dS/m, leading to a 25% income decline and lower yields compared to the national average. Similarly, Rupsha and Batiaghata face salinity levels of 14 dS/m and 11 dS/m, respectively, with farmers experiencing income drops of 30% and 20%. Table 5 summarizes the present impact of salinity on crop production; across all regions, traditional crops are declining due to increased salinity and reduced rainfall. Despite 13% of households reporting no significant effects from salinity, over half have observed declines in crop production, with some also noting reduced fish yields. Dacope is experiencing a freshwater crisis, jeopardizing agricultural activities essential for community livelihoods. Interestingly, shrimp farming, particularly *bagda*[1], has emerged as a lucrative alternative; however, this also raises its own sustainability concerns. Communities are increasingly aware of the challenges posed by rising salinity, with approximately one-third of those surveyed adopting adaptation strategies, such as crop diversification, to mitigate the crisis. Understanding these perceptions is vital for developing effective solutions.

However, significant findings in this study on the local people's perception of the causes of salinity and its impacts on crop production in Bangladesh's southern region are as follows:

1. **Extent of salinity impact**: Approximately two-thirds of the arable land, surface water, and shallow aquifers in the southern region of Bangladesh are affected by varying levels of salinity.
2. **Perception of causes**: The study examined how local populations perceive the sources of salinity and its impacts on agricultural productivity. While polders were constructed to prevent saline intrusion, their effectiveness has diminished over recent years.
3. **Type of rice production**: The research revealed that the type of rice grown was not significantly related to household characteristics or the land's salinity level.
4. **Adoption of saline-tolerant rice**: A correlation exists between the production of saline-tolerant rice cultivars and factors such as educational attainment and diverse employment among households.
5. **Regional disparities**: Significant regional differences were observed in the adoption of saline-tolerant rice cultivars, with farmers in Dacope and Rupsha adopting these varieties at a higher rate than those in Batiaghata.

These findings highlight the intricate interplay between environmental factors, agricultural practices, and the socioeconomic conditions of communities in southern Bangladesh.

Based on the findings of the study regarding the perception of local people about the causes of salinity and its impacts on crop production in the southern region of Bangladesh, the following recommendations could be made:

1. **Enhanced education and awareness programmes**: it is important to implement community education initiatives that focus on the impacts of salinity on agriculture. This should include promoting the benefits of saline-tolerant rice cultivars and other adaptive practices, especially in regions with lower adoption rates.
2. **Improved agricultural practices**: Farmers should be encouraged to use of integrated farming systems to enhance soil fertility and water management. Techniques such as organic composting, mulching, and crop rotation can help mitigate the effects of salinity.

1 *'bagda' shrimp refers to the black tiger shrimp, a salt-water species.*

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3. **Support research and development**: Investment in research should be enhanced to develop more saline-resistant crop varieties and conduct region-specific studies on local salinity conditions. This information will enable farmers to make informed decisions regarding crop selection and management practices.
4. **Bolster infrastructure**: Improvement of the construction and maintenance of polders and drainage systems should be enhanced for water management. Proper drainage can help manage saline water and prevent it from intruding into agricultural lands.
5. **Community engagement and participation**: Increasing the involvement of local communities in decision-making processes related to agricultural practices and water management is essential. Their traditional knowledge and insights can significantly contribute to effective adaptive strategies.
6. **Diversification of livelihoods**: The promotion of diversification of livelihoods in response to the impacts of salinity should be enhanced. This can include promoting aquaculture, handicrafts, and other non-farming income-generating activities to reduce dependence on agriculture in areas affected by salinity.
7. **Water management strategies**: Modern technology should be considered for implementing sustainable water management practices, including rainwater harvesting, to provide the farming community with fresh water for irrigation and domestic use, thereby reducing their reliance on saline water sources.
8. **Policy support and financial aid**: Necessary initiatives should be taken to advocate for governmental and non-governmental organizations to provide financial support and establish policy frameworks that facilitate the adoption of saline-resistant crops, thereby improving the overall resilience of farming communities.

   By prioritizing these recommendations, stakeholders can work towards mitigating the adverse effects of salinity on crop production and enhancing the livelihoods of local populations in southern Bangladesh.

Contribution of this study

The study contributes to policymaking and aids farmers in several key ways:

a. **Informed policy development**: It provides insights into local perceptions of salinity, helping policymakers understand community challenges and develop targeted interventions.

b. **Efficient resource allocation**: Findings about the effectiveness of polders and the adoption of saline-tolerant rice guide better investment in infrastructure and support where it is most needed.

c. **Promotion of saline-tolerant varieties**: By highlighting the correlation between education and the adoption of these rice varieties, policymakers can support training programs to improve resilience against salinity.

d. **Support for sustainable practices**: The study advocates for policies that promote sustainable agricultural practices to mitigate salinity's effects on farming.

e. **Enhanced community engagement**: It emphasizes involving local communities in decision-making, leading to more effective and accepted policies.

f. **Long-term planning**: The research highlights the need for strategies to address the increasing salinity and its impact on food security in coastal regions. In summary, the study lays a foundation for effective policies that strengthen agricultural resilience and empower farmers to adapt to environmental changes.

CONCLUSION

Bangladesh has an extensive cultivable coastal area; however, agricultural production in this region is highly susceptible to salinity intrusion. This study investigated the relationship between salinity and crop production, with a particular focus on rice, by surveying 200 households in the coastal district of Khulna. The research revealed that some individuals did not recognize their active involvement in adapting to salinity and instead viewed their efforts as part of their routine daily activities. A significant factor contributing to salinity was identified as the reduction in upstream water flow. The study also found no correlation between household characteristics and salinity levels in relation to the cultivation of rice varieties. However, increased education has a positive impact on the adoption of saline-tolerant rice varieties. Furthermore, individuals with multiple sources of income were more likely to cultivate

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saline-tolerant varieties, while poorer segments of the community rarely grew these varieties. The use of saline-tolerant varieties in the region has emerged as a significant and influential trend.

This research on Bangladesh's coastal areas highlights the distinct characteristics of different regions, such as Chittagong's mountainous terrain and Khulna's river flow. It emphasizes the need for further study on salinity and adaptive strategies to guide policymakers. Potential areas for continued research include:

a. **Adaptation strategies:** Investigating successful interventions and their applicability across regions.

b. **Impact on agriculture:** Examining how salinity affects crop productivity and identifying best practices.

c. **Climate change interactions:** Analyzing how climate change affects salinity and potential adaptation strategies.

d. **Policy effectiveness:** Evaluating current policies on water management and salinity control.

e. **Technological innovations:** Exploring new technologies for monitoring salinity and improving infrastructure.

These areas can inform the development of effective policies tailored to regional salinity challenges.

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