# Context of salinization and adaptation preferences in the coastal areas of Bangladesh: Bringing together farmers’ salinity perspectives into policy to achieve SDGs


**Abstract**

The increasing salinization of coastal areas of Bangladesh reduces options for rice intensification but offers a suitable environment for shrimp and salt farming. Under these contested land use settings, adaptation decisions to address salinity require an understanding of the salinity perspectives of all farmer types. Primary data was collected from randomly selected rice, shrimp and salt farmers in two coastal sub-districts through semi-structured interviews at household level. Also, key informant interviews (KIIs) were conducted with personnel from research and extension organisations from different levels (e.g. national and local). Salinity perceptions among the various types of farmer differed. While the majority of rice farmers (87%) perceived increased salinity, just over half of the salt and shrimp farmers perceived that salinity has decreased over the past 20 years. Most rice farmers (62%) perceived anthropogenic factors as the main cause of increased salinity, while the majority of shrimp and salt farmers focused more on natural factors. Rice farmers perceived under saline conditions a yield loss (42%), followed by less income (30%). In contrast, shrimp farmers (70%) and salt farmers (55%) perceived production gains when high salinity prevailed. Rice farmers’ adaptation preferences to cope with salinity is development of salinity-tolerant rice varieties that have greater tolerance at the reproductive stages, while shrimp and salt farmers’ preferences are engineering-based solutions. Thus, research and extension services on integrated coastal resources management need to consider all livelihood perspectives, as this approach could accelerate the pace of achieving the SDGs (i.e.. SDG-1, SDG-2 and SGD-3).



Key words: Coastal areas, livelihoods, salinity perceptions, adaptation preferences

## 1. Introduction

Coastal saline areas generate substantial ecosystem services that provide livelihood options for thousands of millions of people, particularly in the developing regions of the world (Visbeck et al., 2014). These regions are undergoing ever-changing biophysical conditions and impulsive socioeconomic development (Betcherman and Marschke, 2016). Moreover, the increasing population and competing demands for coastal resources present urgent challenges to those policymakers responsible for adaptation planning to address the sustainable development agenda (Neumann et al., 2017). In addition, climate change-induced natural disasters pose significant threats that make these coastal areas vulnerable to environmental stresses (Dessai et al., 2009; Lempert and Groves, 2010). The coastal areas of Bangladesh, which are some of the most vulnerable regions of the world (Yohe et al., 2006), are also exposed to repeated natural disasters (Khan et al., 2015; Talukder and Saifuzzaman, 2016). Among the disasters, salinization is the most opaque in its origins and continuing risk factors, with varying input from both natural and anthropogenic drivers (Hossain et al., 2018a). Salinization also exhibits highly variable temporal and spatial stochastic variations (Clarke et al., 2015), and affects coastal livelihoods in diverse ways (Lázár et al., 2015). Hence, salinity is considered one of the greatest challenges for sustaining agricultural productivity in the coastal areas (Kabir et al., 2016; Wassmann et al., 2009), and is placing increasing pressure on the sustainability of agricultural productivity, further threatening the function of ecosystem services (Flörke et al., 2019). Despite these negative consequences on agriculture and biodiversity, coastal saline environments offer opportunities for other livelihoods such as shrimp aquaculture and salt farming, as they are not adversely affected by salinity (Lázár et al., 2015). Thus, it is imperative to have comprehensive adaptation planning that presents various alternatives that reflect the diverse preferences of all farming groups affected by the salinization process (Haasnoot et al., 2013; Herman et al., 2015; Kwakkel et al., 2016). Efficient adaptation planning to combat the salinization problem will explicitly trigger the potential of the coastal areas to achieve the sustainable development goals (SDGs) of no poverty (SDG-1), zero hunger (SDG-2) through proper and integrated utilisation of these resources (Hussain et al., 2018; Islam and Shamsuddoha, 2018).

To achieve the SDG targets, the coastal areas of Bangladesh offer significant potential as these areas occupy around 30% of the total land area of the country (SRDI, 2010), and are characterised by diversified land use opportunities (MoA, 2013). Sustainability in coastal resource utilisation would be achieved by recognising all the livelihood options that the coastal environment offers to the people living there, as well as understanding the diverse perspectives of all types of farmers.

Three major livelihood options exist in the coastal areas of Bangladesh: cropping, shrimp aquaculture and salt farming. Until the 1970s, rice cropping in coastal environments was dominated by monsoon season (Aman season) rice cultivation; however, in the 1970s, with the adoption of irrigation technologies and the development of modern, high-yielding rice varieties, a new cropping opportunity emerged in the dry season (Boro season) that significantly increased rice production (Ahmed and Diana, 2015). Unfortunately, widespread adoption of dry season rice cultivation in the coastal areas did not occur as expected due to increasing salinization (Rahman et al., 2011; Szabo et al., 2016). The biggest breakthrough came in 2006 with the development of salt-tolerant rice varieties that were seen as having the potential to increase the area sown to dry season rice in the coastal areas (Islam and Gregorio, 2013), and influenced policymakers to adopt saline tolerant rice varieties devlopment as an adaptation planning. However, these varieties have a certain limitations to cope with salinity stress during the reproductive stages, which also coincide with the period of highest salinity in the coastal areas (Clarke et al., 2015). In addition, the scarcity of fresh water for irrigation is an issue that has emerged along with the salinity problem, and which might create further challenges in sustaining dry season rice cultivation (Islam et al., 2020; Rahman et al., 2017). Thus, a number of challenges have emerged for sustaining rice productivity, including increasing salinity threats and water security issues, which could further limit the expansion of dry season rice cultivation.

In contrast, shrimp and salt farming, which have been practised for hundreds of years in the coastal environment and were well established before the inception of dry season rice cultivation in the coastal areas, do not require fresh water, and indeed use brackish water (Al Mamun et al., 2014; Datta et al., 2010; Pokrant, 2014). These farming enterprises thus have encroached into previous rice cropping areas in the coastal areas of Bangladesh due to the suitable sub-tropical climate and easy access to tidal saline water (Ahmed, 2013; Ahmed et al., 2010; Ahmed and Diana, 2015; Bagchi and Jha, 2011; Pokrant, 2014). Furthermore, these fast-growing farming enterprises contribute to the socioeconomic status of the local people and society in general through employment and enhancement of household incomes (Al Mamun et al., 2014; BSCIC, 2020; FRSS, 2018). However, once land has been developed for shrimp or salt farming, it no longer offers a viable option for rice farming.

Thus, adaptation decisions that can address the salinization problem in the coastal areas of Bangladesh are increasingly become complicated, as this problem results in various farming systems being affected in diverse ways, as well as policymakers face contested solutions (Herman et al., 2015; Kwakkel et al., 2010). For example, salinization squeezes the options for rice intensification while offering a suitable environment for shrimp and salt farming (Lázár et al., 2015). Similarly, different levels of government (e.g. the Ministry of Agriculture, Ministry of Fisheries and Livestock) favour certain solutions to the salinity issue: promoting the use of salinity-tolerant rice varieties and promoting shrimp and salt farming. Under these contested land use options, adaptation decisions that can address the salinization problem require investigation of both the perspectives of salinization of the local farmers being affected by the increasingly saline environment and their adaptation preferences to cope with salinity (Ramm et al., 2018). In addition, adaptation options generated from the farmers' perspective would enable decision makers to choose from a range of alternative solutions that are interconnected with socioeconomic and natural systems, which would make them more adoptable and less contested (Eakin and Patt, 2011; Wise et al., 2014).

Research that explores farmers' perspectives of salinization and how incorporating this perspective can help policymakers to plan adaptation decisions has attracted limited attention in the existing literature. Furthermore, most studies in the coastal areas of Bangladesh and other regions of the world have investigated farmers' perceptions of salinity based on a single livelihood option such as cropping or shrimp farming (Betcherman and Marschke, 2016; Hossain et al., 2018b; Islam and Tabeta, 2019; Joffre et al., 2018; Kabir et al., 2017; Rahman et al., 2017; Haider and Hossain, 2013). Most of these studies have confined their analysis to the farmers' perceptions of salinity in terms of farm risk and overlooked their preferred options to cope with salinization problem. Understanding these preferences could direct decision makers to undertake holistic salinity adaptation planning. In addition, divergent perspectives of salinization that involve all farming groups from the distal coastal areas are absent in the existing literature. Furthermore, how salinity affects the livelihood options of the different farming groups in the coastal areas of Bangladesh has not been adequately addressed in previous studies. A recent study has shown the importance of salinization perceptions and adaptation strategies in the coastal areas of Bangladesh (Islam et al., 2020); however, this study only considered the perceptions of the single livelihood of rice farmers, and therefore the perspectives of salinization of other farming groups such as shrimp and salt farmers were not included.

Our scientific understanding of the salinization problem in the coastal areas will be improved by examining farmers' perceptions of salinization and the preferred adaptation options of all coastal resource user groups, including rice, shrimp and salt farmers. At the same time, such knowledge will also inform policymakers about local-level resource users' preferences with regard to adaptation planning to address the opaque salinity problems, which will assist policymakers to implement sustainable policy and, in turn, trigger the achievement of the SDGs. This study therefore has the following aims:

- to examine how the salinization problem is framed by the different types of farmers in the coastal areas,
- to investigate how salinity affects the livelihood options of the various coastal farming communities, and
- to investigate farmers' preferred adaptation strategies to combat salinization at a community level.

## 2. Research Methodology

### 2.1 Selection and description of the study area

The coastal areas of Bangladesh are divided into three main regions, western, central and eastern, based on distinct biophysical and geographical characteristics (Karim and Mimura, 2008). In the south-eastern coastal area, most of the land falls under the shallow piedmont zone along with the Chittagong hill tracts, and is more stable in nature. The major rivers of this region are the Karnafuli and its tributaries (BWDB, 2013). The south-western coastal zone is an active delta characterised by the Ganges tidal flood plain and the convergence of a large numbers of creeks and channels. The major rivers of this region are the Gorai and its tributaries (BWDB, 2013; Rahman and Rahman, 2015). Due to a wide range of variations in land topography, river systems and livelihood activities, the salinity dynamics vary significantly in these regions (SRDI, 2010).

The Satkhira district was selected for study as it is one of worst salinity-affected districts of the south-western region, while Chittagong is one of the least-affected districts of the south-eastern coastal region (Table 1 SI). The Assasuni sub-district from the Satkhira district and the Banskhali sub-district from the Chittagong district were selected, as these two sub-districts represent the most salinity-affected areas within these two districts, and also have diversified land use practices (rice farming, shrimp farming and salt farming) (SRDI, 2010). Finally, two villages from two unions of the Assasuni sub-district and two villages from two unions of the Banskhali sub-district were selected for administration of the household survey (Fig. 1).

**2.2 Data sources and data collection methods**

The major sources of data for this study consist of primary and secondary data. The primary data were collected through formal household surveys and key informant interviews (KIIs). The household surveys were conducted from February to April 2018 and in 2019 during the dry season in Bangladesh (from December to May). Prior to conducting household surveys and key informant interviews, human research ethics approval (HREA) was sought and received at the University of New England, Australia (Approval No. HE17-272). A pre-tested and semi-structured interview schedule was used to collect primary data from 109 rice farmers, 107 shrimp farmers and 64 salt farmers. Secondary data were gathered from books, journal articles and reports. The respective sub-district agriculture officer and fisheries officer provided advice on the villages where rice farming was affected by salinity as well as where shrimp and salt farming have emerged as a potential land use. The lists of farmers were obtained from the records of the Agriculture and Fisheries offices in each of the sub-districts. A multi-stage stratified random sampling procedure was followed to select the respondents for the face-to-face interview (Table 2 SI). A similar sampling procedure was followed by other studies that have investigated farmers' perceptions of salinity and climate change in the coastal areas of Bangladesh (Hasan and Kumar, 2020; Islam et al., 2020). The male farmer from each household was selected as the interview respondent, as men are traditionally the household head in Bangladesh.

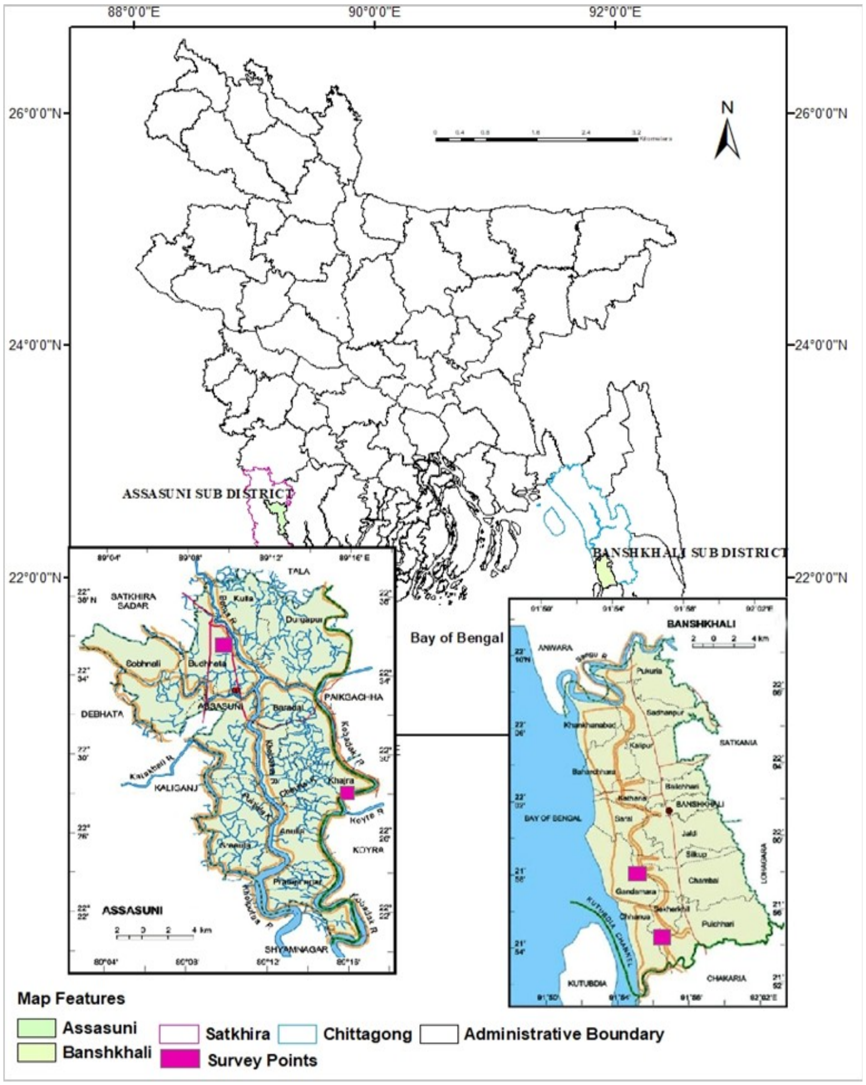


**Fig. 1.** Study locations in the coastal areas of Bangladesh. Assasuni sub-district in Satkhira district (bottom left) and Banskhali sub-district in Chittagong district (bottom right). Location of data collection villages are indicated by pink squares.

Farmers were interviewed about their perception of salinity trends in their locality over the last 20 years and whether salinity has been increasing, decreasing or there has been no change. Their perceptions of the current salinity level as well as conditions 20 years in the past for their locality were also covered. The farmers' perceived causes/drivers of increased salinity, the impacts of salinity on their farming enterprises and their adaptation preferences to cope with the expected extreme salinization were explored by a series of open-ended questions on those topics.

To complement the farmer household interviews, 22 key informant interviews (KIIs) were conducted amongst a wide range of professionals: agricultural extension department personnel, fisheries officers, rice breeders, soil scientists and NGO personnel from the national, district and sub-district levels. These interviews were conducted at the respective offices of the participants, and their voluntary participation was confirmed before the interview. A series of open-ended questions were covered to explore their opinions on the causes of salinization and the adaptation options needed to combat the expected increasing salinity in the future.

**2.3 Data analysis**

Data collected from the interviews of the household head were transferred to usable format by coding the responses. Responses were transcribed from Bengali to English by the lead author who is fluent in Bengali. For open-ended questions, a thematic response matrix was developed and similar responses were placed into these common thematic responses. These were then coded with a number and analysed using IBM SPSS statistical software (Bryman and Cramer, 2012; Seale and Kelly, 2004). ANOVAs were conducted to examine the differences in the independent variables among the different types of farmers. The independent variables examined were age, educational qualifications, total farm size, land ownership, farming experience and monthly average income. The farmers' perspectives of salinity, with particular focus on the trends and causes of salinity and its impacts on their farming enterprises, and their preferred adaptation options were analysed using cross-tab analysis. Chi-square tests were carried out for these categorical variables to test whether farmers' salinity perspectives varied among the different types of farmers (i.e. frequencies against each category). Al-Amin et al.

(2019) conducted similar Chi-square tests to examine categorical variables in their investigation of the significance of intra-household differences in farmers' perceptions of climate change.

The data gathered from the KIIs were transcribed verbatim from Bengali to English and analysed using NVivo 12 plus software. To complement the survey results, they were coded against themes of causes of salinization, key considerations in development and promotion of salt-tolerant varieties and adaption options to cope with future salinization. Several nodes were created under these themes and responses under each theme were coded into the respective nodes. Word frequency search queries were conducted to recall the most important words or phrases as mentioned by the key informants to address specific issues of causes of salinization and adaptation options. Matrix coding queries were also carried out to observe the variations in salinity perspectives (e.g. the causes of salinity) of the different key informants working in different organisations.

## 3. Results

### 3.1 Socioeconomic characteristics of the different types of farmers

Most of the socioeconomic and demographic characteristics differed significantly among the rice, shrimp and salt farmers in the areas studied. Educational qualifications differed significantly among the different types of farmers. Among the three groups of farmers, the shrimp farmers had the greatest number of years at school (8.43) when compared to the rice and salt farmers, who had 6.7 and 3.03 years of schooling, respectively. Total farm size of the shrimp farmers was also significantly higher than that of the rice and salt farmers. Land ownership also differed significantly among the three types of farmers. The shrimp farmers owned the greatest area of land, which was on average 13.00 bigha, while rice and salt farmers possessed 4.6 and 2.02 bigha of land, respectively. Salt farmers had the longest farming experience of 25.58 yrs, while shrimp farmers had 22.23 years. Significant differences were found in monthly average income among the different types of farmers. The shrimp farmers had a monthly income that was almost 1.5 times higher, BDT 19000, than the rice and salt farmers. The average age of famers in all groups was between 46 and 48 years old (Table 1).

**Table 1.** Socioeconomic characteristics of the rice, shrimp and salt farmers in the two coastal study areas

| Characteristics (unit of measurement) | Rice farmer (N=109) | | Shrimp farmer (N=107) | | Salt farmer (N=64) | | F-value |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | |
| Age (yrs) | 47.44 | 8.82 | 46.70 | 8.56 | 47.73 | 8.40 | 0.35NS |
| Education (schooling yrs) | 6.70 | 5.42 | 8.43 | 4.51 | 3.03 | 3.04 | 27.44** |
| Total farm size (bigha[1]) | 7.97 | 5.41 | 28.86 | 27.68 | 7.63 | 5.54 | 46.76** |
| Land ownership (bigha) | 4.61 | 4.51 | 13.00 | 18.85 | 2.02 | 2.26 | 20.82** |
| Farming experience (yrs) | 23.02 | 8.31 | 22.23 | 7.90 | 25.58 | 7.14 | 3.73* |
| Monthly income (BDT) | 11432 | 3856.06 | 19072 | 3224.56 | 12192 | 3695.63 | 139.95** |

** = significant at 5% level of significance, NS = not significant

**3.2 Context of salinity as perceived by the different types of farmers**

Only a small proportion of farmers, regardless of land use, reported no change in salinity in the last 20 years. However, the perspectives of the trend in salinity varied between the different types of farmers in the two coastal study areas (Table 2). While 87.2% of rice farmers reported that salinity has increased over the past 20 years, only 35.5% of shrimp farmers indicated this. Shrimp farmers were more likely to indicate that salinity had decreased in the past 20 years (52.3%). A higher proportion of salt farmers (43.8%) than shrimp farmers (35.5%) indicated that salinity had increased , but the majority of salt farmers (51.6%) reported that salinity had declined in the last 20 years. Among the rice farmers, around 90% reported that the current salinity level in their locality was high, with only a small proportion indicating that the current salinity level was low. In contrast, the proportions of both shrimp farmers (46.7%) and salt farmers (60.9%) who reported the current salinity level as being high were both lower when compared with rice farmers, and therefore a much higher proportion of shrimp farmers (53.3%) and salt farmers (39.1%) considered the current salinity level to be low. This result aligns with the farmers' perceived salinity level 20 years ago, which most rice farmers (84.4%) said was low, while 64.5% of shrimp farmers and 46.9% of salt farmers reported it as being high 20 years ago when compared to the present salinity level.

[1] 1 ha= 7.4 bigha

In terms of the main drivers of increased salinity, 62.1% of rice farmers considered that the human interventions of shrimp farming, salt farming and faulty sluice gates are the main effectors, with less emphasis (27.4%) placed on the natural causes such as cyclones, coastal flood, siltation of rivers and less rainfall. Only a small proportion (10.5%) mentioned both anthropogenic and natural causes. In contrast to rice farmers, more emphasis was placed on natural causes as the main drivers of increased salinity by shrimp farmers (39%). A higher proportion (34.2%) mentioned both human interventions and natural causes as the drivers compared with human interventions on their own (26.8%). Among the salt farmers, the main drivers of increased salinity were human interventions (46.9%), while almost equal emphasis was placed on natural causes and human interventions together (26.9%) or natural causes alone (26.2%) (Table 2).

**Table 2.** Context of salinity among the different types of farmers in the two coastal study areas

| Issues of the salinity problem | % of the respondents | | | |
|---|---|---|---|---|
| | Rice farmer (N=109) | Shrimp farmer (N=107) | Salt farmer (N=64) | Overall (N=280) |
| Trend of salinity over the last 20 years | | | | |
| Salinity increased | 87.2 | 35.5 | 43.8 | 57.5 |
| Salinity decreased | 9.2 | 52.3 | 51.6 | 35.4 |
| No changes in salinity | 3.7 | 12.1 | 4.7 | 7.1 |
| **Chi-square = 68.51**** | | | | |
| Current salinity level | | | | |
| High | 89.9 | 46.7 | 60.9 | 66.8 |
| Low | 10.1 | 53.3 | 39.1 | 33.2 |
| **Chi-square = 46.66**** | | | | |
| Salinity level 20 years ago | | | | |
| High | 15.6 | 64.5 | 46.9 | 41.1 |
| Low | 84.4 | 35.5 | 53.1 | 58.6 |
| **Chi-square = 54.20**** | | | | |
| Drivers of increased salinity | | | | |
| Human interventions (e.g. shrimp farming, salt farming, faulty sluice gate) | 62.1 | 26.8 | 30.8 | 46.9 |
| Natural events (e.g. cyclones, coastal flood, siltation of river, less rainfall) | 27.4 | 39.0 | 10.2 | 26.2 |
| Human interventions and natural events | 10.5 | 34.2 | 59.0 | 26.9 |
| **Chi-square = 41.98**** | | | | |

** indicates significant at 5% level of significance

The findings from the household interviews followed similar trends to the key informant interviews with respect to the perspective that anthropogenic drivers have had a major role in increasing salinity. However, there was a clear polarisation between the representatives of Fisheries and Agriculture departments in their views on the role of natural causes in the increasing salinity. The majority of the coded references (92.3%) from the Fisheries Department officers' KIIs were about the natural drivers of salinity, while only 7.7% of the coded references from the Agriculture Department KIIs mentioned that the natural drivers contributed to increased salinity (Fig. 2).

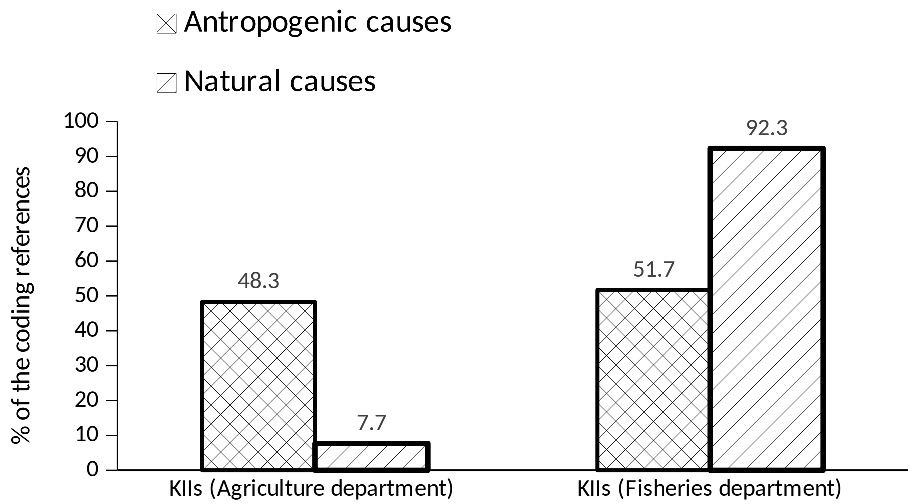


**Fig. 2.** Coding references from the key informant interviews of representatives of the Agriculture and Fisheries departments on the drivers of increased salinity.

The KIIs also identified the same anthropogenic drivers of increased salinity cases as reported by farmers: increases in shrimp and salt farming and faulty management of embankments. However, the majority of the KIIs spoke more often about how the unplanned expansion of shrimp and salt farming has been the greatest anthropogenic driver of increased salinity (Fig. 3).


**Fig. 3.** Anthropogenic drivers of the increased salinity as reported in KIIs (n=22).

The KIIs showed that the natural drivers of increased salinity in the coastal areas were climate change, sea level rise, reduced rainfall, higher temperatures, inundation with saline water and siltation of rivers. However, coded references of the KIIs indicated they were mostly talking about climate change-induced sea level rise, and less rainfall as being one of the greatest drivers of increased salinity in the coastal areas (Fig. 4).

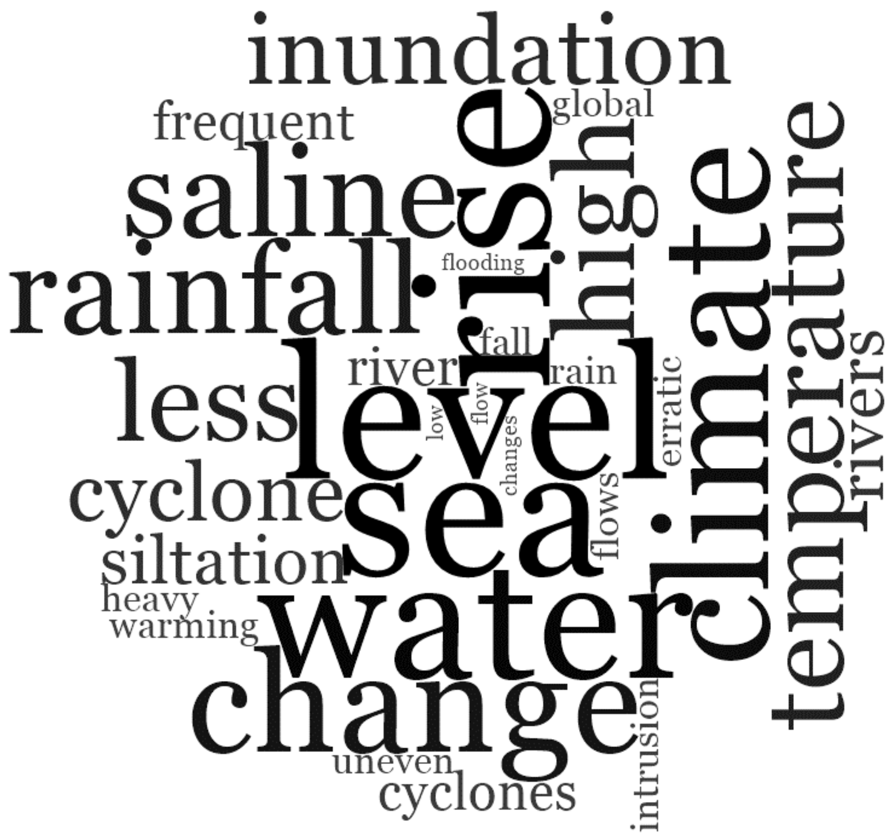


**Fig. 4.** Natural drivers of increased salinity identified from the key informant interviews (n=22).

### 3.3 Farmers' perceived reasons for a decline in salinity

Farmers who said salinity has declined over the last 20 years, were asked why they thought salinity had decreased. Among the rice farmers who said salinity had decreased, which was only a small proportion, 70% of them reported that "rainfall had increased as compared to the last decades", and 30% mentioned "less risk of inundation of saline water due to siltation of rivers and canals". A similar proportion of the salt farmers reported the same reasons for the decline in salinity. In contrast, shrimp farmers who stated salinity had declined placed greater emphasis (69.6%) on "less risk of inundation of saline water due to siltation of rivers and canals" (Table 3).

**Table 3.** Farmers' perceived causes of decline in salinity.

| Farmer type (n) | % of the respondents | |
|---|---|---|
| | Rainfall increased as compared to the previous decades | Less risk of inundation of saline water due to siltation of rivers and canals |
| Rice farmers (10) | 70.0 | 30.0 |
| Shrimp farmers (56) | 30.4 | 69.6 |
| Salt farmers (28) | 67.9 | 32.1 |

### 3.4 Sources of information/farming advice

Farmers in the coastal study areas use different sources for advice and information for their farming enterprises, and there is very little crossover between government departments and enterprises. Rice farmers (50.5%) have a substantial reliance on information and farming advice obtained from the sub-district Agriculture office and the local sub-assistant agriculture officer, and to a lesser extent from neighbouring farmers and local input dealers (26.6%) and neighbouring farmers only (22.9%). Among the shrimp farmers, 51.4% obtain farming advice from neighbouring farmers and 44.9% obtain information from neighbouring farmers and the sub-distrcit Fisheries office. In contrast, salt farmers get farming advice almost exclusively from neighbouring farmers (92.2%), while the remainder also mentioned neighbouring farmers and government personnel (Table 4).

**Table 4.** Sources of information and farming advice of the different types of farmers.

| Farmer type (n) | % of the respondents | | | | |
|---|---|---|---|---|---|
| | Agriculture office and local sub-assistant agriculture officer | Neighbouring farmers | Neighbouring farmers and local input dealers | Neighbouring farmers and local fisheries office | Neighbouring farmers and government personnel |
| Rice farmers (109) | 50.5 | 22.9 | 26.6 | 0 | 0 |
| Shrimp farmers (107) | 0 | 51.4 | 3.7 | 44.9 | 0 |
| Salt farmers (64) | 0 | 92.2 | 0 | 0 | 7.8 |

### 3.6 Impacts of high salinity on the farming enterprise of the different types of farmers

The perceived impacts of high salinity of the different types of farmers in the coastal areas of Bangladesh were very much focused on their main enterprise, with most concerned about impacts on yield. For rice farmers, high salinity had negative consequences on yield, with 42.2% reporting that "rice plants dry up, unfilled grain, lower yield, income reduce", 30.3% also mentioned that "crop cultivation becomes difficult, lower yield, income reduced" and 27.5% that they observe "damage to soil fertility, lower yield, less income". In contrast, increased salinity for shrimp farmers has positive impacts on yield and income potential, with 69.2% mentioning "movement of fish in the pond is noticeable, higher yield, more income", while 30.8% reported that "growth of fish is good, higher yield, more income". Similarly, salt farmers reported positive impacts of increased salinity on yield with 54.7% stating "density of water increase, higher yield", and the remainder that they receive a "higher yield of salt" (Table 5).

**Table 5.** Impacts of high salinity on farming enterprises.

| Farmer types (n) | (% of farmer interviewees) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Rice plants dry up, unfilled grain, lower yield, income reduced | Damaged soil fertility, lower yield, less income | Crop cultivation becomes difficult, less yield, income reduced | Growth of fish is good, higher yield, more income | Movement of fish in the pond is noticeable, higher yield, more income | Density of water increases, higher yield | Higher salt yield |
| Rice farmers (109) | 42.2 | 27.5 | 30.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| Shrimp farmers (107) | 0.0 | 0.0 | 0.0 | 30.8 | 69.2 | 0.0 | 0.0 |
| Salt farmers (64) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 54.7 | 45.3 |

### 3.7 Adaptation preferences to cope with expected high salinity

The household interviews found significant differences in the adaptation preferences under expected high salinity among the different types of farmers in the two coastal areas of Bangladesh. Rice farmers placed the greatest emphasis on agronomic solutions to high salinity, with approximately 60% referring to “salt tolerant rice varieties with greater tolerance during the reproductive stages, and early transplanting”, while a smaller proportion (around 20%) mentioned “develop facilities to harvest rain water during monsoon and use it during the dry season” and around 16% suggested, “improved irrigation facilities”. There was little emphasis (4%) on engineering solutions such as “strengthening of the embankments facilities”. This result contrasts with the adaptation preferences to higher salinity for most shrimp farmers (57%), who suggested engineering solutions such as “strengthening embankment facilities” be used to increasing salinity, while 35% prefer to have “canal excavation”. Salt farmers placed even greater emphasis than shrimp farmers on engineering solutions to increase salinity, with around 74% suggesting “strengthening embankment facilities”, and only around 22% suggesting “canal excavation” as their preferred adaptation options (Fig. 5).

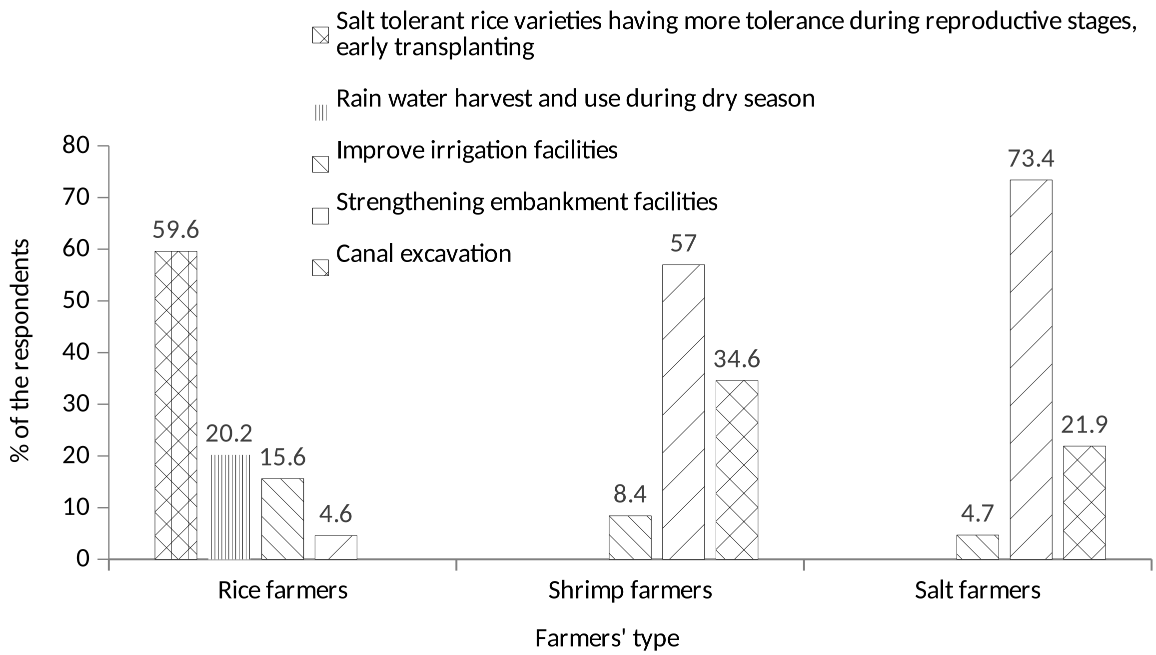


**Fig. 5.** Adaptation preferences to cope with expected high salinity among the different types of farmers.

Adaptation preferences mentioned by the different types of farmers to cope with expected high salinity were also found to align with the KIIs from the service providers to the main enterprises of rice, shrimp and salt farming. Among the coded references related to the adaptation options, 43% were from the Agriculture Extension Department personnel, 39% of coded references were from research organisations and around 10% were from the Fisheries Department. Word frequency query search results showed that use of salt-tolerant rice varieties and irrigation techniques were mentioned as the most preferred options to cope with expected high salinity, but these organisations were also highly represented in the sampling (Fig. 6). The specific options mentioned by the agriculture extension staff were mostly agronomic technical options such as the use of salt-tolerant rice varieties, application of irrigation regularly and early transplanting. In contrast, officers from the Fisheries Department talked mostly of engineering solutions such as canal excavation and strengthening of embankment facilities, although they had a minor representation in the KIIs.


**Fig. 6.** Adaptation options that emerged from the KIIs from the different organisations.

## Discussion

Adaptation decisions to cope with salinization in the coastal areas of Bangladesh are becoming increasingly complicated as this problem not only exhibits spatial-temporal variations but also affects the coastal communities in diverse ways. This research addresses the differential perceptions of farmers to increasing salinity. This study discusses the rice, shrimp and salt farmers' perspectives of salinity in coastal regions (i.e. trends, causes, impacts) and the potential for including their salinity adaptation preferences in policy initiatives that could enhance sustainable livelihoods to achieve the SDGs.

### 3.1 Differential framing of the salinization problem in the coastal areas of Bangladesh

This study showed differential framing of the salinity problem by rice, shrimp and salt farmers. While the majority of the rice farmers and almost 50% of salt farmers perceived that salinity has increased over the last 20 years, just over half of the shrimp and salt farmers believe that salinity had decreased over the same period. This contrary framing of the salinization problem could be due to the relative dependence of the different farming livelihoods on non-saline water sources. For instance, shrimp and salt farmers use brackish saline water for their farming enterprises, which might influence their perceptions of the salinity trends (Deb, 1998). In contrast, as slight increases in salinity negatively affect rice yields (Zeng et al., 2003), rice farmers perceived that the difficulties they have been experiencing during the Boro rice growing season are due to the trends in increasing salinity. Rice farmers in the coastal areas have reported that salinity has been the most significant barrier to dry season rice farming (Islam et al., 2020).

The findings of this study also showed differential perceptions among the different types of farmers of the causes of salinity in the coastal areas. The majority of the rice farmers perceived that a particular human intervention cause of salinity might be the limited land that is available for rice farming following the extension of shrimp farms into the adjacent cropping fields. These shrimp farms are typically twice the size of rice farms. A large body of literature also indicates that shrimp farmers are socioeconomically more powerful, and they have not only converted their own rice fields into shrimp farming but also actively bought up neighbouring farmers' land for shrimp farming, which is a process that has ultimately increased salinity in the coastal areas (Ahmed et al., 2010; Deb, 1998).

In contrast, rather than admit that their own farming enterprises are a contributing factor to the worsening salinity in the area, the shrimp and salt farmers' attribute the causes of increased salinity to the natural drivers . In addition, natural causes like cyclones and frequent inundation may have negatively affected their previous rice yields, and their economic insolvency could have triggered a conversion of their land to shrimp and salt farming. Thus, the shrimp and salt farmers' perceptions of the causes of salinity in the coastal areas emphasise the natural drivers. The literature demonstrates that salinity has caused lowered rice yields, and that these lower yields have influenced those farmers in the coastal areas to convert their cropping land into shrimp and salt farms (Ahmed, 2013; Amin et al., 2011). Those farmers who said salinity has decreased also mentioned that the reasons behind their thinking were related to the level of dependency of their livelihood options on the availability of saline water. As those farmers might encounter difficulty in getting saline water due to siltation of rivers and canals from lower water flows, thus their perceptions of the salinity trends are shaped by these experiences (Mertz et al., 2009).

Different types of farmers perceived that high salinity has impacted on their farming livelihood options in diverse ways. Rice farmers perceived that the negative impact on their farming enterprise of the high salinity is reduction in rice yields. As yields have been drastically reduced due to the impact of high salinity, their overall income from this livelihood option has reduced, which could influence rice farmers' perceived impacts in negative ways. Yield reduction due to high salinity has been reported in the literature (Hasanuzzaman et al., 2009; Joseph and Mohanan, 2013; Zeng et al., 2003), which supports the farmers' perceptions of the impacts of high salinity on sustainable rice farming. On the other hand, the shrimp and salt farmers' perceived positive impacts of high salinity on their livelihood options are most likely due to the requirement for saline water for these farming enterprises, which ultimately increases their farm income.

This study has demonstrated that there are significant differences in the opinion on the adaptation preferences to cope with expected high salinity in the coastal areas. The rice farmers' preferred options to deal with the increasing salinity are to have salt-tolerant rice varieties and improved irrigation facilities, as these appear to be plausible and practical solutions to those farmers who own small areas of land and have a low monthly income. They may also have fewer options to move to other cost-intensive livelihoods and prefer to use salt-tolerant rice varieties to extend the time they can continue cultivation of their current landholding, even though they expect conditions to worsen.

Given the rice farmers are concerned about the anthropogenic drivers as the causes of salinization, they did not suggest cessation of shrimp and salt cultivation in their localities as a solution. However, some of the rice farmers mentioned the need to create facilities for rainwater storage in the wet season that could be used for irrigation in the dry season. As conversion of cropland to brackish water for shrimp and salt farms is almost irreversible, their preferred options are concentrated on their own farming opportunities rather than complete shifts of enterprise.

In contrast, the shrimp and salt farmers' preferred adaptation options are predominantly associated with the engineering solutions of strengthening embankment facilities and canal excavation. As shrimp and salt farmers are more concerned with the natural drivers of the increased salinity, these perceived causes have probably influenced their preferred adaptation options to cope with expected high salinity.

### 3.2 Potential of differential salinity perspectives of farmers to achieve the SDGs, and future research directives

For policymakers in Bangladesh whose aim is to achieve the sustainable development goals, particularly SDG-1, SDG-2 and SDG-3, the coastal areas are the key focus of research and extension initiatives for agricultural development. However, these areas are also considered to be hotspots for several environmental stresses. Salinity, which has been triggered by both natural and human interventions, is but one of these stresses. Salinity affects the coastal farmers in contrasting ways: it negatively affects rice farming, but has positive impacts on shrimp and salt farming. Therefore, policy initiatives that are undertaken to address this polarised problem should consider the preferred adaptation options of all types of farmers.

Achieving the SDGs requires that all types of farmers are able to use their land sustainably to maintain and increase their farm productivity and thus contribute to food security in coastal Bangladesh. Thus, research and extension policy initiatives for rice farmers need to be more localised and targeted to the rice farmers' needs. One initiative should be developing salt-tolerant rice varieties that are tolerant during the reproductive stages when salinity levels are highest and not just during the germination and seedling emergence stages (Islam et al., 2020). Another initiative should be improvement of irrigation facilities to provide fresh water for as long as possible during crop growth. Facilities should also be developed to store monsoon rainwater which can be used for irrigation in dry season rice farming (i.e. Boro season). Although, shrimp and salt farmers' preferred adaptation is strengthening of the embankments, which could protect the land from frequent inundation, canal excavation planning could be more useful for bringing saline water from the sea. Thus, efficient sluice gate management and equitable land zoning and its' strict implementation could help ensure proper utilisation of coastal resources for all types of farmers.

These actions could allow the different types of farmers to use their resources sustainably for their own livelihood improvement, and also to contribute to achievement of the SDGs. However, the contesting of land use by the different types of farmers could create uncertainty for the policymakers in planning these adaptation decisions. Further research is required to explore the threshold yield of dry season rice as perceived by the local farmers, as this information could signal a tipping point for the cessation of rice farming in the coastal saline areas.

## 4 Conclusions

Salinization that has been caused by both natural and anthropogenic drivers is one of the crucial risk factors for coastal livelihoods in Bangladesh. The impacts of this salinization have resulted in highly spatial-temporal variations and contested land uses. Thus, the adaptation decisions being made by policymakers require knowledge of the perspectives of all types of farmers who are affected by increasing salinity, either positively or negatively, in the coastal saline areas of Bangladesh. The findings of this study demonstrated a differential perception of salinity among the various types of farmers. While the majority of the rice farmers perceived an increasing trend in salinity, half of the shrimp and salt farmers perceived it to have declined. Strongly contrasting emphases on the perceived causes of increased salinity in the coastal areas were also found, with rice farmers being more focused on human interventions than natural causes, and shrimp and salt farmers placing less emphasis on human intervention. This study suggests that the way farmers' livelihood options are affected by the salinity has driven their perceptions about the problem. It has also demonstrated that while rice farmers' preferred adaptation options are predominantly linked to agronomic technical solutions like the development of salt-tolerant rice varieties and irrigation improvements, shrimp and salt farmers' preferences are engineering solutions such as strengthening embankment facilities.

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