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ORIGINAL ARTICLE

Determinants of climate change adaptation strategies in the coastal zone of Bangladesh: implications for adaptation to climate change in developing countries

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Abstract
Considering the growing threats of climate change, in addition to mitigation strategies, it is highly and equally critical to understand the socio-economic determinants of climate adaptation in order to develop climate adaptation policies. This study makes a first attempt to explore the determinants of adaptation to climate change and choices of adaptation strategies at a larger spatial scale of the south-west coastal areas in Bangladesh, which is one of the most climate-vulnerable regions in the world. We employ both qualitative and quantitative approaches in order to examine farmers' perception of climate risks, determinants and choices of adaptation strategies to climate change in six coastal districts of Bangladesh. Farmers are adapting to these situations using their knowledge and experience. The study reveals that a number of adaptation strategies have been taken to reduce the negative impacts of climate change. These adaptation strategies are categorized into four groups: crop management, water management, land management, and income diversification. Availability of inputs, high production cost, agricultural extension service, and proper adaptation knowledge and experiences were noted as the main non-climatic challenges, as well as different climatic factors in agricultural adaptation strategies. Statistical analysis indicates that the different socio-economic determinants of farmers significantly influence their choices of adaptation to climate change. Farmers adopt these adaptations mostly autonomously rather than on the advice of government. This study could be useful for developing national adaptation policies in Bangladesh and other similar developing countries.

Keywords Socio-economic determinants · Adaptation · Agriculture · Coastal

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1 Introduction

Global climate change and anthropogenic greenhouse gas (GHG) emissions, which thrust climate shifts, are increasing the vulnerability of agricultural production systems (Sloat et al. 2020). Climate change has become an apparent challenge for humanity and goes beyond the rise in global temperature (Xie et al. 2015). Increased temperature extremes affect agricultural productivity and increase the risk to global food security (Tai et al. 2014). The global temperature is predicted to increase by an average of 1.8 °C to 4 °C by 2100 due to worldwide climate change (IPCC 2013). Agriculture and livelihoods are highly affected in many developing countries due to their lower adaptive capacity and exposure to frequent adverse climate change-induced events (e.g., floods, cyclones, droughts, pest attack, and plant disease) (Adger et al. 2003; Hoque et al. 2019), which is particularly the case of Bangladesh (GCRI 2020; Szabo et al., 2018). The coastal areas of these developing countries are the most vulnerable to climate change and are already experiencing devastating impacts on livelihood (IPCC 2014); such coastal regions are home to two-thirds of the world's population (UN 2017). This large part of the coastal population is likely to experience an increase in adverse societal impacts (IPCC 2014), and the ability to provide ecosystem services for human well-being will be compromised in the future due to climate change (MEA 2005).

Bangladesh is one of the most climate-vulnerable countries in the world, due to its geographical location, topography, socio-economic conditions, and dependency on agriculture (GCRI 2020; Thomas et al. 2013; Maplecroft 2010). Though Bangladesh is historically vulnerable to natural hazards such as flood and cyclone (Dastagir 2015), climate change not only has induced and increased the severity of those risks but also affected social-ecological systems by inducing changes in total rainfall, shifting rainfall seasons, increasing temperature and salinity increase due to sea-level rise in Bangladesh (Hasan and Kumar 2020; Hossain et al. 2016b, 2014). In particular, the coastal zone of Bangladesh is possibly the most climate-vulnerable region in the world (Hossain et al. 2017a). Studies have shown an increase in temperature and rainfall in coastal Bangladesh (Hossain et al. 2014; Chen and Mueller 2018), and extreme precipitation is predicted to be a common climate change-induced event in this region (World Bank 2013). Climate change-induced events (e.g., droughts and sea-level rise) are predicted to intensify the indirect impacts (e.g., soil and water salinity) in this coastal region (Yeo. 2017).

Despite the advancement of agricultural technologies, climate is still considered the key factor that governs agricultural productivity (Wheeler and von Braun 2013). According to Nelson et al. (2014), climate change impacts will decrease yields by around 17% in different regions of the world; the decline in Bangladesh is estimated to be higher than the world average and could reach 30% (Mondal 2010). Agriculture contributes about 19% of gross domestic product (GDP) and employs approximately 48% of the labor force (Hossain et al. 2016a; MoA 2014), and crop farming is the primary source of food for about 150 million people in Bangladesh (BBS 2015). Agriculture is considered a vital livelihood (there are 40 million coastal farmers) in the coastal regions, which cover around 30% of the country's total cultivable land (BBS 2011). Islam et al. (2010) have anticipated that if the temperature increases by 1–2 °C, rice and wheat production will decrease by 28% and 68%, respectively. In addition, an increase of more than 3.5 °C may cause future societal collapse (Hossain et al. 2017b).

Adaptation has been recognized as a crucial response to climate change; even the mitigation strategies have been designed to stabilize earth's climate (IPCC 2001). In general, climate change refers to the changes in the mean and/or variability of climate state, and adaptation refers to adjustment, moderation, or changes to socio-economic and ecological systems in order to avoid and recover from the adverse impacts of climate change and to glean benefits from it (IPCC 2007). Adaptation to climate change has been part of the national development program due to global initiatives such as the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Framework Convention on Climate Change (UNFCCC). Despite several initiatives at global, national, and local levels, climate change impacts are unlikely to reduce in the future (IPCC 2014). Therefore, we need to increase our efforts in adaptation to climate change, as it has the potential to reduce the adverse impacts of climate change on society. However, it has been argued that current knowledge of climate change adaptation is not sufficient for deliberate and rigorous planning or an evaluation of the adaptations and policies of governments (IPCC 2001). In particular, local-level climate change adaptation is often ignored when developing national adaptation policies, despite the fact that communities and individuals at local level are possibly the first to respond to climate change through autonomous (spontaneous and triggered by ecological changes), private (individual, household-level), and reactive (following the impacts of climate change) adaptations, which influence the planned adaptation in combination with scientific discourses at global and national levels. Adaptation is a complex process, and local people often play a key role by trying to offset the negative impacts of climate change (Klein et al. 2007).

Local-scale studies have shown that farmers' climate perceptions are mostly aligned with scientific evidence and local climate change (Halder et al. 2012; Esham and Garforth 2013; Hasan and Kumar 2019). In addition to understanding the climate change impacts, the perception of farmers and locals is highly useful for climate change adaptation and planning (Deressa et al. 2011). Identifying and understanding the determinants of adaptation to climate change at local scale by engaging farmers are absolutely imperative and will undoubtedly assist decision-makers in understanding local climate issues and thus ensuring relevant policy interventions (Tesfahunegn et al. 2016; Islam et al. 2020; Ur-Rahman et al. 2011).

Despite emphasizing the determinants of climate changes across the globe (Ojo and Baiyegunhi 2020; Trinha et al. 2018; Bryan et al. 2013), previous studies have mainly focused on trends in climate change (e.g., Hossain et al. 2014; Nissan et al. 2020), vulnerability and capacity for adaptation to climate change (e.g., Delaporte and Maurel 2018; Hossain et al. 2015), climate change adaptation knowledge and techniques (e.g., Moni and Hossain 2010; Abedin et al. 2019; Kabir et al. 2018; Hossain et al. 2020a, b), and importance of climate change perceptions (e.g., Hasan and Kumar 2019; Uddin et al. 2017; Halder et al. 2012; Hossain and Roy 2012). Though some of the studies have focused on the determinants of adaptation to climate change, their focus was mostly the northern part of Bangladesh (Al-Amin et al. 2019; Alam 2015; Sarker et al. 2013); a few studies have also focused on the Satkhira district (Uddin et al. 2014; Akter and Ahmed 2020) of southern Bangladesh. However, none have studied the south-west coastal zone of Bangladesh in larger spatial scales, even though this is one of the most climate-vulnerable regions in the world. In addition, determinants for choices in adopting different adaptation strategies have not been discussed in previous studies. To the best of our knowledge, our study is the first initiative to examine the importance of the influence of socio-economic determinants on climate change adaptation and choice of adaptation strategies on a larger spatial scale in the coastal areas of Bangladesh.

Therefore, the objective of this study is to explore (1) farmers' perception and adaptation to climate change and the way this perception coincides with the observed climatic trends reported in previous studies; (2) determinants for climate change adaptation strategies and choice of adaptation strategies; (3) challenges and opportunities in climate change adaptation; and (4) policy implications for national adaptation plans in Bangladesh and other similar areas.

This paper comprises four sections. Section 2 details the selection of the study area and methodology of the study. Section 3 sets out the results, in which the socio-economic characteristics (Sect. 3.1) and farmers' perceptions of climate change (Sect. 3.3) and adaptations are presented (Sect. 3.3), before discussing the determinants of adaptation strategies (Sect. 3.4) and choices (Sect. 3.5). The Sect. 4 provides a summary of the results, challenges, and opportunities, before setting out the policy implications of adaptation to climate change. The conclusions are presented in Sect. 5.

2 Methodology

2.1 Study area

The study was conducted in six south-western coastal districts (Barisal, Bagerhat, Jashore, Khulna, Patuakhali, and Satkhira) of Bangladesh (Fig. 1). The total size of this region is about 25,000 km^2 (16% of the total land area of Bangladesh), with a total population of 14 million (Hossain et al. 2020a, b). The wide range of services provided by the regional ecosystem are worth an estimated 1,300 million USD of gross domestic product (GDP) (BBS 2010). The hydrological regime of the study area is governed by the interconnected channels and water courses that form part of the Ganges–Brahmaputra delta.

The social-ecological systems of this region are severely exposed to climatic hazards due to their geo-climatic condition (Brammer 2014; Hossain and Szabo 2017). About 85% of coastal residents depend on agriculture, and 50% have less than 0.2 hectares of land (Abedin et al. 2012). The south-western coastal zone is highly vulnerable to climate change, which has dominated over all other environmental and man-made problems for the last few decades (Hossain et al. 2016b). The social-ecological system of this region is under threat due to increasing temperature, changes in rainfall, frequent tropical cyclone salinity rises (water and soil), and sea-level rises (Thomas et al. 2013). Though the whole coastal region is vulnerable to salinity (both soil and water) increase (Hossain et al., 2015, 2010), Rahman et al. (2013) and Akter et al. (2019) categorized this study area based on the level of salinity (i) high saline zone (Khulna, Bagerhat, Satkhira, and Jashore) and (ii) low saline zone (Patuakhali and Barisal). Due to its overexposure and vulnerability to climate change, it has been recognized as one of the most climate-vulnerable areas in the world (Ahmed et al. 1998; Maplecroft 2010).

2.1.1 Data collection strategies

A combination of qualitative (e.g., focus group discussions) and quantitative (e.g., semi-structured questionnaire surveys) methods have been used in this study in order to examine farmers' perceptions of climate change, current adaptation strategies, and the influence of factors (e.g., socio-economic) on decision-making about adaptation to climate change and adaptation strategies. The overall methodology of the study comprised five research steps: (1) understanding farmers' perceptions of climate change and the effects of climate change-induced events (e.g., change of rainfall pattern) on the locality through

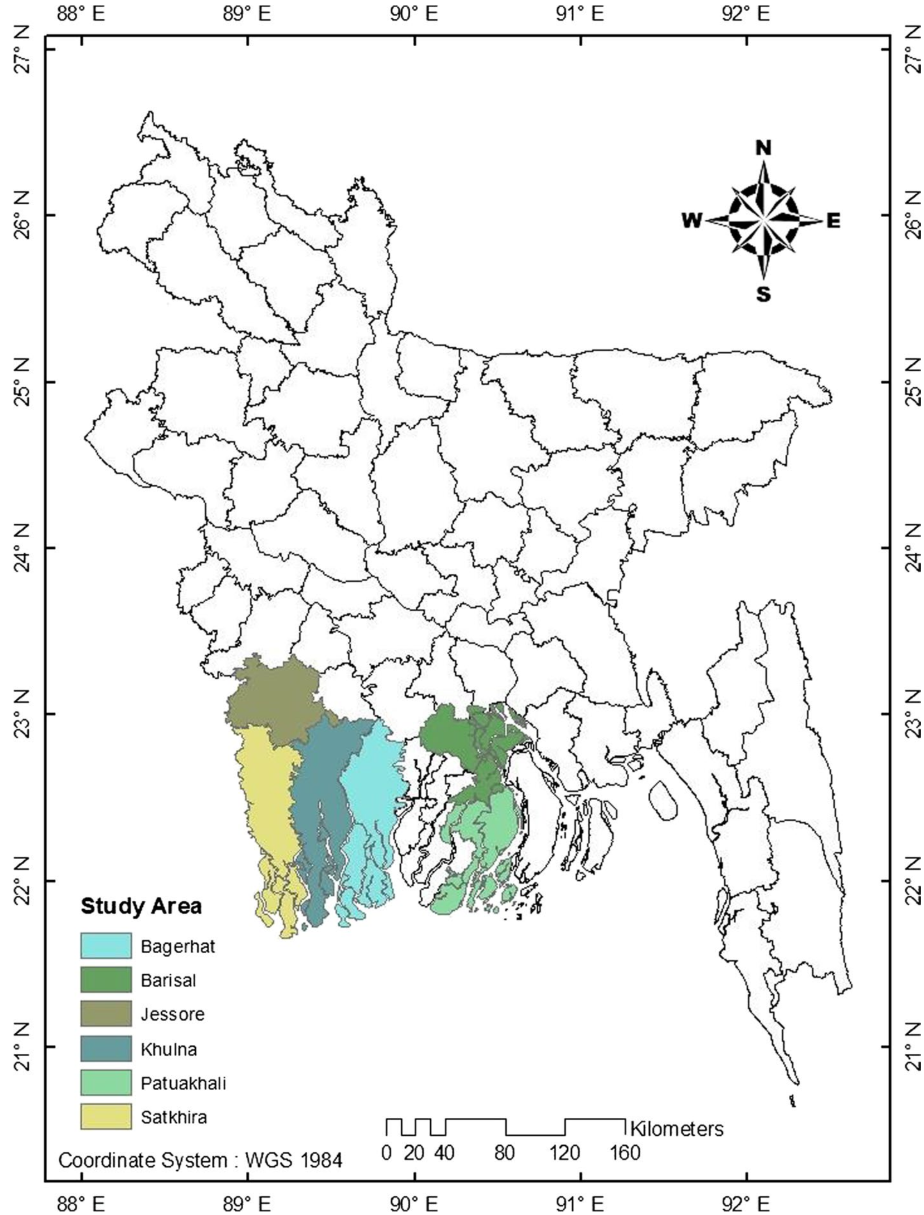

Fig. 1 Map showing location of the six south-western coastal districts used for this study

semi-structured questionnaire surveys; (2) identifying climate adaptation strategies through semi-structured questionnaire surveys and focus group discussions (FGDs); (3) analyzing the influence of socio-economic determinants on adaptation to climate change through the semi-structured questionnaire surveys; (4) using these surveys to investigate the influence of socio-economic determinants on the choice of adaptation strategies; and (5) identifying the challenges and opportunities in climate change adaptation strategies through the semi-structured questionnaire surveys.

2.1.1.1 Focus group discussions (FGDs) At the initial stage, 12 FGDs were conducted in the study area (i.e., two FGDs per district). Each of the FGDs consisted of 10–12 persons, mostly including farmers, NGO workers, local schoolteachers, and agriculture officers. The FGD participants also included senior community members and experienced and educated farmers of a socio-economic background similar to that of the survey participants from the study areas. Agricultural production and deviation over several years, consecutive changes in yields due to change of climate and climate change-induced extreme events over the previous 20 years and the seasonal crop calendar, and identification of existing adaptation strategies in the area were discussed in the FGDs.

In this study, FGDs were conducted in order to identify existing climate change adaptation strategies in the area and to describe these mechanisms on the basis of their current uses. Current agricultural production scenarios were also discussed in order to understand the effect of climate change-induced events on agriculture in the study area.

2.1.1.2 Household surveys We conducted household surveys in order to collect information on farmers' perceptions of climate change and its effects on agricultural production, their adaptation strategies, the reasons behind adopting these strategies, and the challenges faced.

The surveys mostly targeted household heads, using semi-structured questionnaires. Initially, six sub-districts (Upazilas) from six coastal districts were selected, taking into account the government focus on the agricultural activities in these areas and the existing and potential climate effects on agricultural production systems. After selecting the six climate-vulnerable and agriculturally appropriate sub-districts, two villages within a union from each of the sub-districts were purposively selected on the basis of the local agriculture office's information about their exclusive agriculture extension activities (e.g., crop diversification, rainwater harvesting, crop rotations, and so on). The study determined the sample size using Kothari's formula (2014):

$$n = \frac{z^2 pqN}{e^2(N-1) + z^2 pq}$$

Here:

N 38396 (total number of households in six unions)
Z^2 1.96 (at 95% confidence level (Kothari 2004))
p 0.5 (sample proportion)
q 0.5 (1-p)
e 0.1 (10% margin of error, used in other studies, i.e., Sattar et al. (2020))

Using the equation above, our estimated sample size was 97. We surveyed a total of 120 households from the six districts; thus, 20 households from each of the unions were randomly chosen for this study (Supplementary Information (SI) Tab s1).

The questionnaire comprised questions on socio-economic status, perception of climate change and its effects on agricultural production, agricultural adaptation strategies, and their opportunities and challenges. In order to attain an overview of the study area, a reconnaissance visit was conducted before the main visit so as to prepare objectives, identify problems, and prepare the questionnaire. In addition, information from the FGDs was used in the questionnaire (e.g., farmers' adaptation strategies), and both closed-ended and open-ended questions were included. The closed-ended questions covered perceptions of climate change and its effects on agricultural production, agricultural adaptation strategies, and the reasons for adopting those strategies. The open-ended questions, meanwhile, covered socio-economic status (education, farming status, educational status, occupation, experience, income, expenditure, loan, land size and asset), newly introduced crops, and the opportunities and challenges in adaptation strategies. The questionnaire was pre-tested before the final household surveys were carried out.

2.1.2 Statistical analysis

Descriptive statistics such as tabulation, average, frequency, and percentage were used to analyze socio-economic status, adaptation strategies, and adaptation challenges and opportunities. A normality check of the categorical responses on climate change adaptation and adaptation strategies was conducted. Due to the non-normal distribution of the data, a Pearson chi-square test was used to assess whether there was a statistically significant relationship between socio-economic status and the decision-making process of adaptation to climatic change, and the choice of adaptation strategies. The Pearson chi-square test has been widely used in the field of climate change adaptation to analyze the statistical association between variables (Islam and Paul 2018; Prabhakar 2013; Limantol et al. 2016; Korir 2019; Maharjan et al. 2020). In this study, we used the Pearson chi-square test to investigate the relationship between the socio-economic conditions of the farmers and their choice of adaptation strategies (e.g., the ways that a farmer's farming status or education affected their introduction of new crops into the field or their rainwater harvesting).

3 Results

3.1 Socio-economic characteristics of the respondents

According to the questionnaire survey, half of the respondents ($n=60$, 50%) belonged to the 31–50 age group, with most ($n=64$, 53.33%) having farming experience of less than 21 years (Tab s2). Farming was the primary occupation of about 63% ($n=75$), and half ($n=61$, 50.83%) were full-time farmers. Among the respondents, 43.33% ($n=52$) were marginal farmers, and 35% ($n=42$) were small farmers (Tab s2 and s3). The average yearly income range of the respondents was BDT (Bangladeshi taka) 102,733 ± 39,595, and the monthly expenditure range was BDT 3,001 to 9,000 (around 70%, $n=84$). Among the respondents, almost 37% ($n=44$) were under loans from banks, NGOs, and local community-based organizations.

4 Farmers' perceptions of climate change and associated effects on agriculture

The farmers who participated in this survey articulated their perception of climate change-induced events and its effects on coastal agricultural systems in the study location. The survey results showed that most of the farmers ($n=74$, 62%) were aware of the term "climate change" because of the different levels of discussion they had held on the topic with NGOs and government organizations. However, among the surveyed farmers, about 7% ($n=8$) identified deforestation as the cause of climate change, while 3% ($n=4$) blamed industrialization; most farmers, however, were unconscious of the real reasons for climate change. About 43% ($n=51$) of the interviewed farmers claimed that they could predict climate change-induced events (e.g., flood, storm) before they happened, using different natural signals (e.g., color and direction of clouds, tidal height, movement of ants). According to the survey, farmers perceived that there had been an increase in temperature (88%), total annual rainfall (67%), number of cyclones (79%), and frequency of storm surges and floods (59%) over the previous 20 years (Table 1). Around 71%, 83%, 67%, and 78%, respectively, perceived that they could adapt to the changed temperature, rainfall, cyclones, and storm surges and floods (Table 1). The study also found there was a contradictory perception (increased = 40%, decreased = 43%) regarding the number of droughts over the previous two decades; however, almost half of the respondents (51%) perceived an increasing temporal extent of waterlogged situations over the same period (Table 1).

Our survey also investigated the perceived effects of climate change-induced events (i.e., temperature and rainfall change) on local agriculture. According to the survey, between 50% and 90% of respondents perceived an increase in crop yield (68%, $n=81$), weed infestation (67%, $n=80$), pest infestation (88%, $n=106$), disease outbreak (78%, $n=93$), and pesticide use (91%, $n=109$) in agriculture over the previous two decades due to temperature change (Table 2). Moreover, more than half of the respondents perceived that change in temperature affected the growing season of several crops (e.g., winter crops) and water availability during the drought period (Table 2). A different percentage of respondents (around 50%) perceived positive effects on crop yield and grain size and weight, while around 30% perceived negative effects on yield (Table 3) due to change in total rainfall in the study area. However, agricultural production had increased during recent decades due to the use of high-yielding varieties (HYV), pesticides, and fertilizers. The FGD resulted in a comparative study of the yield production of the previous 20 years (Tab s4).

Table 1 Perception of climatic risk and adaptation to climate change (n = number of respondents). Numbers in parentheses indicate percentage value

	Response					
	Climatic variability				Adaptation	
Parameter	Increase	Decrease	No change	Don't know	Yes	No
Change in temperature	n = 106 (88.33)	9 (7.5)	4 (3.33)	1(0.83)	82 (71.30)	33 (28.70)
Change in total rainfall	n = 80 (66.67)	31 (25.83)	7 (5.83)	2 (1.67)	92 (82.88)	19 (17.12)
Change in rainfall variability	n = 99 (82.5)	10 (8.33)	4 (3.33)	7 (5.83)	89 (81.65)	20 (18.35)
Change in number of droughts	n = 49 (40.83)	52 (43.33)	14 (11.67)	5 (4.17)	72 (71.28)	29 (28.72)
Change in number of cyclone and storm surge	n = 95 (79.17)	23 (19.17)	2 (1.67)	0 (0)	79 (66.95)	39 (33.05)
Change in flood intensity	71 (59.17)	37 (30.83)	9 (7.5)	3 (2.5)	84 (77.78)	24 (22.22)
Change in waterlogged situation	61 (50.83)	25 (20.83)	28 (23.33)	6 (5)	57 (66.28)	29 (33.72)

Table 2 Respondents' perception of effects on agriculture due to temperature change ($n = 120$). Numbers in parentheses indicate percentage value

Effect	Response		
	Increase	Decrease	No change
Change in yield	81 (67.5)	37 (30.83)	2 (1.67)
Change in weed infestation	80 (66.67)	23 (19.17)	17 (14.17)
Change in pest infestation	106 (88.33)	6 (5)	8 (6.67)
Change in disease outbreak	93 (77.5)	5 (4.17)	22 (18.33)
Change in pesticide use	109 (90.83)	3 (2.5)	8 (6.67)
	Yes		**No**
Change in growing season	68 (56.67)		52 (43.33)
Affect water availability	69 (57.5)		51 (42.5)

5 Farmers' perceptions of adaptation strategies

Our study shows that farmers used diverse strategies for successive adaptation to climate change-induced extreme events. The study identified 26 existing adaptation strategies in different seasons through the FGDs. We divided these adaptation strategies into four categories: crop management, water management, land management, and income diversification (Table 4).

Our study shows that 72% ($n = 86$) of the respondents introduced new crop varieties into their fields as a mechanism for adapting to climate change-induced event (e.g., change in rainfall pattern). Among these respondents, about 58% ($n = 70$) cultivated crop varieties that needed less water, 32% ($n = 38$) used crop varieties that could tolerate high temperature; and 9% ($n = 11$) used crop varieties that were susceptible to higher salinity. Another mechanism involved altering the planting and harvesting date of crops; about 74% ($n = 89$) of the respondents practiced this adaptation mechanism in their fields (Table 4). The majority of the respondents (72.5%, $n = 87$) also practiced homestead gardening for alternative food sources during climate change-induced disaster periods. Most of the farmers (95.83%, $n = 115$) had increased the amount of chemical pesticide they were using, and about 83% ($n = 99$) were using organic fertilizer on their land. Supplementary irrigation, mainly from groundwater sources, is one of the most popular mechanisms to cope with untimely and prolonged droughts, and 80% ($n = 96$) of the respondents were using this adaptation technique in their fields. Home poultry rearing (79%, $n = 95$) and reduced tillage or deep plowing (73%, $n = 87$) were among the other widely practiced climate change adaptation mechanisms in the study area (Table 4).

About 63% ($n = 75$) of the respondents were cultivating different types of cereal and horticulture crops that were more adaptive to climate change, and about 63% ($n = 76$) were cultivating short duration crop species. Almost half of the respondents (50.83%,

Table 3 Respondents' perception of effects on agriculture due to rainfall change ($n = 120$). Numbers in parentheses indicate percentage value

Effect	Response		
	Increase	Decrease	No change
Change in yield	78 (65)	37 (30.83)	5 (4.17)
Change in grain size	56 (46.67)	31 (25.83)	33 (27.5)
Change in grain weight	55 (45.83)	35 (29.17)	30 (25)

Table 4 Adaptation strategies and percentile distribution of adaptations among different categories

Class	Adaptation strategies	Number of respondent, *n* (percentage, %)		
		Overall	Low saline	High saline
Crop management	Crop diversification	75 (63%)	20 (50%)	55 (69%)
	Introduction of new crops	86 (72%)	26 (65%)	60 (75%)
	Crop rotation	43 (36%)	11 (28%)	32 (40%)
	Change in planting and harvesting date	89 (74%)	26 (65%)	63 (79%)
	Shortening growing season	76 (63%)	18 (45%)	58 (73%)
	Homestead gardening	87 (72.5%)	34 (85%)	53 (66%)
	Plantation in highlands	42 (35%)	15 (38%)	27 (34%)
	Mixed cropping	61 (51%)	16 (40%)	45 (56%)
	Application of pesticides	115 (96%)	37 (93%)	78 (98%)
	Gardening on *Mucha* (bamboo-made structure)	70 (58%)	19 (48%)	51 (64%)
	Change the time of fertilizer use	72 (60%)	17 (43%)	55 (69%)
	Use of organic fertilizer	99 (83%)	34 (85%)	65 (81%)
	Enhancing the efficiency of fertilizer use	68 (57%)	31 (78%)	37 (46%)
	Develop farming practices that minimize susceptibility and diseases of pest	39 (33%)	11 (28%)	28 (35%)
	Introduce measures to decrease salinization in agricultural field	30 (25%)	8 (20%)	22 (28%)
Water management	Water conservation	49 (41%)	21 (53%)	28 (35%)
	Increased use of supplementary irrigation	96 (80%)	23 (58%)	73 (91%)
	Rain water harvesting	39 (33%)	17 (43%)	22 (28%)
	Floating garden	10 (8%)	0 (0%)	10 (13%)
	Net aquaculture	59 (49%)	13 (33%)	46 (58%)
	Poultry rearing at home	95 (79%)	32 (80%)	63 (79%)
	Re-digging of canal	52 (43%)	15 (38%)	37 (46%)
Land management	Soil conservation techniques	49 (41%)	15 (38%)	34 (43%)
	Reduced tillage and deep plowing	87 (73%)	25 (63%)	62 (78%)
Income diversification	Off farm employment	57 (48%)	17 (43%)	40 (50%)
	Leased crop land	66 (55%)	25 (63%)	41 (51%)

$n=61$) practiced mixed cropping (e.g., rice-pulse, rice-turmeric, pulse-chili, chili-garlic-onion, sunflower-sesame-pulse, maize and red amaranth, watermelon and garlic, or lentil and mustard) to enable the supplementation (e.g., space, nutrients, water) and disease suppression of one crop with another during different climate change-induced adverse events. Many farmers (58%, $n=70$)) were using *Mucha* (bamboo-made structures that stand above the ground) to grow vegetables (Table 4). Most of the respondents (60%, $n=72$) had altered the times at which they used fertilizer, while about 57% ($n=68$) were using techniques (e.g., use of crop managers, Guti urea) that increased the efficiency of fertilizer.

Around 35% of the respondents were practicing crop rotation (e.g., rice and legume crops) in their fields and planting different trees (e.g., mahogany, rain trees) on the highlands. Other techniques for climate change adaptations in the crop fields included integrated and local knowledge-based pest management techniques and reducing the salinization of lands (e.g., controlling the entry of saline water by creating small earthen barriers and use of fertilizers).

Many of the farmers (around 41%, $n=49$) practiced water conservation techniques (e.g., storing rainwater for agricultural fields, re-excavating existing canals to store more water). Almost half of the respondents (49%, $n=59$) practiced aquaculture. About 41% ($n=49$) of respondents used soil conservation techniques such as making conservation tillage, and 8% ($n=10$) made use of floating gardens in permanently or semi-permanently inundated lands (Table 4). Our study examined adaptation strategies across two saline zones and found a reasonable differences of the adoption of climate change adaptation strategies. In crop management measure category, change in planting and harvesting date (79%), shortening growing season (73%), and introduction of new crops (75%) adoption were higher in high saline zone compared to low saline zone. In water management strategy category, increased use of supplementary irrigation (91%), in land management strategy category, reduced tillage and deep plowing (78%) were higher in high saline zone compared to low saline zone.

5.1 Determinants influencing adaptation to climate change

We investigated the determinants that influence the decision-making process in adaptations to climate change and choice of adaptation strategies. In order to do this, we examined the association between the socio-economic determinants, adaptation to climate change, and choice of adaptations, using Pearson chi-square tests.

5.2 Determinants of adaptation to climate change

Our study shows that farmers' age ($\chi2=16.879$, $p=0.010$), experience ($\chi2=10.728$, $p=0.097$), farming status ($\chi2=6.830$, $p=0.007$), secondary occupation ($\chi2=16.022$, $p=0.025$), farm income ($\chi2=12.239$, $p=0.057$), non-farm income ($\chi2=15.024$, $p=0.020$), and loan status ($\chi2=3.244$, $p=0.072$) had a strong association with climate change-induced disaster prediction (Table 5). Meanwhile, adapting to climate change event, i.e., change of temperature ($\chi2=22.785$, $p=0.030$), total rainfall ($\chi2=37.417$, $p=0.000$), and rainfall pattern ($\chi2=24.743$, $p=0.016$), had a strong association with farming experience. Monthly expenditure ($\chi2=28.125$, $p=0.005$) had a strong relationship with adapting to changed rainfall pattern. Adapting to drought had a significant relationship with educational status ($\chi2=20.508$, $p=0.025$), primary occupation ($\chi2=20.626$, $p=0.024$), total expenditure ($\chi2=18.672$, $p=0.097$), and assets ($\chi2=18.672$, $p=0.097$), and non-farm income ($\chi2=22.326$, $p=0.034$) was significantly associated with flood events in the coastal region (Table 5).

5.3 Determinants of adaptation choices

The examination of the association between socio-economic determinants and adaptation choices showed many strong and significant associations. We found a strong association between the age of the respondents and certain adaptation strategies, including plantation

Table 5 Influence of socio-economic determinants on decision-making process of adaptations to climate change

	Predict disaster	Adapting temperature change	Adapting total rainfall	Adapting rainfall variability	Adapting drought	Adapting cyclone and storm surge	Adapting flood intensity	Adapting waterlogging
	$\chi2$ (*p* value)							
Age category	16.879(**0.010**)	13.562.330	18.4590.102	15.444.218	9.740.639	8.696.729	2.767.997	5.217.950
Farming experience	10.728(**.097**)	22.785(**.030**)	37.417(**.000**)	24.743(**.016**)	18.227.109	9.406.668	4.977.959	3.670.989
Farming status	6.830(**.007**)	5.054(**.080**)	.174.917	1.597.540	2.210.331	.210.900	3.563.168	.987.611
Educational status	1.207.944	5.419.862	7.327.694	5.450.859	20.508(**.025**)	4.903.898	6.580.764	7.866.642
Primary occupation	3.094.685	6.945.731	5.225.876	4.144.941	20.626(**.024**)	9.030.529	6.571.765	12.670.243
Secondary occupation	16.022(**.025**)	10.522.723	12.067.601	10.395.733	18.590.181	12.136.595	10.538.722	7.422.917
Farm income	12.239(**.057**)	8.535.742	16.531.168	13.258.351	12.444.411	8.297.762	5.213.950	11.157.516
Non-farm income	15.024(**.020**)	12.521.405	15.419.219	14.246.285	18.008.115	6.375.896	22.326(**.034**)	15.970.193
Total expenditure	7.658.264	2.981.996	15.271.227	28.125(**.005**)	18.672(**.097**)	7.077.852	12.538.404	15.623.209
Loan	3.244(**.072**)	1.730.421	1.524.467	2.536.281	1.012.603	.163.922	1.502.472	.586.746
Land holding	6.434.169	4.651.794	5.450.709	5.049.752	5.215.734	5.704.680	8.432.392	6.786.560
Cultivated land	3.683.159	1.770.778	3.625.459	1.693.792	1.804.772	1.791.774	1.348.853	4.523.340
Assets	9.081.106	5.014.890	13.068.220	12.364.261	17.014(**.074**)	13.368.204	3.685.960	13.484.198

The bold mark represents a significant between 1%-5% level of significance. Few of them also represent significant between 5%-10% level of the significance level in highlands ($\chi2 = 15.536$, $p = 0.016$), farming practice that minimized susceptibility of diseases and pests ($\chi2 = 12.124$, $p = 0.059$), and off-farm employment ($\chi2 = 13.887$, $p = 0.031$) (Tables 6 and 7). Farming experience had a strong relationship with the following adaptation strategies: crops that adapted to saline conditions ($\chi2 = 11.658$, $p = 0.070$), shortening growing seasons ($\chi2 = 11.077$, $p = 0.086$), homestead gardening ($\chi2 = 12.630$, $p = 0.049$), and re-digging of canals ($\chi2 = 12.723$, $p = 0.048$). Educational status had a significant association with changes in planting and harvesting dates ($\chi2 = 9.747$, $p = 0.083$), enhancing the efficiency of fertilizer use ($\chi2 = 14.741$, $p = 0.012$), taking strategies to decrease the salinization of agricultural fields ($\chi2 = 9.453$, $p = 0.092$), increased use of supplementary irrigation ($\chi2 = 13.786$, $p = 0.017$), and leased crop land ($\chi2 = 10.751$, $p = 0.057$). Meanwhile, the primary occupation of the respondents was significantly associated with homestead gardening ($\chi2 = 12.286$, $p = 0.031$), increased use of supplementary irrigation ($\chi2 = 9.979$, $p = 0.076$), floating gardens ($\chi2 = 14.065$, $p = 0.015$), and leased crop land ($\chi2 = 15.008$, $p = 0.010$).

The secondary occupation of the respondents was associated with off-farm employment ($\chi2 = 81.482$, $p = 0.000$) and saline-tolerant crop cultivation ($\chi2 = 18.259$, $p = 0.011$). The farm ($\chi2 = 17.606$, $p = 0.007$) and non-farm ($\chi2 = 68.081$, $p = 0.000$) income of the respondents had strong associations with off-farm employment. The monthly expenditure of the respondents was significantly associated with the use of organic fertilizer in their fields ($\chi2 = 14.676$, $p = 0.023$). Loan status was strongly associated with crop diversification ($\chi2 = 4.632$, $p = 0.031$), introduction of new crops ($\chi2 = 3.526$, $p = 0.060$), crop rotation ($\chi2 = 2.797$, $p = 0.094$), and reduced tillage and deep plowing ($\chi2 = 4.681$, $p = 0.030$). Respondents' farmland ownership was significantly associated with supplementary irrigation ($\chi2 = 12.506$, $p = 0.014$), reduced tillage and deep plowing ($\chi2 = 9.029$, $p = 0.060$), and leased crop land ($\chi2 = 22.949$, $p = 0.000$). Meanwhile, the amount of land cultivated by the respondents had strong associations with the use of organic fertilizers ($\chi2 = 6.470$, $p = 0.039$) and enhancing the efficiency of fertilizer use ($\chi2 = 10.465$, $p = 0.005$).

6 Discussion

6.1 Adaptation to climate change

This study aimed to analyze for the first time the influence of socio-economic determinants on adaptation to climate change and the choice of adaptations strategies related to agriculture in a larger spatial scale in south-west coastal area of Bangladesh. The findings suggest that farmers' perception of the increasing trends in different climate change-induced events (e.g., temperature change, rainfall pattern change, number of cyclones and storm surges, flood intensity) over the last couple of decades in the coastal areas of Bangladesh aligns with the trends shown by analyzing (both linear and nonlinear trend) meteorological data on smaller scales (e.g., Hossain and Roy 2012; Rakib and Anwar 2016), on larger scales (Hossain et al. 2016a, b; Kabir et al. 2016), and in the northern part of Bangladesh (Halder et al. 2012; Esham and Garforth 2013). However, the perception of increasing temperature and change of rainfall pattern and the increase in climate change-induced drought are conflicting findings. This could be because changes in temperature influence perceptions of climate change, and it is often challenging to find a logical direction for changes in terms of farmers' perception (Howe et al. 2013). In particular, the increase in temperature

Table 6 Influence of socio-economic determinants on farmers' choice of adaptation; the significance level was set at 0.1, and therefore, the null hypothesis was accepted if the *p* value was less than 0.1 (marked in bold)

	Crop diversification	Introduction of new crops	New crops that requires less water	New crops that adapted to higher temperature	New crops that adapted to saline condition	Crop rotation	Change in planting and harvesting date	Shortening growing season	Homestead gardening	Plantation in highlands	Mix cropping	Application of pesticide	Construction of embankment	Gardening in Mucha	Change the time of fertilizer use
	$\chi2$ (*p* value)														
Age	5.511 0.480	4.183 0.652	4.621 0.593	5.690 0.459	6.399 0.380	5.791 0.447	5.482 0.484	9.496 0.148	7.799 0.253	15.536 **(0.016)**	4.496 0.610	1.956 0.924	6.612 0.358	6.244 0.396	3.967 0.681
Farming experience	4.950 .550	5.430 .490	6.274 .393	3.977 .680	11.658 **(.070)**	7.073 .314	8.038 .235	11.077 **(.086)**	12.630 **(.049)**	1.608 .952	1.169 .978	3.503 .744	9.917 .128	2.229 .898	10.077 .121
Farming status	.500 .479	.013 .909	.275 .600	.267 .605	.067 .796	.003 .957	.268 .604	.019 .889	.527 .468	.399 .528	.529 .467	1.985 .159	.560 .454	1.601 .206	.356 .551
Educational status	2.894 .716	1.468 .917	7.239 .203	2.556 .768	5.709 .336	9.085 .106	9.747 **(.083)**	5.231 .388	4.100 .535	5.866 .319	3.939 .558	7.059 .216	4.462 .485	4.425 .490	5.561 .351
Primary occupation	5.473 .361	3.584 .611	4.786 .443	5.196 .392	1.995 .850	3.501 .623	3.042 .694	3.335 .648	12.286 **(.031)**	4.606 .466	6.622 .250	.821 .976	4.854 .434	6.889 .229	4.597 .467
Secondary occupation	7.314 .397	4.968 .664	2.285 .942	4.680 .699	18.259 **(.011)**	2.556 .923	8.136 .321	5.365 .615	5.936 .547	6.429 .491	9.341 .229	5.532 .595	2.717 .910	6.848 0.445	12.946 .073
Farm income	6.787 .341	5.383 .496	6.275 .393	1.960 .923	1.046 .984	4.768 .574	1.399 .966	1.817 .936	2.536 .864	2.201 .900	4.281 .639	2.301 .890	4.655 .589	2.854 .827	4.267 .641
Non-farm income	5.179 .521	3.687 .719	6.022 .421	4.259 .642	2.949 .815	2.438 .875	6.329 .387	4.458 .615	3.090 .797	3.336 .766	6.116 .410	4.054 .669	5.224 .515	8.729 .189	5.880 .437
Total expenditure	5.733 .454	8.754 .188	7.659 .264	4.889 .558	3.685 .719	4.405 .622	7.849 .249	4.002 .676	2.890 .823	5.634 .465	5.246 .513	4.017 .674	4.884 .559	5.417 .492	9.055 .171
Loan	4.632 **(.031)**	3.526 **(.060)**	.804 .370	.001 .978	.403 .526	2.797 **(.094)**	1.049 .306	.703 .402	.650 .420	.057 .812	.019 .889	.025 .874	.100 .751	.066 .798	.861 .353
Land holding	1.669 .796	1.320 .858	1.949 .745	.693 .952	10.734 0.30	1.856 .762	3.523 .474	2.411 .661	7.745 .101	2.272 .686	1.740 .783	.862 .930	4.772 .311	1.169 .883	1.002 .910
Cultivated land	2.667 .264	.593 .743	4.251 .119	4.201 .122	2.848 .241	3.203 .202	.368 .832	.157 .925	.597 .742	1.439 .487	.133 .935	1.537 .464	3.299 .192	.860 .650	1.364 .506
Assets	4.763 .445	2.812 .729	2.262 .812	4.639 .462	2.841 .724	3.100 .685	2.949 .708	4.290 .508	4.152 .528	4.938 .424	5.604 .347	2.089 .837	5.507 .357	3.657 .600	4.763 .445

Table 7 Influence of socio-economic determinants on farmers' choice of adaptation; the significance level was set at 0.1, and therefore, the null hypothesis was accepted if the *p* value was less than 0.1 (Marked in bold)

	Use of organic ferti-lizer	Enhanc-ing the effi-ciency of fertilizer use	Farming practice that mini-mize suscep-tibil-ity to diseases and pest	Meas-ures to decrease saliniza-tion of agri-cultural field	Water conser-vation	Increased use of supplemen-tary irrigation		Rain water harvest-ing	Float-ing garden	Cage aqua-culture	Poultry rearing at home	Re-dig-ging of canal	Soil conser-vation tech-niques	Reduced tillage and deep plowing	Off-farm employ-ment	Leased crop land
	$\chi 2$ (*p* value)															
Age	5.030	2.682	12.124	7.875	7.091	7.041	6.253		6.355	3.061	10.416	9.594	4.945	4.492	13.887	5.698
	0.540	0.848	**(0.059)**	0.247	0.312	0.317	0.395		0.385	0.801	0.108	0.143	0.551	0.610	**(0.031)**	0.458
Farming experi-ence	2.770	5.898	2.752	7.242	8.591	6.090	6.494		6.216	7.110	5.577	12.723	2.035	2.646	10.295	4.447
	.837	.435	.839	.299	.198	.413	.370		.399	.311	.472	**(.048)**	.916	.852	.113	.616
Farming status	.105	.025	1.532	.100	.114	.300	.005		1.603	.131	.337	.895	2.108	.251	70.576	1.698
	.746	.873	.216	.752	.736	.584	.946		.205	.717	.561	.344	.147	.616	**(.000)**	.193
Educa-tional status	1.177	14.741	2,514	9.453	6.304	13.786	5.375		3.651	8.569	7.251	8.781	3.115	6.406	5.886	10.751
	.947	**(.012)**	.774	**(.092)**	.278	**(.017)**	.372		.601	.128	.203	.118	.682	.269	.317	**(.057)**
Primary occupa-tion	1.889	5.217	3.188	3.188	2.826	9.979	2.682		14.065	4.981	8.525	6.032	2.343	6.518	4.235	15.008
	.864	.390	.671	.671	.727	**(.076)**	.749		**(.015)**	.418	.130	.303	.800	.259	.516	**(.010)**
Secondary occupa-tion	4.508	9.207	8.245	4.331	9.105	11.208	6.182		6.656	8.232	4.988	8.770	12.884	13.147	81.482	7.105
	.720	.238	.312	.741	.245	.190	.627		.574	.411	.759	.362	.116	.107	**(.000)**	.525
Farm income	7.888	3.555	3.425	5.983	9.464	2.950	4.132		3.347	7.741	2.361	6.964	7.805	2.761	17.606	6.942
	.246	.737	.754	.425	.149	.815	.659		.764	.258	.884	.324	.253	.838	**(.007)**	.326
Non-farm income	9.988	2.828	7.090	2.808	2.993	5.964	1.921		2.143	3.322	5.187	4.618	5.095	2.950	68.081	7.368
	.125	.829	.313	.833	.810	.427	.927		.906	.768	.520	.594	.532	.815	**(.000)**	.288

Table 7 (continued)

	Use of organic ferti-lizer	Enhanc-ing the effi-ciency of fertilizer use	Farming practice that mini-mize suscep-tibil-ity to diseases and pest	Meas-ures to decrease saliniza-tion of agri-cultural field	Water conser-vation	Increased use of supplemen-tary irrigation		Rain water harvest-ing	Float-ing garden	Cage aqua-culture	Poultry rearing at home	Re-dig-ging of canal	Soil conser-vation tech-niques	Reduced tillage and deep plowing	Off-farm employ-ment	Leased crop land
Total expendi-ture	14.676 **(.023)**	4.739 .578	6.115 .410	3.563 .736	2.552 .863	8.530 .202	3.261 .775		1.207 .977	6.383 .382	1.942 .925	4.060 .668	3.964 .682	3.492 .745	5.585 .471	3.147 .790
Loan	.022 .881	1.257 .262	1.781 .182	1.722 .189	.000 .990	1.758 .185	1.192 .275		.209 .648	.383 .536	.006 .938	.001 .980	.159 .690	4.681 **(.030)**	1.383 .240	1.485 .223
Land holding	.918 .922	3.691 .449	.833 .934	2.572 .632	3.115 .539	12.506 **(.014)**	3.654 .455		1.700 .791	4.221 .377	3.018 .555	3.303 .508	2.628 .622	9.029 **(.060)**	3.262 .515	22.949 **(.000)**
Cultivated land	6.470 **(0.039)**	10.465 **(0.005)**	.760 .684	.287 .866	.668 .716	.014 .993	4.230 .121		1.101 .577	2.849 .241	1.304 .521	1.826 .401	3.223 .200	.350 .840	4.314 .116	1.172 .556
Assets	8.246 .143	3.941 .558	4.744 .448	3.041 .694	3.201 .669	5.247 .386	3.016 .698		4.369 .498	4.997 .416	3.900 .564	8.766 .119	8.056 .153	.876 .972	5.422 .367	2.667 .751

(Shahid et al. 2012; Syed and Amin 2016) and decrease in rainfall in the pre-monsoon and monsoon seasons (Syed and Amin 2016; Khan et al. 2019; Hossain et al. 2014), when agriculture production requires rain (Rafiuddin et al. 2009), are a possible explanation for the conflicting findings. This decreased rainfall in monsoon season and increased rainfall in post-monsoon season (Hossain et al. 2014; Syed and Amin 2016) also explain the perception and trends of increasing annual rainfall.

This study shows that farmers practiced 26 adaptation strategies, mainly preemptive to crop management, water management, land management, and income diversification, to ensure food security during and after climate change-induced disaster events. Most of these adaptation strategies were adopted for autonomous and reactive reasons and were later supported by different NGOs and government organizations. Support from these institutions for different adaptation strategies is visible in other studies (Islam and Paul 2018), though farmers mostly adopt adaptation options autonomously (Alam et al. 2017; Klenk et al. 2017; Amin et al. 2018).

Farmers' choice of adaptations was found to be influenced by their socio-economic determinants (Asfaw et al. 2019; Islam and Paul 2018; Alam et al. 2017). The age of the farmers correlated to different adaptation strategies; experienced farmers were more likely to adapt to climate change by using saline-tolerant crops, planting crops with short lifespans, homestead gardening, and re-digging canals. Education helped people to understand, cope with, and adapt to adverse climatic conditions. Respondents' educational status thus affected their adaptation strategies; it influenced the use of techniques such as changing crop calendars, enhancing the efficiency of fertilizer use, taking strategies to decrease the salinization of agricultural fields and increased use of supplementary irrigation, and leasing cropland. Farmers who farmed as their primary occupation had a tendency to practice homestead gardening, use supplementary irrigation, construct floating gardens, and lease cropland. Meanwhile, respondents with different secondary occupations were likely to engage in off-farm employment as well as to cultivate saline-tolerant crops. Respondents with off-farm employment were likely to have low farm and high non-farm income, and respondents with high monthly expenditure were likely to use organic fertilizer in their fields.

Loans had a significant influence on choice of adaptation strategies. Respondents who had taken out loans from banks and NGOs were likely to practice crop diversification, introduce new crops, practice crop rotation, and reduce tillage and deep plowing. It was also more likely for respondents with a larger quantity of farmland to use supplementary irrigation, reduced tillage, and deep plowing, as large-scale land needed to be irrigated efficiently and was quite impossible to plow with traditional machinery.

6.1.1 Challenges and opportunities in adaptation to climate change

The household survey shows that each of the respondents adopted a minimum of five adaptation strategies to protect their agriculture production from various climate change-induced events (e.g., heavy rain, drought). According to the respondents, the challenges in adopting these frequently practiced adaptation techniques were factors related to changed climate (e.g., the uncertainty of the rainfall calendar), availability of inputs (e.g., fertilizer, specific seeds, pesticides), lack of irrigation facilities (e.g., high cost, dependence on larger farmers' decisions), lack of profitable crop marketing options, lack of proper knowledge and experience of techniques, and effectiveness of agricultural extension services on adaptation approaches (Table 8). Our study also explored the perceived opportunities in

Table 8 Challenges and opportunities of adaptations to climate change

Challenges	Number of respondents (%)	Opportunities	Number of respondents (%)
Different climatic factors	70%	Economically profitable	65%
Availability of inputs	53%	Minimize environmental stress	57%
Irrigation facilities	45%	High crop production	48%
Marketing problems	41%	Additional income and food source	33%
Lack of experience and knowledge	37%	Sustainable agriculture	21%
Agricultural extension services	30%		

adaptation strategies such as minimizing environmental stress (57%), increasing profitability by protecting crops, and ensuring higher production through proper facilitation of crops (e.g., ensuring soil fertility, incorporating high-yielding varieties), facilitation of additional income and food, and assurance of sustainable agricultural strategies (Table 8).

The main challenge in the climate adaptation strategies was factors related to changed climate conditions. For example, the adopted crop calendar would sometimes fail to align with the actual weather forecast. According to the farmers, pests were highly unpredictable, and pesticides did not always work properly. Moreover, agricultural production was hampered by increased soil salinity level. Net aquaculture and water conservation techniques failed due to untimely floods. The effective adaptation strategies were also challenged by lack of available agricultural inputs such as HYV seeds, pesticides, and fertilizers. Irrigation was somewhat costly, and sometimes farmers depended on larger farmers' decisions about irrigation. Credit facilities were also poor; this has been identified in other studies (Ericksen et al. 1996; Asaduzzman et al. 2005). However, the main benefit that farmers acknowledged from the adoption of climate adaptation strategies was additional economic advantages for families.

6.1.2 Policy implications

Our study is the first attempt to investigate determinants of climate change adaptation and choice of climate change adaptations strategies at a larger spatial scale of the south-west coastal areas in Bangladesh, which is one of the most climate-vulnerable regions in the world. Our multiple findings have notable implications for both researchers and policymakers working on adaptation to climate change. First, the adaptation paradox (e.g., uncertainty of government adaptation strategies to local stakeholder, who experience the climate change locally) must be resolved (Ayers 2011) by planning, implementing, and managing adaptation to climate change on a local level. Although global climate change impacts are experienced locally, national adaptation plans such as the Bangladesh National Adaptation Program of Action (NAPA 2005) and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP 2009) have been designed and implemented without consulting and engaging stakeholders at local level (Alam et al. 2013). The extensive autonomous adoption of adaptations revealed by this study also hints to the fact that the planned adaptations conceptualized in these national adaptation policies have already been partially adopted by local farmers. The strong association shown by this study between experience (both age and farm work experience) and adaptation to climate change (e.g., adapting to temperature change, plantation on highlands, minimization of susceptibility of crops to pests, and adapting crops to saline conditions) implies that experienced farmers' knowledge and experience could be useful in developing the next national adaptation plans in Bangladesh.

Second, the Bangladesh National Adaptation Program of Action (NAPA) has recommended adaptation strategies in a broader context, without incorporating micro-level adaptation techniques into the agricultural sector for different communities. Though credit availability is positively linked to adaptation choices such as crop diversification and rotation and adoption of new crops, national adaptation policies such as BCCSAP have neglected the idea of providing local communities with "climate credit" with very low interest rates. Furthermore, the importance and use of indigenous knowledge and adequate funding for capacity building in adaptation have been excluded from most of the climate policies.

Third, the strong relationship between education and adaptation strategies and choices re-emphasizes the fact that achieving Sustainable Development Goal (SDG) 4: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" is essential in order to meet other SDGs such as SDG 2: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture." However, the fact that only half of the population engaged in agriculture have completed primary education (Hossain et al. 2016a) provides a significant challenge to successful adaptation to climate change and thus the achievement of SDG 2.

Fourth, our study is indicative of the benefits of considering coastal adaptation determinants. Their use would be highly cost-effective (due to asking farmers with age and experience to predict disaster) in many cases, reduce the need for research trials (farmers have experience of introducing new crops), and reduce the disease and pest susceptibilities of crops (farmers can also use their experience to select disease and pest-susceptive crops); this would improve the likelihood that climate adaptations will be successful. Our results also indicate that only rich farmers and farmers with non-farm income can afford organic fertilizer and soil conservation technique. Thus, the availability of these adaptation choices to all farmers through government assistance could help to achieve SDGs and adaptation to climate change at local level.

Fifth, although irrigation from groundwater and use of fertilizer are commonly adopted adaptation choices for coping with prolonged drought and salinity increase, both of these adaptation strategies may degrade soil and environmental quality in the future (Dearing and Hossain 2018; Ahmad et al. 2014; Qureshi et al. 2014). However, the unplanned withdrawal of groundwater for irrigation has not been restricted by any of the adaptation policies.

Sixth, despite this risk of environmental degradation from withdrawing groundwater and applying fertilizer, farmers in the coastal zone of Bangladesh have been successful in adapting to climate change. In particular, their saline-tolerant adaptation strategies and drought resistance coping strategies could be transferrable to other developing countries such as Kenya, where drought has impacted heavily on society and salinity in the groundwater has limited their adaptation strategies. In addition, the way that fertilizer use has boosted agricultural production in Bangladesh could be useful for other developing countries. Locally built embankment and production within a shortened growing season, as well as floating gardens, could provide value-added knowledge of adaptation to climate-vulnerable coastal countries.

Similarly, to many other developing countries, the coastal areas of Bangladesh are managing to adapt to climate change. However, there has been no examination of the limits of farmers' capacity to adapt to climate change and the extent to which these adaptations will be successful. Future studies could also focus on understanding the determinants of farmers' behavior in adapting to climate change. Though our analysis highlights the differences in adaptation strategies in high saline and low saline zones, we limited our understanding on overall adaptation strategies and their determinants using the sample size collected for this study. Future research could consider the social (e.g., urban, rural, poverty) and ecological (e.g., saline, temperature) heterogeneity of adaptation strategies to understand how adaptation strategies vary across social-ecological systems. In general, our study is applicable to areas with similar socio-economic contexts; it provides useful information that can help the developing countries of the world, especially coastal regions, to cope with the changing climate.

7 Conclusion

This study has made a first attempt to investigate farmers' perceptions of climatic change, determinants of climate change adaptation, and choice of climate change adaptations strategies at a larger spatial scale in the south-west coastal zone of Bangladesh.

The results of the study indicate that farmers were well aware of the climate change, though 70% of the respondents did not know the causes of the change. Many farmers had indigenous knowledge that enabled them to predict climate change-induced adverse events. Most had experienced an increase in temperature, total rainfall, change in rainfall pattern, cyclones and storm surges, waterlogged conditions, droughts, and floods in the study area.

Some of the most common adaptation strategies were introduction of new crops, changes in planting and harvesting dates, application of pesticides, increased use of supplementary irrigation, reduced tillage and deep plowing, and leasing cropland. In most cases, they adopted these adaptation strategies for economic benefits.

Farming experience could stimulate adaptation processes. It was shown that the different socio-economic determinants of the farmers were likely to influence their choice of adaptation options for agricultural strategies. The strong linkages between socio-economic determinants and adaptation strategies choice imply that successful achievement of SDGs is essential for successful adaptation to climate change. Resolving the adaptation paradox by engaging local communities in the next national adaptation plan could benefit adaptation strategies at national and local scales. It is notable that farmers adopted those adaptation strategies autonomously instead of taking their lead from the government. The findings of this study could be helpful for adaptation to climate change in other developing countries with similar social-ecological coastal characteristics.

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