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Factors Affecting to Adoption of Climate-smart Agriculture Practices by Coastal Farmers' in Bangladesh

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Abstract

Climate change is projected to have serious environmental, economic, and social impacts on coastal farmers whose livelihood almost depends on nature. This study examines the perception of coastal farmers about climate change and determines the barriers of adoption of climate-smart agriculture practices to adopt the changing climate. Data was collected in January to March of 2018 from 160 randomly selected farmers in four villages of Kalapara sub-district in Patuakhali Bangladesh. A pretested interview schedule was used to obtain data from the farmers. Key informant interviews and focus group discussions were also performed to collect supplementary information from the extension officers and farmers. A binary logistic model was used to assess the determinants of adaptations strategies practiced by the farmers in response to climate change. Results revealed that farmers mainly perform 15 CSA practices to cope with the effects of climate change, such as salinity, floods, cyclones, storm surge, and droughts. The practices are saline tolerant varieties, submergence-tolerant varieties, drought-resistant varieties, an early variety of rice, *Sorjan* method, pond side vegetable cultivation, watermelon cultivation, sunflower cultivation, plum cultivation, relay cropping, urea deep placement, organic fertilizer, mulching, rainwater harvesting, and seed storage in plastic bags. Results from the logit model indicate that farmer's level of education, occupation, family size, cultivated farm size, farming experience, cattle ownership, annual income, market difficulty, access to farm information, training experience, organization affiliation, and perception of climate change, all affect farmers' selection of adaptation strategies for climate change. This study provides direction for policymakers in order to strengthen the adaptation strategies of farmers and guide policies accordingly. These strategies have the potential to minimize the adverse effects of climate change.

Keywords

Adaptation, Bangladesh, Climate Change, Perception, Smart Agriculture

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1. Introduction

Climate change is projected to have serious impacts on different sectors of Bangladesh's economy especially the agricultural sector, with coastal farmers heavily affected since they depend largely on nature for their livelihood. Agriculture and food security are the key sectors for intervention to cope with climate change. Climate change is not a predicted threat anymore; it has already begun to adversely impact livelihoods [1]. It is closely link to crop production, food security, and climate smart agriculture (CSA) [2]. Increased temperature and changes in rainfall

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directly hamper the agriculture production and shrink the scope for food security [3]. Coastal farming is more challenging due to tidal cyclones and soil salinity. Climate change brings droughts and floods making the land unsuitable for agriculture production. The CSA provide options for production, processing, storage, and marketing under the threat of climate change [4].

Climate change is projected to have serious environmental, economic, and social impacts on Bangladesh, particularly on coastal farmers [5]. The extent of these impacts depends largely on awareness and the level of adaptation in response to climate change. It is evident that, Bangladesh is one of the most vulnerable countries to climate change, through the country contributes little to global warming which is main reason of climate change [6]. Due to the physiographical location Bangladesh is going to be the worst hit place on the planet from extreme climate events such as floods, droughts, heavy rainfall, tropical cyclones and storm surges [7]. Bangladesh also has extreme climate variability, naturally alternating between seasons of monsoon and winter, and it is dependent on crop agriculture, highly sensitive to changes in climate [8]. Climate change impacts are already occurring, as measured by increasing temperatures, variable rainfall and an increase in climate-related extreme events such as floods, droughts, cyclone, sea level rise, salinity and soil erosion [9]. These extreme climate events occur in Bangladesh almost every year, and sometimes more than once a year, affecting the crop agriculture sector adversely, particularly rice production [10].

Adaptation to climate change is very important if farmers are to counter its potentially unfavourable impacts [11]. Adaptive measures when implemented can protect the livelihoods of poor farmers and ensure food security by reducing the potential negative impacts and reinforcing the advantages associated with climate change [12, 13]. There are a growing number of studies of farm-level adaptation strategies and their determinants [11, 14]. However, adaptation in agriculture varies across countries. Moreover, different adaptation strategies are practiced by farmers depending on the climatic conditions, farm types and other conditions such as political, economic and institutional factors [8, 11].

There are different ways of adapting to climate change in agriculture [12] and different factors affect the use of any of these adaptation methods [15]. For instance, Fosu-Mensah et al. [16] showed that education level of farmers, farm size, land tenure, better access to markets, extension and credit services, technology, farm assets (labour, land and capital) and information about climate change, affect adaptation to climate change. Adaptation to climate change is a two-step process; the first step requires the farmers to perceive a change in climate and the second step requires them to act through adaptation [15]. Studies on the perceptions of climate change both in developing [17, 18, 19] and developed countries [20] show that the majority of populations have already perceived climate change.

The Bangladesh government and NGOs and researchers are trying to mitigate the adverse effects of climate change through dissemination of CSA practices, such as resistant crop varieties, urea deep placement, and vegetable cultivation in floating bed [5]. However, the adoption of these CSA practices at the farmer's level is less explored. The CSA in agriculture that substantially increases productivity, resilience, reduce the emission of greenhouse gases and enhances the food security. For example, conservation of agriculture, a means of CSA, reduces the soil erosion and salt accumulation due to the lower evaporation; and thereby increases the resilience against drought, salinity, and other hazards. The CSA increases the production and income, and improves the adaptive capacity of farmers through crop diversification, and resilient crop varieties and practices [21]. Farmers' responses to climate change effects, as well as use of adaptation strategies, are influenced by their socio-economic characteristics, with knowledge of the farmers being the most influential [15]. The objectives of the study were:-

a) To explore the perceptions of farmers' about climate change;
b) To identify the Climate Smart Agriculture (CSA) practices adopted by the farmers to adapt to climate change; and
c) To determine the attributes of influencing adaptation of smart agriculture practices by the coastal farmers.

2. Methodology

2.1. Study Area and Methods of Data Collection

The study was conducted in the Kalapara upazila (Sub-district) of the patuakhali district which is the closest to the Bay of Bengal. The study area has been selected based on the expected fair representation of coastal farmers who have been experiencing the coastal extreme climatic events, such as, salinity, coastal flooding, tidal surges, and cyclones and their involvement with farming activities. A household survey was conducted in January-March 2018 where 160 farmers were randomly sampled from four farming communities (Mithaganj, Khaprabhanga, Latachapli, and Dhulasar) (Figure 1) using the random sampling method. Pretested semi-structured interview schedule has been used to collect data through face-to-face personal interview. The respondents were Bengali speaking people, and accordingly, the interview schedule was translated into Bengali. The interview schedule was pretested with 15 respondents from the sampling frame. Necessary modifications and correction were done based on pre-test experience. Length of interview schedule was calibrated with the willingness of the respondents to spent time and the extent of the information needed for the research. Each of the interviews required about one hour. Data was also collected from the farmers through focus group discussion during January-March 2018. In addition to, key informant interviews was conducted. The participants of KII were agriculture officers from the department of agriculture extension who have been working to disseminate Climate Smart Agriculture (CSA) practices among the farmers. A total 15 FGD and 12 KII was conducted. At the end of each of the interviews, spot editing of the collected information was done to check if there any missing information, blank items or need to further clarification.

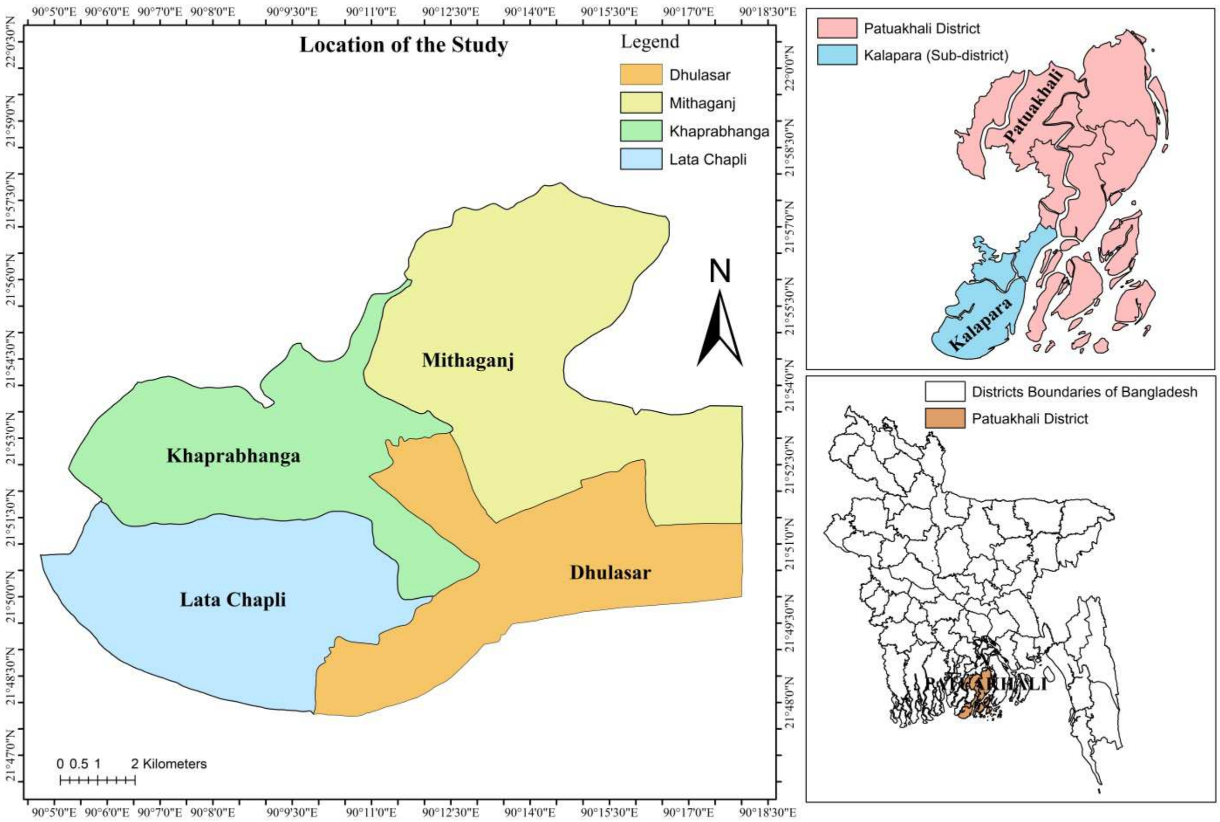

Figure 1. Study Location.

2.2. Hypotheses of Explanatory Variables

The dependent variables in this study is Climate Smart Agriculture (CSA) Adaptation, while the explanatory variables are based on available data that include: household characteristics (the level of education, occupation, family size, income of the household), years of faming experience, cultivated farm size, markets difficulty, access to farm information, cattle ownership, training experience, organization affiliation, and perception of climate change. The independent variables and climate-smart agricultural practices were defined based on Hasan et al. [22] and Hasan and Kumar [23]. The hypotheses explaining how explanatory variables influence the adoption of CSA to climate change.

2.3. Calculation of Adaptation Strategy Index

To identify those adaptive strategies this held relative importance over others an adaptation index procedure was implemented, as measured by the formula presented below (1). Farmers were asked to assess different adaptation strategies by using the four-point rating scale described to rate the importance of each strategy to their agricultural enterprises. The relative importance of adaptation strategies to climate change was calculated based on the following index formula.

$$ASI = ASn \times 0 + ASl \times 1 + ASm \times 2 + ASh \times 3 \quad (1)$$

Where,

ASI = Adaptation Strategy Index.

ASn = Frequency of farmers rating adaptation strategy as having no importance.

ASl = Frequency of farmers rating adaptation strategy as having low importance.

ASm = Frequency of farmers rating adaptation strategy as having moderate importance.

ASh = Frequency of farmers rating adaptation strategy as having high importance.

2.4. Data Analysis

The collected data was entered into Microsoft Excel spreadsheet according to the code instruction provided in the interview schedule. All the information collected from the farmers was reordered under different variables along with the different columns of the spreadsheet, and different cases were recorded along the different rows. Data was processed using Microsoft Excel program to calculate and convert the values of different variables. However, data was analysis using statistical software SPSS (Version 22.0). In order to determine the attributes influencing the adoption of CSA practices and to estimate the effect of the adoption taking into account the farmers' characteristics, two regression models were specified. The average adaptation of CSA practices and personal attributes of farmers were modelled using multiple regressions. On the other hand, adoption of individual CSA practices were considered as binary variables and modelled was formulated as binary logistic regression.

3. Results

The majority of the farmers (106) are already informed about climate change (Table 1). The farmers understand the climate change by different indicators. For instance, 24 farmers understand the climate is changing by increased temperature, 22 by increased salinity level, 19 by increased the occurrences of cyclones, 16 by long summer season.

Table 1. Farmers' perception of Climate Change.

Category	Number of Farmers	Total
Informed about Climate Change	126	160
Not-informed about Climate Change	34	
Increased Temperature	24	126
Unpredictable Rainfall	14	
Occurrence of drought	5	
Occurrence of flood	8	
Occurrence of cyclones	19	
Increased Salinity level	22	
Short winter season	8	
Long summer season	16	
Changes of monsoon season	10	

3.1. Climate Smart Adaptation (CSA) Strategy Practices to Adopt the Effect of Climate Change

The ranking of different adaptation strategies to climate change, as identified by the surveyed farmers, are presented in Table 2. Out of 15 adaptation strategies, seed storage plastic bag/Glass bottle was ranked first and thus most important, among farmers' adaptive strategies to climate change. Vegetable cultivation by pond side was identified as the second-ranked adaption strategy. The third most important adaptation strategy was the sunflower cultivation. The drought tolerant variety cultivation was the least important adaptation strategy.

3.2. Effects of Farmers' Attributes on the Adoption of CSA

Adoptions of selected CSA practices by the farmers were influenced by their socio-economic personal characteristics. Twelve characteristics of the farmers have been used as explanatory variables of adoption of CSA. The explanatory variables have been selected for multiple regressions considering the expected importance to explain the dependent variables. Estimates of the multiple linear regressions show that adoptions of CSA practices are determined by the occupation, annual income, access to farm information, and training experience (Table 3). Occupation significantly predicted the adoption rate of CSA practices. Occupation was measured as farming (rice cultivation, vegetable growing, cattle rearing, poultry rearing, and fish culture) and non-farming (services, wage labour, business, and micro-enterprise). Income of the farmers significantly predicted the adoption rate of CSA practises. Access to farm information related to crop production and plant protection is another dimension of successful farm operation. There was a significant relationship between access to farm information and CSA adoption rate. It was found that the farmers having larger days of training experience have higher level of adoption of CSA.

The other independent variables, namely personal education, family size, farming experience, cattle ownership, market difficulty, perception of climate change, organization affiliation have not exhibited any significant effect on the overall adoption.

Table 2. Ranked order of the adaptation strategies to climate change.

Adaptation Strategy	High	Medium	Low	No	ASI	Rank
Seed storage plastic bag/Glass bottle	113	13	11	23	376	1
Vegetable cultivation by pond side	118	5	11	26	375	2
Sunflower cultivation	103	27	7	23	370	3
Organic fertilizer/vermicomposte	109	11	13	27	362	4
Rain water harvesting in canal and pond	97	24	8	31	347	5
Relay cropping	76	48	18	18	342	6

Adaptation Strategy	High	Medium	Low	No	ASI	Rank
Submergence tolerant Variety	84	30	12	34	324	7
Early variety of rice crop	92	19	7	42	321	8
Urea deep placement	85	18	6	51	297	9
Plum cultivation	78	18	12	52	282	10
Watermelon cultivation	62	16	10	72	228	11
Mulching	52	27	8	73	218	12
Salinity tolerant Variety	35	40	20	65	205	13
Vegetable cultivation by *Sorjon* method	43	22	14	81	187	14
Drought tolerant Variety	18	32	26	84	144	15

Table 3. Multiple Linear Regression of Adaptation.

Farmers Attributes	Co-efficient	Robust SE
Personal Education	0.003	0.047
Occupation	0.34*	0.19
Family Size	0.001	0.032
Cultivated Farm Size	0.267	0.450
Farming Experience	0.010	0.006
Cattle Ownership	0.006	0.036
Income	-0.177*	0.066
Market Difficulty	0.069	0.080
Access to farm Information	0.31***	0.074
Perception of Climate Change	0.176	0.098
Training experience	-0.001*	0.000
Organization Affiliation	0.010	0.010
Multiple R^2	0.27	
Goodness of fit	F (12, 145) = 4.55*** p = 0.000	

*, **, and *** donate significant at 5%, 1%, and 0.1% Level of Probability.

Tables 4 and 5 shows the marginal effects on the probability of adoption of all 15 CSA practices. In order to have a clear picture of effects of the independent variables on the adoption, we need to disaggregate these CSA practices. In this case, adoption was considered as a dichotomous variable that can take two variables ('1' for adoption and '0' for non-adoption). Thus the adoptions of different CSA practices were regressed using logit model. This model shows that the probability of adoption of different CSA practices does not depend on the same set of independent variables.

Table 4. Marginal effects on the probability of adoption of different CSA practices.

Farmers Attributes	SAL	SUM	DRT	SRJ	REL	UDP	MUL
Personal Education	0.17	-0.27	-0.72*	-0.07	-0.46	-0.14	-0.77*
Occupation	0.78	4.20*	21.25	0.85	4.00*	3.10*	1.30
Family Size	-0.46*	0.07	-0.05	-0.19	-0.07	0.09	-0.57*
Cultivated Farm Size	6.09	4.22	-2.74	-0.80	7.89	1.00	3.05
Farming Experience	0.08*	0.14*	-0.05	0.03	-0.03	0.07	0.02
Cattle Ownership	-0.14	-0.35	0.14	0.42*	-0.51	-0.10	0.22
Income	-1.29*	-1.80*	-0.98*	-0.39	-0.74	-1.09*	-0.08
Market Difficulty	0.52	-0.58	0.43	0.43	-0.86	-0.25	0.12
Access to farm Information	0.82	1.76	1.87*	0.03	2.10	0.45	-0.45
Perception of Climate Change	-0.13	1.06	-0.47	0.68	0.23	1.04	1.31*
Training experience	-0.03***	-0.04*	0.00	0.00	-0.03*	-0.02*	-0.03***
Organization Affiliation	0.02	-0.16	-0.06	0.01	-0.12	0.01	0.03
LR χ^2 (12)	68.41***	93.16***	55.96***	20.14***	41.35***	67.33***	64.14***
Nagelkerke R^2	0.47	0.69	0.39	0.16	0.45	0.49	0.45

*, **, and *** donate significant at 5%, 1%, and 0.1% Level of Probability.

Note: SAL stands for salinity resistant varieties, SUM for submergence tolerant varieties, DRT for drought resistant varieties, SRJ for vegetable cultivation in sorjon method, REL for relay cropping, UDP for urea deep placement, MUL for mulching.

Table 5. Marginal effects on the probability of adoption of different CSA practices.

Farmers Attributes	WTR	SUN	PUM	SEED	OF	MEL	VEG	EVR
Personal Education	-1.35*	-1.00*	-0.35	-1.45	-1.35	-0.04	0.06	-0.19
Occupation	-0.27	1.92	0.60	6.15*	7.96*	0.07	2.03	4.93*
Family Size	-0.09	-0.20	0.10	0.07	0.03	-0.15	0.01	-0.03
Cultivated Farm Size	2.38	-4.50	-4.53	7.14	4.46	0.05	6.74	2.68
Farming Experience	-0.10*	-0.09*	-0.03	0.05	0.22	0.01	0.10	0.10
Cattle Ownership	-0.49	0.01	-0.52	0.03	0.52	-0.45*	-0.48	0.10

Farmers Attributes	WTR	SUN	PUM	SEED	OF	MEL	VEG	EVR
Income	-2.02*	0.73	-0.19*	-3.15	-3.53	-0.92*	-0.35	-1.67*
Market Difficulty	1.65*	-0.90	0.11	-2.96*	0.85	0.17	-1.66	-0.58
Access to farm Information	-0.09	-1.77	0.57	1.64	1.15	0.86	-0.18	1.65
Perception of Climate Change	2.00*	0.96	-0.08	0.40	1.69	-1.03	1.35	1.01
Training experience	-0.01	0.00	-0.01	-0.01	-0.05*	0.00	-0.04***	-0.03*
Organization Affiliation	0.04	-0.02	-0.04	-0.04	-0.01	-0.09	0.12	-0.08
LR χ^2 (12)	59.11***	24.14***	37.00***	76.74***	98.66***	40.28***	53.13***	94.31***
Nagelkerke R^2	0.50	0.25	0.29	0.68	0.79	0.30	0.48	0.66

*, **, and *** donate significant at 5%, 1%, and 0.1% Level of Probability.
Note: WTR stands for rain water harvesting, SUN for sunflower cultivation, PUM for plum cultivation, SEED for seed storage, OF for organic fertilizer, MEL for watermelon cultivation, VEG for vegetable cultivation by pond side, EVR for early variety of crops.

Personal education level has negative effect on the adoption of drought resistant varieties, mulching practices, rain water harvesting, and sunflower cultivation. The farmers whose major occupation is farming had higher probability of adoption of submergence tolerant varieties, relay cropping, urea deep placement, seed storage, organic fertilizer, and early variety of crops. Larger family size of the farmers had the less probability of adoption of salinity tolerant varieties and mulching practices. However, larger cultivated farm size provides greater opportunity to perform CSA practices, but in this research we only considered the smallholder farmers whose cultivated land was small. Farming experience has positive effects on adoption of salinity and submergence tolerant varieties and has negative effects on adoption of rainwater harvesting and sunflower cultivation. Annual household income of the farmers has significant negative effect on the adoption of salinity, submergence, drought tolerant varieties, urea deep placement, rainwater harvesting, plum cultivation, water melon cultivation, and early variety of crops cultivation. Market difficulty has significant positive effects on adoption of rain water harvesting and negative effects on seed storage. However, better access to farm information is crucial for adoption of new technologies and accordingly, drought tolerant varieties have significant positive effects on adoption. On the other hand, perception of climate change does not have significant effect on the overall adoption but it has significant positive on the probability of adoption of mulching and rain water harvesting. Finally, the training experience has significant negative effect on adoption of saline and submergence tolerant varieties, relay cropping, urea deep placement, mulching, organic fertilizer, vegetable cultivation by pond side, and early variety of crop cultivation.

4. Discussion

Farmers should be able to adapt in order to reduce the negative impact of climate change. Adaptation to climate change is a two-step process which requires that farmers perceive climate change in the first step and respond to changes in the second step through adaptation. Different socio-economic and environmental factors affect the abilities to perceive and adapt to climate change. The long-term rise in temperature reported in a number of scientific reports closely conforms to the belief held by most respondents. Similar correlation has been found between the local observations and meteorological records about changes in high tidal water level and salinity. Respondents also reported experiencing climate change in terms of changes in rainfall, cyclonic activates, storm height and wind speed but these are not substantiated by scientific evidence [21, 24]. In the study area the most frequently mentioned climatic characteristics causing risk to life and livelihoods are associated with climate extreme events notably intense heat and increased cyclonic activities; changes in pattern in rainfall characterised by late onset of rainy season and decline in seasonal rainfall; and the impacts of climate change on physical environments such as rising tidal water level and salinity intrusion [25]. It appears that the adverse impacts of climate events on aquaculture play an important role in shaping people's risk perception of climate change although they affect other spheres of life too. The underlying reason of this association is understandable; aquaculture dominates the rural economy in the south-central coastal region and this farming practice is very much sensitive to changes in hydro-climatic conditions [26]. When the required hydro-climate conditions exceed the normal range, farmers experience adverse impacts on fish production. Whether this altered condition is a short-term variability or a long- term change, it appears to local farmers as indicative of climate change [12, 16].

Higher level of education is believed to be associated with access to information on improved technologies and higher productivity [27]. Evidence from various sources indicates that there is a positive relationship between the education level of the household head and the adoption of improved technologies and adaptation to climate change [15, 28]. The findings in this study are consistent with these results. On the contrary, the influence of household size on use of adaptation methods can be seen from two angles. The first assumption is that households with large families may be forced to divert part of the labour force to off-farm activities in an attempt to earn income in order to ease the consumption pressure imposed by a large family. The other assumption is that large family size is normally associated with a higher labour endowment, which would enable a household to accomplish various agricultural tasks. For instance Croppenstedt et al. [29] argue that households with a larger pool of labour are more likely to adopt agricultural technology and use it more intensively because they have fewer labour shortages at peak times. Here it is expected that households with large families are more likely to adapt to climate change. Our results are corroborated with these results. The farmers whose major occupation is farming had higher probability of adoption of CSA. On the other hand, studies on adoption of agricultural technologies indicate that farm size has both negative and positive effects on adoption, showing that the effect of farm size on technology adoption is inconclusive [12]. However, because farm size is associated with greater wealth, it is hypothesized to increase adaptation to climate change. Farm size increases the chances of adopting different crop varieties as opposed to a no adaptation strategy. The positive effects of farm size on adopting different adaptation strategies found from this study are consistent with other studies [13]. The farmers having larger cultivated farm size have higher level of adoption, because they have higher opportunity to apply CSA practices in their fields. In other studies, it was also found that farm size or cultivated land has positive effect on adoption of climate-smart technology. The level of farming experience of the head of the household increases the possibility of undertaking different adaptation strategies, since experienced farmers are knowledgeable and better informed on climate change [15]. Various studies shows a strong positive relationship between access to information and the adoption behaviour of farmers and that access to information through extension increases the likelihood of adapting to climate change. These findings are consistent with several other research works [30, 31]. The market difficulty reduces the adoption of CSA because most of the farmers reported that they have not got better access to input and output markets. Better perception of climate change demonstrates better understanding of the causes, consequences, effect of and adaption to climate change. When farmers understand that their soil is becoming saline, they try to find suitable agriculture practices that can cope with soil fertility. Then they try to grow saline tolerant crops and practice vegetable cultivation in *sorjon* methods. When they can understand that their lands may not be usable throughout the year due to cyclonic storms, they try to increase cropping intensity through relay cropping, so they can harvest before the probable time of cyclones. When they can understand that chemical fertilizers harmful for environment, they try to reduce the use of those agrochemicals and increase the use of organic fertilizers.

5. Conclusions

The coastal area of Bangladesh is frequently hit by extreme climatic events, such as cyclones, storm surge, droughts, and salinity. The DAE, NGOs, and researchers are trying to disseminate CSA along the coastal farmers to cope with these climatic effects. The present research has been carried out to assess the CSA practices adopted by coastal farmers and determine the factors influencing the adoption of CSA practices. The coastal farmers understand that the climate is changing, and they adopt different CSA practices to cope with climate change. The majority of farmers have better perception of climate change and the adaptation options. This study has identified 15 different CSA practices that have been adopted by the coastal farmers. These practices include saline tolerant varieties, submergence-tolerant varieties, drought-resistant varieties, an early variety of rice, *sorjan* method, pond side vegetable cultivation, watermelon cultivation, sunflower cultivation, plum cultivation, relay cropping, urea deep placement, organic fertilizer, mulching, rainwater harvesting, and seed storage in plastic bags. Among the all CSA practices adoption of seed storage in plastic bag/Glass bottle, vegetable cultivation by pond side, and sunflower cultivation are more promising. The results of logit specify the farmers level of education, occupation, family size, cultivated farm size, farming experience, cattle ownership, annual income, market difficulty, access to farm information, training experience, organization affiliation, and perception of climate change, all have a statistically significant impact on the different adaptation strategies. These significant variables are expected to enhance farmers' adaptive capacities which have potential policy implications. The present study has emphasized only crop sector of the CSA practices. Future research will be incorporated livestock, fisheries, and forestry sector in the CSA to have accurate effect of adoption of CSA.

Conflicts of Interest

The authors declare no conflict of interest.

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