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Adoption of climate-smart agriculture in the coastal area of Bangladesh

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ABSTRACT

Adopting climate-smart agriculture in the coastal area of Bangladesh faces challenges, as well as farmers' vulnerability to frequent natural disasters and salinity intrusion. The main aims of this study were to assess the extent of CSA technologies adopted by the farmers and to explore the contributions of the selected characteristics of the coastal farmers to the adoption of CSA. An interview schedule was used to collect data from 354 coastal farmers of three districts, namely Satkhira, Khulna, and Bagerhat, through a 'Multistage random sampling method' in 2022. Both inferential and descriptive statistics were used. A complete model multiple regression analysis was used to investigate how the predictor variables affected the outcome variables. Results indicate that about 57.91% of the coastal farmers had medium adoption, followed by 22.88% high and 19.21% poor adoption of CSA. Out of the 19 identified CSA technologies, "the use of thread pipe/plastic pipe for irrigation" ranked first and indicated the highest extent of adoption by the coastal farmers. Farmers' annual agricultural income, extension contact, training exposure, knowledge of CSA, and attitude towards CSA significantly positively contributes to their adoption of CSA. Extension services, community-based training, and awareness campaigns can play a vital role in escalating farmers' adoption of CSA. Therefore, addressing climate change and building climate resilience in agriculture requires practical support to enable farmers to adopt and sustain CSA.

Keywords: Adoption, CSA, Coastal farmers, Extension service

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Introduction

The 147 upazilas (sub-districts) of 19 districts that comprise Bangladesh's coastal zone are used for forestry, shrimp and fish farming, agriculture, and other purposes. These upazilas account for roughly 70% of the country's paddy-cropped area and about 16% of its total rice production (Huq *et al.*, 2005). It encompasses 28% of Bangladesh's total population and 32% of its land area (Islam, 2004). Tropical cyclones that cause flooding and the resulting saltwater intrusion are becoming more frequent in these areas (Roy *et al.*, 2019). Some degree of soil salinity, ranging from very slight (0.328 million hectares) to very strong (0.101 million hectares), already affects about 62% of coastal land (1.06 million out of 1.70 million hectares) (FAO, 2012). Before 2050, it is predicted that higher soil and water salinity will reduce high-yielding rice varieties' yield by 15.6% (Dasgupta *et al.*, 2014). Among the occupational groups, the incidence of poverty is the highest among agriculture labourers. Their wages are low and employment is also not regular because of the seasonal character of agriculture. The effects of coastal hazards have been reducing these areas' potential, which has raised national and international concerns about the need to protect coastal agriculture by implementing various initiatives, including creating the Master Plan for the Southern Agricultural Development (MoA and FAO, 2013).

Agricultural systems will need to undergo drastic changes to address climate challenges. In a global scale, these systems must become more robust and efficient. In order to produce more food sustainably, they must increase their resource efficiency (using less land, water, and inputs) and fortitude in the face of shocks and changes. In this context, FAO has proposed the idea of climate-smart agriculture (CSA) as a way forward for food security in a changing climate. CSA aims to improve food security, help communities adapt to climate change and contribute to climate change mitigation by adopting suitable technology, creating institutions and policies that facilitate it, and raising the necessary funds (Mahashin and Roy, 2018). CSA is a strategy for changing and refocusing agricultural development in light of the new climate change realities (Lipper *et al.*, 2014). According to FAO (2013), CSA is "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces and/ or removes greenhouse gases (mitigation) where possible, and enhances achievement of national food security and development goals". According to these definitions, the main objective of CSA is food security and development (Lipper *et al.*, 2014; FAO, 2013), and the three interconnected pillars required to achieve this goal are productivity, adaptation, and mitigation.

However, farmers have been facing several problems in continuing agricultural production. In the field level, they need to adopt appropriate CSA technologies to ensure crop production because they have no other alternatives to cope with adverse climatic conditions. Already, a number of CSA technologies, such as salinity-tolerant HYV variety of crops (e.g., BRRI dhan 47, BRRI dhan 61, etc.), submergence-tolerant HYV variety of crops (e.g., BRRI dhan 51, BRRI dhan 52 etc.), rainwater harvesting, thread/plastic pipe for irrigation, mulching, ridge plantation, etc., have been used by the farmers of the coastal regions. Farmers have been using agricultural technologies to different degrees in their production systems. Mia (2005) found that 32% of vegetable farmers used IPM practices frequently, 63% used them moderately, and 5% used them rarely. Again, Mandal *et al.* (2016) found that only 16.38% of the respondents had high adoption of improved farm practices, 62.93% had adoption, and 20.69 % had low adoption of improved farm practices in their rice cultivation. If the extent of CSA adoption and associated information can be known, necessary interventions can be taken to reduce vulnerability and improve the situation. This study is thus carried out for the following objectives: assessing the extent of adoption of CSA, describing selected characteristics of the coastal farmers, and investigating how these characteristics contributed to their adoption of CSA.

Methodology

Study area

The study was conducted in three coastal upazilas (sub-districts): *Tala, Dacope,* and *Morrelgonj,* under the districts of Satkhira, Khulna, and Bagerhat, respectively. Table 1 provides basic information on the research area, including the agroecological zone (AEZ), region, population, literacy rate, important crops, etc. (BBS, 2013).

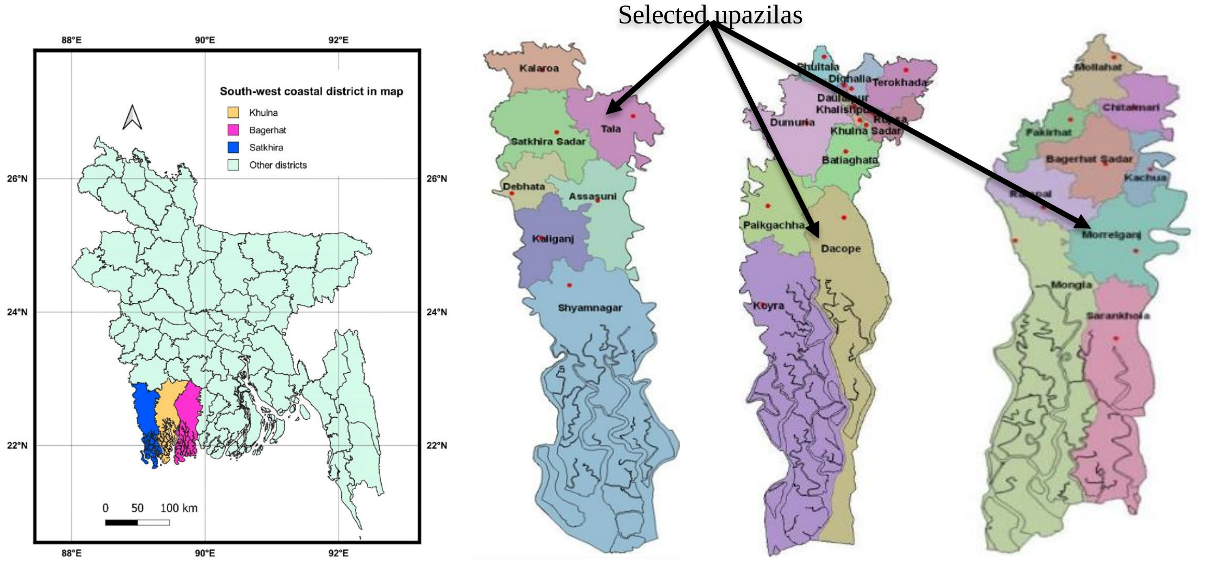

Fig. 1. Left side: Bangladesh map showing its administrative districts. Right side: maps of Satkhira, Khulna, and Bagerhat districts indicating the chosen upazilas, namely, *Tala, Dacope* and *Morrelgonj,* respectively.

Table 1. Basic information on the study area.

Study area	AEZ	Area (km^2)	Population (000)	Literacy	Major crops	Operated land area (acre)	Cropping intensity
Morrelgonj, Bagerhat	13	460.90	295	60.7%	Rice, Potato, sugarcane	79618	132
Dacope, Khulna	13	991.58	152	56%	Rice, Pea Watermelon, Potato, mustard	44497	114
Tala, Satkhira	11	344.15	300	50.9%	Rice, Jute, Wheat, Potato, Mustard	64939	198

Population and sample of the study

Three districts, namely Satkhira, Khulna, and Bagerhat, were purposively chosen out of Bangladesh's 19 coastal districts as the study area. Nine villages from these three districts were selected following a multistage random sampling method. From the nine selected villages, a total of 4489 farm households were identified; these were regarded as the population of the study. Because of differences in the number of farmers in each village, a "proportionate random sampling" technique was employed from each site, and 354 people made up the sample. In order to create a representative sample from the population, Kothari's formula (2004) was utilized.

$n = [Z^2 P QN] / [(N-1) e^2 + Z^2 P Q]$
Where, n = Sample size
Z = Table value at 1 d.f. (1.96)
P = Probability (assume 0.5)
Q = Remaining from probability (1-P) = 0.5
N = Total population = 4489
e = The level of precision (5%)

The sample size was calculated by entering the values in the formula above as follows-

$$n = \frac{Z^2 PQN}{(N-1)e^2 + Z^2 PQ}$$

$$n = \frac{(1.96)^2 \times 0.5 \times 0.5 \times 4489}{(4489-1) \times (0.05)^2 + (1.96)^2 \times 0.5 \times 0.5}$$

$$n = 353.95 \approx 354$$

Variables and instruments for data collection

An interview schedule was used to collect data from 354 coastal farmers in 2022. The main focus of this study was the adoption of climate-smart agriculture, which was regarded as the dependent variable. The independent variables included age, education, farm size, annual agricultural income, farming experience, extension contact, training exposure, innovativeness, credit availability, decision-making ability, knowledge of CSA, and attitude towards CSA.

Measurement of the variables

Measurement of adoption of CSA: A four-point rating scale was used for each of the CSA technologies to assess the extent of CSA adoption by the farmers. The respondents chose an acceptable response from four options, including "frequently," "occasionally," "rarely," and "never," to reflect their adoption of specific CSA technologies. The four responses above received scores of 3, 2, 1, and 0 in that order. Thus, respondents' adoption scores for CSA technologies may vary from 0 to 57, with 0 denoting no practice and 57 denoting frequent use of various CSA technologies in the workplace.

Furthermore, an attempt was made to compare the relative use of different technologies and calculate the "extent of adoption of CSA" score for each of the 354 respondents. To achieve this goal, a CSA technologies adoption index (CSAAI) was created using the formula below-

$$CSAAI = N_1 \times 3 + N_2 \times 2 + N_3 \times 1 + N_4 \times 0$$

Where,

CSAAI = CSA technologies Adoption Index
N_1 = Number of farmers used CSA technologies frequently
N_2 = Number of farmers used CSA technologies occasionally
N_3 = Number of farmers used CSA technologies rarely
N_4 = Number of farmers never used CSA technologies
Each CSA practice may have a CSAAI between 0 and 1062.

Furthermore, to determine the extent of adoption of CSA practices by the coastal farmers, the term 'Relative adoption' has been used based on Adoption quotient. The adoption quotient is a ratio scale used to measure an individual's adoption behavior (Chattopadhyay, 1963). Because it incorporates all of the associated ideas, such as potentiality, extent, time consistency, and weighting, the adoption quotient technique is more accurate. The relative adoption (A_R) scale has been developed by modifying the adoption quotient (AQ).

The following formula has been used to compute relative adoption (A_R)-

$$\text{Relative Adoption} = \frac{\text{Mean score of Adoption}}{\text{Possible highest score of adoption}} \times 100$$

$A_R = (A_{ms} \div A_{phs}) \times 100$

The A_R value could range from 0-100. A_R value 100 is only possible when the 'mean score of adoption' (A_{ms}) and 'possible highest score of adoption' (A_{phs}) become the same. When all the respondent farmers use the CSA technologies frequently, the values of A_{ms} and A_{phs} become the same. Because in that case, the adoption score of all the farmers becomes the maximum possible score, and there is no possibility of variation in score among the respondent farmers. In this situation, it can be said that the technologies are fully adopted by the farmers and the programme is quite successful. So, A_R can be a measure of adoption that indicates the degree to which farmers in a community are practicing the technology; also it may be an indicator of adoption by which we can easily understand the success of a programme that the technology was disseminated and intended to be adopted by the farmers. Thus, it will help the government and policymakers to take further action.

Measurement of independent variables

Table 2 below provides the independent variable measurement process based on earlier research, such as Mia *et al.* (2023).

Table 2. Measurement of independent variables.

Variables	Measurement
Age	Actual years from his/her birth to the time of the interview
Education	Number of years spent in school
Farm size	Total area under cultivation in hectares, including fishing and gardening
Annual agricultural income	Total income from farming per year
Farming experience	How many years a farmer has been farming
Extension contact	A respondent's overall scores on the type and frequency of 14 chosen extension media
Training exposure	The total number of days a responder spent participating in various agricultural and climate-smart agriculture-related training programmes
Innovativeness	Respondent farmers scored 5, 4, 3, 2, and 1 for innovators, early adopters, early majority, late majority, and laggards, respectively.
Credit availability	Percentage of the loan amount obtained compared to the amount requested
Knowledge on CSA	The sum of a respondent's scores from a series of 20 CSA-related questions
Attitude towards CSA	A respondent's overall score was derived from 18 CSA-related statements, each with a 5-point rating scale.
Decision-making ability	The score derived from the six chosen items on a 3-point rating scale

Data entry and analysis

The data from each interview schedule were coded, tabulated, and examined in line with the study's objectives. Tools for data checking, such as multi-collinearity removal and outlier checking, were used. The Pearson product-moment correlation test initially revealed no significant correlation ($r > 0.8$) between two or more regression model predictors. The SPSS software, version 21, was used to conduct the analysis. Mean, standard deviation (SD), range, numbers, and percentage distribution were all used in descriptive analysis. The contribution of predictor variables to the outcome variable was determined using full model multiple regression analysis.

Results and Discussion

Adoption of CSA

Adoption score of CSA was observed from 20 to 36 against a possible range of 0 to 57. The coastal farmers were divided into three groups based on their adoption scores: "poor adoption," "medium adoption," and "high adoption" (Table 3).

Table 3. Distribution of the farmers according to their practice of CSA.

Categories	Number	Percent	Mean	SD
Poor adoption	68	19.21	28.47	5.19
Medium adoption	205	57.91		
High adoption	81	22.88		
Total	354	100.00		

According to the findings, 57.91% of coastal farmers adopted CSA at a medium rate, followed by high adoption (22.88%) and poor adoption (19.21%). This indicates that most farmers (77.12%) have poor to medium adoption of CSA. This group requires additional attention to CSA because poor adoption suggests a weak agricultural producing environment. Similar findings were made by Mia *et al.* (2013) that the majority of vegetable growers (63%) also used IPM practices to a medium degree.

Relative adoption

Relative adoption (A_R) has been calculated by the following formula-

$$\text{Relative Adoption} = \frac{\text{Mean score of Adoption}}{\text{Possible highest score of adoption}} \times 100 = \frac{28.47}{57} \times 100$$

= 49.94

The coastal farmers' relative adoption might be between 0 and 100, with 100 denoting the highest adoption and 0 denoting no adoption. The higher value of relative adoption indicates the greater adoption of CSA practices. Therefore, it can be said that the coastal farmers had medium relative adoption; i.e., adoption was almost 50% done.

Comparison of the extent of selected CSA practices adoption

It's noteworthy to notice that coastal farmers were the ones who mostly embraced water-smart agriculture technologies. The combination of "best-fit" water management techniques that improve water availability, access, and the efficacy, efficiency, and equity of water distribution and usage is known as "water-smart agriculture" (Nicol *et al.,* 2015). Water-smart agricultural technologies made up the top six technologies in the ranking. Water scarcity during the dry season and rising soil and water salinity may be the cause of this, which is impeding crop production in the coastal regions.

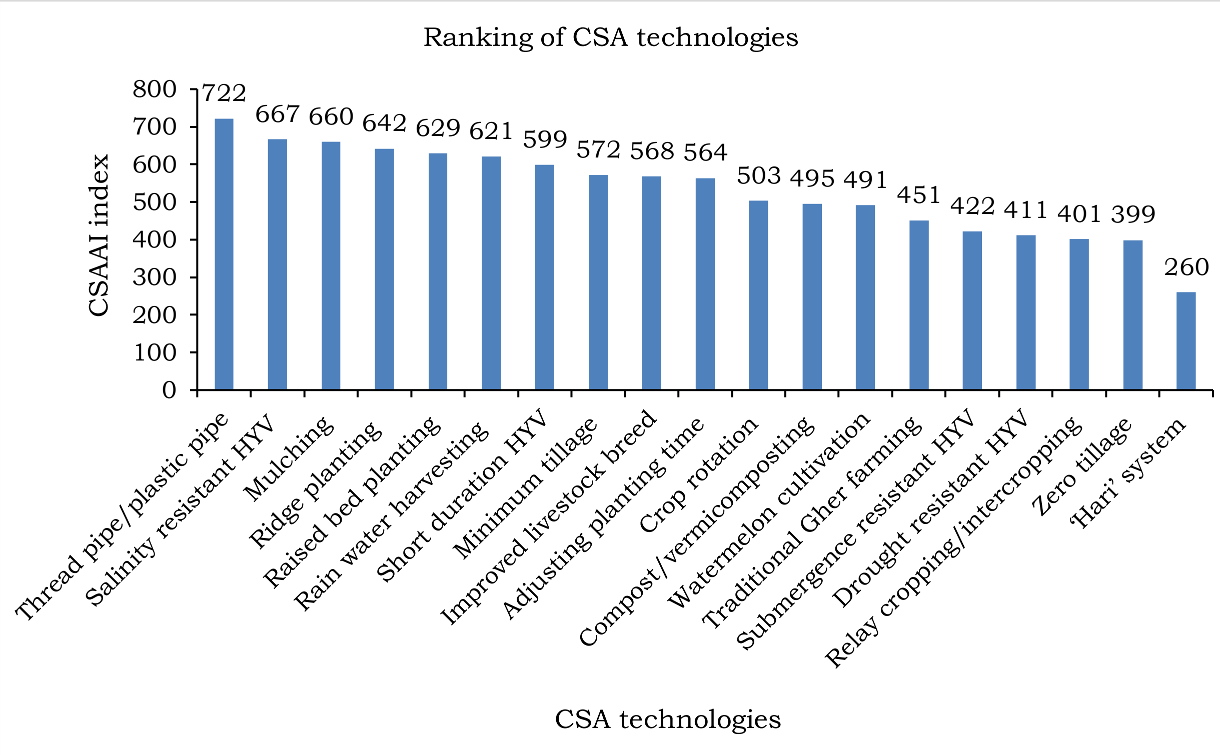

Fig. 2. Comparison of the CSA technology that the responding farmers have adopted.

Out of the 19 CSA technologies, "using thread pipe/plastic pipe for irrigation" came in top place and showed the highest level of acceptance by coastal farmers. The reasons for this are as follows: i) the majority of the land needs irrigation, and plastic pipe is less expensive than concrete irrigation channels; ii) it is temporarily installed on the land and is easily transportable due to its light weight; and iii) water loss is far lower than with earthen channels. "Cultivation of salinity-resistant and HYV crop varieties" ranked second in the ranking order. Due to the rising saltwater intrusion and salt concentration, farmers were forced to adopt HYV cultivars that are resistant to salinity. The third was "mulching" since the local extension office encouraged them to do so to maintain soil moisture easily and because mulch (such as water hyacinth, straw, etc.) is readily available there. The 4th was 'ridge planting (bank of pond/gher/in ails)'. In many places, rising salinity and water stagnation are causing a progressive decline in arable land. In order to grow vegetables, the farmers attempted to exploit areas that are often uncultivated, such as banks of a pond or the *gher* (a large and shallow water body usually used for aquaculture) and the ails between lands. The "*hari system* (rice cultivation in dry season and aquaculture in rainy season in the same land of low-lying areas)" and "*zero tillage*," on the other hand, came in last on the list since fewer lands were appropriate for implementing these two technologies.

Selected characteristics of the coastal farmers

About half of the respondents (50.56%) had poor annual agricultural incomes, with some earning up to Tk. 150000 annually (Table 4). Medium-income farmers (40.68%) came next, and high-income farmers (8.76%) made up the smallest percentage. Mia *et al.* (2013) found similar result that nearly half (44%) of the vegetable growers had low annual income, 47% had medium income and only 9% had high annual income. Medium extension contact was most common among farmers (68.64%), followed by low media contact (17.51%) and high media contact (13.85%). Mandal *et al.* (2016) found the almost similar result that the majority (52.59%) of the farmers had medium extension contact. Approximately 73.45% of coastal farmers had no training, whereas 20.06%, 3.95%, and 2.54% received low, medium, and high training. Training improves one's knowledge and abilities, which may inspire individuals to adopt agricultural technologies. Nevertheless, the vast majority of farmers along the shore lacked training. The majority of farmers (75.14%) had a medium level of CSA knowledge, followed by 14.13% with a little knowledge and 10.73% with good knowledge. The largest percentage of farmers (61.01%) had a moderately positive attitude toward CSA, whereas 18.65% and 20.34% had low and highly positive attitudes, respectively.

Table 4. Salient features of the selected characteristics of the farmers (n=354).

Characteristics	Measuring unit	Range		Categories	Number	Percent	Mean	SD
		Possible	Observed					
Age	Years	Unknown	27-68	Young (<40)	76	21.47	48.42	9.97
				Middle-aged (40 to 59)	220	62.15		
				Old (> 59)	58	16.38		
Education	Year of schooling	Unknown	0-15	Illiterate (0-0.5)	45	12.71	7.53	3.51
				Primary education (1-5)	71	20.06		
				Secondary education (6-10)	210	59.32		
				Higher secondary education (11-12)	19	5.37		
				Tertiary education (>12)	9	2.54		
Farm size	Score	1-5	2-5	Marginal farmer (0.021-0.2)	36	10.20	3.26	0.73
				Small farmer (0.21-1.0)	214	60.5		
				Medium farmer (1.01-3.0)	80	22.6		
				Large farmer (> 3.0)	24	6.8		
Annual agricultural income	Score	1-10	1-10	Low-income farmer (<150)	179	50.56	3.94	1.85
				Medium income farmer (151-300)	144	40.68		
				High income farmer (>300)	31	8.76		
Farming experience	Year	Unknown	10-50	Low experienced farmer (<15)	65	18.36	24.60	9.9
				Medium experienced farmer (15-35)	247	69.77		
				High experienced farmer (>35)	42	11.87		

Extension media contact	Score	0-42	15-31	Low contact farmer (< 18)	62	17.51	23.13	4.66
				Medium contact farmer (18-28)	243	68.64		
				High contact farmer (>28)	49	13.85		
Training exposure	No. of days	Unknown	0-7	No trained farmer (0)	260	73.45	0.61	1.26
				Low trained farmer (1-2)	71	20.06		
				Medium trained farmer (3-4)	14	3.95		
				High trained farmer (>4)	9	2.54		
Innovativeness	Score	1-5	1-5	Innovator (5)	39	11.03	3.39	0.92
				Early adopter (4)	122	34.46		
				Early majority (3)	140	39.54		
				Late majority (2)	45	12.71		
				Laggard (1)	8	2.26		
Credit availability	Score	0-100	0-83	No credit farmer (0)	288	81.36	9.84	21.16
				Low credit farmer (<50)	18	5.08		
				Medium credit farmer (50-70)	43	12.15		
				High credit farmer (>70)	5	1.41		
Decision making ability	Score	6-18	11-17	Low decision making (<12)	39	11.02	13.76	1.77
				Medium decision making (12-15)	246	69.49		
				High decision making (>15)	69	19.49		
Knowledge on CSA	Score	0-40	17-32	Little knowledge (up to 20)	50	14.13	25.45	3.86
				Medium knowledge (>20-30)	266	75.14		
				Good knowledge (>30)	38	10.73		
Attitude towards CSA	Score	0-72	35-57	Low positive attitude (<44)	66	18.65	49.16	5.36
				Moderately positive attitude (44-54)	216	61.01		
				Highly positive attitude (54<)	72	20.34		

Source: Mia et al. (2024)

Contribution of selected characteristics of the farmers to their adoption of CSA

The results of a complete model multiple regression analysis on the adoption of CSA with 12 independent variables are described in Table 5. The R^2 value (0.551) indicates that all of the 12 variables were responsible for 55.1% of the variation in adoption of CSA in the coastal area of Bangladesh. Below is the regression equation that was thus determined-

$$Y = b_0 + b_4X_4 + b_6X_6 + b_7X_7 + b_{11}X_{11} + b_{12}X_{12} + E$$

Or,

$$Y = -0.264 + 0.443X_4 + 0.212X_6 + 0.314X_7 + 0.332X_{11} + 0.442X_{12}$$

i.e., Adoption of CSA = -0.264 + 0.443 (annual agricultural income) + 0.212 (extension contact) + 0.314 (training exposure) + 0.332 (knowledge on CSA) + 0.442 (attitude towards CSA)

For increasing every 1 score (1 score = Tk.50000) of annual agricultural income, an extra 0.443 adoption score was obtained. For increasing every 1 score of extension contact, an additional 0.212 adoption score was obtained. Respondents will embrace CSA more if they frequently employ extension media and contact. According to Mia *et al.* (2013), farmers' adoption of IPM practices was positively and significantly correlated with their annual income and extension contact. An adoption score of 0.314 was raised for each additional training day. An additional 0.332 adoption score was attained for each increase in CSA knowledge score. Islam *et al.* (2023) found a similar result that the adoption of rice production technology was significantly correlated with knowledge of IPM. An additional 0.442 adoption score was attained for each increase in attitude towards CSA. Kamal *et al.* (2018) found that farmers' adoption of IPM practices was positively and significantly correlated with their exposure to training and attitude toward IPM practices.

Table 5. Contribution of selected characteristics of the farmers to their adoption of CSA.

Variable entered	'b' Value	Value of 't' (with probability level)
Age (X_1)	-0.048	-1.478 (0.140)
Education (X_2)	-0.026	-0.361(0.718)
Farm size (X_3)	-0.203	-0.514 (0.608)
Annual agricultural income (X_4)	0.443**	2.817 (0.005)
Farming Experience (X_5)	-0.012	-0.339 (0.735)
Extension contact (X_6)	0.212**	3.977 (0.000)
Training exposure (X_7)	0.314*	2.284 (0.023)
Innovativeness (X_8)	- 0.279	-1.239 (0.216)
Credit availability (X_9)	-0.015	-1.714 (0.087)
Decision making ability(X_{10})	-0.282	-1.945 (0.053)
Knowledge on CSA (X_{11})	0.332**	4.723 (0.000)
Attitude towards CSA (X_{12})	0.442**	9.960 (0.000)
Multiple R = 0.742, R-square = 0.551, Adjusted R-square = 0.535, F-ratio = 34.885 at 0.000 level of significance, Standard error of estimate = 3.53792, Constant = -0.264		

**Significant at 0.05 Level, **Significant at 0.001 Level*

Conclusion and Recommendations

Coastal farmers are using a good number of CSA technologies to cope with up changing climate. The majority (57.91%) of the coastal farmers had a medium adoption of CSA. Relative adoption indicates that almost fifty percent of CSA adoption was done in the study area. Among 19 identified CSA technologies most commonly used technology was "using of thread pipe/plastic pipe for irrigation" due to its availability, low cost and ease of use. Wider implementation of CSA and improvement of livelihood require capacity building and growing resilience against climate change. Farmers' annual agricultural income, extension contact, training exposure, knowledge and attitude are the most considered factors for full implementation of CSA. In light of the study's findings, the following suggestions can be made-

- To increase adoption of CSA, farmers' agricultural income needed to be increased by ensuring price of agricultural products, reducing input cost of production, providing subsidies or other forms of financial assistance; the number of extension media and communication frequency should be raised for those who have minimum contact or are outside the extension contact.
- By means of extension contact, training, motivational campaigns, result and method demonstrations, personal contact and intensive communication, experience sharing, etc., can increase knowledge, form positive attitude which ultimately contributes to adoption of more CSA technologies by a large number of farmers.

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