Research Article

Determinants of CSA Technologies Adoption in Coastal Bangladesh

Prema Das Antu[1], Md. Mamun-Ur-Rashid[1], A.K.M. Kanak Pervez[2*], Moriom Akter Mousumi[3] and Md. Ektear Uddin[1*]

[1]Department of Agricultural Extension and Rural Development, Patuakhali Science and Technology University, Bangladesh; [2]Department of Agronomy and Agricultural Extension, University of Rajshahi, Rajshahi-6205, Bangladesh; [3]Department of Plant Pathology, Patuakhali Science and Technology University, Dumki, Patuakhali.

Abstract | Climate change impact is a global problem which has been affecting food security, health, environment and livelihoods as well. As coastal Bangladesh is the hotspot of climate change impact, continuous adoption of climate-smart agriculture (CSA) technology is a sustainable option for farmers This article examines CSA technology adoption in agricultural regions on the north coast of the Bay of Bengal and its socioeconomic drivers. Multi-stage random sampling obtained data from 156 farmers in central coastal district of Bhola, Patuakhali, and Barguna . During January–March 2020 farmers were interviewed using a scheduled timetable. 25 CSA technologies were divided into weather-, water-, carbon-, nutrient-, and knowledge-smart groups to evaluate their adoption. CSA technology adoption of a farmer was measured dichotomously (yes/no) and total score was obtained by summing 25 items. Socio-economic determinants of CSA technology adoption were assessed using linear regression model. Mixed method was followed to triangulate the results. CSA technology implementation in coastal Bangladesh through 2020 is considerable but not complete. Overall adoption extent of majority group (58%) can be labelled as "medium". Farmers used carbon-smart, nutrient-smart, and weather-smart CSA technology most often. The current CSA adoption of farmers were influenced by land holding, personal knowledge, peer farmers, relatives and the use of television (TV). If they can acquire credible, simple, and local information on CSA technology, Bangladeshi farmers are eager to try them in their fields. Lack of awareness, inadequate technology, the challenging nature of CSA technology, low extension activity, and traditional farming behaviour have been identified as major problems. In contrast, mass media promotion, market promotion, insurance and subsidy, strengthening extension services, arranging demonstration and fair have been suggested as solutions. State Agriculture officials should consider this in designing CSA awareness programs for farmers in target locations. Awareness should be built not just as individual farmers' awareness but as community awareness so trainees can share their knowledge and experiences with nearby farmers. The decision to adopt should be conceived, formally or informally, as a family and community decision, not merely an individual farmer's decision, to maximize coverage of the technologies. Television and, by implication, other forms of information and communications technology should be employed. The result, if successful, will be more sustainable and climate-resilient agriculture, as well as improved food security for Bangladesh as we approach the climate tipping point.

Received | September 28, 2024; **Accepted** | June 20, 2025; **Published** | December 30, 2025
***Correspondence** | Md. Ektear Uddin and A. K. M. Kanak Pervez, Department of Agricultural Extension and Rural Development, Patuakhali-8660, Bangladesh; Department of Agronomy and Agricultural Extension, University of Rajshahi-6205, Bangladesh; **Emails:** ektear@pstu.ac.bd, kp@ru.ac.bd
Citation | Antu, P.D., M. Mamun-Ur-Rashid, A.K.M.K. Pervez, M.A. Mousumi and M.E. Uddin. 2025. Determinants of CSA technologies adoption in coastal Bangladesh. *Sarhad Journal of Agriculture,* 41(5): 346-358.
DOI | https://dx.doi.org/10.17582/journal.sja/2025/41.4.346.358
Keywords | Agricultural extension, Bangladesh, Climate smart technology, Climate change

Introduction

Climate change is a global crisis affecting socioeconomic and biophysical systems, which are multifaceted, interrelated and lead to poverty (Waaswa *et al*., 2021). Exposed sectors like agriculture are being most affected in food insecure regions of Africa and Asia (Rezaei and Yamac, 2023). Bangladesh is the innocent victims of global climate change in Asia (The Daily Star, 2024). Climate change impacts like tidal floods, storm surges, saline intrusion, drought, river bank erosion etc have devastated coastal agriculture and food security (Murshed *et al*., 2022; Paul and Rashid, 2016). One-third of the country's arable land and 28% of its people are on the shore (Ahmed, 2019; Uddin, 2009, 2012). The government of Bangladesh has spent over $10 billion on disaster relief and coastal agriculture over the last 35 years. Despite this effort, the Government's climate resilience program has failed to improve coastal farmers' production, sustainability, and climate change adaption. Thus, government policy must ensure coastal people's food and nutritional security. CSA (Climate-smart agriculture) is the suggested solution to many governments to adapt to climate change-induced natural catastrophes beyond human control.

Adapting agriculture to climate change is the goal of CSA. CSA is "agriculture that sustainably improves productivity, develops resilience, decreases greenhouse emissions when practicable, and advances national food security and development goals" (FAO, 2022). Thus, CSA is the most excellent solution for climate-change-induced calamities. Moreover, CSA technology is practical and economical. Therefore, farmers worldwide adopt it.

Research and the local knowledge of residents have developed some technologies that have been shown to work in adapting to disaster-prone environments (Lin and Chang, 2020). Combining traditional knowledge with modern scientific research opens a door for more innovation (Ghosh and Sahoo, 2011). Thus, the Government have decided, in principle, that farmer adoption of CSA technologies is a subsidiary goal of their policy to implement the (Sustainable Development Goals) SDGs in agriculture.

Conversely, the acceptance and spread of technology is a gradual and social process. Governments cannot legislate it or impose it on farmers instantly by decree. However, some CSA technologies have been shown to be adopted more quickly by farmers who can see their utility in making them better farmers (Yapa, 2020). On the other hand, although a good number of climate-smart technologies, especially saline and submergence-tolerant crop varieties, have developed, adoption at the farmers' level is not satisfactory (Ali and Meisner, 2023).

Technologies are the engines of economic growth (Bresnahan and Trajtenberg, 1995). Adoption is equally important as technology. Research is therefore needed to explore the determinants that facilitate the diffusion and adoption of technology. Little attention has been paid in this regard before the Government's promotion of agricultural technologies to the coastal areas of Bangladesh.

Reviews on farmers' characteristics and adoption of CSA

Farm revenue increases with productivity, which may require farmers to adopt more Community Supported Agriculture (CSA) practices (Waaswa *et al*., 2021). Thus, more productive farmers may use CSA methods. However, farmers noted that CSA methods required synthetic fertilisers, improved crop types, and herbicides for low-tillage, among other enhancements, which boosted agricultural output and acreage. Thus, farmers may enhance productivity by embracing CSA technology.

CSA adoption does not affect off-farm revenue. Farmers' usage of CSAs drops by 98% for every unit rise in annual off-farm wages (Waaswa *et al*., 2021). Researchers reached similar findings. Non-farming activities gave farmers a faster return on their time, money, and labour than CSA technology. Other studies have discovered that additional wealth from non-farm earnings stimulates CSA, such as improved crop varieties, by funding innovative new agricultural techniques (Mmbando *et al*., 2016).

The increased costs of CSA technology, which encourages farmers to produce more, may dissuade less successful farmers (Waaswa *et al*., 2021). Some studies have shown poor adoption rates for agricultural innovations that require higher financial commitments (Wakweya, 2023; FAO, 2022; Ajayi *et al*., 2011).

CSA technologies are also favourably associated with having children, as they represent the farmer's land's legacy value (Lynch and Lovell, 2003). Brown *et al*. (2018) measured the physical ability to implement CSA technology in agricultural equipment and the distance from institutional infrastructure to crops. Financial, technical, and risk perception issues delayed Kenya's soil fertility management methods (Marenya and Barrett, 2007).

CSA adoption in Ethiopia was highly associated with household head age. Older farmers were wary of CSA technological investments (Diro, 2022). Ketema and Bauer (2011) found a substantial and positive correlation between CSA usage and the age of the household head. Compared to younger farmers, elderly farmers in Kenya were more likely to employ CSA technology. The research also showed that male homeheads were more inclined to employ CSA technology than female homeheads. Gender, particularly among potato producers, was linked to the adoption of agricultural technology and climate change adaptation (Murage *et al*., 2015).

Research indicates that farming families with higher levels of education and experience are better equipped to adjust to climate change (Sardar *et al*., 2019). In addition, the research suggested tailored training to assist participants in handling Pakistan's climatic fluctuation. Sardar *et al*. also found that farmers required financial and psychological support to creatively adopt CSA technology, thereby becoming more climate resilient (Sardar *et al*., 2019; Brown *et al*., 2018).

Brown *et al*. (2018) measured the physical ability to implement CSA technology, utilising agricultural equipment and institutional infrastructure, in relation to the distance from crops. Financial, technical, and risk perception issues delayed the implementation of Kenya's soil fertility management methods (Marenya and Barrett, 2007). Extension programs and frequent meetings have also helped farmers in Brazil, Australia, and Finland become more climate resilient (De Souza Filho *et al*., 1999; D'Emden *et al*., 2006). CSA adoption was only beneficial for full-time farmers in northeastern Italy, as socio-demographic factors in farmer research demand higher expertise and farm presence. CSA technologies are also favourably associated with having children, as they represent the farmer's land's legacy value (Lynch and Lovell, 2003; Tosakana *et al*., 2010).

Andati *et al*. (2022) viewed that Kenyan farmers who joined farmer groups and shared crop management and crop protection technology were more likely to use CSA technologies. By facilitating financial services, connecting farmers with markets, and providing agricultural and climate knowledge through farmer associations, social networking facilitates farmers' adaptation to climate change (Bizikova *et al*., 2020). Farmer organisations and clubs have the ability to reduce service delivery costs through economies of scale, and they facilitate communication between extension staff and their members. Ngigi *et al*. (2017) found that group-based tactics and participation aided CSA technology in agriculture.

Conceptual framework

CSA is a collection of agricultural techniques and technologies that lower greenhouse gas emissions, increase resilience, and enhance production simultaneously (World Bank, 2024). Climate, water, crop, nutrient, carbon/energy, and institution/knowledge smart are the six aspects of the circular economy (CSA). Weather-smart technologies help farms adapt to weather abnormalities, such as floods, rainfall, salinity, and cyclones. Weather forecasting helps farmers plan their farm activities in advance, assisting in protecting crop loss and maintaining production despite sharp changes in weather patterns. Water-smart technologies contribute to water savings and groundwater recharge. Water-smart technologies also help maintain production in cases of water scarcity or excessive water. Carbon-smart technologies play a crucial role in carbon and energy management, helping to mitigate carbon emissions and improve productivity. Nutrient smart technologies focus on the need-based application of nutrients to minimise fertiliser overuse and reduce greenhouse gas (GHG) emissions (Chakraborty *et al*., 2023). Knowledgeable CSA technologies enhance farmers access to usable climate information and various adaptation options, promoting local innovation platforms (Figure 1).

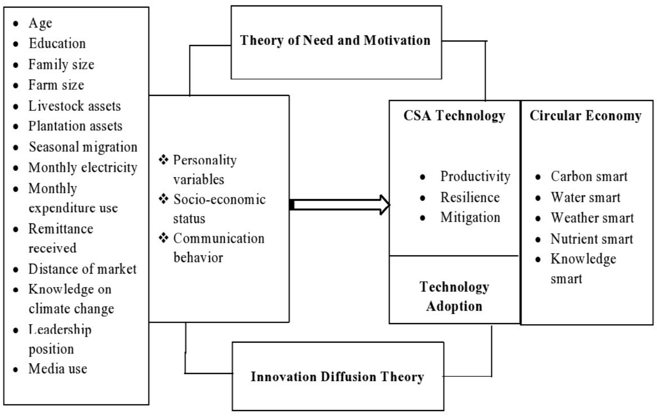

Figure 1: *Conceptual framework of the study.*

According to the Diffusion of Innovation (DoI), a theory coined by Rogers (1962), taking up a new habit, behavior, product, or thought that is at odds with the societal structure. Some individuals are more receptive to innovation than others. People who embrace innovation sooner tend to exhibit distinct traits compared to those who accept it later, according to research. Rogers explained that innovativeness the degree to which a person adopts innovation than other members of a social system of a person can explain this difference in acceptance of technologies (Figure 1). Various social variables can influence a person's innovativeness, which can be categorized into three categories: (i) socioeconomic status, (ii) personality variables, and (iii) communication behavior (Rogers, 1995). Socioeconomic characteristics encompass age, education, income, social mobility, and farm size. Personality variables include empathy, ability to deal with obstructions, rationality, intelligence, attitude towards change, ability to cope with uncertainty, fatalism and aspirations. Communication behaviour involves contact with change agents, exposure to mass media, exposure to interpersonal communication channels, knowledge of innovation, and the degree of opinion and leadership (Rogers, 1995).

Materials and Methods

Three coastal districts of Bangladesh namely, Patuakhali, Barguna, and Bhola were selected purposively for this study (Figure 2). A multi-stage random sampling technique was followed to select study area and sample as well. One sub-district was selected randomly from each district. From each sub-district, one village council (Union Parishad) was selected randomly (Table 1). Since it is expected that many coastal farmers will have experienced extreme weather events, such as salinity, coastal floods, tidal surges, and cyclones, and still continue to practice farming, the study site was selected.

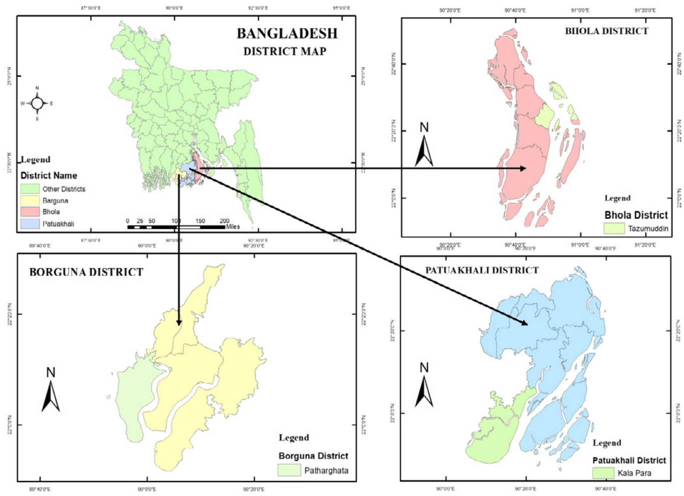

Figure 2: *Map showing study areas.*

Patuakhali is in southern Barishal division. Fruit and agricultural cultivation are the primary drivers of the region's economy. This region is good for growing rice, potatoes, mugs, lentils, khesari, gram, sesame, chili, mustard, linseed, coriander seed, ground nut, betel leaf, sugarcane, watermelon, and other vegetables (BBS, 2022). The District's main fruits include coconut, watermelon, betel nut, palm, wood nut, kaiju nut, etc. (BBS, 2022).

Barguna relies on agriculture. Farmers own 145,260 of 201,929 district landholdings (BBS, 2022). Rice and mungbean dominate this region. Other crops include bananas, betel leaf, betel nut, watermelon, and sunflower, among others. Barguna has 104,231 hectares of farmland.

Table 1: *Population and sample statistics of the study.*

District	Sub-district	Union	Village	Population	Sample
Patuakhali	Kalapara	Chakamoiya	Chungapasa	100	56
Barguna	Patharghata	Charduani	Saherabad	80	50
Bhola	Tazumuddin	Chadpur	Chadpur	80	50
Total			(Population frame) 260		156

Table 2: *Salient feature of socioeconomic characteristics of the respondent.*

S. No	Variables	Measuring techniques	Mean	SD	Mode
1	Age	Years	47.32	12.39	45
2	Education	Year of schooling	3.53	3.30	0
3	Family size	Number of a family member	5.77	1.96	4.00
4	Farm size	Decimal (1 acre = 100 decimal)	152.66	173.47	80
5	Livestock assets	Thousand Taka	112.24	131.89	0
6	Plantation assets	Thousand Taka	71.65	122.76	20
7	Leadership position	Yes/No	Yes=12	No=144	No
8	Monthly electricity use	Taka	250.53	432.25	300
9	Monthly expenditure	Thousand Taka	21.35	66.82	15
10	Media use	Score	10.31	4.470	8
11	Knowledge on climate change	Score	11.53	6.33	17
12	Seasonal migration	Yes/No	Yes=65	No=91	No
13	Remittance received	Yes/No	Yes=25	No=131	No
14	Distance of market	Km	3.11	2.33	2
15	Adoption of CSA technologies	Score	15.05	3.48	18

Although 63.64% of Bhola district's revenue comes from agriculture, 80% of its residents are fishermen. Farmers own 222,431 of 347,515 district landholdings (BBS, 2022). Bhola's principal crops include cucumber, watermelon, potato, peanut, chilli, coconut, betel leaf, betel nut, and vegetables.

The coastal areas are the most vulnerable to climate change, particularly sea level rise, which is why they were selected as the study sites. The study employed a several-phase random sampling technique. First, the block agricultural officer (SAAO) selected 260 farmers, which has been considered as the population frame. Next, an online sample size calculator randomly picked 156 farmers. The sample size is determined by 95% confidence and 3% error.

This research employed a planned interview schedule to get accurate data from respondents. Closed questions were scheduled. Simple and straightforward questions and scales were used to gather information during the interview. Rural agricultural systems and lifestyles were swiftly and similarly characterised using the Rural Household Multi-Indicator Survey (RHoMIS). Each household head or spouse was questioned (Hammond *et al*. 2017, www.rhomis.org). RHoMIS collects information on family composition, the size and productivity of farms, understanding of climate change, spending patterns, education, and physical and natural capital resources (such as land tenure, ownership, and financial resources).

Twenty per cent of the sample pre-tested the data-gathering device after its construction. The pre-test helped evaluate questions and statements related to the schedule. After then, the interview schedule was determined with pre-test adjustments.

Before data collection, agriculture officers of the areas were contacted to ensure support and collaboration. Face-to-face interviews collected the data. Farms and homes visit was used for interviews. To get respondents to open up, the researcher built rapport with them before the interview. The researcher clarified each query. Each area of the three chosen districts had two (02) Focus Group Discussions (FGD).

Table 3: *Features of CSA technologies.*

CSA characteristics of technology	CSA technologies
Weather smart	
Adapted to flood and rainfall	Raised-bed cultivation
Adapted to flood and rainfall	*Sorjan* method
Adapted to flood, cyclone and rainfall	Underground seed storage
Adapted to continuous rainfall	Polythene shade
Adaptation decision support	Weather app
Water smart	
Adapted to drought and salinity	Drip irrigation
Adapted to drought and salinity	Rainwater harvest
Adapted to drought and salinity	Rain-fed cropping
Adapted to flood	Floating bed agriculture
Adapted in drought	Use of mulching
Carbon smart	
Mitigate Carbon emission, improve productivity	Agroforestry
Mitigate greenhouse gas emission	Alternate crop of irrigated rice
Mitigate Carbon emission, improve food security	Homestead gardening
Mitigate Carbon emission	Minimum tillage
Mitigate Carbon emission	Cultivation of c4 crops
Nutrient smart	
Mitigate Carbon emission	Organic manure
Mitigate Carbon emission	Legume crop
Mitigate Carbon emission	Urea Deep Placement (UDP)/guti urea use
Mitigate Carbon emission	Use of crop residues
Mitigate Carbon emission	Use of soil test/colour chart
Knowledge smart	
Adapted to the stress and disaster	Planting time adjustment
Adaptation and food security	Tolerant varieties (salt/flood)
Adaptation and food security	Seed Bank
Food security/productivity	Crop rotation
Increase income/productivity	High-value crop

The dependent variable was the adoption of CSA technology. Following, Mahashin and Roy (2017), five smart dimensions weather, water, carbon, nutrient, and knowledge were used to assess farmer adoption of CSA technology. From each smart dimension, five CSA technologies were selected (Table 3). Five CSA dimensions and 25 technologies were compiled through a literature review (Talucder *et al*., 2024), expert consultation, and field observation.

Thus, adoption rates included 25 CSA technologies. Farmers employed these 25 CSA technologies or not (Yes = 1, No = 0). Thus, a respondent's adoption scores may be 0–25.

Age, education, family size, farm size, livestock assets, plantation assets, leadership position, media usage, climate change understanding, seasonal migration, remittance received, and market distance were the fourteen independent factors for coastal people. Due to the numerous independent factors, an appropriate scale was created and used. Table 2 summarises independent variables and evaluation methodologies.

Data collectors assisted in desk editing (central editing) immediately after data collection. Coding occurred. Coded data were moved to a master sheet for usage computer analysis followed by tabulation and compilation. Linear regression models identified the determinants of CSA technology adoption. Model-1 was run with a large set of variables (12) from where variables appearing significant were further employed in model-2 to achieve a best fitted model. Additionally, descriptive statistics were produced, including frequency, percentage, mean, median, and standard deviation. The data was statistically extracted using SPSS 21.0. The analysis of the qualitative data was done using a thematic method.

Results

Demographic characteristics

The demographic features of Table 2 indicate that the average respondent farmer was middle-aged (45 years old) with primary to no schooling and mostly came from a medium-sized family. Farmers were mostly smallholders, their only assets being trees , with few livestock and birds. The average monthly household expenditure was more than 20,000 BDT (approximately US$197), and most households paid around 300 BDT monthly for electricity. About 42% of the farm family heads migrated seasonally for work, and 16% of the households' received remittances. However, few have leadership positions in society (12 out of 156), and many are aware of climate change but are below-average users of information media.

CSA technology adoption

From 0-25, CSA technology adoption varied from 7-23. Mode (18) and mean (15.05) imply above-average CSA technology usage. CSA technology use was medium for 58% of farmers and low for only 5% (Table 4).

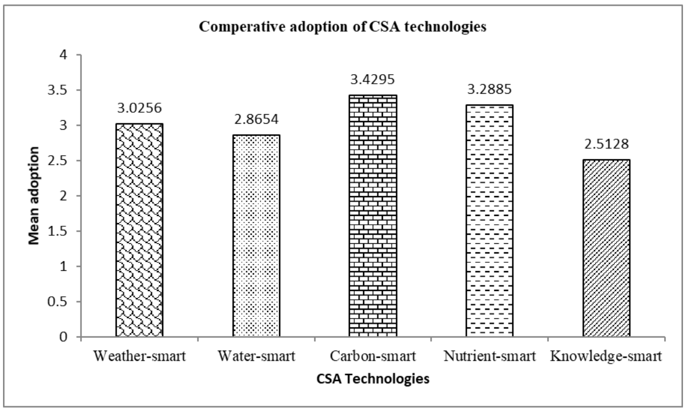

Figure 3: *Comparative adoption of CSA technologies.*

Figure 3 indicates the types of CSA technology adopted. Carbon-smart technology was the most widely used CSA technology, followed by nutrient-smart and weather-smart technologies. Some promising carbon-smart CSA technologies include agroforestry practices, supplementary crops for irrigated rice such as mung beans, and intensification of homestead agriculture (Table 4).

Despite the dominance of carbon-smart CSA technology in the locality, it is very difficult to say that farmers are truly aware of carbon-smart technology. During an FGD session, a farmer from Barguna district was asked to describe the carbon smart CSA features of the agroforestry system. He replied agroforestry practices maximise total yield and ensure proper use of land. Similarly, farmers had very limited knowledge that irrigated rice cultivation causes greenhouse gas emission. A senior farmer from Patuakhali district, in this regard, said, "I don't see any harm in irrigated rice cultivation." I do not cultivate rice because of high labor cost, high irrigation cost and lack of knowledge on pump operation; rather mungbean cultivation is comperatively cheaper".

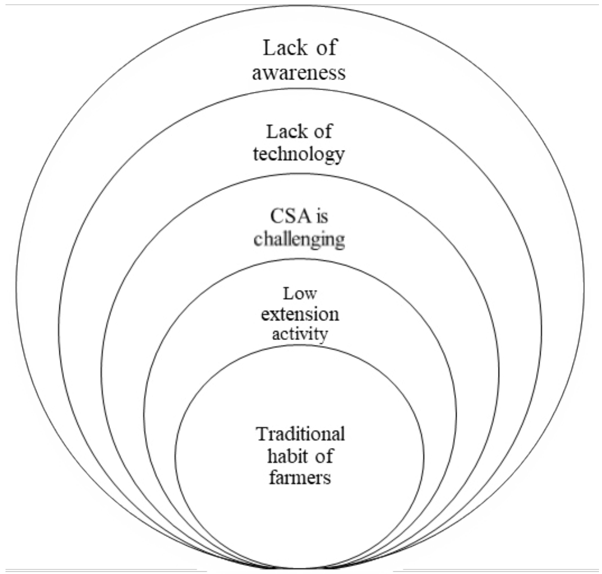

Figure 4: *Problems of CSA adoption in coastal Bangladesh.*

On the other hand, the least-adopted CSA technology was knowledge-based. Due to ignorance and low cropping intensity, farmers often fail to follow crop rotation. Similarly, many farmers are unaware of adjusting planting time, adoption of tolerant varieties and keeping extra seed for the next season. The outcome is in line with the demographic characteristic that the majority of farmers had just completed elementary education, were illiterate, and knew very little about CSA technology.

We regret to say that almost none of the farmers had knowledge of the three pillars of CSA, but they had need-based practices in place. During FGD, a farmer of Bhola said "I don't know anything about CSA technology. As I live in a hazardous area, I try to protect my crops and animals from extreme weather by using my personal knowledge and by following the practices of my peers and relatives in the community. Sometimes I succeeded and often I failed also".

Table 4: *Overall adoption of CSA technologies.*

Adoption categories	No. (N=156)	%	Possible range	Observed range	Mean	SD	Mode
Low (< 8)	7	4.49					
Medium (8-16)	91	58.33	0-25	7-23	15.05	3.48	18
High (> 16)	58	37.18					

Table 5: *Determinants of CSA technology adoption by the Coastal farmers.*

Socio-economic variables	Model 1					Model 2				
	B	SE	Beta	T	P	B	SE	Beta	t	p
Education	0.003	0.062	0.003	0.048	0.962					
Farm size	0.002	0.001	0.12	1.862	0.065	0.002	0.001	0.12	1.893	0.06
Livestock asset	0.001	0.002	0.043	0.739	0.461	0.001	0.002	0.045	0.779	0.437
Plantation asset	0.001	0.002	0.049	0.754	0.452	0.001	0.002	0.05	0.782	0.435
Leadership position	0.493	0.857	0.037	0.575	0.566	0.51	0.839	0.038	0.608	0.544
Electricity use	-.0004	.000	-0.006	-0.1	0.921					
Climate change knowledge	0.261	0.043	0.472	6.051	.000	0.263	0.041	0.474	6.407	.000
Seasonal migration	-0.057	0.423	-0.008	-0.135	0.893					
Distance of market	0.104	0.092	0.07	1.126	0.262	0.107	0.09	0.072	1.187	0.237
Media: Neighbour	0.753	0.22	0.227	3.416	0.001	0.748	0.215	0.225	3.48	0.001
Media: TV	0.252	0.128	0.116	1.968	0.05	0.251	0.122	0.115	2.051	0.042
Media: Relative	0.555	0.184	0.24	3.022	0.003	0.555	0.179	0.24	3.103	0.002
Model summary	Ad. R^2 =.539, F =15.921, p =.000					Ad. R^2 =·.549, F =21.672, p = .000.				

However, indigenous CSA knowledge and traditional information are sometimes inadequate to cope with the rapid and unpredictable changes in local climate. A farmer of Patuakhali told "I have been observing that many of my fellow farmers have been cultivating watermelon successfully in mild saline soil. But this year, when I tried watermelon, the heavy rains made it unpalatable. If I could know the weather information earlier, I could take some measures". Farmers need location-specific, credible information and CSA technology to tackle the effects of climate change. In almost all FGDs, farmers felt that they need a good seed supply and resistant crop varieties that can tolerate various degrees of waterlogging.

Fourteen socioeconomic characteristics of the respondent farmers were used as independent variables in regression models and fit by SSPS: these were age, education, family size, farm size, livestock asset, plantation asset, electricity use, household expenditure, remittance received, seasonal migration, the distance of the market, use of information media, leadership position, and knowledge of climate change. A set of twelve variables entered in model-1 where model summary (Ad. R^2 =.539, F =15.921, p =.000) appears poorly fitted. At later stage model-2 was run with 9 promising variables of model-1 to achieve the best-fitted model (Ad. R^2= ·.549, F =21.672, p = .000). However, age, family size, household expenditure, remittance, and overall media use did not enter into the regression model (Table 5), meaning no significant correlation was found with CSA technology adoption at the specified confidence level. The use of CSA technology was, however, significantly correlated with the use of TV (p = 0.042), neighbours (p = 0.001), and relatives (p = 0.002). In both models, climate change knowledge (p=0.000) was the most significant determinant of CSA technology adoption, although this correlation is so low as to be tenuous. Of course, knowing about climate change should logically make a person more willing to adopt CSA technology, but may be this is a trivial statement. Farm size was also revealed to be a major factor in CSA technology adoption, although with a moderate association (p = 0.06). In comparison to proprietors of small and marginal farms, farmers with bigger farms were more likely to use more CSA technology.

Problems of CSA technology adoption and its suggested solutions

Problems of CSA technology was probed through FGDs, which can be found in Figure 4. Results shows that CSA was a new term to farmers. A respondent of Barguna district replied to FGD enumerator "I learnt the term CSA first time from you". Discussion revealed that some CSA technologies are age-old practices, but farmers do not know them as CSA, for example, the raised bed and sorjan method. On the other hand, some ICT-based technologies and resistant crop varieties, for example, the use of weather forecasting apps and saline-tolerant rice varieties, are really new to them. Promotion through TV and advertisement board can help them, they replied (Figure 5). Seed of a resistant variety and apparatus for a modern drip irrigation system are rare in the locality, which were requested to be made available in the local market. A farmer of Patuakhali study area mentioned that "every year we are facing different climatic risks beyond our knowledge. We are worried about loss and damage. Government should pay for it". Common farmers excused the state department of agriculture for being less available to their community with CSA-related programs. A farmer of Bhola study area expressed in ways "we like to do what we know well. Only hearing is not enough to practice a new technology. We like to see it and its performance as well". It implies that farmers expect regular visits, technology fairs, and result demonstrations on CSA technologies in the locality for the promotion of CSA adoption.

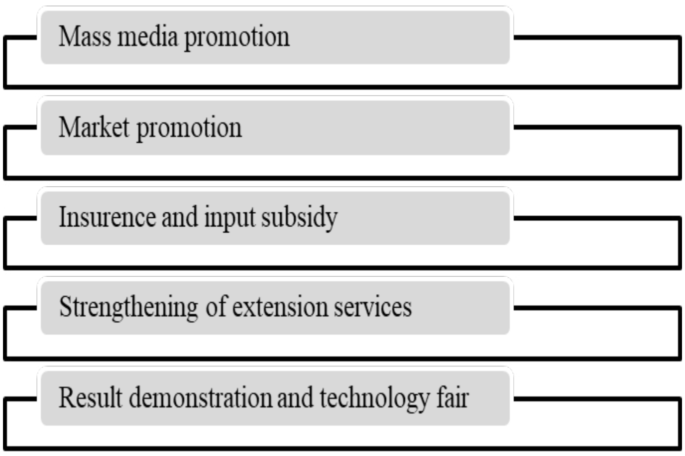

Figure 5: *Suggested solutions to promote CSA adoption in coastal Bangladesh.*

Discussion

Only five of the 12 socioeconomic parameters incorporated into the regression model were substantially connected with CSA technology adoption: farm size, understanding of climate change, and usage of neighbours, TV, and family as information sources. Numerous studies have revealed no correlation between the adoption of CSA technology and farm size. Bigger farms are more likely to implement CSA technology because they have more possibilities for adoption trials and money to embrace new agricultural technologies. Small farmers are less likely to use such technology. Kide (2014) discovered that bigger farm families were more likely to use alternative farming methods. Farm acreage also influenced farmers climate change adaptation choices, such as the adoption of CSA technology.

Farmers readiness to adopt CSA technology depends on their knowledge and capabilities regarding climate change resilience. Farmers view CSA as a means to cope with climate change, but also consider other challenges, such as living in a harsher environment. Recent literature supports this result. According to Tran *et al.* (2019), climate change also affects the adoption of CSA technology. Marie (2020) found that farmers knowledge affects adoption decisions. Thus, climatic variability information is crucial for CSA application. The lack of awareness about climate change and CSA technology affects farmers desire to adopt them (Ado *et al.*, 2020; Kide, 2014). Bewket (2009) found a correlation between climate change understanding and CSA adoption. Social networking helps small-scale farmers learn and apply CSA methods.

In our sample, media use did not significantly affect Bangladesh's CSA technology adoption by coastal farmers. However, recourse to neighbours, relatives, and television as sources of information favoured the adoption of CSA technology. This is because people near them are the most accessible media for the farmers of Bangladesh. On the other hand, TV is a popular medium in rural Bangladesh because it provides information, weather forecasts and entertainment.

While internet access is far from universal in rural Bangladesh, cable TV is rather standard. Moreover, almost all cable TV channels have programming, especially for farmers, including a daily weather forecast. Hence cable TV can be a secret weapon for reaching Bangladeshi farmers with information and new technology. Onyeneke *et al.* (2018) also found that exposure to mass media like TV increased the likelihood of CSA technology adoption in Africa.

However, this study did not find support in the data for household size as a determinant of adoption of CSA technologies (Ngema *et al.*, 2018). There are logical reasons to believe that larger families are better equipped to cope, both financially and in terms of a greater labour supply needed to implement CSA technologies, as these researchers have explained. It is not clear why this is not also true on the coast of Bangladesh. To fully investigate this issue, further study is required.

Conclusions and Recommendations

The term CSA is yet to be widely known among common farmers in Bangladesh. Many farmers adopt CSA technologies as adaptation strategies, but are still unclear about the CSA concept. The results of this research suggest that cable TV and the farmers' local communities may be the most effective means for the government to reach out to them and encourage more farmers to adopt CSA technology. Perhaps the information about CSA options should be presented to farmers not one by one, but to farming communities, which, the data suggest, may have a snowball effect in raising the CSA consciousness and use among communities. Not only should information about CSA technologies be presented, but awareness should also be raised on cable TV and in community training about climate change in general and how CSA can help communities cope with its adverse effects.

However, the government will need to address the likelihood that only farmers operating large farms will choose CSA technology. Unless they are willing to collectivise the farms on this issue alone, The Government will have to tackle the cost and labor requirements needed for small farmers to use CSA technologies. Subsidies for farmers with small holdings who wish to adopt CSA technologies, both to cushion them against the financial risk of adopting new technologies, which probably makes them hesitant, and to pay some of the costs of the technologies, including hiring extra labor to implement them, seem to be an attractive, moderate option. Based on implication of findings some policy recommendations are suggested as follows:

- Since farmers rely more on neighbors and relatives, in case of CSA adoption, more attention should be paid in "farmer-to-neighbor" technology transfer approach.
- Coastal farmers are less aware of knowledge-smart technologies which need to be increased. Some modern smart practices can be adopted in a state extension approach, such as using mobile phones to access weather information through the internet and various apps.
- Extension services should be strengthened through media promotion, market promotion, result demonstration, and technology fairs.

NGOs working in coastal agriculture, such as the Jagonari Foundation and CODEC, for example, should come forward with more CSA-based education to increase farmers knowledge and thereby promote CSA technology adoption.

Acknowledgements

This research was carried out with the research grant (Ag-06/5921) of Training and Research Center (RTC) of Patuakhali Science and Technology University (PSTU). We acknowledge the sincere help of Mr. Maruf during data collection period. Thanks also go to Dr. Jack for his native English editing service.

Novelty Statement

This study added new insights to the adoption context of CSA technologies in coastal Bangladesh. It has clearly identified the hidden problems of CSA technologies adoption and their probable solutions which depicts the overall scenario of CSA technologies used by the coastal farmers of Bangladesh.

Author's Contribution

The study was conceptualized, research design was developed and text was ultimately written by **Md. Ektear Uddin** and **Prema Das Antu**.
The performed data collecting, statistical analysis, and data interpretation have been harmonized by **A.K.M. Kanak Pervez** and **Moriom Akter Mousumi** .
Mamun-Ur-Rashid thoroughly contributed to the conceptual framework sub-section.
Every author has reviewed and approved the work.

Generative AI and AI-assisted technology statement
During writing the draft of this article authors used google scholar for getting insight which were further edited thoroughly. No advanced AI tools were used for generating content of this article.

Conflict of interest
The authors have declared no conflict of interest.

References

Ado, A.M., P. Savadogo, A.K.M.K. Pervez and G.T. Mudimu. 2020. Farmers perceptions and adaptation strategies to climate risks and their determinants: Insights from a farming community of Aguie district in Niger. Geo J., 85(4): 1075-1095. https://doi.org/10.1007/s10708-019-10011-7

Ahmed, H., 2019. Bangladesh coastal zone management status and future. J. Coast Zone Manage., 22: 1.

Ajayi, O.C., F. Place, F.K. Akinnifesi and G.W. Sileshi. 2011. Agricultural success from Africa: the case of fertilizer tree systems in southern Africa (Malawi, Tanzania, Mozambique, Zambia and Zimbabwe). Int. J. Agric. Sustain., 9(1): 129–136. https://doi.org/10.3763/ijas.2010.0554

Ali, M. and C. Meisner. 2017. Climate-Smart Agriculture in Bangladesh. https://doi:10.13140/RG.2.2.35102.84805.

Andati, P., E. Majiwa, M. Ngigi, R. Mbeche and J. Ateka. 2022. Determinants of adoption of climate smart agricultural technologies among potato farmers in Kenya: Does entrepreneurial orientation play a role? Sustain. Tech. Entrep., 1(2): 100017. https://doi.org/10.1016/j.stae.2022.100017

BBS. 2024. Population and Housing Census 2022. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh.

Bewket, W., 2009. Rainfall variability and crop production in Ethiopia: Case study in the Amhara Region. Proceeding of the 16th International conference of Ethiopian Studies, Addis Ababa, Ethiopia.

Bizikova, L., E. Nkonya, M. Minah and M. Hanisch, R.M.R Turaga, C.I. Speranza, M. Karthikeyan, L. Tang, K. Ghezzi-Kopel, J. Kelly, A.C. Celestin and B. Timmers. 2020. A scoping review of the contributions of farmers' organisations to smallholder agriculture. Nat. Food, 1(10): 620–630. https://doi.org/10.1038/s43016-020-00164-x

Bresnahan, T. and M. Trajtenberg. 1995. General purpose technologies' engines of growth? J. Econ., 65: 83-108. https://doi.org/10.1016/0304-4076(94)01598-T

Brown, C., P. Alexander and M. Rounsevell. 2018. Empirical evidence for the diffusion of knowledge in land use change. J. Land Use Sci., 13(3): 269–283. https://doi.org/10.1080/1747423X.2018.1515995

Chakraborty, M., R. Godara, G.D. Sharma and G. Hetta. 2023. Climate smart agriculture: Dimensions and practices. Hortic. Magaz., 2(5): 135-138.

De-Souza Filho H.M., T. Young and M.P. Burton. 1999. Factors influencing the adoption of sustainable agricultural technologies. Tech. Forecast. Soc. Change, 60(2): 97–112. https://doi.org/10.1016/S0040-1625(98)00040-7

D'Emden, F.H., R.S. Llewellyn and M.P. Burton. 2006. Adoption of conservation tillage in Australian cropping regions: An application of duration analysis. Tech. Forecast. Soc. Change, 73(6): 630–647. https://doi.org/10.1016/j.techfore.2005.07.003

Diro, S., A. Tesfaye. and B. Erko. 2022. Determinants of adoption of climate-smart agricultural technologies and practices in the coffee-based farming system of Ethiopia. Agric. Food Sec., 11(1). https://doi:10.1186/s40066-022-00385-2

FAO, 2022. Climate-smart agriculture sourcebook. United book prints.

Ghosh, P.K. and B. Sahoo. 2011. Indigenous traditional knowledge. Orissa review.

Hammond, J., S. Fraval and J. Etten, J.G. Suchini, L. Mercado, T. Pagella, R. Frelat, M. Lannerstad, S. Douxchamps, N. Teufel, D. Valbuena and M.T. Wijk. 2017. The rural household multi-indicator survey (RHoMIS) for rapid characterisation of households to inform climate smart agriculture interventions: Description and applications in East Africa and Central America. Agric. Syst., 151: 225–233. https://doi.org/10.1016/j.agsy.2016.05.003

Ketema, M. and S. Bauer. 2011. Give to AgEcon Search determinants of manure and fertilizer applications in eastern highlands of Ethiopia. Quar. J. Int. Agric., 50(3): pp.237–252. Available at: https://ageconsearch.umn.edu/record/155533/files/2_Ketema.pdf [Accessed 11 Aug. 2022].

Kide, G.T., 2014. Smallholder farmers adaptation strategies to climate change in Ethiopia: Evidence from Adwa Woreda of Tigray Region.

MSc thesis, Department of Economics, Mekelle University. Retrieved from

Lin, P.S.S. and K.M. Chang. 2020. Metamorphosis from local knowledge to involuted disaster knowledge for disaster governance in a landslide-prone tribal community in Taiwan. Int. J. Disaster Risk Reduct., 42: 101339. https://doi.org/10.1016/j.ijdrr.2019.101339

Lynch, L. and S.J. Lovell. 2003. Combining spatial and survey data to explain participation in agricultural land reservation programs. Land Econ., 79(2): 259–276. https://doi.org/10.2307/3146870

Mahashin M. and R. Roy. 2017. Mapping practices and technologies of climate smart agriculture in Bangladesh. J. Environ. Sci. Nat. Res., 10(2); 29-37.

Marenya, P.P. and C.B. Barrett. 2007. Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. Food Policy, 32(4): 515–536. https://doi.org/10.1016/j.foodpol.2006.10.002

Marie, M., 2020. Farmers choices and factors affecting adoption of climate change adaptation strategies: Evidence from Northwestern Ethiopia. Heliyon, 6(4). https://doi.org/10.1016/j.heliyon.2020.e03867

Meisner, C.A. and M.Y. Ali. 2023. Bangladesh under possible climate change threat. In: Ahmed, R., Al-Maruf, A., Jenkins, J.C. (eds). Transforming Bangladesh. World Regional Geography Book Series. Springer, Cham., https://doi.org/10.1007/978-3-031-45093-8_13

Mmbando, F.E. and L.J.S. Baiyegunhi. 2016. Socio-economic and institutional factors influencing adoption of improved maize varieties in Hai District, Tanzania. J. Hum. Ecol., 53(1): 49–56. https://doi.org/10.1080/09709274.2016.11906955

Murage, A.W., J.O. Pittchar, C.A.O. Midega, C.O. Onyango and Z.R. Khan. 2015. Gender specific perceptions and adoption of the climate-smart push–pull technology in eastern Africa. Crop Prot., 76: 83–91. https://doi.org/10.1016/j.cropro.2015.06.014

Murshed, S., A.L. Griffin, M.A. Islam, X.H. Wang and D. Paull. 2022. Assessing multi-climate-hazard threat in the coastal region of Bangladesh by combining influential environmental and anthropogenic factors. Prog. Disast. Sci., 16(2022). https://doi.org/10.1016/j.pdisas.2022.100261

Ngema, P., M. Sibanda and L. Musemwa. 2018. Household food security status and its determinants in maphumulo local municipality, South Africa. Sustainability, 10: 3307. https://doi.org/10.3390/su10093307

Ngigi, M.W., U. Mueller and R. Birner. 2017. Gender differences in climate change adaptation strategies and participation in group-based approaches: An intra-household analysis from rural Kenya. Eco. Econ., 138: 99–108. https://doi.org/10.1016/j.ecolecon.2017.03.019

Onyeneke, R.U., C.O. Igberi, C.O. Uwadoka and J.O. Aligbe. 2018. Status of climate-smart agriculture in southeast Nigeria. Geo J., 83: 333–346. https://doi.org/10.1007/s10708-017-9773-z

Paull, B.K. and H. Rashid. 2016. Coastal hazards in Bangladesh: Non-structural and structural solutions. Elsevier Inc. https://doi.org/10.1016/B978-0-12-805276-1.00008-9

Rogers, E.M. 1962. Diffusion of innovations. 3rd Edition, the Free Press, New York

Rogers, E.M. 1995. Diffusion of innovations. 4th Edition, the Free Press, New York.

Rezaei, E.E. and S.S. Yamac. 2023. Modelling the impact of climate change on agriculture in North Africa and Southwest Asia. Burleigh Dodds Science Publishing.

Sardar, A., A.K. Kiani and Y. Kuslu. 2019. İklim Açısından Akıllı Tarımın (CSA) Benimsenmesi Konusundaki Istekliliğin Çiftçilerin Uyum Kapasitesi Belirleyicileri Aracılığıyla Değerlendirilmesi. YüzüncüYıl Üniversitesi Tarım Bilimleri Dergisi, pp. 781–791. https://doi.org/10.29133/yyutbd.631375

Talucder, M.S.A., U.B. Ruba, S.J. Prova and M.A.S. Robi. 2024. Moringa-based homestead to achieve Sustainable Development Goals: A case study from Jaintiapur of Sylhet, Bangladesh. Heliyon, 10. https://doi.org/10.1016/j.heliyon.2024.e37889

The Daily Star, 2024. Climate Apartheid and Bangladesh. The Daily Star, 24 October 2024. Retrieved from https://www.thedailystar.net/opinion/views/news/climate-apartheid-and-bangladesh-3735431

Tran, Jr. S. and N.N. Reiner 2019. Determinants of adoption of climate-smart agriculture technologies in rice production in Vietnam. Int. J. Clim. Change Strategies Manage., 12(2): 238-256. https://doi.org/10.1108/IJCCSM-01-2019-0003

Tosakana, N.S.P., L.W. Van Tassell, J.D. Wulfhorst, J. Boll, R. Mahler, E.S. Brooks and S. Kane. 2010. Determinants of the adoption of conservation practices by farmers in the Northwest Wheat and Range Region. J. Soil Water Conserv., 65(6): 404–412. https://doi:10.2489/jswc.65.6.404

Uddin, M.E., 2012. Household food security status of marginal farmers in selected storm surge prone coastal area of Bangladesh. Agriculturist, 10(1): 98-103. https://doi.org/10.3329/agric.v10i1.11070

Uddin, M.E., 2009. Job satisfaction of SAAOs working in coastal area of Bangladesh: A case study of Patuakhali district. The Agriculturist, 7(1 and 2): 22-28. https://doi.org/10.3329/agric.v7i1.5249

Waaswa, A., A.O. Nkurumwa, A.M. Kibe and J.K. Ng'eno. 2021. Understanding the socioeconomic determinants of adoption of climate-smart agricultural practices among smallholder potato farmers in Gilgil Sub-County, Kenya. Discover Sustainability, 2(1). https://doi.org/10.1007/s43621-021-00050-x

Wakweya, R.B., 2023. Challenges and prospects of adopting climate-smart agricultural practices and technologies: Implications for food security. J. Agric. Food Res., 14: 1-8. https://doi.org/10.1016/j.jafr.2023.100698

World Bank, 2024. Climate Smart Agriculture. Available at: https://www.worldbank.org/en/topic/climate-smart-agriculture

Yapa, S., Poesche and K.I. Jurgen 2020. Why adoption of some technologies is faster? An explanation through sequential coherence. https://doi.org/10.4038/sljms.v1i2.49