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Factors Influencing Farmers' Barriers to Adopting Climate Smart Agriculture Practices in the Coastal Area of Bangladesh

Avijit Biswas[a] · Prome Debnath[b] · Dae Koo Kang[c*]

[a]Ph.D. Student, Department of Agricultural Industry Economy and Education, Sunchon National University, Korea
[b]Ph.D. Student, Department of Geography, Chonnam National University, Korea
[c]Professor, Department of Agriculture Education, Sunchon National University, Korea

방글라데시 해안 지역 농업에서 기후에 대응한 스마트 농업 적용에 대한 농업인의 장애 영향요인

아비짓 비스와스[a] · 쁘로미 데브나스[b] · 강대구[c]

[a]순천대학교 농산업경제.교육과 박사과정 (전라남도 순천시 중앙로 255)
[b]전남대학교 지리학과 박사과정 (광주광역시 북구 용봉로 77)
[c]순천대학교 농업교육과 교수 (전라남도 순천시 중앙로 255)

Abstract

This study aims to identify the factors influencing farmers' barriers to adopting climate-smart agriculture (CSA) practices in the coastal area of Bangladesh. We have used a semi-structured, pre-tested questionnaire to collect quantitative and qualitative data from 160 coastal farmers who had at least 10 years of farming experience. We found that internal consistency (Cronbach's alpha) values for the items of agricultural vulnerability, adopted CSA practices, and perceived barriers to adopting CSA practices were 0.72, 0.74, and 0.79, respectively. The Agricultural Vulnerability Index (AGVI) found increased soil salinity in the dry season, reduced freshwater resources, poor seed germination, and more pests and diseases as vulnerabilities in agriculture. The Adoption Index (ADI) identified most adopted CSA practices as including growing HYVs of vegetables on high land, short-duration HYVs of rice, using compost, proper fertilizer management, and sarjon cultivation methods. The Barrier Index (BI) showed that high initial investment costs, poor embankment infrastructure, low crop prices, a lack of solar-powered irrigation systems, and insufficient technical assistance from local extension organizations are the main barriers to the adoption of CSA practices. Farmers' age, education, training experience, job satisfaction, and use of information sources have influenced barriers to adopting CSA practices. The study suggested policies on coastal farmer competency development, ensuring crop insurance, providing interest-free credit policies, and a fair pricing system for crops.

Key words: agricultural vulnerability, climate-smart agriculture, adoption, barrier

요약

이 연구는 방글라데시 해안 지역에서 기후에 대응한 스마트 농업 (CSA) 방법의 채택에 대한 장애요인을 도출하고자 하였다. 반구조화된 설문지를 사용하여 최소 10년 이상의 농사경험이 있는 160명의 연안 농부들로부터 정량적 및 정성적 데이터를 수집하였다. 농업 취약성, 채택된 CSA 관행, 그리고 CSA 관행 채택에 대한 인식된 장벽 항목의 내적 일관성(Cronbach's alpha)은 각각 0.72, 0.74, 0.79로 나타났다. 농업 취약성 지수 (AGVI)는 토양 염분 증가, 담수 자원의 감소, 불량한 씨앗

Key words: agricultural vulnerability, climate-smart agriculture, adoption, barrier

* Corresponding author (Dae Koo Kang) Tel. 061-750-3355, e-mail: kang@scnu.ac.kr

발아, 해충과 질병의 증가를 농업의 취약점으로 확인하였다. 채택 지수(ADI)는 다수성 채소 재배, 단기간 다수성 쌀 재배, 퇴비나 바이오가스 사용, 적절한 비료 관리, 그리고 소르존 재배 방법 등을 공통 CSA 방법으로 파악하였다. 그러나 장벽 지수(BI)는 높은 초기 투자 비용, 열악한 제방 인프라, 낮은 작물 가격, 태양광 관개 시스템의 부족, 기술 지원의 부족이 CSA 채택을 저해하는 것으로 파악되었다. 또한 농부의 나이, 직무 만족도, 교육 수준, 훈련 경험, 정보원 사용이 CSA 방법 채택 장벽에 영향을 미치는 것으로 나타났다. 연구는 CSA 관행을 장려하기 위해 해안 농부 역량 개발, 농작물 보험, 무이자 대출 정책, 그리고 공정한 농작물 가격 체계를 제안하였다.

주요어: 농업 취약성, 기후 스마트 농업, 채택, 장애

1. Introduction

Bangladesh is situated on predominantly flat, floodplain terrain at the confluence of the Ganges-Brahmaputra-Meghna (GBM) Basins, which is recognized as a nation very susceptible to climate change (Ruane et al., 2013). According to IPCC (2014), the extensive low-lying coastal area of Bangladesh is especially susceptible to climate change threats. Increased temperature, unpredictable weather pattern, land submergence, soil salinization, reduced fresh groundwater, and permanent coastal erosion significantly impact the deltaic region's agriculture, leading to substantial farm production losses, alternation of agro-ecosystem boundaries, limited livelihood diversification, compromised household well-being, and heightened food security risks (Khanom, 2016; Khatri-Chhetri et al., 2016; IPCC, 2014). Prediction suggest that the population of Bangladesh may exceed 200 million by 2045 (UNDESA, 2024) and this growing population of Bangladesh poses challenges to agricultural systems, particularly when considering long-term climatic issues such as shifting flood patterns, increasing sea levels, and changing temperature and rainfall patterns (Raza et al., 2019; Kumar et al., 2022). Furthermore, agriculture itself contributes significantly to climate change (Vetter et al., 2017).

Climate change is rapidly increasing agricultural vulnerability in the coastal region of Bangladesh. Already, the decrease in agriculture production in coastal areas is a sign of negative impact of climate change on agricultural system (Rabbani et al., 2015). According to SRDI (2010), revealed 27% increase in salt-affected coastal and offshore areas between 1973 and 2009, which poses a substantial threat to coastal farming. Additionally, the rise in temperature and alternations in precipitation patterns are adversely affecting plant growth, yield, and the biology of and distribution of insect pests (Ngoune and Shelton, 2020). It is expected that the coastal agriculture of Bangladesh will also experience additional degradation in the future due to the rise in sea level (Rabbani et al., 2015). The agro-resources in these areas are deteriorating due to salinity intrusion, which ranges from 0 to 20 ppt, and the 0.83 million ha of land that are vulnerable to sea level rise (Uddin et al., 2011). Furthermore, climate change has caused alternations in microbial populations and their enzymatic activities in soil (Malhi et al., 2021). The coastal area of Bangladesh comprises 32% of the total area of the country and houses 28% of the total population (Islam, 2004). If food production continuously decreases in these regions, it will have a significant impact on food security in the rest of the country. Global concerns are influencing integrated, multidimensional efforts through strategic management and implementation to ensure sustainable agriculture and food security.

The adoption of climate-smart agriculture practices has become an essential strategy to mitigate these climate change impact in coastal agriculture. The adoption of CSA practices means taking up agricultural practices and technologies that can increase agricultural productivity while also contributing to climate change adaptation and mitigation (Abedin, & Shaw, 2013). Climate-smart agriculture refers to a range of agricultural practices, technologies, and interventions aimed at increasing crop production, enhancing adaptive capacity, and decreasing the release of greenhouse gases from agricultural operations (FAO, 2014; Lipper et al., 2014). Several studies showed CSA practices can increase crop yields, make more efficient use of resources, increase farm income, decrease the release of greenhouse gases, and make farms more resistant to climate change (Khatri-Chhetri et al., 2016; Zheng et al., 2024). Additionally, increasing land area in coastal regions of Bangladesh (Abdullah et al., 2019) creates an opportunity for expanding cultivable areas through the adoption of CSA practices. However, the adoption of CSA practices among coastal farmers remains limited (Palanisami et al., 2015). Coastal farmers have been unwilling to adopt CSA practices (Kundu et al., 2020), and barriers including technological, social, economic, organizational, informational, and environmental (Ishtiaque et al., 2020; Birkmann and von Teichman, 2010; Moser and Ekstrom, 2010; Lamichhane et al., 2022), are hindering the adoption of CSA practices in coastal agriculture of Bangladesh.

Barriers are challenges that arise within a specific context and can be effectively overcome by making the required adjustments (Moser and Ekstrom 2010). Islam et al. (2014) investigated the farming community in Bangladesh and found that there were barriers in the form of natural, technical, social, economic, and institutional processes that were mostly connected and affected decisions about CSA adoption. Barriers to adopt CSA practices also arise from insufficient funding, inadequate technological expertise, limited institutional capacity (IPCC, 2007), and a lack of understanding of climate change issues (Gifford et al., 2011). Farmers in coastal Bangladesh struggle to adopt CSA practices due to limited inputs, financial constraints, water scarcity, market unpredictability, insufficient credit, land shortages, and a lack of resilient crop varieties (Kabir et al., 2022). Poor coordination at the local level, limited access to information, top-down approach of knowledge flow, farming differences, and corruption are significant barriers to adopting CSA practices (Ishtiaque et al., 2020).

Most previous research aimed to understand the adaptation mechanism of climate change in coastal agriculture through CSA practices, and identify the factors that contribute to climate change adaptation in coastal areas of Bangladesh (Kabir et al., 2021; Anzum et al., 2023; Rahman et al., 2023; Hassan et al., 2024). There is a lack of empirical evidence of what specific barriers are faced by coastal farmers to adopting CSA practices (Kundu et al., 2024) that can minimize climate-induced vulnerabilities and ensure food security. Local knowledge is widely recognized as critical for successful adoption of new practices and for understanding the barriers to adopting new agricultural technologies (Šūmane et al., 2018). To investigate the existing barriers to CSA adoption and to gain a deeper understanding of how and why these barriers emerge, the following research question has been formulated: (i) What climate-induced vulnerabilities are experiencing by coastal farmers, and what CSA practices have been adopted to mitigate these vulnerabilities? (ii) What are the barriers to adopting CSA practices, and which factors are contributing to these barriers? We have utilized both qualitative and quantitative data to create a realistic scenario that addresses these research questions. We can use the findings to guide policies and find out the gaps in the existing extension system that support the increased adoption of CSA practices in coastal areas of Bangladesh. Furthermore, the findings of this study will be useful in driving efficient community engagement techniques, capacity-building attempts, and improving CSA adoption plans for coastal areas of Bangladesh.

2. Previous Studies

In Bangladesh, coastal farming is negatively impacted by climate variables like temperature, rainfall, humidity, and day-length, as well as drought and salinity intrusion, which are also influenced by climate change. The Salinity intrusion in the coastal area is creating a serious implication for the coastal land that was affecting crop cultivation (Sikder and Xiaoying, 2014). Climate change is significantly contributing to increased salinity intrusion in coastal Bangladesh which in turn is destroying biodiversity, loss of agricultural jobs, reduction in agricultural production and mounting food and human insecurity in the area in cascading and consequential orders over different time horizons (Huq et al., 2015). From 1973 to 2021, Bhuyan et al. (2023) observed a more than 60% increase in soil salinity in the southern-central coastal region during drought periods. Furthermore, coastal agriculture is vulnerable to storm surges, cyclones, sea-level rise, foods, waterlogging, river bank erosion, coastal inundation, and seawater intrusion, while both coastal and non-coastal farming systems are susceptible to climatic and non-climatic stresses (Gopalakrishnan et al. 2019). Climate change, as has been estimated, will reduce overall rice production in Bangladesh by an average of 7.4% every year over the period 2005-2050 (Yu et al., 2010). Climate change also affect the physiological and morphological characteristics of plant, insect pest distribution, nutrient uptake, decrease soil fertility, and ultimate decline the yields of the crops (Kumari et al., 2022). So, to combat with this extremity the adoption of CSA practices is situation demand for every victimized area. Several international institutions, like the FAO and the World Bank, have supported and encouraged the adoption of CSA practices to ensure food security in the context of climate change impacts (Karlsson et al., 2017).

According to Food and Agriculture Organization (FAO), CSA refers to agricultural approach that aims to sustainably improve production, resilience (adaptation), reduce/remove greenhouse gases (mitigation), and enhance the fulfilment of national food security and development goals (FAO, 2010). Another definition given Li et al. (2023) that, CSA practices are agricultural production-related strategies that can effectively adapt agriculture to climate change and enhance agricultural production capacity. Researchers are encouraged to adopt CSA practices in four key areas: 1) The adaptation of agricultural production to climate change; 2) greenhouse gas mitigation in agriculture; 3) the effects of climate change on agricultural systems; and 4) carbon storage in agroecosystems (Lou et al., 2024).

2.1. Discussed CSA practices

Bangladeshi coastal farmers have adopted CSA practices to increase crop yield and income while protecting their livelihoods from climate change-induced crop loss (Islam & Farjana, 2024). Coastal farmers already adopted different CSA practices including cultivation of stress tolerant crop varieties, raised seedbed, planting large size amon rice seedlings, practicing the sarjon cultivation method and agroforestry, using low lift pump and pheromone traps, using appropriate amount fertilizer and mulching, storing seed, producing fodder crops, using organic fertilizer, maintaining crop diversification, and cultivating watermelon to minimize climate change impacts and increase their income (Anzum et al., 2023). Li et al. (2023) reviewed the adopted CSA practices from January 2013 and July 2023, and provided a list of adopted CSA practices (Table 1) that are commonly used to minimize climate-induced agricultural vulnerabilities and ensure better production.

In Bangladesh farmers have also adopted floating vegetable cultivation in areas where flooding occurs once or twice in a year and where waterlogging is found for 4 to 6 months (Kabir et al., 2022). Alternate wetting and drying (AWD) irrigation system have proved to be a successful irrigation strategy and is recognized as an economically feasible CSA

〈Table 1〉 List of adopted CSA practices from January 2013 and July 2023

Categories	List of CSA practices
Crop planting	Agroforestry, changing cropping calendar, mulching, crop diversification / multiple cropping, crop rotation, crop-livestock integration, HYVs of crop, intercropping, planting trees, and relocated crops
Farmland management	Crop residual turnover, formula of fertilizer and soil testing, green manure, laser land leveling, micro-dosing fertilizer, organic composting, organic fertilizer/farmyard manure, plot resizing, reforestation ridge planting, soil restoration soil testing and formula fertilization, and zero/minimum tillage
Irrigation management	Water harvesting, changing irrigation time, solar powered irrigation, drip irrigation/sprinkler/small-scale irrigation, infrastructure development, alternate wetting and drying (AWD) irrigation system, and terracing
Pest and weed management	Biological control of insects and diseases, changing timing and amount of chemical inputs, integrated pest management, and non-chemical weed control
Livestock management	Improved forage, livestock diversity

Source: adopted from (Li et al., 2023)

practices in coastal regions of Bangladesh. Now the Bangladeshi government is also prioritizing the adoption of CSA practices in coastal areas to ensure food security and combat climate change (Assefa et al., 2021).

2.2. Perceived barriers to adopting CSA practices

Lamichhane et al., (2022) found that adoption of CSA techniques can be significantly hampered by upfront investment costs and transaction costs among different kind of activities. As most farmers reported having poor access to input and output markets, the market difficulty also decreased the adoption of CSA (Saha et al., 2019). According to Huq et al. (2015), the main interruption to the adoption of CSAT derived from physical vulnerability, dull economic situation, the depletion of their resource base, the lack of resourcefulness of formal institutions, and outside forces all worked together. Fusco et al. (2020) posits that the primary obstacles to the adoption of CSA practices were inadequate financial resources, limited availability or difficulty obtaining agricultural inputs such as fertilizers, seeds, and equipment, and in certain instances, a shortage of manpower to execute the practice. However, according to Barnard et al. (2015), there are software and hardware barrage that hinder the adoption of CSA practices. In software barrage may include organizational, traditional, directive and governing environment; intelligence, expertise and techniques; methods and innovations, among others; and hardware barrage may include physical inputs like land, human capital, tools and materials, structure, and economy. According to Thorlakson (2012), adoption rates can be raised by instructive farm visits including effective management techniques. Farmers have determined that the two biggest barriers to CSA practice adoption are a lack of information about current methods and a poor comprehension of CSA ideas (Li et al., 2023). Adoption of CSA is greatly influenced by information and knowledge accessibility. According to AGRA (2014), "for the effective implementation of CSA, structured, exclusive, and out of the box thinking capacity are essential, as it is clearly knowledge-intensive." According to Descheemaeker et al. (2016), significant institutional obstacles that impede adoption potential include land tenure, instability, and access to necessary information and markets. Furthermore, in order to remove obstacles that prevented the poor from successfully adopting CSA practices, Neufeldt et al. (2011) identified few crucial points in his study to overcome the hurdle in adopting CSA, those were, imposing equal, legal and political environment; easy market access; bottom-up level participation in decision-making process; enhancing tenure rights; removing the inequality in high opportunity costs associated with land; and enhancing transparency in access to capital.

2.3. Factors influencing the adoption of CSA practices

According to Pannell et al. (2006), and Knowler and Bradshaw (2007) the barriers to adopting CSA practices are impacted by a range of socio-demographic and economic characteristics of farmers. The physical activity, labor supply, and willingness to take risks are associated with age of farmers (Li et al., 2023), which may affect the adoption of CSA practices. Educated farmers are more likely to understand the impact of climate change on agriculture and keep motivated to adopt CSA practices (Mthethwa et al., 2022). Furthermore, trained farmers will also be informed about the reason behind the climate change issue in agriculture, and learn how to tackle this situation in the future, which may pose fewer barriers to adopting CSA practices (Aryal et al., 2018). Farm size also has an influence on decisions in the adoption of CSA practices (Masud et al. 2017). However, institutional support, income, technical assistance from local extension organization, and resource accessibility increase satisfaction among farmers and all have an impact on reducing barriers to adopting CSA practices (Kundu et al., 2024). Membership in farmers' organizations, climate conditions, access to credit, land tenure security, access to extension services, and annual income are contributing factors in reducing barriers to the adoption of CSA practices (Li et al., 2023; Antwi-Agyei et al., 2021;

Masud et al., 2017). Access to information about the existing and near-future impacts of climate change can motivate farmers to adopt CSA practices to avoid yield loss and ensure food security (Abegunde et al., 2019). Additionally, access to market related information helps to minimize the barriers and increasing the adoption of suitable CSA practices (Iqbal, & Aziz, 2022).

3. Methodology

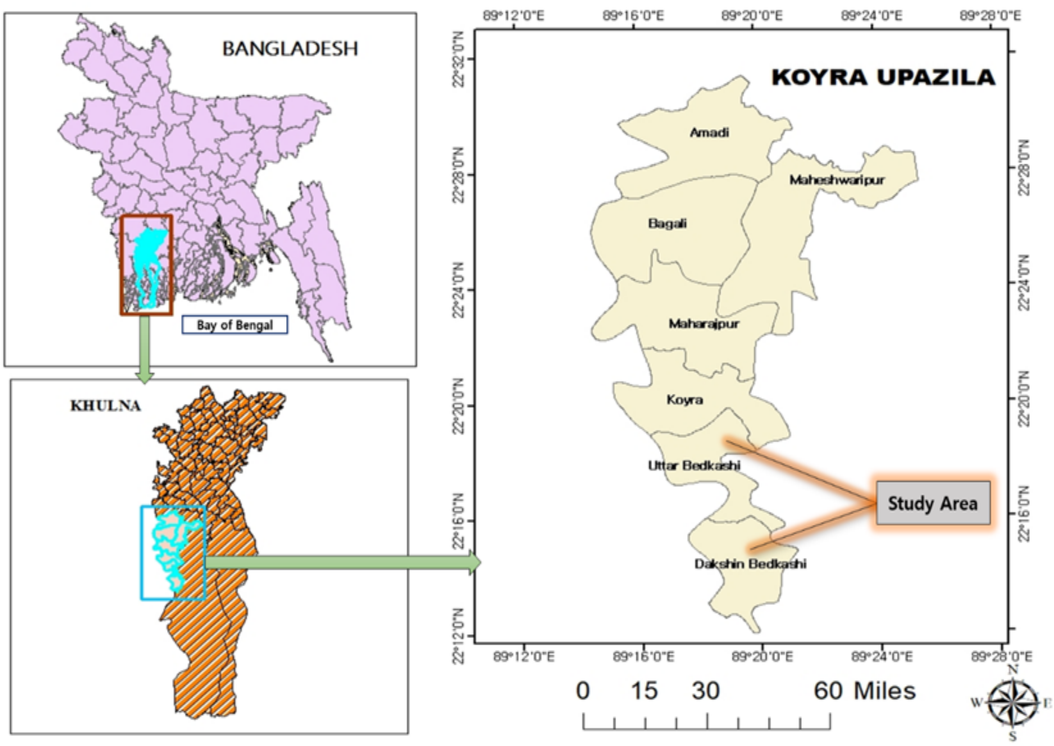
3.1. Study area

The study was carried out in the Koyra upazila of the Khulna District (Figure 1) due to its coastal location, and climatic variabilities (change in temperature, rainfall pattern, and humidity) have been shown throughout the year (Hossain et al., 2019). This study area is also faced with a range of environmental hazards such as cyclones, flooding, storm surges, deforestation, salinity, soil loss, and unregulated shrimp cultivation (Iqbal & Aziz, 2022).

3.2. Data collection

We identified a population of 410 coastal farmers, as reported by the local agricultural extension office. This population was selected based on criteria that farming as their primary occupation, active participation in coastal farming, and more than 10 years of farming experience. Then we conduct simple random sampling and selected 160 (confidence level 90%, margin of error5%) coastal farmers as a sample of this study.

The study used a mixed-method approach to explore the barriers to adopting CSA practices in the coastal region of Bangladesh. A semi-structured, pre-tested questionnaire was developed for gathering quantitative data. Initially, we developed the questionnaire in English, but before starting the survey, we translated into Bengali by a professional



Source: developed by the author

〈Figure 1〉 Location of the study area

translator. We also conducted a pilot survey with 25 respondents to check the validity and reduce the items of the questionnaire. Before starting the face-to-face interview, we clarified the objectives of the study to the respondents. After getting the findings from the survey results, we also employed two focus group discussions. Each discussion was consisted of 7 members, including 5 experienced coastal farmers and two local extension agents. We used a structured and open-ended set of questions based on the survey result. During the focus group discussion, we aimed to get an in-depth understanding of existing climate-induced vulnerabilities, the reason behind the adoption of CSA practices, and barriers to adopting CSA practices. The local extension workers also assisted us in identifying the gaps in agricultural policies for coastal regions. The qualitative data obtained from FGDs has been integrated into the results of the study according to their relevance.

3.3. Measurement

For this study, we selected socioeconomic and demographic characteristics of farmers, job satisfaction, use of information source, perception of agricultural vulnerability, and adoption of CSA practices as predictor or independent variables. We initially identified items related to agricultural vulnerability, adopted CSA practices (Masud et al., 2017; Anzum et al., 2023; Uddin et al., 2017; Chowdhury et al., 2022; Islam et al., 2015; Hoque et al., 2019), and barriers to adopting CSA practices (Masud et al., 2017; Anzum et al., 2023; Lamichhane et al., 2022; Antwi-Agyei et al., 2021) through a review of previous research articles. After conducting the pilot survey, we finalized eight agricultural vulnerability items, 17 CSA practices, and 16 barriers, categorizing the barriers into personal, organizational, economic, technological, and social groups. The internal consistency (Cronbach's alpha) of the items of agricultural vulnerability, adopted CSA practices, and perceived barriers to adopting CSA practices was 0.72, 0.74, and 0.79, respectively. The measurements of socioeconomic characteristics of farmers, perceptions on agricultural vulnerabilities, adoption of CSA practices, and barriers to adopting CSA practices are shown in Table 2.

In this research, we employed the Adoption Index (ADI) to ascertain the most prevalent CSA practices within examined coastal farming communities (Kassem et al., 2020). We also assess the level of adoption of CSA practices and rank them based on their priority. Equation (1) was employed to compute the ADI

$$\text{Adoption Index (ADI): } \Sigma \frac{W}{A \times N} \quad (1)$$

〈Table 2〉 Measurements of variables

Variables	Measurement
Age of the respondents	Score 1 for each year
Education of the respondents	Can't read and write=0; Primary (1-5) = 1; Secondary (6-10) = 2; Higher Secondary (11-12) = 3; Graduate = 4; Postgraduate = 5
Service experience	Score 1 for each year of experience
Annual Income	Score 1 for each Bangladeshi taka. (1$ = 117.65 BDT)
Farm size of the respondents	Score 1 for each hectare (1 hectare = 247.128 decimal)
Training experience	Score 1 for each day of experience
Job satisfaction	Highly satisfied = 4; moderately satisfied =3; least satisfied = 2; dissatisfied = 1
Use of Information Sources	3-4 time/week = 4; 2-3 time/15 days = 3; Once/ month = 2; Don't use = 1
Agricultural vulnerability	4 = High; 3 = Moderate; 2 = Low; 1= Not at all (Ndamani & Watanabe, 2017)
Adoption of CSA practices	Always = 4, Often= 3, Rarely = 2, Do not Use = 1 (Antwi-Agyei et al., 2021)
Barriers to adopt CSA Practices	4 = High; 3 = Moderate; 2 = Low; 1= Not sure (Ndamani & Watanabe, 2017)

Where, W is the weight assigned to each statement by the respondents, with a range of 1 to 4. A represents the highest possible answer value (4), and N is the total number of respondents.

We have analyzed the farmers perceptions of climate-induced agricultural vulnerabilities and existing barriers to adopting CSA practices by using the following equation that was derived from the existing literature sources (Anzum et al., 2023; Debnath and Biswas, 2022; Kantamaneni et al., 2020).

$$\text{Agricultural Vulnerability Index (AGVI)}: AGV_h \times 4 + AGV_m \times 3 + AGV_l \times 2 + AGV_n \times 1 \quad (2)$$

Where, AGV_h, AGV_m, AGV_l, and AGV_n represent the frequencies of respondents who reported high, moderate, low, and no agricultural vulnerability, respectively.

$$\text{Barrier Index (BI)}: BI_h \times 4 + BI_m \times 3 + BI_l \times 2 + BI_{ns} \times 1 \quad (3)$$

Where, BI_h = frequency of respondents who stated very high barriers; BI_m = frequency of respondents who stated moderate barriers; BI_l = frequency of respondents who stated low barriers; BI_{ns} = frequency of respondents who were not sure.

3.4. Analysis

After an extensive data collection process, the study proceeds with an in-depth statistical analysis, focusing on the farmers' perceptions of the barriers to adopting CSA practices and identifying the factors that contribute to these barriers. The quantitative data was analyzed in SPSS. We used descriptive statistical methods such as range, mean, standard deviation, frequency, and percentage distribution to describe or calculate the predictor and criterion variables. In this research, we applied the agricultural vulnerability index (AGVI), adoption index (ADI), and barrier index (BI) to determine the perception of farmers on agricultural vulnerabilities, ascertain the most adopted CSA practices, and identify the barriers that farmers face. Multiple linear regression analysis was employed to identify the contributing factors in barriers to adopting CSA practices in the coastal region of Bangladesh. We calculated the variance inflation factor (VIF) and found less than 4, indicated that no multicollinearity among predictor variables. After getting the results from analyzed quantitative data, we conjugated the qualitative data from FGDs against related findings to describe the actual scenario of the research area.

4. Results

4.1. Socioeconomic characteristics of respondents

The socioeconomic profile (Table 3) of coastal farmers reveal that 71.9% of coastal farmers belong to the middle and old-aged group, with average age of respondents is 50.56. According to the study 21.9% had no formal education, and only 6.8% of farmers hold a graduate degree. The study area reflects a perception that farming lacks economic vibrancy as a profession among the educated populace. Regarding income distribution, the study indicates that 85.6% of farmers fall into the low annual income group (> 1,30,000 Bangladeshi Taka/year) or (>1105$), and only 3.1% in the high annual income group (above 3,00,000 Bangladeshi Taka/year) or (above 1836$). Inadequate income poses economic stress and uncertainty, hindering agricultural activities during periods of climate vulnerability. Moreover, low income in farming discourages educated and talented individuals from pursuing farming as a career option.

Farmers had an average farming experience of 28.21 years. It was found that experienced farmers expressed more understanding and expertise regarding the impact of climate change on agriculture. The majority (71.9%) of the coastal farmers did not receive any training on climate change adaptation, only 28.1% had received training on climate change adaptation. The mean value of the training received was 1.29 days. These findings indicate that there is a competency gap in the coastal farming community on climate change adaptation.

The study also found that the majority (82.5%) of farmers had small farms (<0.7 hectares), and only 3.1% had large farms (exceeding 1.5 hectares). In terms of job satisfaction, 45% respondents reported low satisfaction (up to 11), 49.4% reported medium satisfaction (12-16), and only 9% reported high satisfaction (above 16). Farmers' dissatisfaction mainly related to two main factors: the "lack of recognition" for their efforts and achievements and "insufficient technical support" from the Department of Agricultural Extension (DAE). When farmers feel neglected and unsupported, farmers lose their motivation to continue farming, which ultimately affects agricultural productivity.

Additionally, most of the farmers (59.4%) showed low usage of information sources, and only 4.4% of farmers frequently use different information sources for agricultural

〈Table 3〉 Socioeconomic characteristics of respondents (N =160)

Characteristics	Categories	Respondent (%)	Mean	SD
Age	Young (Up to 43)	28.1%	50.56	11.27
	Middle Aged (44-59)	50.7%		
	Old Aged (Above 59)	21.2%		
Education	Illiterate (no education)	21.9%	1.65	1.23
	Primary (1-5)	23.8%		
	Secondary (6-10)	30%		
	Higher secondary (11-12)	17.5%		
	Graduate (13-16)	5.6%		
	Post graduate (〉16)	1.2%		
Annual Income	Low Income (up to 1,30,000 BDT/year) or (up to 1105$)	85.6%	93.43	48.24
	Medium Income (1,31,000-2,16,000 BDT/year) or (1106$ - 1836$)	11.3%		
	High Income (Above 2,16,000 BDT/year) or (above 1836$)	3.1%		
Farming Experience	Short (〈25 years)	46.2%	28.32	11.52
	Medium (26-42 years)	43.2%		
	Long (〉42 years)	10.6%		
Training Experience	No	71.9%	1.29	2.66
	Yes	28.1%		
Farm Size	Small (〈 .7)	82.5%	0.48	0.38
	Medium (.7 - 1.5)	14.4%		
	Large (〉 1.5)	3.1%		
Job Satisfaction	Low (up to 11)	45%	12.23	2.61
	Medium (12-16)	49.4%		
	High (above 16)	5.6%		
Use of Information Source	Low (up to 14)	59.4%	14.04	3.07
	Medium (15-20)	36.2%		
	High (above 20)	4.4%		
Farmers perception on agricultural vulnerability	Low (up to 19)	2.5%	28.48	3.54
	Medium (20-25)	10.6%		
	High (above 25)	86.9%		
Adoption of CSAT	Low (up to 35)	18.1%	41.41	8.62
	Medium (36-49)	68.1%		
	High (above 49)	13.8%		

Source: Field survey of the research, Note: SD = Standard Deviation, N = total number of respondents information. Farmers are communicating with "input dealers," "progressive farmers," and watching "television" as their primary source of agricultural information. We also found that local government extension agents had failed to establish rapport with local farmers. On the other hand, agriculture related television programs such as "Mati O Manush," "Hridoye Mati o Manush," "Deepto Krishi," and "Krishi o Projukti" have popularity among coastal communities.

4.2. Perceptions on agricultural vulnerability

The Agricultural Vulnerability Index (Table 4) indicates that the most severe agricultural vulnerability is the increased soil salinity (AVI=614) during the dry season. This phenomenon occurs as water evaporates, leaving behind concentrated salts in clay loam and groundwater Reducing freshwater resources (AVI=595) is another example of the agricultural vulnerabilities that are increasing day by day in coastal areas of Bangladesh. Increasing sea levels also exacerbate the intrusion of saltwater into freshwater reservoirs in coastal areas, adversely affecting coastal agriculture. Higher incidence of pests and diseases (AVI= 579), and poor seed germination (AVI= 562) are decreasing crop yields and increased production costs. Changes in temperature and precipitation patterns have a significant effect on the process of seed germination. Furthermore, increased temperatures speeding up insect development, leading to earlier adulthood and higher pest populations, causing greater crop damage.

The result also revealed that climate change impact has led to extinction of crop species (AVI=558), suboptimal vegetative growth of plant (AVI=544), poor harvests (AVI=525), and alternation in farming calendar (AVI=520). Farmers have observed suboptimal vegetative growth when cultivating vegetables in low-lying coastal regions. Unpredictable rainfall can also lead to either excessive water accumulation or drought-induced stress, which can hinder the absorption of nutrients and impede the proper growth and development of crops. Changes in precipitation patterns, increased temperatures, and increased salinity are leading to adjust the agricultural calendar, affecting planting, harvesting, and other farming activities. Moreover, climate induced vulnerabilities forced farmers to stop cultivating oil seeds and traditional rice cultivars such as Najirsail and Boran.

4.3. Adoption of CSA practices

The CSA adoption index (Table 5) indicated that cultivating high-yielding varieties (HYVs) of vegetables on high land, growing short-duration HYVs of rice, utilizing compost, employing appropriate fertilizer application, and employing the sarjon cultivation method were the predominant practices among farmers, with corresponding ADI scores of 0.93, 0.85, 0.76, 0.73, and 0.70, respectively. In focus group discussions (FGDs), farmers emphasized that the introduction of multiple high-yielding varieties (HYVs) of vegetables and the

〈Table 4〉 Agricultural vulnerability index (CVI) based on farmers' perceptions (N=160)

Perceived Vulnerability	High (W = 4)	Moderate (W = 3)	Low (W = 2)	Not at all (W = 1)	AVI	Rank
Increasing soil salinity in dry season	141 (88.1%)	13 (8.1%)	5 (3.1%)	1 (.6%)	614	1st
Reducing freshwater resources	130 (81.2%)	20 (12.5%)	5 (3.1%)	5 (3.1%)	595	2nd
Higher incidence of pests and diseases	122 (76.2%)	20 (12.5%)	13 (8.1%)	5 (3.1%)	579	3nd
Poor seed germination	125 (78.1%)	27 (16.9%)	3 (1.9%)	5 (3.1%)	562	4th
Extinction of crop species	101 (63.1%)	40 (25%)	15 (9.4%)	4 (2.5%)	558	5th
Suboptimal vegetative growth of plant	115 (71.9%)	31 (19.4%)	7 (4.4%)	7 (4.4%)	544	6th
Poor harvests	87 (54.4%)	41 (25.6%)	22 (13.8%)	10 (6.2%)	525	7th
Alteration of farming calendar	79 (49.4%)	57 (35.6%)	9 (5.6%)	15 (9.4%)	520	8th

Source: Field survey of the research
Note: "W" is the weight assigned to each statement provided by the respondents, AVI = Agricultural Vulnerability Index

cultivation of vegetables on elevated land adjacent to their homesteads had increased productivity and delivered positive returns on investment. Due to Top of FormDueDueflash flooding. local farmers opted to grow short-season rice varieties during the Aman season. The adoption of compost, biogas, and appropriate fertilizer usage was initiated by local extension organization. In this area, farmers are using sarjon cultivation method by establishing ridged beds (1 - 1.5m in height) and furrows.

Additionally, we also observed that farmers are using the mulching technique in vegetable production (ADI 0.70), which helps to maintain soil moisture, and using nets over ponds (ADI 0.69) to produce creeping vegetables, which is suitable when land is scarce. Bottom of FormRecently, coastal farmers have adopted watermelon cultivation (ADI 0.65) because of the favorable environmental conditions that are suitable for watermelon cultivation. Furthermore, many farmers have adopted CSA practices such as intercropping (ADI 0.62), alternate wetting and drying irrigation management (ADI 0.61), crop diversification (ADI 0.55), using crop residues (ADI 0.53), and integrated rice-fish farming (ADI 0.51) to mitigate vulnerabilities in coastal agriculture. Alternate wetting and drying irrigation management help to reduce salinity in soils; crop diversification and use of crop residues helps to improve soil fertility and maintain biodiversity; and integrated rice-fish farming helps to get irrigation water in the dry season.

Several CSA practices exhibit low adoption rate include floating bed cultivation of vegetables (ADI 0.35), rainwater harvesting (ADI 0.36), use of solar-powered irrigation (ADI 0.39), and zero tillage sowing (ADI 0.40). Farmers' adoption of various CSA practices differed, impacted by their perceived necessity to enhance resilience in the face of climate change. Our focus group discussions revealed that younger farmers exhibit greater willingness to adopt CSA practices compared to older members of the farming community. But their limited experience with climatic variability and agricultural vulnerability poses challenges to ensuring the profitability of these CSA practices.

〈Table 5〉 CSA adoption index based on farmers' perceptions (N = 160)

CSA Practices	Always (W = 4)	Often (W = 3)	Rarely (W = 2)	Don't use (W = 1)	ADI	Rank
Cultivation HYVs of vegetables on high land	143 (89.4%)	2 (1.2%)	1 (.6%)	14 (8.8%)	0.93	1st
Cultivation of Short-duration HYVs of rice	118 (73.8%)	6 (3.8%)	18 (11.2%)	18 (11.2%)	0.85	2nd
Use of Compost	75 (46.9%)	40 (25%)	21 (13.1%)	24 (15%)	0.76	3nd
Proper fertilizer management	37 (23.1%)	85 (53.1%)	26 (16.2%)	12 (7.5%)	0.73	4th
Sarjon cultivation method	75 (46.9%)	20 (12.5%)	26 (16.2%)	39 (24.4%)	0.70	5th
Use of Mulching	63 (39.4%)	44 (27.5%)	11 (6.9%)	42 (26.2%)	0.70	6th
Growing creeping vegetables on nets over ponds	72 (45%)	20 (12.5%)	27 (16.9%)	41 (25.6%)	0.69	7th
Cultivation of watermelon	52 (32.5%)	39 (24.4%)	19 (11.9%)	50 (31.2%)	0.65	8th
Intercropping	56 (35%)	25 (15.6%)	21 (13.1%)	58 (36.2%)	0.62	9th
Use of alternate wetting and drying (AWD) irrigation system	65 (40.6%)	19 (11.9%)	2 (1.2%)	74 (46.2%)	0.61	10th
Crop Diversification	45 (28.1%)	16 (10%)	25 (15.6%)	74 (46.2%)	0.55	11th
Use of crop residues as organic manure	53 (33.1%)	10 (6.2%)	0 (0%)	97 (66.6%)	0.53	12th
Integrated rice-fish farming	41 (25.6%)	9 (5.6%)	23 (14.4%)	87 (54.4%)	0.51	13th
Zero tillage sowing	8 (5%)	26 (16.2%)	20 (12.5%)	106 (66.2%)	0.40	14th
Use of solar-powered irrigation	27 (16.9%)	7 (4.4%)	0 (0%)	126 (78.8%)	0.39	15th
Rain water harvesting	3 (1.9%)	7 (4.4%)	47 (29.4%)	103 (64.4%)	0.36	16th
Floating vegetables cultivation	16 (10%)	5 (3.1%)	11 (6.9%)	128 (80%)	0.35	17th

Source: Field survey of the research
Note: "W" is the weight assigned to each statement provided by the respondents, ADI = Adoption Index

4.4. Barriers to adopting CSA practices

The study investigated the barriers encountered by studied coastal farmers in adopting CSA practices (Table 6), and it was classified the barriers into five categories: personal barriers (PB), organizational barriers (OB), economic barriers (EB), technological barriers (TB), and social barriers (SB). Result reveals that the foremost barrier was "high initial investment cost (BI=604)", followed by "poor infrastructure of embankment (BI=575)", and "low price of crops (BI=573)" among the other barriers encountered by farmers during CSA adoption.

Farmers highlighted that the initial costs, price of stress-tolerant crop varieties, irrigation systems, fertilizers, labor, operational equipment, and infrastructure, pose a significant barrier for small-scale farmers. Conversely, the low prices of crops in relation to production costs also discourage coastal farmers from adopting CSA practices. Moreover, the unstable infrastructure of embankments presents a considerable risk for flash floods, especially during the rainy season.

The study identified that due to a lack of solar-powered irrigation systems (BI=569), farmers are using diesel or petrol pumps, which strongly contribute to climate change. Farmers pointed out that the cost of solar panels and batteries is very high for small-scale farmers. Inadequate technical support from extension organizations (BI=567) and limited understanding regarding climate change vulnerability (BI=565) were also important barrier that were interconnected with each other. In this region, most of the farmers (71.9%) did not receive any extension education programs from local extension organizations, which is essential to improving their

〈Table 6〉 Barrier index (BI) based on farmers' perceptions (N = 160)

Perceived Barriers		High (W = 4)	Moderate (W = 3)	Low (W = 2)	Not Sure (W = 1)	BI	Rank
Personal Barriers							
PB1	Lack of understanding on climate change vulnerability	104 (65%)	42 (26.2%)	9 (5.6%)	5 (3.1%)	565	6th
PB2	Lack of competency to implement CSA practices	75 (46%)	44 (27.5%)	6 (3.8%)	35 (21.9%)	485	12th
PB3	Challenges in assessing the effects or outcomes of CSA practices	36 (22.5%)	32 (20%)	56 (35%)	36 (22.5%)	388	16th
Organizational Barriers							
OB1	Insufficient technical assistance from extension organization	105 (65.6%)	45 (28.1%)	2 (1.2%)	8 (5%)	567	**5th**
OB2	Ineffective policies and strategies	97 (60.6%)	36 (22.5%)	9 (5.6%)	18 (11.2%)	532	9th
OB3	Lack of interaction with extension agents	106 (66.2%)	30 (18.8%)	11 (6.9%)	13 (8.1%)	549	8th
OB4	Farmer's competency not considered in innovation decision process	80 (50%)	31 (19.4%)	7 (4.4%)	42 (26.2%)	469	14th
Economic Barriers							
EB1	High initial investment costs	124 (77.5%)	36 (22.5%)	0 (0%)	0 (0%)	604	**1st**
EB2	Limited access to credit facilities	87 (54.4%)	51 (31.9%)	4 (2.5%)	18 (11.2%)	527	10th
EB3	Uncertain outcomes and returns	59 (36.9%)	52 (32.5%)	31 (19.4%)	18 (11.2%)	472	13th
EB4	Low prices of crops	113 (70.6%)	28 (17.5%)	18 (11.2%)	1 (0.6%)	573	**3rd**
Technological Barriers							
TB1	Poor infrastructure of embankment	121 (75.6%)	15 (9.4%)	22 (13.8%)	2 (1.2%)	575	**2nd**
TB3	Weak telecommunication system and internet facility	63 (39.4%)	58 (36.2%)	29 (18.1%)	10 (6.2%)	494	11th
TB4	Unavailability of solar-powered Irrigation system	119 (74.4%)	21 (13.1%)	10 (6.2%)	10 (6.2%)	569	**4th**
Social Barriers							
SB3	Unfavorable land tenure system	61 (38.1%)	51 (31.9%)	14 (8.8%)	34 (21.2%)	459	15th
SB4	Shaky marketing facilities	112 (70%)	30 (18.8%)	6 (3.8%)	12 (7.5%)	562	7th

Source: Field survey of the research
Note: "W" is the weight assigned to each statement provided by the respondents, BI = Barrier Index

competency to understand climate induced vulnerabilities and climate change adaptation in coastal agriculture. Farmers stated that due to the difficult communication system in coastal region, extension agents have failed to establish rapport with all coastal farmers, resulting in insufficient opportunities for training, demonstration programs, and sharing relevant information, which are crucial for the adoption of CSA practices.

Additionally, farmers faced challenges when selling their products directly due to a lack of transportation facilities. Furthermore, they are experienced with unfair profit distribution because of the presence of middlemen and intermediaries in agricultural marketing. The limited access to alternative marketing opportunities, such as farmer cooperatives or direct-to-consumer sales, further exacerbates this problem (Pingali et al., 2019). Recently, the government has initiated Climate Field Schools (CFS) to promote CSA practices through outreach activities (Akter et al., 2022), but farmers point out the importance for more robust government support, special subsidies, insurance policies, and export opportunities. The frequently access of credit facilities with low interest and a government-regulated pricing system could enhance the motivation of farmers to adopt CSA practices in the coastal region of Bangladesh.

4.5. Factors affecting farmers' barriers to adoption of CSA practices

To evaluate the factors contributing to barriers encountered by farmers to adopt CSA practices, we conducted a multiple linear regression analysis (Table 7). VIF was from 1.101 to 3.116. The finding showed that the farmers age, education level, training experience, satisfaction with farming profession, and use of information source all are contributing to the barriers to the adoption of CSA practices. The model explained 40.6% of the variation in barriers to adopting CSA practices. Age (β = .216), education (β = -.156), and use of information source (β = 0.159), were significant at the level of 5%. On the other hand, training experience (β = -0.285), and job satisfaction (β = -.272) were significant at the level of 1%.

The findings of the model revealed that older farmers have more barriers to adopting CSA practices due to their unwillingness to change their traditional or existing cultivation methods. Older farmers also encountered difficulties in adopting CSA practices due to a lack of competency to handle

〈Table 7〉 Factors affecting farmers' barriers to adoption of CSA practices (N = 160)

Independent Variable	Measurement	β - Value	Std. Error
Age	Score 1 for each year	.216**	.063
Education	Can't read and write = 0; Primary (1-5) = 1; Secondary (6-10) = 2; Higher Secondary (11-12) = 3; Graduate = 4; Postgraduate = 5	-.156**	.416
Annual Income	Score 1 for each year of experience	-.135	.017
Farming Experience	Score 1 for each Bangladeshi taka. (1$ = 117.65 BDT)	.058	.044
Training Experience	Score 1 for each hectare (1 hectare = 247.128 decimal)	-.285***	.191
Farm Size	Score 1 for each day of experience	.120	2.096
Job Satisfaction	Highly satisfied = 4; moderately satisfied =3; least satisfied = 2; dissatisfied = 1	-.272***	.189
Use of Information Source	3-4 time/week = 4; 2-3 time/15 days = 3; Once/ month = 2; Don't use = 1	.159**	.157
Total Barrier score, (mean ± SD) = (52.40 ± 7.34), R2=0.406, adj-R2 = 0.374, F = 12.884***			

Note: ** p<.05 , ***p<.01 Dependent variable = Barriers to adoption of CSA practices
Barrier was measured by four-point scale including 4 = High; 3 = Moderate; 2 = Low; 1= Not sure

new technologies. Farmers who had higher academic education and received training to increase their competency faced fewer barriers to adopting CSA practices than others. Surprisingly, the model indicated that farmers who make higher use of information sources faced higher barriers. Then we investigated and found that most of the farmers are interacting with local input dealers, old farmers, and watching television for their farming information. But the information from these sources is leading to misconceptions, and do not providing a clear understanding of climate change impact and possible solution in agriculture. These misconceptions and improper guidance are developing confusion, and discouraging the adoption of new technology. Additionally, the lack of interaction with governmental extension agents results in farmers being less willing to accept or seek information from these government extension agents. In Bangladesh, the government extension workers under the Ministry of Agriculture are primarily responsible for agricultural extension services. Due to lack of communication, local farmers are not getting necessary information and policy support that could help them adopt CSA practices and mitigate climatic vulnerabilities.

Extension agents also acknowledge that the shaky transportation system makes it difficult to maintain regular farm and home visits, conduct method and result demonstrations, field days, training programs, motivational tours, and other extension programs that could decrease barriers and increase motivation. Therefore, it is crucial for local extension organizations to maintain frequent communication with local farmers. This increased communication helps them to get appropriate information and extension policy support, which may reduce their barriers to adopting CSA practices.

Furthermore, the results indicated that job satisfaction had negative contribution in barriers to adopting CSA practices. It is expected that farmers who had higher job satisfaction tend to faced lower barriers when adapting CSA practices to mitigate vulnerabilities in coastal agriculture. Farmers' dissatisfaction mainly related to two main factors: the “lack of recognition” for their efforts and achievements and “insufficient technical support” from the local extension organization. When farmers feel neglected and unsupported, farmers lose their motivation to accept new technology. Local farmers expressed that if the extension organization involved them in the decision-making process regarding their coastal area, they could describe their challenges and the necessary extension support needed, but extension organization does not engage local farmers in this process. During FGDs, farmers also emphasized that local extension agents tend to prioritize farmers affiliated with ruling government party when provide extension support and subsidies.

5. Conclusion

The study addressed the adoption of CSA methods, the perceived barriers to adopting CSA practices, and the views of agricultural vulnerabilities among coastal farmers. Most coastal farmers were young to middle-aged with little formal education, minimum agricultural experience, modest farm sizes, poor incomes, and insufficient training in climate-adaptive methods. Anzum et al. (2023) and Bhuyan et al. (2024), also found the similar findings in their research that were usually young to middle-aged farmer with tiny farms, equivalent farming experience, little education, and poor earnings. According to Aryal et al. (2020), just 7% of farmers have had training on adapting to climate change. Among those drawbacks, the positive side is recently there has been a discernible rise in the proportion of people (almost 28%) obtaining this kind of training on agriculture's response to climate change.

In the study area most, dangerous climate component was salinity, which had an influential impact on plant germination, growth, and development as well as lowering production. Furthermore, day by day the freshwater sources are diminished, and saltwater intrusion is getting worse by rising sea levels (Bobba, 2002). Salinity disrupts photosynthesis, damages stomata and chloroplast structures, and impairs chlorophylls and enzymes, ultimately leading to crop desiccation (Santos et al., 2022). Hasan and Kumar (2020) also pointed out that salt intrusion and sea level rise results in a considerable decrease in agricultural production. Coastal farmers also affected by many climate-related vulnerabilities, such as a rise in insect infestations, insufficient seed germination, improper plant growth, and reduced crop yields. The high concentration of Na+ and Cl— ions also disrupts cellular homeostasis and nutrient uptake, leading to nutrient deficiency, oxidative stress, and ultimately cell death in seed and young plants (Sarwar et al., 2022). According to previous research, pest feeding, performance, and dispersal are all improved by climate change, especially higher temperatures, which might result in infestations and crop loss (Subedi et al., 2023). Additionally, Reed et al. (2022) showed that climate change result in decreased germination rates, increased seed dormancy, and other effects that are detrimental to plant development and yields.

Certain CSA practices have already been adopted by farmers in the study area to cope up with present climate change situation. Actually, the main purpose of adopting CSA practices in this area are to increase agricultural output, not to improve climate resilience or lessen agriculture's impact on climate change. According to Ali and Hossain (2019), the production of high-yield vegetables (HYVs) in household areas using a tower system, known locally as "macha," was shown to be especially appropriate for sites where rainfall and tidal water intrusion impeded vegetable cultivation, particularly during the rainy season. Beside more, composting has an impact on the storage of soil carbon and the decrease of N2O emissions, both of which lessen the impact of climate change on agriculture (Favorino and Hogg, 2008). Sarjon approach also lessened losses from flooding and severe rains while also reducing soil salinity (Ruba et al., 2024). However, the careless use of traditional fertilizers has resulted in serious environmental issues, especially the production of greenhouse gases like nitrous oxide (N2O) that contribute to climate change (Menegat et al., 2022). So, farmers are now using the proper quantity of fertilizer to reduce climate change impacts. Farmers also adopted mulching to provide a protective layer on the soil by minimizing the rate of evaporation and retaining the moisture in the soil (Ali & Hossain., 2019). Our research also revealed that as watermelon needs more salty conditions, so coastal farmers are giving emphasize on growing it. On the other side, the adoption rates of crop diversity, integrated rice-fish farming, crop wastes as organic manure, alternating wetting and drying irrigation systems, and intercropping were all found to be rather low in our study, because it is influenced by a number of factors, including location-specific regulations, opportunities for capacity building, access to critical knowledge, and the growth of institutional and social capacity (Akter et al., 2022). Additionally, due to the high cost of inputs and the lack of cooperation from the local extension office, farmers are not interested in using solar-powered irrigation, rainwater collecting, or floating vegetable growing (Kangogo et al., 2021; Chowdhury and Moore, 2017).

In this study the biggest obstacles to adopt CSA were high investment costs, inadequate embankment infrastructure, low crop prices, restricted access to solar-powered irrigation, inadequate technical support from extension organizations, and unstable marketing facilities. Fusco et al. (2020) highlighted that economic barriers significantly act as dominant barriers hindering the adoption of CSA practices. For smallholder farmers the upfront costs of CSA practice implementation as a major deterrent to adoption (Gemtou et al., 2024; Lamichhane et al., 2022). Agbenyo et al. (2022) also noted that a major obstacle to the implementation of CSA techniques is the low pricing of commodities relative to production expenses. On the other hand, in coastal area waterlogging has occurred due to riverbed sedimentation and climate change-induced cyclones caused by nonfunctional coastal embankment infrastructure (Rahman et al., 2021). As the foremost goal of coastal embankment projects was to reduce crop damage and prevent flooding, but the increased flash floods indicating that the embankments in place today are insufficient to control flooding and causing serious harm to coastal agriculture (Adnan et al., 2019). In previous research found that solar-powered irrigation systems were not installed by local farmers and extension organizations because of their high cost (Hossain et al., 2024). In addition, Barua et al. (2021) noted that the existence of middlemen in the agricultural marketing system hinders farmers' ability to get their true profit and that unstable agricultural marketing facilities are a barrier to climate change adaptation. According to findings lack knowledge about the vulnerability of climate change, a lack of competency to implement CSA practices, difficulties evaluating the effects or outcomes of CSA practices, an unfavorable land tenure system, limited access to credit facilities, uncertain outcomes and returns, and a lack of interaction with extension agents, all were also influenced to not adopting CSA practices in the study area. Similar obstacles to adapting to climate change have also been identified by earlier research (Mondal et al., 2019; Long et al., 2016; Masud et al., 2017; Lamichhane et al., 2022). Beside more, older farmers experienced more obstacles because of their lack of technical competency and reluctance to modify their conventional or present agriculture methods. In Nigeria and Vietnam, it was discovered that farmers' age was adversely correlated with their adoption of CSA methods (Tran et al., 2020) and aged farmers are often risk-averse and reluctant to implement better agricultural practices (Zheng et al., 2021). According to Belay et al. (2022), one-year increase in education results in a 21.40% increase in the likelihood to decrease the barriers to adopting CSA practices. Additionally, having access to necessary training will have a good impact on farmers' issues and the adoption of CSA techniques (Silva et al., 2024).

Farmers are becoming more reliant on local input dealers, elderly farmers, and television shows to get the essential agricultural information due to the minimal interaction between local extension personnel and farmers. Many researchers discovered that peer farmers and private input suppliers were the main source for agricultural information among farmers (Waaswa et al., 2021; Kumar et al., 2020). In the study area's farmers who have greater access to information sources also exhibit higher barriers. Kumar et al., (2020) also showed that farmers had less of a barrier to adopting CSA methods the more information they have access to. Remarkably, as input dealers only ever offered information that benefited their company and the older farmers were unwilling to embrace new technology, and many television programs shows exclusively highlighted the positive results without discussing the difficulties, so times it leading to a rise in barriers and misunderstandings among coastal farmers. According to Li et al. (2023), peer farmers, input dealers, television, and radio are less important than government extension agents when it comes to think about adopting CSA techniques. Governmental extension services play a great role to give more information about CSA practices and climate change through the dissemination of information (Asfaw et al. 2016). Additionally, farmers can acquire the skills they need through field guidance and related training (Shahzad and Abdulai 2020). And furthermore, farmers can apply CSA practices more conveniently by receiving supplementary inputs (like transport vehicles and machinery) from extension services (Ma et al. 2017). But adopting CSA techniques is more difficult for farmers who are dissatisfied with their jobs. The reason behind this dissatisfaction is insufficient transportation facilities for the local extension organization to continue providing regular extension support services. Also centralized decision-making process makes feel like lack of recognition among coastal farmers.

Like all other studies, this study also has some limitations. This study was conducted in selected upazilla from the coastal region of Bangladesh. So, it is very difficult to generalize the results to the entire coastal area of Bangladesh. The sample size was small, and only two FGDs were employed due to resource limitations. We used only eight independent variables to explore the contributing factors to the barriers to adopting CSA practices. The results showed that the research model explained 40.6% of the variation in barriers to adopting CSA practices, indicating that other relevant factors were not included in our study. To provide generalize recommendations or policies for minimizing these barriers, further research should be conducted in other coastal regions of Bangladesh.

The research aids in comprehending the apparent obstacles and underlying factors of the barriers to the adoption of CSA practices. The study recommends to give emphasized on execution of extension education program as a source of information for better agricultural practices. The government should offer transportation facilities for its extension workers to build rapport and facilitate the more seamless implementation of extension services. Coastal populations should more engage in farming if policies such as interest-free lending and crop insurance are implemented. According to Singh (2020), Khan et al. (2021) and Muneer et al. (2023), crop insurance encourages farmers to adopt innovative technology. Ensuring access to marketing facilities should be the first step towards developing a fair pricing structure. Using low-cost CSA techniques and sell their goods at high prices, also encourage farmer to adoption of CSA (Li et al., 2023). Local extension organizations can assist farmers in adopting CSA techniques and enhancing their quality of life by giving knowledge linked to climate change (Abegunde et al. 2020). An organization of farmer should be built by local government and non-governmental organizations, to support the implementation of CSA practices, to exchange social capital, production experience, information, and skills. Flash floods can be prevented and fresh water supply for irrigation can be guaranteed by building durable embankments and developing infrastructure for rainwater gathering. But it is now situation demand, to lower the salinity, it is necessary to forbid the construction of additional shrimp ponds. Also, to deduction of agriculture's impact on climate change, a cooperative solar-powered irrigation system can be set up. By taking the initiative and implementing these suggestions, policymakers, local communities, NGOs, and agricultural extension organizations may collaborate to increase resilience in this coastal area.

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Mr. Avijit Biswas is a PhD student at Department of Agricultural Industry Economy and Education, Sunchon National University, South Korea. His research interests are agricultural extension education, agricultural vulnerability mitigation, agricultural sustainability, and competency development.
Address: Department of Agriculture Education, Sunchon National University, South Korea
E-mail: avijitpstu@gmail.com
phone: *** - **** - ****

Ms. Prome Debnath is a PhD student at Department of Geography, Chonnam National University, South Korea. Her research interests are disaster risk reduction, agricultural sustainability, and flood risk analysis.
Address: Department of Geography, Chonnam National University, South Korea
E-mail: hritekaprome56@pstu.ac.bd
phone: *** - **** - ****

Dr. Dae Koo Kang is a Professor of Department of Agriculture Education, Sunchon National University, South Korea. His research interest is competency development, agricultural education methods, and career development.
Address: Department of Agriculture Education, Sunchon National University, South Korea
E-mail: kang@scnu.ac.kr
phone: *** - **** - ****