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ADAPTATION STRATEGIES OF FARMERS FOR COPING WITH THE IMPACTS OF CYCLONES IN SOUTHWEST COASTAL REGION OF BANGLADESH

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Abstract

The study aimed to investigate the adaptation strategies of rice-producing farmers against cyclones in the southwest coastal regions of Bangladesh. The rationale for focusing on this region lies in its high vulnerability to frequent cyclones, which severely impact agricultural productivity and food security. A total of 400 cyclone-affected farmers have been chosen randomly to collect primary data using in-depth interviews, focus group discussions, key informant interviews, and case study methods. Along with the descriptive statistics, a poison regression was used to identify the determinants of the number of adaptation strategies adopted by farmers to cope with the impacts of cyclones on rice production. The study findings revealed significant regional disparities in terms of implementing adaptation strategies. Farmers greatly depend on traditional practices and external assistance in Satkhira district whereas in Khulna district, farmers adopt more diverse adaptive measures, including alternative cropping and community-based support systems. The Poisson regression results reveal that access to loans, family size, and GO/NGO assistance significantly influence the number of adaptation strategies farmers adopt. The research findings contribute to the broader context of climate change adaptation, providing valuable insights for policymakers and practitioners to develop effective adaptation strategies for vulnerable coastal farming communities.

Key words: Climate change adaptation, Natural disasters, Coastal farmer, Vulnerability assessment, Agricultural resilience.

Introduction

Background of the study: Climate change has posed a significant challenge for farmers across the world, affecting agricultural productivity, livelihoods, and food security. Farmers have been implementing diverse adaptation strategies to mitigate these risks (Magesa *et al.* 2023). These strategies involve agricultural practices such as modifying cropping patterns, selecting resilient plant varieties, optimizing fertilizer use, implementing irrigation systems, and enhancing agricultural knowledge and skills (Atasa 2024, Mamun *et al.* 2021). Farmers with inclusive familiarity with climate dynamics are more inclined to adopt effective adaptation strategies (Tshikororo 2022). Moreover, farmers' perceptions of climate change and the availability of suitable adaptation strategies also influence their decision-making processes (Biswas *et al.* 2020, Yetişgin *et al.* 2022). The vulnerability of farmers to natural hazards such as tropical cyclone and flood significantly influences their decisions to either sustain agricultural activities or proactively adopt mitigation measures (Hidalgo 2024).

Farmers' adaptation strategies against climate change vary from region to region. For example, organic farming has emerged as an effective adaptation strategy against climate change in Indonesia, where agriculture is the central to the country's economy (Fachrista 2019). Similarly, maize growing farmers have embraced various adaptation approaches to confront climate

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challenges in Nigeria, underlining the significance of farm-level adaptation solutions (Adeagbo *et al.* 2021). Initiatives focused on bolstering farmers' resilience through enhanced income opportunities, expanded irrigation facilities, and adoption of climate-resilient rice varieties in Benue State, Nigeria (Kim *et al.* 2017). A farmer resilience index has been developed to address the complexity of coastal farming communities and farming systems in response to disasters like cyclones in Tamil Nadu, India (Jayadas and Ambujam 2021). Similarly, inundation, seawater intrusion, soil salinity, and tropical cyclones pose critical challenges to sustainability in coastal agricultural contexts (Gopalakrishnan *et al.* 2019). Moreover, the role of local stakeholders and community networks in disaster risk reduction and recovery is pivotal in bolstering resilience to cyclones and other natural disasters. For instance, local networks, community leaders, and administration play crucial roles in mitigating risks during and after cyclones in coastal West Bengal of India, indicating the significance of community engagement in resilience building (Krishnan and Twigg 2019).

The agriculture sector confronts a formidable challenge posed by cyclones and salinity in coastal regions of Bangladesh (Haq 2022). Coastal afforestation activities emerged as a cost-effective and ecologically sound strategy to safeguard coastal areas and islands from cyclones and storm surges in recent years (Rahman *et al.* 2019). Households in coastal regions employ diverse adaptation and coping measures to mitigate vulnerability to cyclones and salinity intrusion in the country (Saha 2017). Natural hazards such as cyclones stand out as primary climate risks farmers have been facing in the country's southwest coastal belt, showing the necessity of effective adaptation strategies (Aryal *et al.* 2020). Despite the efforts to protect lands from cyclones, events such as cyclone Alia in 2009 showed farmers' vulnerability to natural disasters (Ayeb-Karlsson *et al.* 2016). The combined impact of Cyclone Yaas in 2021, exacerbated by the COVID-19 pandemic, underlined the need for well-enacted policies and community-driven adaptation initiatives (Subhani *et al.* 2021). In addition, change in climatic variables posed emerging threats compelling farmers to adopt diverse agricultural practices in coastal Bangladesh (Islam and Shrivastava 2018).

Farmers have increasingly resorted to various adaptation strategies in response to tropical cyclones, salinity intrusion, and other extreme climatic conditions in Bangladesh (Alam and Mallick 2022). Effective climate hazard adaptation strategies depend crucially on policy options and investment capital to support the farmers (Ali *et al.* 2021). Assessment of social vulnerability and responses to natural disasters in disaster-prone coastal villages indicates the critical role of integrated approaches and traditional technologies in fostering sustainable livelihoods in the country (Kabir and Hossain 2021). The potential for climate-induced migration in coastal regions emphasizes the urgency for proactive adaptation measures to mitigate loss and damage in vulnerable communities of the country (Naz 2024). Migration has emerged as a pivotal strategy to enhance adaptive capacity, particularly in response to cyclones (Ahmed 2023). However, inadequate policy implementation impedes effective adaptation, necessitating deeper inquiry into community perceptions and responses to cyclonic disasters (Mallick *et al.* 2017). Limited adaptive capacity and recurrent exposure to adverse climate events render agriculture and livelihoods highly vulnerable in developing nations such as Bangladesh (Kabir *et al.* 2021).

Farmers contend with substantial climate risks and have embraced diverse adaptation tactics to bolster resilience, including livelihood diversification in the southwest coastal region of the country (Aryal *et al.* 2020). Concurrently, local households have employed a range of adaptation measures to mitigate cyclone hazards and salinity intrusion (Saha 2017). Regarding disaster risk reduction, local communities possess invaluable indigenous knowledge and adaptive capacities that can enhance the country's cyclone and storm surge mitigation efforts (Wedawatta *et al.* 2016).

Livelihood diversification has emerged as pivotal for marginalized coastal farmers in confronting storm surges and food insecurity, emphasizing core activities like crop cultivation and livestock rearing (Roy and Basu 2020). Nevertheless, effective policy implementation and exploration of coastal communities' perceptions, responses, and adaptation strategies to cyclonic disasters remain imperative (Mallick *et al.* 2017).

Objective of the Study: This study investigates the adaptation strategies taken by cyclones Amphan and Bulbul-affected rice producing farmers in coastal Bangladesh. This study appears to be the first attempt to investigate the adaptation strategies of cyclone-affected farmers in coastal Bangladesh since such research is not found in the existing literature. Primary data were collected from the cyclone-affected household to carry out the research objective.

Research Hypothesis

The hypothesis of the study is as follows:

Null Hypothesis (H_0):

Socioeconomic and institutional factors do not significantly influence the number of adaptation strategies adopted by farmers in cyclone-prone coastal regions of Bangladesh.

Alternative Hypothesis (H_1):

Socioeconomic and institutional factors significantly influence the number of adaptation strategies adopted by farmers in cyclone-prone coastal regions of Bangladesh.

Research Questions

The research questions of the study are as follows.

a) How do farmers perceive their vulnerability to cyclones in coastal Bangladesh?

b) What adaptation strategies do farmers use to cope with cyclones in coastal Bangladesh?

c) What role do socioeconomic factors play in influencing farmers' adaptation choices?

Methods

Study area selection: The research focused on the adaptation strategies of rice-producing farmers to cope with the impacts of cyclones in the southwest coastal region of Bangladesh. The selected study areas were Shyamnagar Upazila in Satkhira District and Koyra Upazila in Khulna District (Fig. 1) because the regions were significantly affected by Cyclones Amphan and Bulbul because these cyclones caused extensive agricultural damage and losses. Shyamnagar Upazila is located in the southwest part of Satkhira, with a position between 21°40' and 22°24' north latitudes and 89°00' and 89°19' east longitudes. The area is covered with 1,968.24 square kilometers at the Sundarbans mangrove forest's borders. Therefore, the region is highly vulnerable to cyclones and tidal surges. On the other hand, Koyra Upazila is situated between 22°12' and 22°31' north latitudes and 89°14' and 89°29' east longitudes situated near the Bay of Bengal spanning 1,775.41 square kilometers. Due to its proximity to the coast and its network of rivers and canals, the upazila is vulnerable to cyclonic impacts and saline water intrusion.

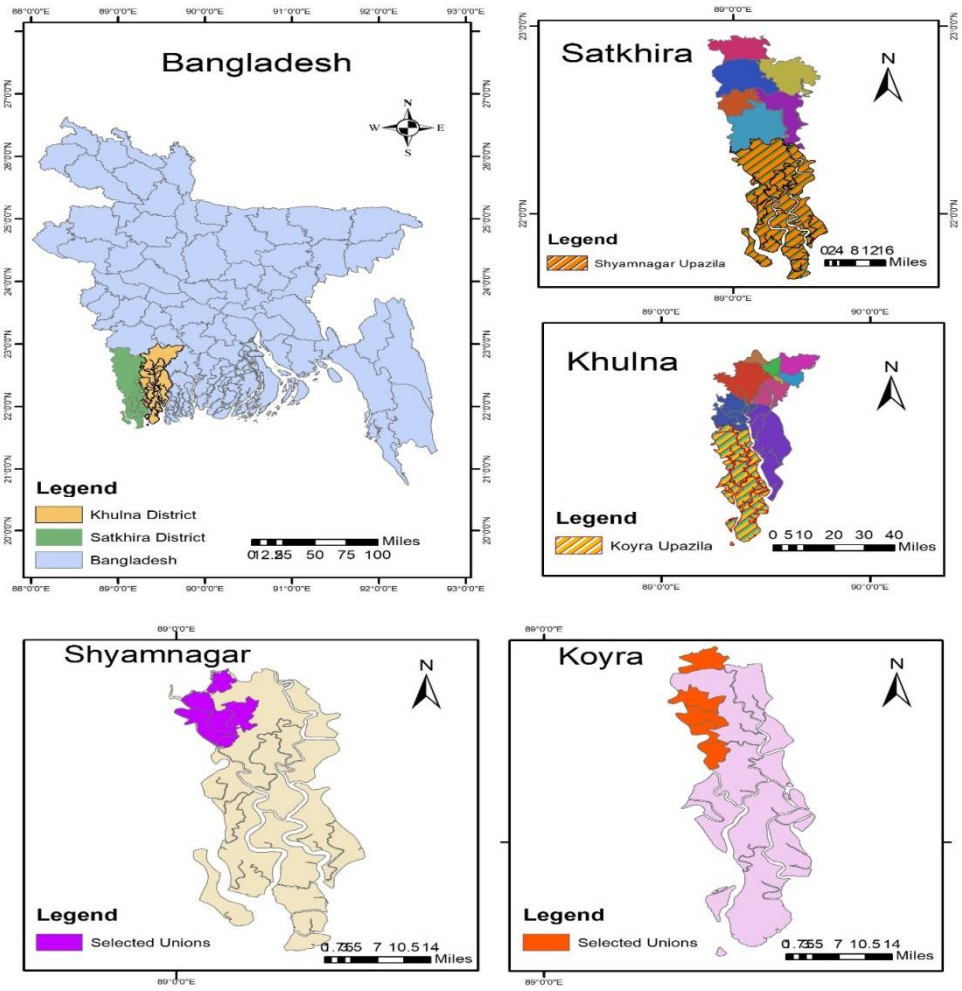

Fig. 1. A map showing the location of the unions where the study was carried out.

For this study, five unions from each upazila have been selected based on the extent of damages and losses caused by these cyclones. The selected unions are Bhurulia, Ishwaripur, Koikhali, Nurnagar, and Ramjannagar from Shyamnagar Upazila and Uttar Bedkashi, Dakshin Bedkashi, Koyra, Amadi, and Moharajpur unions are from Koyra Upazila. The selection of these areas aligns with the objectives of the study due to the significant exposure to cyclones, particularly Amphan and Bulbul. These areas represent critical zones where the impacts of cyclones on farmers are severe, providing a relevant context for studying adaptation strategies.

Sampling Technique: The sample selection process included the rice-producing farmers who have been significantly affected by the cyclones. Therefore, a total of 400 cyclone-affected farmers from the selected unions were chosen using the simple random sampling technique to capture a diverse range of experiences and adaptation strategies.

A total of 200 farmers were selected from 5 unions (40 farmers from each union) from both Shyamnagar and Koyra Upazilas, respectively for the study. Only cyclone-affected rice-cultivating farmers were included to ensure the data's relevance and reliability. This criterion was established to ensure that the selected farmers comprehensively understood the agricultural practices and challenges in the region, particularly in the context of recurring cyclones.

Data Collection: The study employed multiple qualitative methods to gather comprehensive and in-depth data from the selected farmers. The process was taken to ensure the richness and reliability of the data to understand adaptation strategies in cyclone-affected regions. Data were collected from March to August 2023.

In-Depth Interviews: Face-to-face in-depth interviews were conducted with cyclone-affected farmers from the selected unions in Shyamnagar and Koyra Upazilas. A pretested semi-structured questionnaire guided these interviews, allowing for flexibility while confirming that all relevant topics were covered.

Focus Group Discussions (FGDs): Focus Group Discussions (FGDs) were also conducted to complement the individual interviews. A total of 10 FGD comprising 6-10 participating farmers from each union were performed. The FGDs provided a platform for collective discussion, enabling participants to share their experiences and perspectives in a group setting. This method was valuable for identifying common themes and variations in adaptation strategies and understanding the community-level responses to cyclones.

Key Informant Interviews (KIIs): Key Informant Interviews (KIIs) were conducted with local leaders, agricultural experts, and government officials to gather expert opinions and contextual information. These informants provided valuable insights into the broader socio-economic and policy environment affecting farmers' adaptation strategies. KIIs were crucial for understanding the institutional and infrastructural support available to farmers, as well as identifying gaps and areas for improvement.

Case Study: A case study approach was used to collect qualitative data from a particularly affected union, providing an in-depth analysis of the impacts and adaptive responses. This method involved comprehensive data collection from multiple sources, allowing for a thorough examination of farmers' unique challenges and innovative adaptation strategies.

Data Analysis Methods: The data analysis method involved a combination of quantitative and qualitative approaches to provide a comprehensive understanding of farmers' adaptation strategies in the cyclone-affected regions. Descriptive statistics were used to summarize the key demographic characteristics of the respondents, as well as the types and extents of damages. The qualitative data from in-depth interviews, Focus Group Discussions with each FGD comprising 6–10 farmers), Key Informant Interviews (KIIs) with 15 local leaders, agricultural experts, and government officials and 3 case study were analyzed to summarize the qualitative responses. This multi-method approach ensured a robust and detailed understanding of the adaptation strategies, capturing a deeper insight into the underlying factors influencing the responses of farmers to cyclones.

Poisson Regression Model: Poisson regression is a widely utilized statistical method for modeling count data, particularly when the response variable consists of non-negative integers. The Poisson regression is employed in this study to identify the determinants adaptation strategies adopted by farmers, as the dependent variable is count data. The model assumes that the mean and variance of the count are equal, making it suitable for this type of non-negative integer data. It also requires that observations are independent, meaning one farmer's decision does not influence

another's. Given these conditions, Poisson regression is an appropriate method for identifying the key factors influencing farmers' decisions to adopt various adaptation strategies.

The Poisson regression model assumes that the count of adaptation strategies y_i for each farmer i follows a Poisson distribution, where the log of the expected count $E(y_i)$ is modeled as a linear function of the predictors (Equation 1).

$$\log(E(y_i)) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_7 X_7 \quad \ldots \quad (1)$$

Where, $E(y_i)$ is the expected count of the outcome for observation i, in this case the number of adaptation strategies taken by i^{th} farmer. β_0 is the intercept. X_1, X_2,…,X_7 are the independent variables. For instance, X_1 indicates gender of the respondent measured in dummy (male =1, 0 otherwise). X_2 shows the family size measured in number and X_3 indicates farming experience in years. X_4 is a dummy of getting agricultural extension help is 1, 0 otherwise. Similarly, getting GO or NGO help is 1, 0 otherwise (X_5), receiving weather information takes 1, 0 otherwise (X_6) and taking loan is 1, 0 otherwise (X_7). $\beta_1, \beta_2, \ldots, \beta_7$ are the coefficients associated with each predictor.

Cameron and Trivedi Test for Overdispersion: The overdispersion test is performed after fitting the Poisson model. It is based on the Pearson goodness-of-fit statistics. The test compares the observed and expected counts from the Poisson model using the following statistic:

$$\chi^2 = \sum_{i=1}^{n} \frac{(yi - \hat{y}_i)^2}{\hat{y}_i}$$

Where, y_i is the observed number of adaptation strategies for each farmer. $\hat{y}_i$ is the expected number of strategies from the Poisson model, n is the total number of observations. If the ratio of χ^2 to the degrees of freedom (df) is significantly greater than 1, it suggests overdispersion.

Results and Discussion

This section provides estimated results and discusses the relevant data from the survey. The following segments provide a summary of the respondents' statistics along with the adaptation strategies against cyclones adopted by the farmers in the study area.

Sociodemographic characteristics of the farmers: The sociodemographic characteristics of farmers in two coastal districts, namely Satkhira and Khulna of Bangladesh are provided in Table 1. These regions are highly vulnerable to cyclones, and understanding the sociodemographic profile of respondents is crucial for analyzing their adaptation strategies.

Regarding age distribution, farmers in both regions tend to be middle-aged to the elderly. In Satkhira, 44 percent of the respondents are aged 50 years or older, followed by 30 percent in the 40-50 years age group. Similarly, in Khulna, the largest age group is also 50 years and above 58 percent, while 23 percent are between 40-50 years. The relatively older age of the respondents in both areas may reflect their long-standing experience in farming, which plays a role in shaping their coping mechanisms and adaptation strategies during cyclones.

Regarding gender distribution, farming in both regions remains male-dominated. In Satkhira, 93 percent of the respondents are male, and only 7 percent are female. In Khulna, this gap is even more comprehensive, with 98 percent of the respondents being male and just 2 percent female

among the survey respondents. This disparity highlights how gender contributes to agricultural practices in coastal Bangladesh, influencing decision-making during cyclone events.

Table 1. Social profile of the respondents

Category	Percent	
	Satkhira	**Khulna**
Age of the Respondent (in Year)		
20-30	9	5
30-40	17	14
40-50	30	23
50 and more	44	58
Gender of the Respondent		
Male	93	98
Female	7	2
Educational Status of the Respondents		
Cannot Read or Write	10	8
Primary	42	37
Secondary	38	46
Tertiary	10	9
Number of Family Member (in Number)		
1-3	13	19
4-6	75	67
6-9	12	14

Source: Author's calculation

Educational attainment reveals a mixed profile of literacy among the farmers. In Satkhira, 42 percent of the respondents have received primary education, while 38 percent have secondary-level education. Only 10 percent have completed tertiary-level education, and an equal 10 percent have no institutional education. In Khulna, 46 percent of the respondents attained secondary education followed by 37 percent primary education. A smaller proportion, 8 percent, of the farmers have no institutional education, while only 9 percent have completed tertiary-level education. The relatively low levels of education, especially tertiary education, could present challenges in understanding and adopting more advanced adaptation strategies, particularly those requiring technical knowledge.

Family size is an another important demographic indicator, showing 75 percent of the farmers in Satkhira and 67 percent in Khulna have medium-sized families comprising 4-6 members. A smaller percentage of larger families having 6-9 members are observed among 12 percent of respondents in Satkhira and 14 percent in Khulna. Only 19 percent of the respondents in Khulna have smaller families with 1-3 members compared to 13 percent in Satkhira. The size of a household can also influence labor availability and decision-making during cyclonic events, where larger families may have more hands to assist but also face higher risks.

Preventative strategies used by farmers: The preventative strategies employed by farmers to mitigate the impact of cyclones have been stated in Table 2. These strategies are categorized into four broad primary actions: protection of homes, protection of household members, ensuring food and water security, and protection of agricultural production.

Table 2. Actions taken by farmers to reduce the impact of cyclone

Actions	Prevention strategies	Taken by Farmers (%)	
		Satkhira	Khulna
Protection of homes	Roof securing	36	42
	Windows and door securing	58	63
	Supporting walls by posts	58	51
Protection of household members	Seeking shelter in school or cyclone shelter	41	32
	Moving family members to other areas	25	13
	Ensuring enough food reserves for the family members	54	50
Food and water security ensuring	Storing food in flood flood-free place	68	62
	Storing pure drinking water for post-cyclone use	88	81
Protection of agricultural production	Storing rice seeds in a dry place	89	77
	Moving livestock to a safe place	78	69

Source: Author's calculation

Most farmers prioritized securing their homes against cyclone damage in Satkhira and Khulna districts. Roof securing was a common practice, with 36 percent of the farmers in Satkhira and 42 percent in Khulna implementing this strategy. Securing windows and doors was slightly more prevalent, indicating that 58 percent of the population adopted it in Satkhira and 63 percent in Khulna. This reflected a proactive approach to reducing structural damage during cyclones. Additionally, supporting walls with posts was practiced by 58 percent of farmers in Satkhira and 51 percent in Khulna, which showed the importance of fortifying homes against strong winds. Ensuring the safety of household members during cyclones was also a critical concern. A significant 41 percent of the farmers in Satkhira and 32 percent in Khulna sought shelter in schools or designated cyclone shelters, demonstrating the reliance on communal safety measures. Meanwhile, a smaller percentage of farmers opted to relocate family members to other safe areas, with 25 percent in Satkhira and 13 percent in Khulna. In addition, preparing food reserves for family members was a more widespread strategy. Around 54 percent of the farmers in Satkhira and 50 percent in Khulna kept enough provisions, indicating the importance of food security during emergencies.

Securing food and water supplies was paramount in the aftermath of cyclones. A high percentage of the farmers, 68 percent in Satkhira and 62 percent in Khulna stored food in flood-

free places to safeguard against spoilage. The practice of storing pure drinking water was even more prevalent. About 88 percent of the farmers in Satkhira and 81 percent in Khulna engaged in this preventative measure, emphasizing the critical need for potable water following cyclone events. Agricultural resilience was a priority, as evidenced by the substantial number of farmers who stored rice seeds in dry places, 89 percent in Satkhira and 77 percent in Khulna, respectively. This practice ensured seed viability for future planting seasons. Moreover, moving livestock to safe locations was also another key strategy. About 78 percent of farmers in Satkhira and 69 percent in Khulna prioritized livestock protection, indicating livestock's economic and subsistence importance in these regions.

Perceptions of farmer on cyclone damages: Table 3 examined the farmers' perceptions of cyclone-induced damage across various impact types in Satkhira and Khulna districts. The damage levels are categorized into zero damage, small damage, moderate damage, and high damage, respectively.

Table 3. Farmer perceptions of cyclone damages

Impact types	Damage levels (%)							
	Zero damage		Small damage		Moderate damage		High damage	
	Satkhira	Khulna	Satkhira	Khulna	Satkhira	Khulna	Satkhira	Khulna
Damage due to flood	0	3	31	41	57	32	13	25
Damage to houses	8	11	19	57	44	23	30	10
Damage to school	30	86	42	15	29	0	0	0
Damage to roads	3	24	16	67	72	9	10	0
Damage to crops	0	0	2	30	49	52	50	19
Injury to livestock	1	42	19	58	55	0	26	0
Injury to people	34	71	55	29	12	0	0	0

Source: Author's calculation

The perception of flood damage differs significantly among the farmers in Satkhira and Khulna. In Khulna, a mere 3 percent of farmers reported zero damage due to flooding, while in Satkhira, this percentage is zero. Small damage was reported 31% by the farmers in Satkhira, compared to a striking 41 percent in Khulna. However, perceptions of moderate damage reversed this pattern, with 57 percent in Satkhira and 32 percent in Khulna, suggesting a more significant impact in Satkhira. A high damage was perceived by 13 percent of Satkhira farmers and 25 percent of Khulna farmers, indicating the severe impact on some farmers in both the regions. The perceptions of housing damage also revealed regional differences. In Satkhira, 8 percent of the farmers perceive zero damage compared to 11 percent in Khulna, indicating that some houses

withstand cyclones well. A small amount of damage was reported by the farmers of Satkhira and a larger 57 percent in Khulna, suggesting that farmers in Khulna experienced more minor structural impacts. However, moderate damage was significantly higher in Satkhira (44%) than in Khulna (23%), whereas high damage was stated by 30 percent of Satkhira farmers versus 10 percent in Khulna, revealing more severe housing damage in Satkhira.

Perceptions of school damage featured stark contrasts between the respondents in the two districts. A significant 30 percent of Satkhira farmers experienced zero damage to schools, while a substantial 86 percent in Khulna reported no damage. This indicated that Khulna was better infrastructure or location away from cyclone paths than Satkhira. Small damage to school was noted by 42 percent of farmers in Satkhira and 15 percent in Khulna. Whereas, moderate damage was reported by 29 percent farmers in Satkhira and zero percent in Khulna districts, respectively. No high damage was described in either region, suggesting that schools generally withstand cyclones. The respondents' perceptions of road damage due to cyclones show varied experiences. In Satkhira, only 3 percent of the respondents reported zero damage compared to 24 percent in Khulna, suggesting more resilient infrastructure in Khulna. About 16 percent of the farmers in Satkhira and 67 percent in Khulna stated small damage. Besides, moderate damage was significantly higher in Satkhira (72%) than in Khulna (9%). However, no farmers in Khulna reported high damage, while 10 percent of Satkhira farmers did, demonstrating more severe road damage due to cyclones in Satkhira.

Farmers' perceptions of crop damage are critical given the reliance on agriculture. None of the farmers in both regions reported zero damage. In addition, small damage was minimal, with 2 percent in Satkhira and 30 percent in Khulna. However, moderate damage was reported by 49 percent of farmers in Satkhira and 52 percent in Khulna. Moreover, high damage perceptions were 50 percent in Satkhira and 19 percent in Khulna, showing severe agricultural impacts in Satkhira. Only 1 percent of farmer conveyed zero livestock damage in Satkhira, compared to a high 42 percent in Khulna. Small damage to livestock was reported by 19 percent farmers in Satkhira and 58 percent in Khulna. Moderate damage is expressed by 55 percent of Satkhira farmers, while none reported it in Khulna, suggesting significant livestock loss in Satkhira. About 26 percent of the respondents revealed high damage to livestock in Satkhira and zero percent in Khulna, respectively, indicating critical losses in Satkhira. A significant 34 percent of the farmers in Satkhira reported zero injuries, compared to 71 percent in Khulna, expressing a better safety measure in Khulna. Around 55 percent in Satkhira and 29 percent in Khulna noted small injury to people. However, moderate damage was minimal, with 12 percent in Satkhira and none in Khulna, and no high damage was reported in either region.

Assessments of farmers on the impacts of cyclone: Table 4 presents farmers' assessments of cyclone impact in the Satkhira and Khulna districts by focusing on damage to rice land, location, stored rice, and food sufficiency during cyclones.

There was a sharp contrast in damage perceptions of rice cultivating land between Satkhira and Khulna. All farmers reported some levels of damage, with 70 percent experiencing damage between 25 to 50 percent and 26 percent of the farmers responded 50 to 75 percent damage in Satkhira. On the other hand, 69 percent of the farmers indicated no damage in Khulna. Only 20 percent experienced damage between 25 to 50 percent, and none stated damage beyond 50 percent, reflecting more effective protective measures or less exposure in Khulna. The location of rice cultivating damage land reveals differing vulnerabilities. Around 57 percent of the damage to land occurred on plain land, while 34 percent occurred near rivers, emphasizing these areas'

susceptibility to flooding in Satkhira. However, 50 percent of the land damage was reported near roads, indicating a different pattern of impact possibly related to infrastructure or topography in Khulna. The damage near ponds was minimal in both regions, with 9 percent and 7 percent in Satkhira and Khulna, respectively.

Table 4. Farmer assessment of the impact of cyclone.

Indicator	Response	% of Farmers	
		Satkhira	Khulna
Percent of rice land damage by cyclones	None	0	69
	Less than 25%	5	12
	25% to 50%	70	20
	50% to 75%	26	0
	More than 75%	0	0
Location of damaged rice land	Plain land	57	38
	River side land	34	6
	Land near pond	9	7
	Land near road	4	50
Did cyclones damage your stored rice?	Yes	31	24
	No	69	76
If yes, what percentage of stored rice was damaged?	Less than 25%	8	6
	25% to 50%	23	0
	50% to 75%	40	0
	More than 75%	5	0
Did you have insufficient food during cyclones?	Yes	61	23
	No	40	77
If yes, how many months of food was insufficient?	<1 month	80	94
	1-2 month	9	4
	>2 month	2	0

Source: Author's calculation

The damage of stored rice was more prevalent in Satkhira, with 31 percent of farmers reporting damage, compared to 23 percent in Khulna. However, 40 percent of affected respondents reported 50 to 75 percent damage in Satkhira, while farmers in Khulna reported no damage beyond 25 percent. The findings suggested that farmers in Khulna had more effective storage practices or facilities that better withstand cyclone impacts. Food insufficiency was a significant concern, especially in Satkhira, where 61 percent of the farmers reported insufficient food during cyclones, compared to 23 percent in Khulna. Most affected farmers in both districts stated that food shortages lasted less than one month (80% in Satkhira, 94% in Khulna), indicating relatively quick recovery times. However, the respondents in Satkhira experienced longer periods of food insufficiency, with 2 percent facing shortages over two months, revealing more severe food insecurity issues in this region.

Coping strategies of farmers to deal with rice damage by cyclones: Table 5 demonstrates the coping strategies employed by farmers in Satkhira and Khulna districts to address damage to rice production caused by cyclones by concentrating on land protection, food security, and income loss mitigation.

Table 5. Farmers coping strategies to deal with rice production damage by cyclones

Topic	Coping strategy taken	%	
		Satkhira	Khulna
To protect cultivable land	Repeated rice planting	76	48
	Waiting for the next rice season	32	61
	No cultivation of land	11	13
	Planting other type of crops instead of rice	27	63
To ensure food security	Purchasing additional foodstuffs	47	40
	Decreasing food consumption	17	15
	Cultivating vegetables in front of house	52	70
	Collecting food from relatives	14	52
	Collecting food from neighbors	12	13
	Getting helps from GO or NGOs	24	11
To take steps against income loss from cyclones	Sending family members outside for a job	48	10
	Taking loan from friends and relatives	18	9
	Sending family small children to land for work	8	12
	Sending family old children to an outside area for work	12	20
	Taking out boys from school	6	5
	Taking out girls from school	6	7
	Renting own land to others	8	9
	Taking loan	27	44

Source: Author's calculation

Farmers in Satkhira and Khulna adopted different strategies to protect their cultivable land after cyclone-induced rice production damage. About 76 percent of the farmers engaged in repeated rice planting as a primary strategy in Satkhira, compared to 48 percent in Khulna. This suggested a strong reliance on traditional farming practices in Satkhira. Conversely, 61 percent of farmers in Khulna preferred waiting for the next rice season, indicating a more conservative approach to land recovery. Additionally, planting alternative crops was more prevalent in Khulna, with 63 percent opting for this strategy, compared to 27 percent in Satkhira, reflecting diversification efforts in Khulna to mitigate risks.

When ensuring food security, farmers in Khulna were more likely to cultivate vegetables in front of their houses (70%) compared to those in Satkhira (52%). This strategy showed emphasis on the self-sufficiency of farmers in Khulna. However, farmers in Satkhira were more reliant on purchasing additional foodstuffs (47%) compared to 40 percent in Khulna. This suggested a higher immediate need for external food sources. Notably, 52 percent of Khulna farmers collected food

from relatives, a practice significantly less common in Satkhira (14%). Assistance from government or NGOs was more frequently sought in Satkhira (24%) than in Khulna (11%), indicating differences in external support reliance. To cope with income loss, farmers in Satkhira often sent family members outside for jobs (48%), contrasting sharply with only 10 percent in Khulna. This indicated a greater need for additional income sources in Satkhira. In contrast, farmers in Khulna were more likely to take loans (44%) compared to Satkhira (27%), reflecting differing financial coping mechanisms. Additionally, Khulna farmers were slightly more inclined to send grown-up children outside the area for work (20%) compared to 12 percent in Satkhira. Sending young children to work and taking children out of school were fewer common strategies in both regions.

Determinants of Adaptation Strategies of Farmers to cope with Impact of Cyclone

Table 6 presents the results from a Poisson regression model, which estimates the factors influencing the number of adaptation strategies adopted by farmers in the Satkhira district (Model 1). The regression includes robust standard errors to account for potential heteroskedasticity. The coefficient for family members is negative and statistically significant at the 5% level ($\beta = -0.033$, $p = 0.036$), indicating that a one-unit increase in family size is associated with a 3.3% decrease in the expected number of adaptation strategies. This suggests that larger families may face resource constraints or labor allocation challenges that reduce the number of strategies they can implement. Taking a loan has a positive and highly significant effect ($\beta = 0.285$, $p < 0.001$), implying that farmers who take loans are expected to adopt 32.9% more adaptation strategies, holding other variables constant. This result underlines the critical role of financial access in enabling farmers to diversify their adaptation approaches. The variable for assistance from GO/NGO programs is marginally significant at the 10% level ($\beta = 0.105$, $p = 0.068$), suggesting that such support may play a role in encouraging farmers to adopt more strategies, though the effect is weaker. Other variables, including gender, farming experience, agricultural extension help, and climate information, do not show statistically significant effects in this model. The goodness-of-fit test ($\chi^2 = 110.16$, $p = 1.000$) indicates that the model adequately fits the data, as the Pearson chi-square statistic is not significant, suggesting no evidence of overdispersion.

Model 2 of Table 6 shows the Poisson regression results for farmers in Khulna district, estimating the factors influencing the number of adaptation strategies adopted. The model also employs robust standard errors to ensure accuracy. The coefficient for taking a loan is positive and highly significant ($\beta = 0.262$, $p < 0.001$), indicating that farmers who take loans are expected to adopt 30.0% more adaptation strategies, highlighting the critical role of financial support in adaptation in the region. Other variables, such as gender, family size, farming experience, agricultural extension help, and GO/NGO assistance, do not show statistically significant effects, suggesting these factors do not strongly influence the number of strategies adopted in this context. The Pearson goodness-of-fit test ($\chi^2 = 112.70$, $p = 1.000$) supports the model fit, indicating no evidence of overdispersion and that the model adequately captures the variation in the data.

Model 3 of Table 6 demonstrates the results from the Poisson regression model estimating the factors influencing the number of adaptation strategies adopted by farmers across both districts (Satkhira and Khulna). The model also employs robust standard errors for accuracy. The coefficient for taking a loan remains highly significant ($\beta = 0.274$, $p < 0.001$), suggesting that farmers who access loans are expected to adopt 31.5% more adaptation strategies. This underscores the importance of financial access in facilitating adaptive capacity among farmers. Other variables, including gender, family size, farming experience, agricultural extension help, GO/NGO assistance, and climate information, do not have statistically significant effects in this

combined model. The Pearson goodness-of-fit test ($\chi^2 = 225.48,\ p = 1.000$) indicates a well-fitting model with no evidence of overdispersion, suggesting that the Poisson specification adequately captures the data variation.

Table 6. Factors affecting the adoption of farmers' adaptation strategies

Variables	Model (1)	Model (2)	Model (3)
	Satkhira	Khulna	Both
Gender (Male =1, 0 = Otherwise)	-0.0593	-0.0188	-0.0671
	(0.0705)	(0.0941)	(0.0633)
Family size (number)	-0.0332**	0.00678	-0.0103
	(0.0158)	(0.0116)	(0.00982)
Farming experience (year)	0.00318	0.00207	0.00213
	(0.00198)	(0.00224)	(0.00149)
Access to agricultural extension help (Yes =1, 0 = Otherwise)	-0.000132	0.00494	-0.00911
	(0.0840)	(0.0543)	(0.0396)
Access to GO or NGO help (Yes =1, 0 = Otherwise)	0.105*	-0.201	0.0609
	(0.0576)	(0.302)	(0.0436)
Access to weather information (Yes =1, 0 = Otherwise)	-0.0661	0.0387	-0.0605
	(0.0522)	(0.188)	(0.0485)
Access to loan (Yes =1, 0 = Otherwise)	0.285***	0.262***	0.274***
	(0.0504)	(0.0483)	(0.0349)
Constant	1.560***	1.659**	1.489***
	(0.109)	(0.725)	(0.0834)
Observations	200	200	400
Model Statistics:			
Wald chi2(7)	44.89	33.22	71.56
Prob > chi2	0.00	0.00	0.00
Goodness-of-fit chi2	110.16	112.70	225.47
Prob > chi2(192)	1.00	1.00	1.00

Source: Author's calculation

This study examined farmers' adaptation strategies in the southwest coastal region of Bangladesh to cope with cyclones. The results indicated that these farmers employed a variety of strategies to mitigate the impacts of cyclones, with notable differences between the Satkhira and Khulna districts. Farmers prioritize the protection of their homes, household members, food, water, and agricultural production. High percentages of farmers employ structural fortification measures, such as securing roofs, windows, and doors, reflecting an awareness of the need to

protect their homes from cyclone damage. The reliance on communal shelters and food reserves indicates a strong community network and an understanding of the importance of food security during emergencies. These findings suggest that while there is a common recognition of essential preventative measures, the implementation rates vary, reflecting differences in resources and accessibility (Rakotobe *et al.* 2016).

The varying perceptions of cyclone damage highlight regional disparities in vulnerability and resilience. Satkhira farmers reported higher levels of moderate and high damage to houses, roads, crops, and livestock compared to Khulna. This suggests that Satkhira may have less resilient infrastructure or be more exposed to severe cyclone impacts. The higher reports of no damage in Khulna, particularly for schools and roads, suggest better infrastructure or more effective preventative measures in place. These findings underscore the need for targeted interventions that address the specific vulnerabilities of each district (Afroz *et al.* 2018). The assessments reveal significant differences in the impact of cyclones on rice land, stored rice, and food sufficiency. Satkhira farmers experienced higher levels of damage to rice land and stored rice and faced more severe food insufficiency during cyclones. This indicates that Satkhira is more vulnerable to agricultural disruptions, which can impact food security and livelihoods in the long-term. The contrasting experiences between the two districts highlight the need for improved storage facilities and food security measures in more vulnerable areas (Shamsuzzoha *et al*. 2021).

Farmers employ diverse coping strategies to deal with rice damage, food insecurity, and income loss. The preference for repeated rice planting in Satkhira indicates a reliance on traditional farming practices, while Khulna's higher adoption of alternative crops suggests a more adaptive approach. The cultivation of vegetables and reliance on external food sources in Khulna reflect efforts to enhance self-sufficiency. The higher incidence of seeking government or NGO assistance in Satkhira suggests a greater need for external support in this district (Islam and Walkerden 2015). Income loss mitigation strategies such as sending family members for jobs and taking loans, reveal the financial pressures faced by these communities and the need for economic support mechanisms. The study's findings highlight the necessity for region-specific adaptation strategies. In Satkhira, where damage levels are higher and food insufficiency is more prevalent, there is a critical need for enhanced infrastructure, improved storage facilities, and strengthened food security measures. Relative resilience in Khulna suggests that effective strategies, such as better infrastructure and diversification of crops, can be replicated in more vulnerable areas. Policy interventions should focus on providing resources and support tailored to the unique needs of each district, enhancing their capacity to withstand and recover from cyclone impacts (Mamun *et al.* 2024).

The results from the three Poisson regression models for Satkhira, Khulna, and the combined sample reveal consistent patterns with some variations. Across all models, taking a loan is a significant predictor of the number of adaptation strategies adopted by farmers, with a positive effect observed in all cases. The magnitude of the effect is strongest in Satkhira (32.9%) and slightly lower but still significant in Khulna (30.0%) and the combined model (31.5%), emphasizing the crucial role of financial access in supporting adaptation efforts. In contrast, variables like gender, family size, farming experience, and assistance from GO/NGO programs show no significant effect in any model, suggesting these factors may not substantially influence adaptation behavior in this context. The goodness-of-fit tests across all models show no evidence of overdispersion, indicating that the Poisson model is well-suited for the data in all cases. Thus, while the models highlight the centrality of financial access (taking loans), other socioeconomic and institutional factors appear less influential across the different regions.

Our findings on the importance of financial access, regional variation in adaptation, and the influence of family and institutional support align with existing literature, underscoring both shared and unique aspects of adaptation among farmers in cyclone-prone areas. Similar to studies by (Adeagbo *et al.* 2021, Ali *et al.* 2021), we found that access to loans significantly increases the diversity of adaptation strategies, with farmers in Khulna particularly benefiting from crop diversification. This contrasts slightly with Ali *et al.* (2021), who observed a limited impact on crop variety, suggesting the critical role of local resource availability. Regional disparities in adaptation align with (Gopalakrishnan *et al.* 2019) and (Aryal *et al.* 2020), who noted better infrastructure in specific areas led to more diverse adaptation practices. However, unlike their findings of uniform adaptation across coastal India, our results reveal significant differences between Satkhira's reliance on traditional methods and Khulna's broader strategies, indicating a strong influence of local socio-economic conditions. Additionally, like (Biswas *et al.* 2020) and (Kabir *et al.* 2021), our study finds that larger family sizes can constrain adaptation efforts, while government and NGO support moderately enhance adaptive capacity, especially in resource-limited regions.

Necessary Policy Options for Supporting Farmers' Adaptation in Bangladesh

To effectively enhance the resilience of coastal farmers in Bangladesh, a suite of targeted policy measures is essential. First, improving financial access through low-interest loans, crop insurance, and structured emergency funds can empower farmers to diversify and implement critical adaptive practices. Investment in cyclone-resistant infrastructure, including fortified housing, flood-proof storage, and resilient road systems, is also vital to mitigate physical vulnerabilities in cyclone-prone areas. Moreover, region-specific agricultural extension services should be established to address unique coastal challenges, such as soil salinity and water management, by disseminating climate-resilient farming practices. Strengthening community-based disaster preparedness through coordinated efforts between government agencies and NGOs can further bolster local capacity for resilience, facilitating timely support and the development of community-driven adaptation strategies. Finally, a data-driven approach that continuously monitors climate impacts and tracks adaptation outcomes will enable effective policy adjustments and resource allocation, fostering an adaptive agricultural sector capable of withstanding climatic challenges in Bangladesh's vulnerable coastal regions.

Conclusion

This study investigated the diverse adaptation strategies employed by farmers in the cyclone-prone regions of Shyamnagar Upazila in Satkhira and Koyra Upazila in Khulna, Bangladesh. The research uncovered the significant differences in how farmers in these districts cope with cyclone impacts using qualitative methods, including in-depth interviews, focus group discussions, key informant interviews, and a detailed case study. Farmers in Satkhira, who faced higher damage levels and food insufficiency, relied more on traditional practices like repeated rice planting and sought greater external assistance from the government or NGOs. Conversely, farmers in Khulna adopted more diverse and adaptive strategies, such as planting alternative crops, cultivating vegetables in their garden yard, and leveraging community-based support systems. Access to loans, family size, and GO/NGO assistance are significant determinants of the number of adaptation strategies adopted by farmers in both Satkhira and Khulna. Farmers with loan access are more likely to implement more strategies, highlighting the crucial role of financial resources in

supporting adaptation efforts. Conversely, larger family size is associated with fewer adaptation strategies, potentially due to resource constraints.

The findings brought attention to the critical need for region-specific adaptation strategies that consider each district's unique vulnerabilities and capacities. Enhancing infrastructure, such as resilient housing and storage facilities, improving food and water security measures, and supporting agricultural resilience were essential for helping these communities withstand and recover from cyclone impacts. Policymakers should focus on providing tailored resources and support to bolster the adaptive capacities of these farming communities. This research contributed valuable insights into the broader discourse on climate change adaptation and resilience in coastal regions of Bangladesh. By emphasizing the importance of targeted interventions, it emphasized the need for comprehensive, context-specific policies to support sustainable livelihoods and mitigate the country's adverse effects of climate change. Future research should continue to explore the long-term effectiveness of these strategies and identify additional measures to enhance the resilience of farmers in cyclone-prone areas.

Author Contribution

SB solely conceived and designed the study, collected and analyzed the data, and prepared the manuscript. SB also reviewed and approved the final version for submission.

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