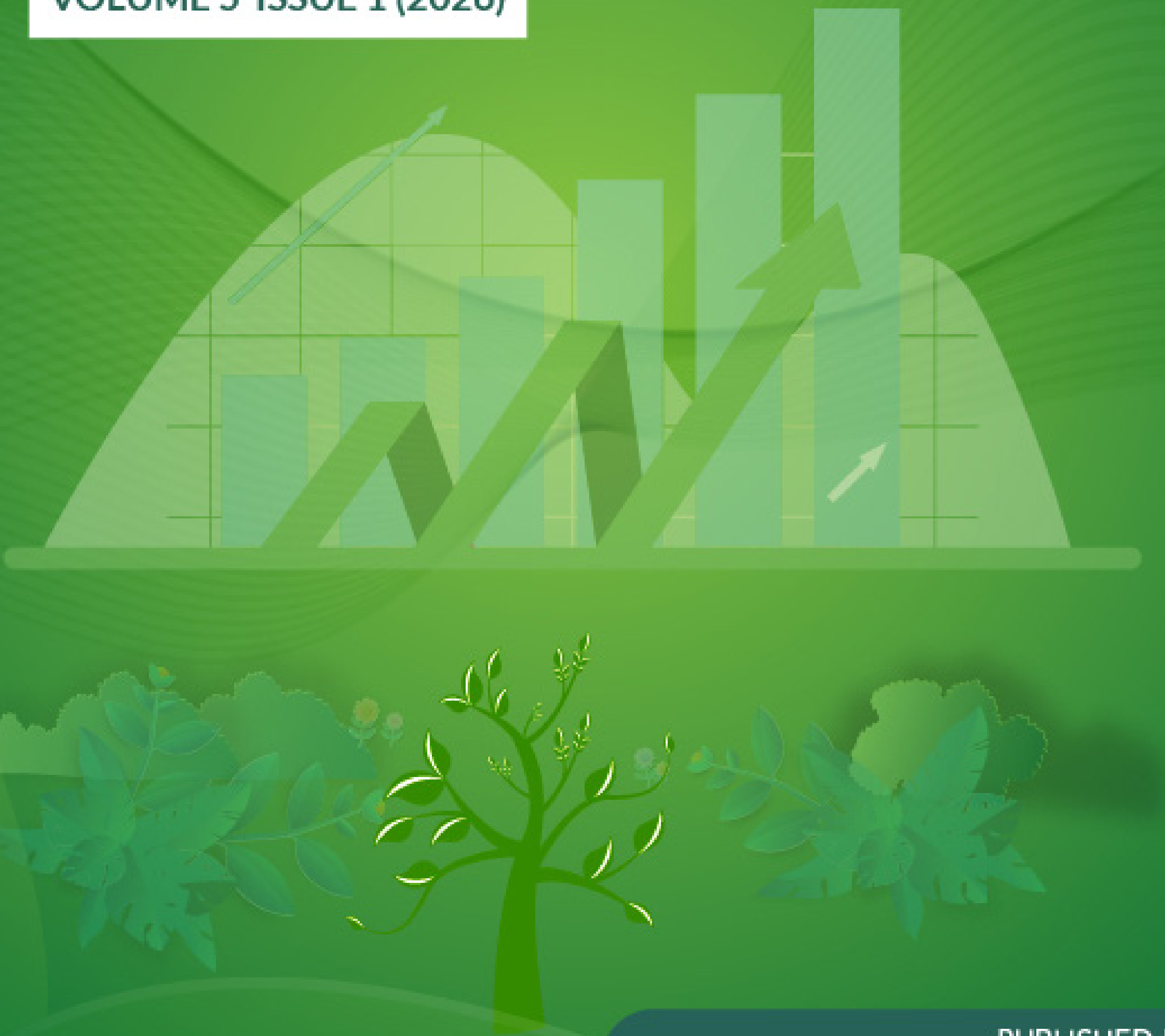
American Journal of Environmental Economics (AJEE)

ISSN: 2833-7905 (ONLINE)

VOLUME 5 ISSUE 1 (2026)



PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Environmental Economics (AJEE)

Volume 5 Issue 1, Year 2026
ISSN: 2833-7905 (Online)
DOI: https://doi.org/10.54536/ajee.v5i1.6350
https://journals.e-palli.com/home/index.php/ajee

Perceived Costs-Benefits, and Barriers of Climate Adaptation among Smallholder Farmers in the Barind Tract, Bangladesh

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Article Information

Received: October 10, 2025

Accepted: November 17, 2025

Published: January 04, 2026

Keywords

Bangladesh, Barind Tract, Climate Adaptation, Perceived Costs-Benefits, Smallholder Farmer

ABSTRACT

Climate change adaptation refers to the process by which farmers adjust their agricultural practices to reduce climate-related risks and enhance resilience. In the Barind Tract, several studies have explored climate change adaptation and barriers. However, most of these studies focused on general adaptation strategies or structural/economic barriers and did not examine perceived costs-benefits of adaptation and how these perceptions interact with barriers when deciding whether to adopt specific practices. Addressing this gap, the present study investigates the most commonly adopted adaptation strategies and analyzes farmers' evaluations of the associated costs-benefits alongside the barriers that hinder effective adaptation. Data were collected from 180 smallholder farmers across three upazilas using a multi-stage equal allocation sampling approach. A structured questionnaire captured socio-economic characteristics, adaptation strategies, perceived costs-benefits, and barriers. Descriptive statistics, chi-square test, Relative Importance Index (RII), and Weighted Average Index (WAI) were used for the analysis. The results show that irrigation (RII = 0.9593), tractor tillage (0.9389), row planting (0.8556), and improved seed varieties (0.8407) were the most widely adopted practices. Initial and ongoing costs were mainly within Tk 5001–10000 and Tk 2500–5000, and 74 percent of farmers reported that the benefits of adaptation outweighed the costs. The major barriers included resource scarcity (WAI = 4.35), limited availability of technology (4.29), and financial constraints (4.01). The study provides new empirical evidence on how perceived costs-benefits and barriers jointly shape adaptation decisions among smallholder farmers. Strengthening access to loans, agricultural inputs, technology, training, and rural infrastructure is essential for building climate resilience and promoting sustainable agriculture in the Barind Tract.

INTRODUCTION

Climate change remains one of the most pressing challenges of the 21st century, with agriculture being among the most vulnerable sectors globally. Extreme weather events such as droughts, floods, and prolonged heat waves directly undermine crop yields, disrupt planting cycles, and increase production risks (Gwambene *et al.*, 2023). For smallholder farmers, who constitute the majority of the rural poor in developing countries, these threats are especially acute. Dependence on rain-fed agriculture, limited access to technology, and weak institutional support systems increase their vulnerability (Ahmed *et al.*, 2023). The economic consequences of climate change are significant. Mendelsohn *et al.* (1994) estimated yield reductions of 10–30%, while Kumar and Parikh (2001) found a decrease of 10–20%. However, Deschênes and Greenstone (2007) found positive profit effects of weather variability in the United States, with annual gains of around 4%. In Sub-Saharan Africa, similar studies predict that without adaptation, agriculture could lose billions of dollars annually (Nkonya *et al.*, 2016). Overall, Nelson *et al.* (2014) projected global yield declines by 2–6%. In this respect, the Intergovernmental Panel on Climate Change warned of reduced food production and increased malnutrition in climate-stressed regions (IPCC, 2013).

Bangladesh, one of the world's most climate-affected countries, faces significant risks due to its heavy reliance on agriculture for livelihoods and food security. The Barind Tract, located in the country's northwestern districts of Rajshahi, Chapai Nawabganj, and Naogaon, is especially vulnerable. It is characterized by low and erratic rainfall, extreme summer temperatures exceeding 45°C, and declining groundwater levels (Uddin *et al.*, 2020). These conditions threaten rice, wheat, and other staple crops, with projections of 15–30% yield declines if effective adaptation strategies are not adopted (BCAS, 2021; Das *et al.*, 2025). To overcome the challenges, smallholder farmers in the Barind Tract need to adopt a range of adaptation practices to cope with a changing climate. However, the costs and benefits of these strategies, as perceived by farmers themselves, remain poorly understood. Understanding farmers' perspectives is crucial because decisions to adopt adaptation practices depend not only on economic viability but also on perceptions of effectiveness, affordability, and institutional support (Ricart *et al.*, 2023). Against this background, the present study investigates the perceived costs, benefits, and barriers to climate change adaptation practices among smallholder farmers in the Barind Tract. The study is modeled on the approach of Baffour-Ata *et al.* (2025), who examined similar dynamics in Ghana. By applying comparable methods, this research provides context-specific evidence from Bangladesh

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while contributing to the broader literature on climate adaptation in developing countries.

LITERATURE REVIEWS

Climate-smart agriculture (CSA) has emerged as a dominant framework for addressing climate challenges, encompassing crop diversification, irrigation management, soil conservation, and the use of drought-tolerant varieties (Anita *et al*., 2010). Similarly, Baffour-Ata *et al*. (2025), studying Ghana's Ahafo Ano South District, found that crop diversification, changing planting dates, and cover cropping were the most common strategies. Numerous studies demonstrate that these practices significantly improve yields and resilience. For example, Deressa *et al*. (2009) found that Ethiopian farmers' adaptation increased yields by 10-20%, while Bryan *et al*. (2013) estimated gains of 20-50%. Similarly, in Nigeria, Olutumise *et al*. (2024) observed a 15-30% rise in farmer incomes, and Nkonya *et al*. (2016) estimated benefits of USD 2–5 billion annually across Africa due to adaptation. However, the literature on cost-benefit analyses (CBAs) highlighted both opportunities and challenges. Mendelsohn and Dinar (2003) recognized the potential of adaptation to reduce climate damages; they also emphasized adjustment costs as the main obstacle. In Sub-Saharan Africa, Di Falco *et al*. (2011) reported that drought-tolerant crops raised incomes by 15-30% with a benefit–cost ratio of 2:1. Similarly, Bryan *et al*. (2013) found ratios between 1.5 and 3.5, suggesting high returns. However, Baffour-Ata *et al*. (2025) identified that although initial and ongoing costs were high for adaptations, perceived benefits included reduced losses and improved soil fertility in Ghana. This study also identified barriers as financial constraints, limited technology, and lack of awareness.

In South Asia, farmers commonly employ ex-ante strategies (e.g., crop diversification, early planting, drought-tolerant seeds) and ex-post measures (e.g., reduced consumption, migration) (Di Falco, 2014; Zeleke *et al*., 2021). In Bangladesh, climate change has already disrupted traditional cropping systems. Studies report rising irrigation costs, declining yields, and greater reliance on groundwater (Salam *et al*., 2020). Islam (2012) emphasized that adoption depends heavily on access to education and credit. Empirical findings from Bangladesh underscore both vulnerability and adaptation. Mahedi *et al*. (2025) estimated rice yield losses of up to 30% under drought, forcing many farmers to migrate or diversify income sources. Chowdhury *et al*. (2025) demonstrated that training and access to information significantly improve adaptation outcomes. Mardy *et al*. (2018) found that low incomes and weak extension services limit adaptation in Dinajpur. Kamruzzaman *et al*. (2023) confirmed that farmer perceptions of climate change align with meteorological data, but institutional support remains inadequate.

Despite extensive global studies on climate adaptation, research in Bangladesh's Barind Tract remains limited. While previous work identifies common strategies and challenges, few studies explicitly assess farmers' perceptions of the costs and benefits of specific adaptation practices in this drought-prone region. Furthermore, little is known about how farmers balance short-term costs with long-term benefits, or how local institutional weaknesses exacerbate these barriers. This study addresses these gaps by systematically analyzing adaptation practices, perceived costs and benefits, and obstacles among smallholder farmers in the Barind Tract.

Objectives

This study aims to understand smallholder farmers' understanding of the costs and benefits of adaptation practices and the barriers they face when adopting them. More specifically, the study pursues the following objectives:

1. To assess the most commonly used adaptation practices and farmers' perceptions of costs and benefits of these practices.
2. To identify the main barriers that limit the adoption of these practices.

MATERIALS AND METHODS

Study Area

The Barind Tract covers parts of Rajshahi, Naogaon, and Chapai Nawabganj districts in northwestern Bangladesh. Characterized by drought, high temperatures, and clay soils, it is one of the country's most climate-stressed regions (Islam *et al*., 2019). Annual rainfall ranges from 1460 to 2170 mm, with long dry seasons. Temperatures can exceed 45°C in summer and fall below 8°C in winter (Khan *et al*., 2021). Declining groundwater availability makes irrigation increasingly costly here. Despite these constraints, the region is a major producer of rice, wheat, and mango, earning it the label "breadbasket of Bangladesh" (Karim *et al*., 2020).

Sampling and Data Collection

This study is based on a pragmatic research philosophy, focusing on real-world problems and practical solutions. The aim is to understand how farmers adapt to climate change and what challenges they face. To do this, a quantitative research approach was used. A multi-stage equal allocation sampling method was employed to collect data. Three upazilas Godagari (Rajshahi), Gomostapur (Chapai Nawabganj), and Niamatpur (Naogaon) were purposively selected for their agricultural significance and climate vulnerability. From each upazila, 60 farmers were randomly chosen across unions and villages, yielding 180 respondents. A structured questionnaire, pre-tested for clarity, was used to collect data on socio-demographics, farming activities, adaptation practices, costs and benefits, and barriers. Interviews were conducted in Bangla between May and July 2025. Ethical protocols ensured informed consent, anonymity, and voluntary participation.

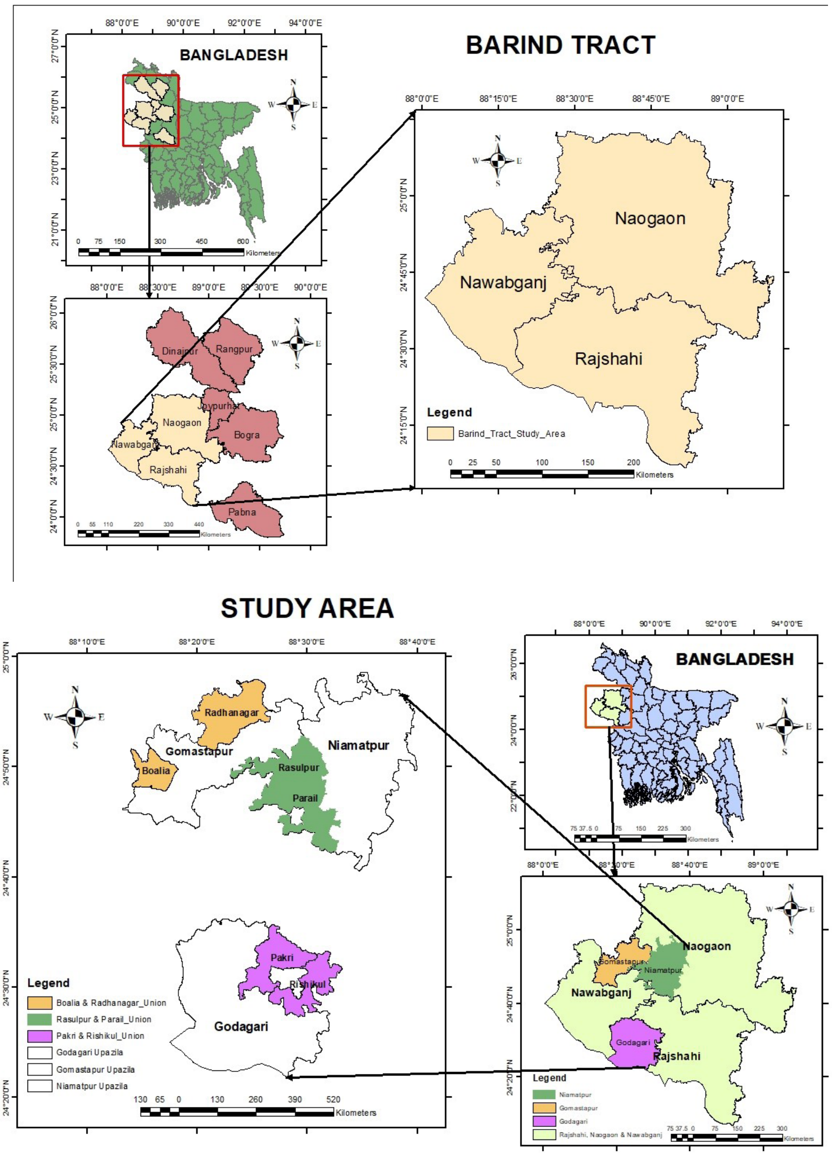

Figure 1: The location of Barind Tract and the specific study area (prepared by using ArcGIS, 2025)

Data Analysis

Data were analyzed using descriptive statistics, chi-square tests, and index-based rankings.

Adaptation Strategies - Relative Importance Index (RII): This is calculated by ranking adaptation practices according to farmers' frequency of use (Baffour Ata *et al.*, 2025). Each respondent assigns a weight to each adaptation practice based on how often they use it. The weights range from 1 to 3, where weights: 1 = unused, 2 = seldom used, 3 = commonly used. Then the RII is calculated with the formula:

$$RII = \sum W/(A \times N) \quad ....(1)$$

Where, W is the weight given by respondents, A is the highest possible weight (which is 3), and N is the total number of respondents.

The RII value ranges from 0 to 1. A higher RII indicates that the practice is more important or more commonly used.

Barriers to Adaptation - Weighted Average Index (WAI): To identify the main obstacles preventing farmers from adopting adaptation strategies, the Weighted Average Index (WAI) was used (Baffour Ata *et al.*, 2025). Farmers rated the severity of each barrier on a scale from 1 (strongly disagree) to 5 (strongly agree). The WAI is calculated as:

$$WAI = (\sum(P_i - F_i))/N \quad ....(2)$$

Where, P_i is the severity score given by the respondent, F_i is the number of respondents who gave that score, and N is the total number of respondents.

RESULTS AND DISCUSSION

Socioeconomic Characteristics

Most respondents were male (97%), reflecting the male-dominated farming in Bangladesh (Azumah *et al.*, 2023). Nearly half (46%) were aged 40–49, and over 85% had more than 10 years of farming experience. Education levels were low: 31% had no schooling, 34% had only primary education, and just 12% had studied beyond secondary level. Land tenure was dominated by rentals (54%), suggesting limited investment in farming. Access to financial capital (32%), training (33%), and climate information (48%) was also limited. This profile reveals structural barriers that reduce adaptive capacity, consistent with findings by Mamun *et al.* (2024).

Table 1: Socioeconomic Characteristics of Respondents

Variables		**Upozila**			
		Godagari (n=60)	**Gomostapur (n=60)**	**Niamothpur (n=60)**	**Total (n=180)**
Age	20–29 years	1 (1.67%)	5 (8.33%)	1 (1.67%)	7 (3.89%)
	30–39 years	15 (25.00%)	10 (16.67%)	13 (21.67%)	38 (21.11%)
	40–49 years	31 (51.67%)	24 (40.00%)	27 (45.00%)	82 (45.56%)
	50 years and above	13 (21.67%)	21 (35.00%)	19 (31.67%)	53 (29.44%)
Gender of Participants	Male	59 (98.33%)	58 (96.67%)	58 (96.67%)	175 (97.22%)
	Female	1 (1.67%)	2 (3.33%)	2 (3.33%)	5 (2.78%)
Years of Schooling	No education (0 years)	15 (25.00%)	17 (28.33%)	23 (38.33%)	55 (30.56%)
	Primary (1-5 years)	25 (41.67%)	21 (35.00%)	15 (25.00%)	61 (33.89%)
	Secondary (6-10 years)	16 (26.67%)	9 (15.00%)	17 (28.33%)	42 (23.33%)
	Above secondary (>10 years)	4 (6.67%)	13 (21.67%)	5 (8.33%)	22 (12.22%)
Farming experience	Less than 5 years	0 (0.00%)	1 (1.67%)	0 (0.00%)	1 (0.56%)
	5 to 10 years	6 (10.00%)	9 (15.00%)	10 (16.67%)	25 (13.89%)
	More than 10 years	54 (90.00%)	50 (83.33%)	50 (83.33%)	154 (85.56%)
Size of farming land	Small (1-2 Bigha)	1 (1.67%)	3 (5.00%)	1 (1.67%)	5 (2.78%)
	Medium (2-5 Bigha)	37 (61.67%)	37 (61.67%)	35 (58.33%)	109 (60.56%)
	Large Smallholder (>5 Bigha)	22 (36.67%)	20 (33.33%)	24 (40.00%)	66 (36.67%)
Type of Farming Land	Owned land	21 (35.00%)	16 (26.67%)	28 (46.67%)	65 (36.11%)
	Rented-in land	32 (53.33%)	35 (58.33%)	31 (51.67%)	98 (54.44%)
	Shared land	7 (11.67%)	8 (13.33%)	1 (1.67%)	16 (8.89%)
	Homestead land	0 (0.00%)	1 (1.67%)	0 (0.00%)	1 (0.56%)

Adaptation Practices (RII)

Adaptation practices, their Relative Importance Index (RII), and the ranks of these adaptations are shown in table 2 and 3. However, Table 2 shows the results across upozilas, whereas Table 3 summarizes the findings across all three upozilas. It is found that in Godagari, the most widely adopted practice was tractor ploughing (RII = 0.94). then irrigation (RII = 0.92), followed by improved seeds and row planting. However, in Gomostapur and Niamothpur, irrigation got ranked first (RII = 0.98), followed by tractor ploughing and row planting.

Table 2: Adaptation practices, their RII, and ranks across Upozila

Godagari			**Gomostapur**			**Niamothpur**		
Adaptation Strategy	**RII**	**Rank**	**Adaptation Strategy**	**RII**	**Rank**	**Adaptation Strategy**	**RII**	**Rank**
Tractor ploughing	0.938	1	More Irrigation	0.977	1	More Irrigation	0.977	1
More Irrigation	0.922	2	Tractor ploughing	0.927	2	Tractor ploughing	0.950	2
Using improved seeds	0.911	3	Row planting	0.861	3	Row planting	0.850	3
Row planting	0.855	4	Diversification of crops	0.816	4	Using improved seeds	0.811	4
Refill of seedlings	0.844	5	Using improved seeds	0.800	5	Diversification of crops	0.783	5
Use of drought-tolerant crop varieties	0.805	6	Changing crop type	0.705	6	Land management	0.716	6
Changing crop type	0.705	7	Refill of seedlings	0.700	7	Use of drought-tolerant crop varieties	0.694	7

Land management	0.694	8	Use of drought-tolerant crop varieties	0.650	8	Diversifying income sources	0.683	8
Water management	0.677	9	Diversifying income sources	0.644	9	Changing crop type	0.672	9
Diversifying income sources	0.661	10	Land management	0.644	10	Refill of seedlings	0.666	10
Change in planting dates	0.572	11	Water management	0.627	11	Water management	0.644	11
Migration to urban areas	0.555	12	Use of early-maturing crop varieties	0.605	12	Change in planting dates	0.594	12
Diversification of crops	0.505	13	Change in planting dates	0.588	13	Migration to urban areas	0.577	13
Use of early-maturing crop varieties	0.500	14	Migration to urban areas	0.544	14	Use of early-maturing crop varieties	0.566	14
Capacity building programs	0.422	15	Capacity building programs	0.461	15	Capacity building programs	0.450	15
Participating in CSA programs	0.372	16	Investing in climate-resilient infrastructure	0.444	16	Investing in climate-resilient infrastructure	0.444	16
Investing in climate-resilient infrastructure	0.366	17	Participating in CSA programs	0.411	17	Participating in CSA programs	0.438	17

Overall, it can be said that farmers relied heavily on inputs and labor-intensive practices (as shown in Table 3). Across the Barind tract, irrigation ranked first, followed by tractor ploughing, row planting, and the use of improved seeds as the most widely adopted adaptation strategies. Then the crop diversification and drought-tolerant varieties were moderately adopted. Institutional measures such as CSA programs, training, and climate-resilient infrastructure ranked as the least adopted. These are the lowest, which may be due to poor availability, support, and awareness of these strategies. These findings align with those of Aryal *et al.* (2021), who found similar preferences across South Asia.

Table 3: Overall climate change adaptation practices using RII

Adaptation Strategy	RII	Rank
More Irrigation	0.9593	1
Tractor ploughing	0.9389	2
Row planting	0.8556	3
Using improved seeds	0.8407	4
Refill of seedlings	0.7370	5
Use of drought-tolerant crop varieties	0.7167	6
Diversification of crops	0.7019	7
Changing crop type	0.6944	8
Land management	0.6852	9
Diversifying income sources	0.6630	10
Water management	0.6500	11
Change in planting dates	0.5852	12
Migration to urban areas	0.5593	13
Use of early-maturing crop varieties	0.5574	14
Capacity building programs	0.4444	15
Investing in climate-resilient infrastructure	0.4185	16
Participating in CSA programs	0.4074	17

Source: Author's own calculation from the field data. RII is calculated by taking the average of the three RIIs from Table 1 and then ranking according to the highest score.

Perceived Costs and Benefits

Regarding the cost-benefits (Table 4), it was found that initial adaptation costs were substantial for farmers: 62% spent BDT 5,001–10,000, while 15% spent more than BDT 10,000. Annual maintenance costs ranged from BDT 2,500 to 5,000 for 62% of farmers. However, these burdens varied across upazilas. These differences may be due to variations in resources, external support, market access, or awareness. Such factors shape how farmers adopt and finance adaptation strategies. This aligns with existing literature, which emphasizes that localized economic conditions and institutional support significantly affect feasibility and adoption (Ricart *et al.*, 2023; Baffour Ata *et al.*, 2025).

Along with the initial cost, ongoing expenses emerged, which may be a concern. Around 60% of farmers indicated that continuing to implement their chosen adaptation strategies cost them more than BDT 5,000 annually. Farmers from Gomostapur and Niamatpur reported slightly higher ongoing expenditures than those from other areas. Although the variation in ongoing costs was not statistically significant at the 5% level ($\chi^2 = 12.51$; p = 0.051), the data suggest a persistent financial burden. This highlights a critical policy issue: adaptation support must extend beyond one-time investments to address long-term affordability and sustainability (Baffour Ata *et al.*, 2025).

Despite these cost-related challenges, farmers acknowledged several essential benefits. About 63% observed moderate to significant reductions in crop losses, though 29% reported no change or increased losses. Water-use efficiency improved by 84%, with less irrigation water used across upazilas ($\chi^2 = 32.22$; $p < 0.001$). This disparity suggests that certain areas have adopted more effective water-saving techniques, such as drip irrigation, mulching, or improved scheduling, which may not yet be widely available or used in other areas (Onyekuru *et al.*, 2023). When examining labor implications, 41.67% of farmers reported that adaptation practices increased labor requirements, particularly for activities such as constructing water-saving structures or maintaining soil health. Although these increases were not significantly different across upazilas ($\chi^2 = 7.26$; p = 0.298), they suggest that adaptation often comes at a cost of higher human effort. Interestingly, perceptions of labor efficiency (e.g., getting more output per labor hour) varied significantly ($\chi^2 = 16.95$; p = 0.009). Nearly half of the farmers reported moderate improvements, with Gomostapur leading at 63.33%, while Godagari had a high share of respondents reporting no change. This may imply that adaptation efforts in Gomostapur were more skill-based and productivity-oriented, while those in Godagari were more labor-intensive and yielded no immediate productivity gains.

Overall, 74% agreed that benefits outweighed costs, with Gomostapur showing the most positive sentiment. This highlights that farmers' overall willingness to adopt and maintain adaptation practices is strongly influenced by their local experience with cost-benefit trade-offs and when practices prove effective. These results echo those of Ricart *et al.* (2023) and Baffour-Ata *et al.* (2025), who found that farmers valued long-term resilience despite high upfront costs.

Table 4: Upazila-wise farmers perceived costs and benefits of adaptation

Survey question	Godagari N=60	Gomostapur N=60	Niamatpur N= 60	Total N=180	Chi² value	p-value
What is the initial cost of implementing climate change adaptation strategies?						
Less than 2,500	3 (5.0%)	2 (3.33%)	0 (0.0%)	5 (2.78%)	18.03	0.006
2,500 – 5,000	14 (23.33%)	15 (25.0%)	8 (13.33%)	37 (20.56%)		
5,001 – 10,000	42 (70.0%)	32 (53.33%)	37 (61.67%)	111 (61.67%)		
More than 10,000	1 (1.67%)	11 (18.33%)	15 (25.0%)	27 (15.0%)		
Have you noticed a reduction in crop losses due to extreme weather events after adoption?						
Significant reduction	16 (26.67%)	12 (20.0%)	15 (25.0%)	43 (23.89%)	12.51	0.051
Moderate reduction	15 (25.0%)	31 (51.67%)	24 (40.0%)	70 (38.89%)		
No reduction	8 (13.33%)	1 (1.67%)	6 (10.0%)	15 (8.33%)		
Increased losses	21 (35.0%)	16 (26.67%)	15 (25.0%)	52 (28.89%)		
Have the adaptation strategies changed the amount of water used for irrigation?						
Much less water use	27 (45.0%)	10 (16.67%)	12 (20.0%)	49 (27.22%)	32.22	0.000
Slightly less water use	17 (28.33%)	46 (76.67%)	40 (66.67%)	103 (57.22%)		
More water use	16 (26.67%)	4 (6.67%)	8 (13.33%)	28 (15.56%)		
Do the adaptation strategies require labor/change in labor patterns?						
More labor required	24 (40.0%)	28 (46.67%)	23 (38.33%)	75 (41.67%)	7.26	0.298
A little more labor	18 (30.0%)	24 (40.0%)	22 (36.67%)	64 (35.56%)		
Less labor	15 (25.0%)	8 (13.33%)	14 (23.33%)	37 (20.56%)		
No labor	3 (5.0%)	0 (0.0%)	1 (1.67%)	4 (2.22%)		

Have you observed changes in soil quality since implementation?						
Significant improvement	17 (28.33%)	8 (13.33%)	11 (18.33%)	36 (20.00%)	16.95	0.009
Moderate improvement	18 (30.00%)	38 (63.33%)	32 (53.33%)	88 (48.89%)		
No change	19 (31.67%)	13 (21.67%)	11 (18.33%)	43 (23.89%)		
Deterioration	6 (10.00%)	1 (1.67%)	6 (10.00%)	13 (7.22%)		
What is the ongoing cost of maintaining the adaptation strategies?						
Less than 2,500 BDT	14 (23.33%)	9 (15.00%)	12 (20.00%)	19.44%	12.51	0.051
2,500–5,000 BDT	43 (71.67%)	37 (61.67%)	32 (53.33%)	62.22%		
5,001–10,000 BDT	3 (5.00%)	12 (20.00%)	15 (25.00%)	16.67%		
More than 10,000 BDT	0 (0.00%)	2 (3.33%)	1 (1.67%)	1.67%		
Do the benefits of implementing climate change adaptation strategies outweigh the cost?						
Strongly disagree	5 (8.33%)	0 (0.00%)	1 (1.67%)	6 (3.33%)	20.72	0.008
Disagree	7 (11.67%)	5 (8.33%)	2 (3.33%)	14 (7.78%)		
Neutral	8 (13.33%)	5 (8.33%)	13 (21.67%)	26 (14.44%)		
Agree	24 (40.00%)	35 (58.33%)	20 (33.33%)	79 (43.89%)		
Strongly agree	16 (26.67%)	15 (25.00%)	24 (40.00%)	55 (30.56%)		

Barriers to the Adoption

Table 5 shows the overall ranking of barriers to adopting climate change adaptation practices in the Barind Tract. The results show that some problems are more severe than others and directly affect how farmers respond to climate risks. The most serious barrier is resource constraints (WAI = 4.35). Many farmers lack basic inputs such as seeds, fertilizer, labor, and tools. Without these essentials, it is challenging to implement new practices. Similar issues were noted by Ricart *et al.* (2023) and Onyekuru *et al.* (2023), who pointed out that a lack of access to key farming resources often prevents farmers from adapting effectively. The second barrier is limited access to technology (4.29). Farmers usually lack the machinery, modern tools, and improved methods needed to manage changing weather conditions. Asante *et al.* (2024) also reported this challenge, noting that poor access to technology makes it harder for farmers to adapt to changing weather patterns.

Financial constraints are ranked third (4.01). Even when farmers know about climate-smart practices, they often cannot afford the costs, especially the high initial investments. Similar findings were found by Baffour-Ata *et al.* (2025). Political resistance comes fourth (3.98). Weak policy or institutional support reduces farmers' motivation to adopt. Other barriers include lack of accurate information (3.86) and inadequate infrastructure (3.85), both of which limit awareness and access to markets or irrigation. Lack of awareness (3.58) appears to be a minor barrier, but it remains a relevant issue. Finally, cultural barriers (2.54) are the least important, indicating that most farmers are open to change when they receive the proper support.

Table 5: Barriers to the Adaptation Practices

Barrier	WAI Value	Rank
Resource constraints	4.35	1
Limited access to technology	4.29	2
Financial constraints	4.01	3
Political resistance	3.98	4
Lack of accurate information	3.86	5
Inadequate infrastructure	3.85	6
Lack of awareness	3.58	7
Cultural barriers	2.54	8

CONCLUSION

This study highlights both the progress and challenges of climate change adaptation in the Barind Tract. Farmers predominantly adopt irrigation, mechanization, and improved seeds strategies that deliver clear benefits in reducing losses, saving water, and improving productivity. However, the high costs of adoption, combined with resource shortages, limited access to technology, and weak institutional support, hinder wider adoption. Based on these findings, the policy recommendations can be suggested as:

1. Financial support: Subsidies, low-interest loans, and targeted grants to ease initial and ongoing costs.
2. Extension services: Strengthened training programs,

mobile-based advisory systems, and regular field visits.

3. Input delivery: Timely access to drought-tolerant seeds, water-saving technologies, and organic fertilizers.

4. Infrastructure investment: Irrigation canals, storage facilities, roads, and rural electrification.

5. Inclusive adaptation: Programs designed to involve farmers through targeted training and support.

However, the study is based on farmers' self-reported perceptions, which may be subject to recall or social desirability bias. The cross-sectional survey design limits insights into long-term impacts and dynamic adaptation behaviors. Therefore, future studies can conduct detailed cost-benefit analyses of individual practices and apply longitudinal and econometric methods to capture dynamic adaptation processes. Comparative research across other drought-prone districts would also provide valuable insights for scaling adaptation policies.

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