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Original Article

The role of integrated prawn farming in climate change adaptation in Bangladesh: ecosystem services, economic viability and barriers

Md. Asadur Rahman[1] • Md. Mehedi Alam[1] • Sadman Sakib[2] • Rupesh Das[2] • Md. Hasan Faruque[2,3]

[1] *Department of Fishery Resources Conservation and Management, Khulna Agricultural University, Khulna 9100, Bangladesh*
[2] *Water Quality and Fisheries Management Laboratory, Department of Fisheries, University of Dhaka, Dhaka 1000, Bangladesh*
[3] *Department of Fisheries, University of Dhaka, Dhaka 1000, Bangladesh*

Correspondence
Md. Hasan Faruque; Department of Fisheries, University of Dhaka, Dhaka 1000, Bangladesh
hasanfaruque28@du.ac.bd

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Abstract
The integrated rice-prawn-vegetable culture (RPVC) is an effective farming method that ensures the efficient utilization of water and land. This study aims to evaluate the role of RPVC in climate change adaptation, its ecosystem services, and economic sustainability in Bangladesh. Integrated RPVC provides farmers with ecosystem services, including reducing use of the fertilizers and insecticides and lowering financial instability. The vegetable platform shades prawn ponds naturally, while prawns consume insects in rice fields. After rice plants are harvested, their roots can serve as food for prawns. Majority of the respondents (85%) reported that adopting RPVC increased the overall productivity. Farmers faced a variety of climatic hazards; ranked as: drought (86.3%) > erratic and sudden heavy rainfall (81.5%) > temperature fluctuation (69.6%) > salinity intrusion (67.2%) > storm (28.5%). The ecosystem services provided by RPVC helped farmers to mitigate the adverse impacts of these climate-induced challenges through ecosystem-based adaptation. Integrated RPVC has also enabled farmers to maintain a consistent cash flow throughout the year. By promoting the production of multiple commodities—rice, prawns, and vegetables—the system reduces the risk of financial destitution. Despite benefits, farmers also encountered several challenges in implementing RPVC including water shortage (85.2%), disease (73.5%), theft (60.4%), increased feed costs (70.7%), lack of information (65%), increased labor cost (58.8%), and not getting expected market value of farming products (63.2%). However, if these barriers are addressed, the integrated RPVC system holds significant potential to foster long-term socio-economic growth in the southwest region of Bangladesh.

Keywords: adaptation; climatic hazards; economic suitability; ecosystem services; integrated prawn farming

1 | INTRODUCTION

The cultivation of freshwater prawn (*Macrobrachium rosenbergii*) is a globally significant industry, contributing to food security, economic development, and ecosystem sustainability (Haslawati *et al.* 2022; Islam *et al.* 2023; Yaakob *et al.* 2024). Integrated agriculture-aquaculture systems that incorporate prawn farming with other agricultural practices are recognized for enhancing resource efficiency, supporting livelihoods, and providing ecosystem services (Murshed-E-Jahan and Pemsl 2011; Marques *et al.* 2016; Alam *et al.* 2022; Bell *et al.* 2023). These systems are particularly valuable in climate-vulnerable regions, where sustainable farming practices enhance resilience and adaptive capacity (Ahmed *et al.* 2014; Ahmed and Diana 2015; Jamal *et al.* 2023).

Bangladesh is a prime example of a country leveraging its natural resources and traditional practices for sustainable prawn farming (Ahmed *et al.* 2008a; Kazal *et al.* 2020). In the fiscal year 2021–22, Bangladeshi prawn farms produced approximately 54,352 MT of prawns, accounting for 18.06% of the country's total aquaculture output (DoF 2022). Prawns are a key export commodity, with 5,772.98 MT exported during the same period, generating US$ 80.72 million in export revenue (DoF 2022). The country's subtropical climate, extensive shallow water bodies, and availability of wild prawn larvae make it an ideal location for freshwater prawn aquaculture (Ahmed *et al.* 2008a).

In southwest Bangladesh, the traditional rice-prawn farming system exemplifies the synergy between agriculture and aquaculture (Woźniacka *et al.* 2025). Farmers modify rice fields into 'gher' (a Bengali term for 'perimeter,' refers to an enclosure for fish and prawn cultivation created by raising dikes around rice fields and excavating a canal to retain water during the dry season) for prawn farming, creating a system that yields both rice, the staple food of the nation, and prawns, a high-value cash crop (Williams and Khan 2001). By incorporating vegetables into these systems, farmers achieve diversified production, enhancing food security and economic resilience (Alam *et al.* 2022). The rice-prawn-vegetable culture (RPVC) system provides essential ecosystem services (ES), including improved soil fertility, water conservation, and biodiversity support, while enhancing yields and resource efficiency (Costanza *et al.* 1997; Giap *et al.* 2005). Given Bangladesh's shrinking water bodies (Islam *et al.* 2010), RPVC optimizes soil and water use, boosting agricultural productivity with a high cost-benefit ratio and low production costs (Giap *et al.* 2005; Lan *et al.* 2008). Additionally, RPVC supports climate adaptation through cost-effective, multifunctional ES, a principle known as Ecosystem-based Adaptation (EbA) (Saroar *et al.* 2019).

As Bangladesh faces growing climate challenges, including cyclones, floods, salinity intrusion, and riverbank erosion, sustainable integrated systems like RPVC provide a viable adaptation strategy. Integrated system can be used as a tool in adaptation to climate change (Bosma *et al.* 2012). Unlike unplanned shrimp farming, which exacerbates soil salinity and threatens long-term agricultural sustainability (Chowdhury *et al.* 2011), RPVC integrates ecological and economic goals. However, its potential for climate adaptation and economic viability, particularly in southwest Bangladesh—an area highly vulnerable to climatic hazards—requires further evaluation (Jamal *et al.* 2023). Previous studies have explored various aspects of integrated aquaculture, including rice-fish farming (Tsuruta *et al.* 2011; Rahman *et al.* 2012; Haque *et al.* 2015), organic rice-prawn culture (Nair *et al.* 2014), and the benefits of integrating vegetables with rice-prawn systems (Alam *et al.* 2022). Building on this foundation, the present study aims to assess RPVC's role in climate change adaptation, its ES, and economic sustainability in Bangladesh. Additionally, it seeks to identify barriers to scaling up RPVC, offering insights that may inform policymakers and researchers working towards sustainable aquaculture practices globally.

2 | METHODOLOGY

2.1 Study area

Due to the suitable environment (i.e. low-lying lands, abundant wild larvae, and warm climate), integrated RPVC is mainly practiced southwest region of Bangladesh (Ahmed *et al.* 2010). After the initial literature review, a scoping study was conducted in the different parts of southwest Bangladesh to find a suitable study area. The study was conducted in Dumuria (22°48′29.88″N 89°25′30.00″E) and Phultala Upazila (22°58′30.00″N 89°27′29.88″E) of Khulna district; Fakirhat Upazila (22°46′50.16″N 89°42′29.88″E) of Bagerhat district, located in southwest Bangladesh (Figure 1). These study areas have been considered due to the prevalence of integrated rice-prawn-vegetable farms (Rahman *et al.* 2020).

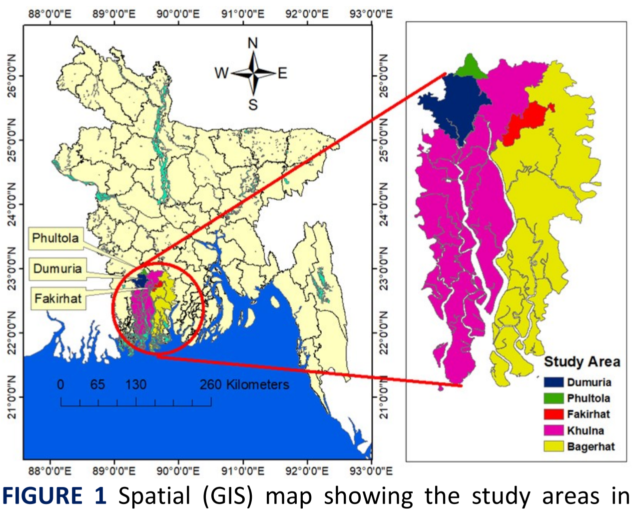

FIGURE 1 Spatial (GIS) map showing the study areas in Dumuria and Phultala Upazila of Khulna district and Fakirhat Upazila of Bagerhat district.

2.2 Data collection

2.2.1 Semi-structured interviews

This study employed a mixed-methods approach, utilizing participatory rural appraisal tools to collect both quantitative and qualitative data for an in-depth understanding of the integrated RPVC system. Semi-structured interviews were conducted with RPVC farmers to gather comprehensive insights. All respondents were actively engaged in RPVC. To ensure a representative sample, respondents were selected using a randomized transect walk method (Helen *et al.* 2019). This approach involved dividing the study area into distinct zones based on geographical and accessibility criteria, and then randomly selecting farmers within each zone. This method was chosen to minimize selection bias and ensure that farmers from both accessible and less accessible areas were included. A total of 133 semi-structured interviews were conducted across three study locations: Dumuria (*n* = 50), Phultala (*n* = 40), and Fakirhat (*n* = 43). The randomization process ensured that the sample was representative of the entire RPVC farmer population in the study area, reducing the risk of overrepresenting or underrepresenting specific groups of farmers.

During the interviews, basic demographic and socioeconomic information was collected, including age, years of education, occupational experience, primary and secondary occupations, income from primary activities, and participation in training programs. Data on farmers' net returns from vegetables, rice, and prawns for each production cycle were recorded. Given the region's vulnerability to climatic hazards, information on these hazards and the farmers' adaptation strategies was also collected. Additionally, data on the ES provided by RPVC, which aid in adaptation, were gathered. The study also identified the major barriers faced by farmers in the RPVC sector. Responses to open-ended questions were manually recorded on the questionnaire during the interviews. The questionnaire survey was conducted between October 2021 and February 2022.

2.2.2 Focus group discussions (FGDs)

FGDs aimed to provide in-depth insights and clarify issues that emerged during the semi-structured interviews. A number of visits were made to the farming areas, and discussions were held with key informants, including local Upazila Fisheries Officers, influential community members, and representatives from feed and chemical companies, to find the locations of the clusters of integrated RPVC farmers. A total of three FGDs were conducted, one in each study site. A purposive sampling technique was used to ensure a targeted and balanced selection of RPVC farmers for the FGDs. Farmers were stratified by experience level, from novice to highly experienced. Key experienced farmers with at least 10 years of integrated RPVC farming experience were included to get in-depth insights. Additionally, efforts were made to engage less vocal but highly experienced farmers through referrals from local stakeholders and trust-building techniques during recruitment (Billson 1989; Patton 2002). Each discussion was divided into two sessions, with 8 – 10 farmers participating in each session. The discussions lasted approximately two hours per session. With the participants' permission, the discussions were audio-recorded for accuracy and thorough analysis. The FGDs focused on several key areas: the ecological benefits farmers perceive from practicing RPVC, the barriers they face in adopting and sustaining RPVC, their strategies for adapting to the adverse impacts of climate change, and the role of RPVC in their overall adaptation process. These discussions provided valuable qualitative data to complement the findings from the semi-structured interviews.

2.2.3 Key informant interviews (KIIs)

To validate the information gathered from semi-structured interviews and FGDs, a total of eight KIIs were conducted. Additionally, the KIIs provided in-depth insights into critical topics, including the major climatic hazards affecting farmers, the future potential and ecological sustainability of RPVC, measures to enhance the efficiency of RPVC, and its role in climate change adaptation. Key informants included individuals with substantial knowledge of RPVC, such as the Senior Upazila Fisheries Officer (SUFO), experienced and skilled RPVC farmers, and representatives from government and non-government organizations. Each interview lasted 45–60 minutes. With the participants' permission, the discussions were audio-recorded to ensure accuracy and detailed analysis.

2.3 Data analysis

The audio recordings from the FGDs and KIIs were carefully processed to ensure data reliability. The data collected through semi-structured interviews were thoroughly cleaned and edited before being entered into a database using MS Excel (version 2019). Quantitative data were analyzed using IBM SPSS (Version 26), applying descriptive statistics such as mean, percentage, and standard deviation (SD). The results were then presented in tables and figures for clarity and ease of interpretation. Qualitative data were analyzed using a modified grounded theory approach (Strauss and Corbin 1990). This process involved three key steps: data preparation and organization, coding to categorize the data into themes, and representation of findings in figures and tables. This comprehensive approach ensured robust analysis and effective presentation of both quantitative and qualitative findings.

3 | RESULTS

3.1 General characteristics

The respondents had a mean age of 38.23 ± 12.75 years, with an average education (schooling years) of 9.22 ± 3.94 years and an occupational experience of 10.68 ± 5.90 years. The mean income from their primary occupation was US$ 2365.04 ± 517.56 year^{-1}, ranging from US$ 1084.25 to 3532.57. In integrated RPVC farms, about 63.90% of respondents engaged in finfish farming, 1.50% in part-time driving (e.g., rickshaws, vans, battery-operated small vehicles, etc.), 23.30% in other businesses (e.g., grocery stores, fish/poultry feed and fertilizer sales, mobile SIM and recharge shop), 3.80% in computer-based outsourcing (e.g., freelancing, online services), and 7.50% had no secondary occupation (Table 1). The mean family size was recorded as 4.20 ± 1.63 members, ranging from 2 to 7, with an average of 1.90 ± 1.14 school-going children per household (range: 0 to 4). A total of 27.10% of the respondents had received training on prawn farming, covering culture techniques, water quality management, and disease prevention and treatment. Furthermore, 80.50% believed that training is essential for successful prawn farming, while the remaining respondents disagreed.

TABLE 1 General characteristics of the respondents (*n* = 133).

Characteristics	%	Mean ± SD	Range
Age (years)	-	38.23 ± 12.75	18–74
Education (years)	-	9.22 ± 3.94	0–20
Experience (years)	-	10.68 ± 5.90	1–26
Farm size (ha)	-	1.29 ± 0.90	0.13–7.35
Income from primary occupation (USD$ year^{-1})	-	2365.04 ± 517.60	1084.25–3532.57
Secondary occupation			
Finfish farming	63.90		
Part-time driving	1.50		
Other business	23.30		
Outsourcing	3.80		
**N/A*	7.50		
Family members (no.)		4.20 ± 1.63	2–7
No. of school-going children	-	1.90 ± 1.14	0–4
Received training in prawn farming	27.10	-	-
Farmers' perceptions of the importance of training for prawn farming		-	-
Yes	80.50		
No	19.50		

3.2 Rice-prawn-vegetable culture (RPVC) system

Integrated RPVC is a popular and sustainable farming system in the southwest Bangladesh. In this system, Boro rice (primarily BRRI-28) is cultivated from January to April. After the Boro rice cycle, farmers begin stocking prawns during the rainy season. Rainwater is stored in the paddy fields, allowing prawns to swim freely throughout the flooded areas. Prawns are generally harvested between December and January.

Farmers construct bamboo platforms with nets around the pond's embankment to grow various vegetables (Figure 2), such as bottle gourd (*Lagenaria siceraria*), ash gourd (*Benincasa hispida*), bitter gourd (*Momordica charantia*), and watermelon (*Citrullus lanatus*). They also cultivate cucumber (*Cucumis sativus*) and tomato (*Solanum lycopersicum*) on the pond's dyke. These vegetables are grown from April to August, with tomatoes produced between September and November.

FIGURE 2 Vegetables on the embankment in the integrated rice-prawn-vegetable culture system during the rainy season (photo taken by the first author).

3.3 Ecosystem services of rice prawn culture and its impact on yield

The farmers receive a variety of ES from RPVC (Figure 3). A majority of the respondents (65.4%) reported that less fertilizer is needed in their prawn ponds. Similarly, 60.2% noted a reduced need for insecticides in their prawn ponds. In the southwest coastal region, temperature is a critical factor, as elevated pond water temperatures can lead to prawn mortality. According to 73.4% of the respondents, the platform used for vegetable cultivation serves as a natural shade for the prawns, helping to mitigate this risk. The result reveals that 83.7% of respondents associate integrated RPVC with a reduced risk of financial hardship, as it facilitates the simultaneous cultivation of rice, prawns, and vegetables within the same farming system. In the event of prawn disease, which is a common concern, losses can be offset by the income from rice and vegetable production.

Survey results show that 68.5% of respondents reported RPVC maximizes the use of soil and water resources. Eighty-five percent of the respondents reported increased overall yields after adopting integrated RPVC. Besides, 60.5% of the farmers shared that they use the roots of rice plants to feed prawns. After harvesting rice, they store and process the rice plant roots, which produce insects that prawns find attractive and nutritious.

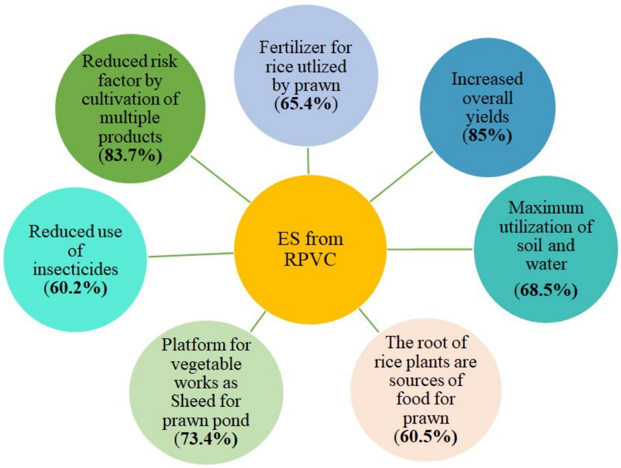

FIGURE 3 Ecosystem services from rice-prawn-vegetable culture.

3.4 Impacts of climatic hazards and role of rice-prawn-vegetable culture in ecosystem-based adaptation to climate change

3.4.1 Impacts of climatic hazards

The southwest region of Bangladesh is highly vulnerable to natural climatic hazards. In this study, farmers identified and ranked a range of climatic hazards, including drought, erratic and heavy rainfall, temperature fluctuation, salinity intrusion, and storm.

Drought was the most frequently mentioned climatic hazard by farmers. It was ranked as the top hazard by 86.3% of the respondents. Drought leads to water shortages (Table 2), which cause multiple challenges for farmers. One respondent explained, "*a lot of prawns died in my pond due to excessive temperatures during the drought. I couldn't recover from that loss in that season*." Drought also causes a reduction in groundwater levels, making it difficult for farmers to store water for irrigation, as the stored water seeps into the soil. Farmers reported that both vegetables and rice are severely damaged due to drought and its associated water shortage. Enhancing irrigation system efficiency, such as installing deep water pumps or digging canals to store river or rainwater, can be effective adaptations to mitigate drought impacts.

Erratic and sudden heavy rainfall was ranked second by 81.5% of the respondents (Table 2). Such rainfall reduces temperature, pH, and salinity, while increasing turbidity in prawn ponds. This can hamper prawn growth and even lead to mortality. Sudden heavy rainfall also results in waterlogging, which adversely affects the vegetable plants grown on the pond embankments. The respondents reported that their ponds had been washed away due to heavy rainfall. Prolonged rainfall can reduce sunlight and significantly lower the dissolved oxygen levels in the pond. To protect against this, fencing can be installed around the dyke to prevent prawns from being washed away during heavy flooding. Additionally, maintaining optimal temperature, pH, and dissolved oxygen levels is crucial until conditions normalize.

TABLE 2 Climatic hazards and adaptation by the rice-prawn farmers.

Climatic hazards	Rank	Respondent (%)	Adaptation(s)
Drought	1	86.3	• Enhancing the efficiency of the irrigation system, i.e. setting up a deep-water pump • Digging canal to store river/rainwater
Erratic and sudden heavy rainfall	2	81.5	• Setting up net fencing around the dyke • Maintaining DO and pH
Temperature fluctuation	3	69.6	• Installing shading structures • Creating deeper ponds
Salinity intrusion	4	67.2	• Culture of saline-tolerant rice and vegetable varieties
Storm	5	28.5	• Going to the cyclone shelter • Livelihood diversification

Temperature fluctuations were ranked as the third climatic hazard by 69.6% of the respondents. Fluctuations in temperature can increase stress and weaken the prawn's immune system, making them more susceptible to disease. This not only reduces prawn production but can also lead to mortality. Temperature fluctuations also negatively affect rice and vegetables. Rising temperatures and reduced rainfall can exacerbate drought, decreasing rice and vegetable yields.

Salinity intrusion was ranked fourth by 67.2% of the respondents (Table 2). When salinity levels exceed the tolerance threshold for prawns, it hampers their growth and may even cause death. Respondents also noted that salinity intrusion impairs the production of rice and vegetables. Although storms are not a constant climatic hazard, they cause significant damage when they occur. Storm was ranked as the fifth climatic hazard by 28.5% of the respondents (Table 2).

3.4.2 Role of RPVC in ecosystem-based adaptation to climate change

The ES from the RPVC system play a significant role in climate change adaptation. ES, also known as EbA, can be crucial to the adaptation process due to its versatility and cost-effectiveness. Livelihood diversification is an effective adaptation strategy for climate change, and RPVC fosters this diversification. By diversifying income sources rather than relying on a single one, farmers can significantly reduce risk, making them more resilient to natural disasters. Since the RPVC system promotes the cultivation of multiple products—rice, prawns, and vegetables—the likelihood of financial destitution is reduced. In the event of prawn diseases, losses can be offset by the income from rice and vegetable production.

The RPVC system ensures a steady cash flow throughout the year (Figure 4). According to 76% of respondents, the RPVC technique helps farmers maintain a consistent revenue stream. Vegetable cycles typically last three to five months, and by selling vegetables year-round, farmers enjoy continuous income. This steady financial flow enhances their living standards and provides support in the aftermath of natural disasters. Additionally, this system reduces the cost of fertilizers and insecticides, as reported by 65.4% and 60.2% of respondents, respectively.

3.5 Cost-benefit analysis

Although prawns had higher mean total costs compared to rice or vegetables, they also generated a higher net return (Table 3). The mean operation cost for rice was 892.54 ± 206.41 US$, which is slightly higher than that for vegetables (595.52 ± 153.58 US$) (Table 3). The mean return was higher for vegetables compared to rice.

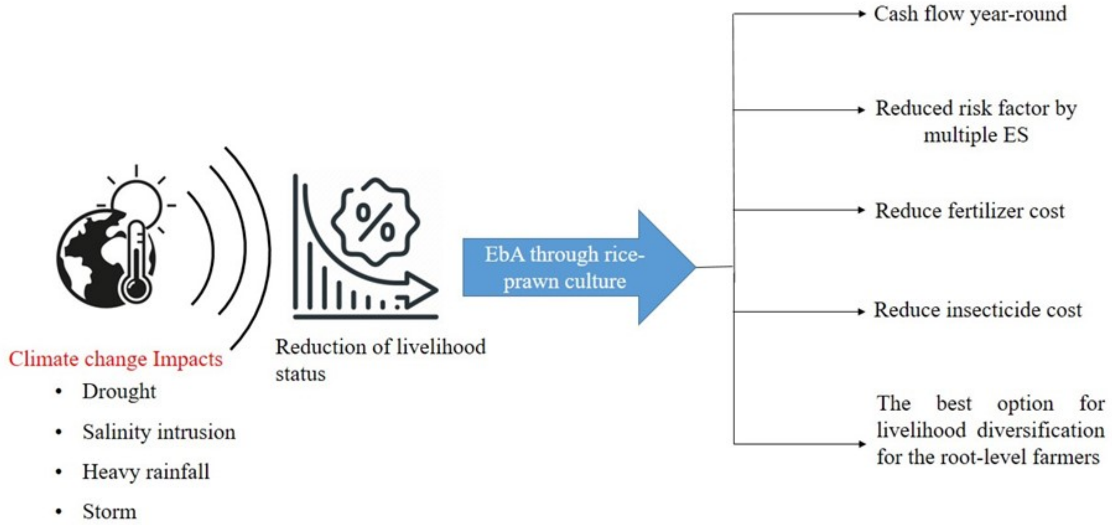

FIGURE 4 Role of RPVC in ecosystem-based adaptation (EbA) to climate change.

TABLE 3 Total cost, selling price and net return from prawn, rice and vegetable.

Amount (US$) (cycle^{-1} ha^{-1})	Mean ± SD	Range
Total cost of prawn	2200.45 ± 359.24	1399.04 – 3147.83
Selling price of prawn	3365.38 ± 438.57	2098.56 – 4896.63
Net return from prawn	1164.92 ± 329.96	279.80 – 2588.22
Total cost of rice	892.54 ± 206.41	594.59 – 1399.04
Selling price of rice	1305.94 ± 315.46	839.42 – 2238.46
Net return from rice	413.40 ± 172.90	139.90 – 979.33
Total cost of vegetable	595.52 ± 153.58	339.42 – 1189.18
Selling price of vegetable	1382.23 ± 410.13	524.64 – 2447.83
Net return from vegetable	786.71 ± 346.49	104.93 – 1648.79

3.6 Barriers to rice-prawn-vegetable culture system in Southwest Bangladesh

Integrated rice-prawn-vegetable farmers encounter multiple barriers that negatively impact their ability to adapt. The most pressing issue, reported by 85.2% of respondents, was water scarcity. Disease outbreaks also pose a major threat, affecting 73.5% of farmers, while 60.4% struggle with theft. Increased feed and labor costs were also barriers for 70.7% and 58.8% of respondents, respectively. About 63.2% of respondents identified not receiving expected market prices as a significant barrier. Furthermore, two-thirds (65%) of respondents identified inadequate information access as a critical constraint (Figure 5). The participants mentioned a lack of information about feed, medicine, and seed prices.

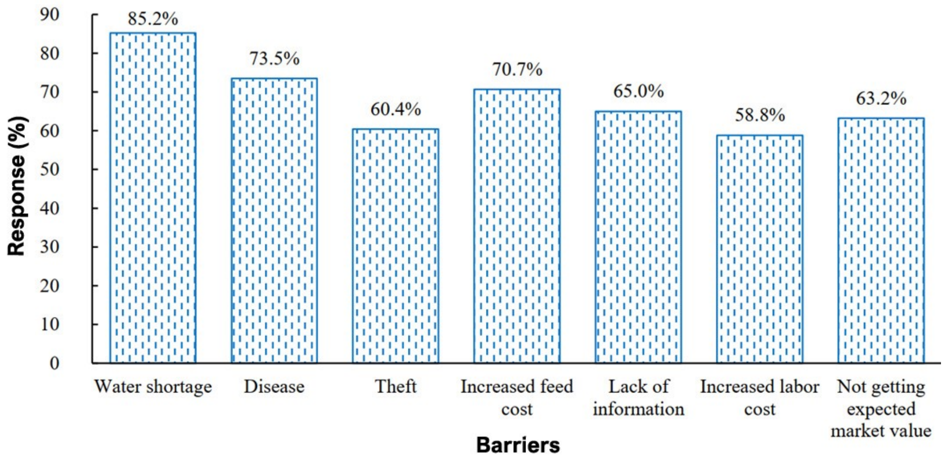

FIGURE 5 Barriers to integrated RPVC in Southwest Bangladesh.

4 | DISCUSSION

The findings of this study underscore the significance of the RPVC system as a sustainable farming practice in southwest Bangladesh. This integrated approach offers numerous ecological and economic benefits to farmers, enhancing their resilience to the impacts of climate change (Ahmed and Diana 2015). Notably, the RPVC system plays a critical role in EbA to climate change. Local farmers benefit from this system through reduced fertilizer and insecticide usage, leading to cost savings and healthier agricultural products. Furthermore, RPVC enhances soil fertility and water quality by reducing dependency on chemical inputs, thereby addressing environmental challenges such as eutrophication and soil degradation (Ahmed *et al.* 2014; Loc *et al.* 2017). The system also improves nitrogen use efficiency by minimizing nitrogen losses from runoff and leaching while enriching nitrogen content in rice straw, thereby promoting soil health (Mirhaj *et al.* 2014). Additionally, RPVC reduces greenhouse gas emissions, particularly methane– a key driver of climate change, making it a more sustainable farming alternative (Cui *et al.* 2023; Alam *et al.* 2024). Integrated systems like RPVC also enhance rice yields and offer higher economic returns compared to monoculture systems, largely due to synergistic crop yield effects and reduced reliance on external inputs (Boock *et al.* 2016; Liu *et al.* 2020, Alam *et al.* 2022).

The southwest region of Bangladesh faces significant climatic hazards (Akter and Ahmed 2021; Mahalder *et al.* 2023). Farmers interviewed during the study identified drought, erratic rainfall, temperature fluctuations, salinity intrusion, and storms as major concerns. Among these, drought was ranked the top hazard, leading to severe water shortages that affect irrigation and damage rice and vegetable crops. Enhancing irrigation efficiency, such as installing deep-water pumps or constructing canals for rainwater and river water storage, could mitigate these impacts (Hossain *et al.* 2016). Erratic heavy rainfall presents additional challenges by reducing temperature, pH, and salinity, and increasing turbidity in prawn ponds, which negatively affects prawn growth and survival. Waterlogging caused by heavy rain also damages vegetable plants on embankments, while some farmers reported pond embankments being washed away. Measures such as fencing dykes to prevent prawns from escaping during floods and managing pH and dissolved oxygen levels until conditions normalize can help mitigate these impacts (Islam *et al.* 2019). High salinity levels, another issue identified by respondents, affect rice and vegetable production and hinder prawn growth. The cultivation of salt-tolerant crop varieties could reduce the adverse effects of salinity intrusion (Paik *et al.* 2020). Although storms are less frequent, their sudden occurrence causes severe damage to infrastructure and farming activities. Diversifying livelihoods could provide a buffer against storm-related economic losses (Islam *et al.* 2021).

Economically, the RPVC system is more cost-effective than monoculture farming (Ahmed *et al.* 2010; Asad *et al.* 2017; Alam *et al.* 2022). New (2002) stated that, profit from rice monoculture could be increased by 2 – 3 times by adopting integrated culture with prawn. In a study by Alam *et al.* (2022), the benefit–cost ratio (BCR) was higher in RPVC (1.58) than conventional rice farming (1.34). In this study, prawn farming entails higher operational costs than rice or vegetable cultivation, but it also yields higher net returns, as highlighted by cost-benefit analyses. Interestingly, while the operational costs of rice and vegetable cultivation are lower than for prawns, vegetables generate higher mean returns than rice, emphasizing the economic potential of vegetable cultivation on pond embankments. These findings align with previous studies that highlight the importance of crop diversification in integrated farming systems for improved profitability and food security (Ahmed *et al.* 2010; Alam *et al.* 2022).

Despite its benefits, the broader adoption and sustainability of the RPVC system face several challenges. Climate change-induced issues, including salinity intrusion, water scarcity from drought, and irregular rainfall, pose significant threats to the system (Ahmed and Diana 2015; Miah *et al.* 2020). These climatic threats may cause reduced production and profit of RPVC system. Several obstacles stood in the way of fishermen's adaptation strategies to mitigate the effects of climate threats (Islam *et al.* 2020). Water shortage was reported as a primary constraint by 85.2% of respondents. In RPVC system, continues supply of water is more necessary to support year-round multiple crops production (rice, vegetables and prawn). During semi-structured interviews, a farmer suggested the need for additional deep-water pumps as the water level continues to decrease. Additionally, rainwater and river water can be stored by digging canals in a planned manner. According to a key informant from Dumuria Upazila, pond depth should be increased by 3 to 5 feet to alleviate water scarcity during the dry season.

Disease outbreaks are another major concern, with 73.5% of farmers highlighting larval-stage mass mortalities of *M. rosenbergii* since 2011, leading to an 80% production decline. This mortality has been linked to the *M. rosenbergii* Golda Virus (MrGV), a newly identified RNA virus related to the yellow head virus and other Nidovirales (Hooper *et al.* 2020). However, these outbreaks could be minimized by adopting good aquaculture practices (GAP) and more advanced culture systems. High production costs, especially for prawn feed, and limited access to wild prawn fry and snail meat—key feed components—further constrain farmers (Ahmed *et al.* 2008b). Farmers listed a lack of information about feed, medicine, and seed prices as a barrier. The pricing of these products also varies from place to place. Respondents claimed that having fixed pricing lists in every store and hatcheries would make purchasing these items conveniently. Additionally, many farmers lack technical expertise in prawn farming, affecting productivity and sustainability (Ahmed and Diana 2015; Akter and Ahmed 2021). Arranging adequate training facilities may overcome this barrier. These challenges may pose adverse impacts on the sustainability and profitability of the RPVC system. Addressing these challenges requires enhanced institutional support to promote improved practices and strengthen the RPVC system, thereby securing the livelihoods of local farmers.

5 | CONCLUSION

The integrated RPVC system is recognized as a sustainable agriculture-aquaculture practice in southwest Bangladesh, boosting productivity through diversification and efficient resource use. The study revealed that farmers adopt a rotational cropping system, cultivating rice (BRRI-28) during the dry season (January to April), farming prawns in the rainy season with harvests primarily in December, and growing vegetables year-round on embankments. This system provides essential ecosystem services: prawns, as omnivorous and detritivorous benthic feeders, accelerate organic matter decomposition through bioturbation and microbial activity, releasing nitrogen and phosphorus that fertilize rice and improve soil quality, thereby reducing reliance on chemical fertilizers. Nutrient-rich sediment strengthens dykes and supports vegetable growth by supplying organic matter, while vegetables and rice provide shade, regulating water temperature and protecting prawns from predators. Prawns also contribute to the control of insects, and pests, boosting overall productivity. However, farmers have significant climate risks, such as drought, erratic rainfall, temperature fluctuation, salinity intrusion, and storm. Mitigation strategies include installing submersible pumps or digging deep canals for water retention, constructing flood-protection fences, providing shade to stabilize water temperature, and cultivating salinity-tolerant rice or vegetables. Additional barriers, including water scarcity, disease outbreaks, theft, and market challenges, hinder the widespread adoption of this system. Addressing these barriers through improved infrastructure, enhanced knowledge dissemination, and market support could enhance the viability of integrated RPVC as a climate-smart agriculture-aquaculture practice in the region.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHORS' CONTRIBUTION

Md. Asadur Rahman: Conceptualization, Methodology, Investigation, Data curation, Software, Formal analysis, Writing – original draft. Md. Mehedi Alam: Conceptualization, Methodology, Investigation, Data curation, Software, Formal analysis, Writing – original draft. Sadman Sakib: Writing – original draft, Formal analysis. Rupesh Das: Formal analysis, Writing – original draft. Md. Hasan Faruque: Conceptualization, Methodology, Supervision, Writing – review & editing.

DATA AVAILABILITY STATEMENT

The data findings of this study are presented in this article.

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MA Rahman https://orcid.org/0000-0002-2677-0789
MM Alam http://orcid.org/0000-0002-4462-8727
S Sakib https://orcid.org/0009-0004-9539-4504
R Das https://orcid.org/0009-0000-0398-7013
MH Faruque http://orcid.org/0000-0003-3230-2284