






## Article

# Economic Viability and Seasonal Impacts of Integrated Rice-Prawn-Vegetable Farming on Agricultural Households in Southwest Bangladesh

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**Abstract:** Integrated aquaculture is an efficient method to address food scarcity and land resources. This study analysed the impacts of integrated rice–prawn–vegetable farms (RPVF) compared with conventional rice farms (CRF) on farming households in southwest Bangladesh, in terms of cropping pattern, financial profitability and viability, and cash-flow. Data were collected through face-to-face recall interviews from farmers of CRF and RPVF. For RPVF, farmers cultivated diverse produce in the wet season, such as prawn/shrimp, carps in reservoirs and vegetables on dikes, and boro rice with vegetables in the dry season, whereas only rice was cultivated in both seasons for CRF. The annual hectare<sup>-1</sup> net revenue from integrated RPVF was USD 2742.7, 3.6 times higher than for CRF (USD 756.6). RPVF had a higher undiscounted benefit–cost ratio (BCR) of 1.58 as compared with 1.34 for CRF. Net Present Value (NPV) and discounted BCR show that the integrated RPVF has higher potential and profitability than CRF. Year-round vegetable production and selling have resulted in a smooth cash-flow in integrated RPVF. Authorised extension agencies, such as the Department of Fisheries and Department of Agricultural Extension collaboratively can promote RPVF in other potential parts of Bangladesh, through which farmers can benefit year after year by investing farm income for the same farm and envisage food security.

**Keywords:** integrated rice–prawn–vegetable farming system; seasonality; profitability; sustainability; Bangladesh



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## 1. Introduction

The ever-growing human population inhabits all available land areas, and there is an increasing global demand for more food [1,2]. Since Bangladesh's independence in 1971, high population growth rates have placed further pressure on scarce land resources. Arable land is declining at a rate of nearly 1% per year due to complex socio-environmental factors, such as population growth, urbanization, limited resources, and the conversion of agricultural lands to non-agricultural activities [3,4]. These factors increase pressure on limited

agricultural resources and pose an enormous threat to food security and environmental sustainability [5–7]. Nevertheless, the economy of Bangladesh is predominately agricultural and this sector affects a wide range of factors, including food security, economic growth, livelihood opportunities, poverty alleviation, human wellbeing, and the use of natural resources such as land, water, and biodiversity [8]. Rice and fish are the staple foods of approximately 166.5 million people in Bangladesh [3]. On average, Bangladeshis consume more than 170 kg and 23 kg of rice and fish per capita per annum, respectively, compared with the world average of 57 kg and 20.5 kg [9–11]. This diet has been an essential part of life in Bangladesh throughout history, and demand is constantly increasing over time [12].

Due to the declining cultivable land in Bangladesh, agriculture has been intensified to meet population growth and economic development needs [11]. However, agricultural intensification comes at the cost of environmental pollution, pesticide resistance, and rising economic costs from the necessary heavy application of chemical fertilizers and organochlorine pesticides [13]. The intensive use of agrochemicals is damaging biodiversity and reducing the abundance and richness of beneficial arthropods in rice fields [14]. Along with agriculture, aquaculture is gaining importance in Bangladesh, which is globally ranked fifth for aquaculture production [10], owing to the adequate supply of protein-rich aquatic food [15,16]. The decline in capture fisheries in Bangladesh means aquaculture has been expanded and intensified [1,17], which had led to a number of associated problems such as polluted wastewater, eutrophication, greenhouse gas emission, and oxygen depletion, as well as poor product muscle quality, off-flavour, and disease susceptibility [16,18–20]. As a result, producing enough rice and fish with an economic return, while minimizing the negative environmental effects, has become a major challenge [13]. Therefore, the sustainable intensification of agricultural and aquaculture systems is needed to address ever-increasing food shortages and environmental pressures. Scientists, policymakers, and researchers are looking toward traditional agriculture as a possible solution [21]. Recognizing the ecological legacy of these traditional agricultural systems, such as integrated farming systems, may be an alternative to developing novel sustainable agriculture in the future resource-limited world [13].

One such option is the traditional rice–fish integrated system for many countries in the world. Integrated rice–fish farming has a long history in Asia and can be traced back to the year 220 AD in China [13]. This system has also been reported in Bangladesh, Egypt, India, Indonesia, the Philippines, Thailand, Vietnam, Malaysia, and part of West Africa [22]. The integrated rice–fish farming system developed gradually and has played a major role in promoting rural revitalization, poverty alleviation, and high-quality production. The benefits of this integrated system reach beyond producing additional fish in the paddy fields. Bashir et al. [7] found that integrated rice–fish farming helped control pests and weeds in paddy ecosystems, facilitating integrated pest management. Furthermore, there is a fertilizing effect from the fish excrement, which increases nutrient availability to the rice crop. This type of culture system may enhance the safe production of food with less/no pesticide application requirements as the cultured animals help reduce weeds and consume insect pests. Integrated rice–fish farming has been suggested as a strategy to provide both grains and meat to humans in the same rice fields while reducing the risks of environmental pollution. Fish produced from an integrated rice-field-based fish seed production system provided the farming households with nutrient-dense food in the ‘hungry gap’ season when supplies of wild fish were very low [23]. Vegetables produced in an integrated floating cage aquageoponics system were found to support the nutrition of farming households in the months when no vegetables were grown in the homesteads of households. Fluctuations in food consumption related to seasonality can cause serious problems for poor households, particularly in the case of nutrient-rich non-staple foods, where integrated aquaculture–agriculture can ensure seasonal food security [24].

In Bangladesh, a variety of fish species are cultured in integrated rice–fish culture systems, such as indigenous (rohu (*Labeo rohita*), catla (*Catla catla*), mrigal (*Cirrhinus cirrhosis*), and kalibous (*Labeo calbasu*)), and exotic carp (silver carp (*Hypophthalmichthys molitrix*), and

common carp (*Cyprinus carpio*), silver barb (*Barbonymus gonionotus*), tilapia (*Oreochromis niloticus*), shrimps, prawns, etc. Currently, giant freshwater prawns (*Macrobrachium rosenbergii*) are a good option for integrated rice-fish culture systems because of their ecological benefits, export potential, and high market value. There are several interactions between rice and prawns in culture systems: generally, the rice fields provide flooded space, shade, and shelter against predators, maintaining the water temperature at tolerable levels in the hot summer months. The rice field has a well-defined spatial distribution in the environment and occupies a small layer at the bottom of aquatic systems. Furthermore, prawns are omnivores and detritivores with a benthic habit; when they feed, the waste decomposition releases nitrogen, phosphorus, and other elements important for the fertilization of rice. Prawn waste increases the amount of organic material in the rice fields, reducing the need for external chemical fertilization. Prawns also contribute to the control of some weeds, insects, and pests. The addition of freshwater prawns to an integrated system may add value to sustainability. New [25] determined that the introduction of prawns in paddy fields does not reduce rice production, rather it increases the profits by 2–3 times that of rice monoculture.

Rice–prawn–vegetable farming in Bangladesh is practiced in modified rice fields, locally known as gher. Gher, a Bengali term meaning ‘perimeter,’ is an enclosure made for fish and prawn cultivation achieved by modifying rice fields by building higher dikes around the field and excavating a canal several feet deep inside the periphery to retain water during the dry season [26]. The gher system is a combination of agriculture, aquaculture, and horticulture, incorporating rice, prawn, and vegetable production. Generally, rice and prawns grow in the enclosure, and a variety of small-scale vegetables and fruits are produced on the dikes. In gher farming of integrated rice–prawn–vegetable farms, seasonality is important because the interactions between agriculture, aquaculture, and horticulture vary with the season. Moreover, seasonality is intensely related to rice cultivation, the stocking of post-larvae (PL) prawn, planting of vegetable or fruit saplings, production, cash-flow, and profit. However, scientific knowledge on the seasonal impacts of integrated rice–prawn–vegetable farming, in terms of profitability, financial viability, and cash-flow experienced by small-scale farmers in southwest Bangladesh is limited. In this study, the underlying hypothesis is that seasonality has a significant impact on the economic profitability and viability, and cash-flow of integrated rice–prawn–vegetable farming. In this context, the objectives of this research were to characterise the only rice farms and farmers practicing integrated rice–prawn–vegetable farming; to assess profitability differences between conventional rice farms and rice–prawn–vegetable farms along with the financial viability of investment; and identify the seasonal impacts on farming households in southwest Bangladesh.

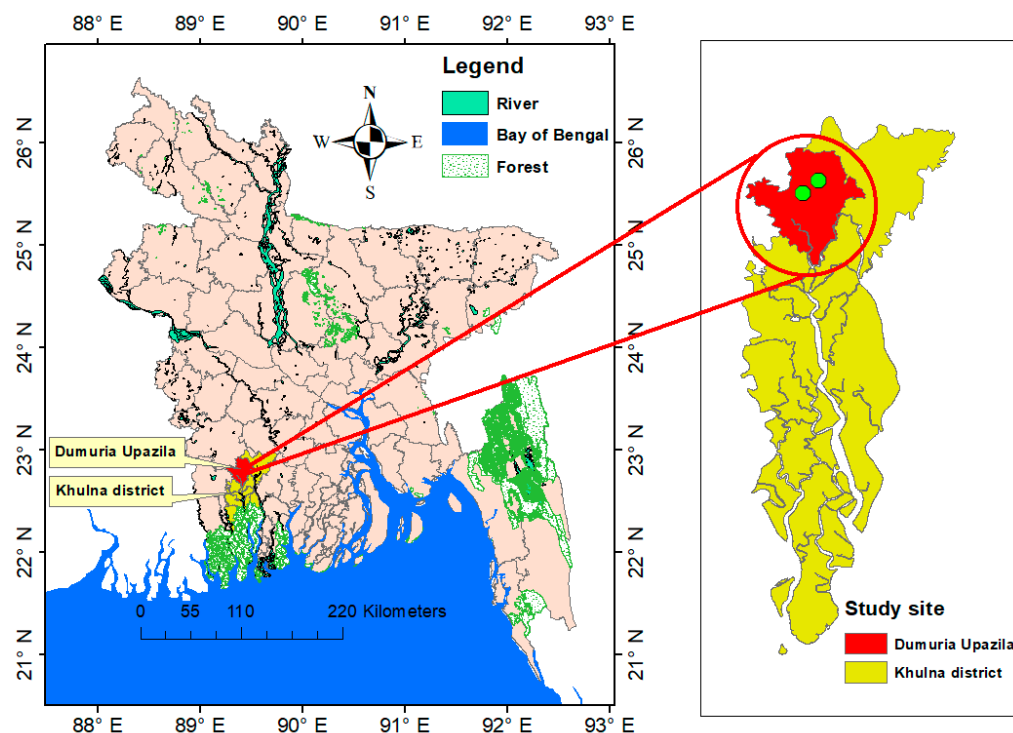
## 2. Materials and Methods

A mixed methodological approach was applied in this study, where quantitative and qualitative data collection were carried out to provide detailed information on farmer characterization, cropping pattern in integrated farming, benefits from conventional rice farms (CRF) vs. integrated rice–prawn–vegetable farms (RPVF), and how the profit is spread across the year to the farmers. Quantitative data were collected through recall surveys from farmers of both CRF and RPVF. Qualitative data were collected using the participatory rural appraisal tool for analyzing the cropping pattern of integrated farming in different seasons of the year. The steps we followed in the entire methodological approach are as follows.

### 2.1. Site Selection

This study was conducted in the following two communities: Bilpabla and Gutudia in the Dumuria Upazila (subdistrict) of Khulna district in Southwest Bangladesh (Figure 1). These areas were selected because the farmers have many years of experience in both gher and conventional rice farming. The demographics of those villages are very similar to other

villages where rice–prawn–vegetable farming is practiced. Dumuria is the leading rice-producing area in the region due to the favourable resources and agroecological conditions such as fertile soil, availability of irrigation water, warm climate, and cheap abundant labour ([27], Table 1). This is also an old rice production region that still has a fairly rich species diversity. Furthermore, it has a high concentration of freshwater prawn farms, corresponding to 50% (accounting for 6598 MT) of the district’s total production [9]. The widespread rice–prawn production has led to the development of hatcheries and irrigation infrastructure, the availability of wild post-larvae, adoption of compatible rice varieties, and a dense water network of many canals and rivers.



**Figure 1.** Map of Bangladesh showing the study sites at Dumuria Upazila in Khulna district. Scale applies to the map of Bangladesh only.

**Table 1.** Characteristics of study sites.

Category	Khulna (No. of Upazila, <i>n</i> = 9)	Dumuria (Study Site)	% of Total Upazila
<i>Rice farming status</i>			
■ Area of rice farming (ha)	148,764.0	30,860.0	20.7
■ Boro	60,915.0	22,350.0	36.7
■ Aman	91,880.0	15,575.0	16.9
<i>Rice production (MT)</i>			
■ Boro	273,251.0	100,144	36.6
■ Aman	260,179.0	44,298.0	17.0

Table 1. Cont.

Category	Khulna (No. of Upazila, $n = 9$ )	Dumuria (Study Site)	% of Total Upazila
<i>Prawn farming status</i>			
Area of prawn farming (ha)	19,016.40	11,146.0	58.6
No. of prawn farming ponds/gher	38,892	18,712.0	48.1
No. of prawn farmers	51,614.0	17,800	34.5
Prawn production (MT)	13,324.90	6598.0	49.5
No. of prawn hatcheries	2.0	1.0	50.0
No. of prawn auction places	22.0	7.0	31.8

Source: Department of Agricultural Extension [27] and Department of Fisheries [9].

## 2.2. Farmers Selection

Relatively knowledgeable farmers were selected through direct observations and a transect walk to obtain adequate and accurate information. The transect walk is an informal survey which involves a walk over the transect of an area to observe and document similarities and differences in socioeconomic and bio-physical features described by Participatory Planning Monitoring and Evaluation (PPM and E). A transect walk, which is a widely used participatory rural appraisal tool for data collection, was conducted to obtain a snapshot of farming communities and identify potential farmers from the study areas. A total of 10 transect walks were carried out with the assistance of Upazila Fisheries Officer, Dumuria, and discussions with the representative of local rice–prawn farmers. The transect walk is a directly observational tool; it facilitates informal discussions with the villagers who accompany the walk.

The selected farmers and farms were categorised based on various sociodemographic characteristics such as age, farming experience, education level, occupation, household size, farm size, land ownership, and number of hired labourers (as followed by [4]). The three age categories were defined as young (<30 years old), middle-aged (31–50 years), and old (>51 years). Farming experience classifications were defined as less than  $\leq 5$  years, 6–15 years, and  $\geq 15$  years. The four education levels of the farmer were defined as illiterate (no schooling), primary (1–5 years of schooling), secondary (6–10 years of schooling), and above secondary (>10 years of schooling). Farm size classifications were defined as marginal (<0.4 ha), small (0.5–1.0 ha), and medium/large (>1.0 ha). Land ownership classifications were defined as the percentage of owned or leased land for farming activities.

## 2.3. Questionnaire Interview

Twenty farmers (10 from each CRF and RPVF) were randomly selected and interviewed face-to-face using three separate structured parts of a single questionnaire. A limited number of farmers were questioned to obtain accurate seasonal details of integrated farming systems. A total of 10 interviews were conducted in Bilpabla, and 10 in Gutudia— both with 5 CRF and 5 RPVF farmers. Respondents were first asked about basic demographic characteristics, that is names, address, age, education, experiences, family members, farm size, pond numbers, etc. Next, the farming system, seed selection, duration, agricultural calendars, and schedule for each crop were investigated. Finally, profitability and cash-flow analysis, such as production costs, average yields, revenue, capital transfer, and benefits in recent years were discussed. Each interview took approximately 50–60 min. The questionnaire was developed in English and translated into Bengali before the survey with farmers. Detailed notes were taken. A draft questionnaire was pre-tested by interviewing four independent farmers, other than those questioned in this study, with two from each site. The questionnaires were revised twice before finalization. The interviews were conducted by two graduate students who had completed a master's degree in Aquaculture.

#### 2.4. Cropping Pattern Analysis

Cropping patterns and seasonality were analysed using the participatory rural appraisal tool, particularly a key informant interview with 3 CRF and 3 RPVF farmers, over a specific period of the year considering farmers' practices, as suggested by Barmon et al. [28]. In integrated farming, farmers grow various crops at different seasons of the year along with prawn and fish, with an inherent relationship between expenditure and income. Due to production of different crops, the expenditure and income of the farmer varies in different seasons. A cash-flow analysis is an efficient technique to unpack the variation of income and expenses and profit at the end of production. The cropping pattern and seasonality analysis of integrated farming are essential when carrying out a cash-flow analysis. In this study, cash-flow was determined based on monthly cash inflows and outflows for operation of the farming system in the study area.

#### 2.5. Data Processing and Analyses

Data from the interviews were entered into a database using MS Excel software. Before analysis, data were cleaned, edited, and cross-checked thoroughly. The statistical package for social science (SPSS 23; SPSS Inc., Chicago, IL, USA) software was used to analyse the data, thereby producing descriptive statistics. The averages ( $\pm$  standard error) and frequencies of values were used to summarise the socio-economic data of the farmers. An independent sample *t*-test was applied to determine the significance of the differences between CRF and RPVF. The level of significance was set to  $p < 0.05$ .

Based on the data collected through the survey from farmers, a simple profitability analysis was performed to obtain a clear image of the economic comparison between a hectare of CRF and RPVF. The calculation of profitability analysis in CRF and RPVF includes investment cost, gross cost, gross revenue, net revenue, and undiscounted benefit–cost ratio (BCR). The investment cost for every individual input and the benefit from all individual outputs were calculated separately. Net revenue was calculated by subtracting gross cost from gross revenue for an operational year. The undiscounted BCR was calculated by dividing gross revenue by total production cost. The profitability analysis was based on the farm-gate prices of prawn/shrimp/fish and current local market prices of all other items expressed in US dollars (USD 1 = BDT 85.13). Furthermore, the long-term profitability metrics in terms of NPV (Net Present Value) and discounted BCR were calculated to evaluate the financial viability of CRF and integrated RPVF. These economic metrics are widely used to assess the financial viability and cash-flow of agricultural farming including fisheries and aquaculture [29,30]. The positive NPV implies that the farming venture is financially viable and feasible. The discounted BCR indicates the rate of return per unit of cost. A higher ratio indicates a greater profit on net investment. The financial viability analysis was carried out over a period of 5 years according to the local leasehold tenure of land; after this period, extensive restructuring is usually required to ensure a farm is running again. The interest rate on agricultural loans from government agencies is around 9%; therefore, the discount rate for NPV calculation was considered as 9%. The NPV and discounted BCR were calculated using the following formula (1) to (2):

$$NPV = \sum_{t=0}^n \frac{B_t - C_t}{(1+r)^t} \quad (1)$$

where, NPV = Net present value;  $B_t$  = Benefits in year;  $C_t$  = Cost in year;  $t$  = Time period;  $r$  = Discount rate.

$$\text{Undiscounted BCR} = \frac{\sum_{t=0}^n \frac{B_t}{(1+r)^t}}{\sum_{t=0}^n \frac{C_t}{(1+r)^t}} \quad (2)$$

### 3. Results

#### 3.1. General Characteristics

Descriptive statistics of sociodemographic characteristics between CRF and RPVF are summarised in Table 2. The average age of conventional rice farmers ( $49.2 \pm 4.70$  years) was higher than that of rice–prawn–vegetable farmers ( $41.8 \pm 3.90$  years; NS,  $p > 0.05$ ). The average farming experience of conventional rice farmers was  $20.0 \pm 3.30$  years, which was significantly higher ( $p < 0.05$ ) than rice–prawn–vegetable farmers ( $10.6 \pm 1.80$  years). In contrast, education level, farm size, and the number of hired labourers were significantly higher ( $p < 0.05$ ) in RPVF than in CRF (Table 2). In CRF and RPVF, respectively, approximately 80% and 60% of farmers had an alternative occupation, with fishermen and crop farming being the dominant secondary professions, respectively. There was no significant difference ( $p > 0.05$ ) between the farmers in terms of household size, number of males, number of females, number of children, number of school-going children, and percentage of own land and leased land value (Table 2). The average area of land owned by conventional rice farmers was  $73.2 \pm 8.53$  ha which is relatively larger than that of RPVF ( $65.5 \pm 10.5$  ha). The number of hired labourers employed in RPVF was significantly higher than in CRF ( $p < 0.05$ ), while the average annual household income of RPVF households ( $7018.7 \pm 64.5$  USD) was significantly higher ( $p < 0.05$ ) than that of CRF households ( $2117.8 \pm 120.1$  USD).

**Table 2.** Demographic and socioeconomic features of farmers of conventional rice farms (CRF) and rice–prawn–vegetable farms (RPVF).

General Characteristics	CRF ( $n = 10$ )		RPVF ( $n = 10$ )		$p$ -Value
	Frequency	Mean $\pm$ SE	Frequency	Mean $\pm$ SE	
<b>Age</b>		<b><math>49.2 \pm 4.70</math></b>		<b><math>41.8 \pm 3.90</math></b>	<b>0.244</b>
Young (< 30 years)	1		3		
Middle (31–50 years)	4		5		
Old (> 50 years)	5		2		
<b>Farming experience</b>		<b><math>20.0 \pm 3.30</math></b>		<b><math>10.6 \pm 1.80</math></b>	<b>0.027 **</b>
< 5 years	1		3		
5–15 years	3		5		
> 15 years	6		2		
<b>Education level</b>		<b><math>3.8 \pm 1.20</math></b>		<b><math>11.7 \pm 1.30</math></b>	<b>0.001 **</b>
Illiterate (no schooling)	3		0		
Primary (1–5 years of schooling)	5		1		
Secondary (6–10 years of schooling)	1		3		
Above secondary (> 10 years of schooling)	1		6		
<b>Secondary occupation</b>	<b>8 (80%)</b>		<b>6 (60%)</b>		
Crop farming	1		2		
Land business	1				
Fishermen	3		1		
Livestock, poultry, fish feed, and chemicals seller	1		1		
Small business	2		1		
Primary school teacher			1		
<b>Household size</b>		<b><math>5.7 \pm 0.42</math></b>		<b><math>4.8 \pm 0.49</math></b>	<b>0.182</b>
Number of males		$2.4 \pm 0.26$		$2.2 \pm 0.20$	0.557
Number of females		$3.3 \pm 0.30$		$2.6 \pm 0.37$	0.161
Number of children		$1.9 \pm 0.23$		$1.5 \pm 0.34$	0.349
School going children		$1.5 \pm 0.16$		$1.1 \pm 0.23$	0.182

Table 2. Cont.

General Characteristics	CRF ( <i>n</i> = 10)		RPVF ( <i>n</i> = 10)		<i>p</i> -Value
	Frequency	Mean ± SE	Frequency	Mean ± SE	
<b>Farm size</b>		<b>0.7 ± 0.12</b>		<b>2.2 ± 0.46</b>	<b>0.010 **</b>
Marginal (< 0.4 ha)	3		1		
Small (0.4–1.0 ha)	4		2		
Medium/large (> 1.0 ha)	3		7		
<b>Land ownership</b>					
Own land (%)		73.2 ± 8.53		65.5 ± 10.5	0.553
Leased in (%)		26.8 ± 8.53		35.0 ± 10.5	0.553
<b>Number of hired labour</b>					
Full-time labour (non-family)		0.6 ± 0.16		2.1 ± 0.48	0.013 **
<b>Average income per year (USD)</b>		<b>2117.8 ± 120.1</b>		<b>7018.7 ± 64.5</b>	<b>0.046 **</b>
From farms		536.6 ± 87.9		6033.9 ± 52.8	
From secondary occupation		1581.2 ± 152.3		984.8 ± 76.2	

\*\* indicates a significant difference between CRF and RPVF at *p* < 0.05.

### 3.2. Cropping Pattern of Rice–Prawn–Vegetable Farming

In CRF, two crops of rice, aman, and boro, are normally produced in a year. Aman is summer rain-fed, transplanted in the monsoon season in August, and harvested in December. Boro is winter irrigated and produced in the dry season between January and May. In the study area, 40–45-day old boro rice seedlings were transplanted, with most farmers finished by the third week of January and crops harvested in April–May (Table 3).

In RPVF, the cultivation system and period of boro rice in gher were similar to CRF, which was produced from January to May. Along with rice farming, farmers sow bottle gourd (*Lagenaria siceraria*) seeds and make a hanging platform using bamboo and a net surrounding the embankment. Generally, 3–5 seeds are sown 2.0 m apart in a 3.0 cm deep pit across the entire embankment. The cultivation of a bottle gourd takes 4 months; however, it reaches a marketable size within 2 months. At the end of the boro rice cultivation period, farmers start stocking the fish (prawn, shrimp, and carp) in the gher during the rainy season. In this period, the rice field and adjacent ditches are filled with rainwater, allowing prawns and other fishes to move freely around the entire flooded paddy field. Farmers start to harvest prawns and fish in December; however, many prawns will not have reached a marketable size and are kept in the gher for rearing until they are large enough. In July, seedlings of vegetables such as cucumber (*Cucumis sativus*) and bitter melon (*Momordica charantia*) are sown in the embankment of the enclosure. After a 1.5-month interval, the vegetables will be a marketable size and are then sold until November (Figure 2). Farmers also produced tomato (*Solanum lycopersicum*) along with other vegetables between September and December on the gher embankment (Table 3).



**Table 3.** Cropping patterns and seasonality for conventional rice farms (CRF) and rice–prawn–vegetable farms (RPVF).

Crops	Months											
	January	February	March	April	May	June	July	August	September	October	November	December
<b>CRF</b>												
Boro rice	← ○ ————— ● ————— →											
Aman rice								← ○ ————— ● ————— →				
<b>RPVF</b>												
Boro rice	← ○ ————— ● ————— →											
Bottle gourd	← ○ —●———— →											
Bitter gourd								← ○ —●———— →				
Cucumber								← ○ —●———— →				
Tomato									← ○ —●———— →			
Prawn								← ○ ————— ● ————— →				
Shrimp								← ○ —●———— →				
Carp								← ○ ————— ● ————— →				

○ indicates the period up until the planting of rice and vegetables, and stocking of prawn, shrimp, and carp;  
 ● indicates starting of harvesting period.



**Figure 2.** Integrated rice–prawn–vegetable farming system in wet season showing the vegetables on the embankment (Photo by the first author).

### 3.3. Economic Benefit Analysis

Table 3 presents the comparative profitability analysis, showing that the financial efficiency of RPVF was much higher than CRF for gross revenue, net revenue, and benefit–cost ratio (BCR). In CRF, the average per hectare production costs of boro and aman rice were USD 1233.6 ha<sup>-1</sup> year<sup>-1</sup> and USD 985.9 ha<sup>-1</sup> year<sup>-1</sup>, respectively, with a total cost of USD 2219.4 ha<sup>-1</sup> year<sup>-1</sup>. The dominant cost items were lease value (USD 1033.7 ha<sup>-1</sup> year<sup>-1</sup>) and labour payment for tillage, seed transplantation, cleaning and weeding, fertilizer use, application of drugs and chemicals, harvesting, threshing, etc. (USD 831.6 ha<sup>-1</sup> year<sup>-1</sup>). The average grain production of boro and aman rice was 6900 kg ha<sup>-1</sup> year<sup>-1</sup> and 4200 kg ha<sup>-1</sup> year<sup>-1</sup>, respectively. The gross cost of CRF was USD 2219.4 ha<sup>-1</sup> year<sup>-1</sup>, while the gross and net revenue was USD 2760.0 ha<sup>-1</sup> year<sup>-1</sup> and USD 540.6 ha<sup>-1</sup> year<sup>-1</sup>, respectively. However, in RPVF, three crops (fish, rice, and vegetables) were produced in a single production year. The gross cost and revenue of RPVF were USD 4741.0 ha<sup>-1</sup> year<sup>-1</sup> and USD 7363.7 ha<sup>-1</sup> year<sup>-1</sup>, respectively. The net revenue was USD 2622.6 ha<sup>-1</sup> year<sup>-1</sup>. The highest return came from vegetables, which amounted to USD 3179.0 ha<sup>-1</sup> year<sup>-1</sup>, followed by prawn–fish (USD 2572.3 ha<sup>-1</sup> year<sup>-1</sup>), and rice production (USD 1612.0 ha<sup>-1</sup> year<sup>-1</sup>). The undiscounted BCR was higher in RPVF (1.58) than in CRF (1.34) (Table 4).

**Table 4.** Comparative profitability analysis between a hectare of conventional rice farms (CRF) and rice–prawn–vegetable farms (RPVF) (1 USD = 85.13 BDT).

Input/Item/Produce	Description and Amount (Weight/No.)	Unit Price (USD/ha)	Cost/Revenue (USD/ha)		
			CRF		RPVF
			Boro	Aman	Boro
<b>A. Cost: rice and vegetables</b>					
Lease value	Yearly lease value for 1 ha land	1033.7	516.9	516.9	1033.7
Inorganic fertilizer					
Urea (kg)	CRF: boro @120; aman @90; RPVF @160	0.23	27.6	20.7	36.8
TSP * (kg)	CRF: boro @80; aman @50; RPVF @110	0.26	20.8	13	28.6
MP * (kg)	CRF: boro @60; RPVF @90	0.23	13.8	0.0	20.7
DAP * (kg)	CRF: aman @20; RPVF@30	0.26	0.0	5.2	7.8
Gypsum (kg)	CRF: boro @50	0.21	10.5	0.0	0.0
Seed					
Rice seed	Seed and seedling		93.9	60.5	85.5
Vegetable seed	Seed and seedlings		0.0	0.0	29.4
Drugs and chemicals	Insecticides, pesticides, herbicides, etc.		52.9	0.0	205.6
Irrigation	Used borehole pump in the dry season		35.2	0.0	29.4
Labour (no.)	Tillage, transplantation, weeding, fertilizing, applying chemicals, harvesting, threshing, etc. (CRF: boro @75; aman @60; and RPVF @185)	6.16	462.0	369.6	1139.6
<b>Total cost from A</b>			1233.6	985.9	2617.1
<b>B. Cost: aquaculture</b>					
Fish feed					
Traditional feed (kg)	Mixture of rice bran, wheat bran, soybean meal, etc. @840	0.31			260.4
Commercial feed (kg)	Sinking feed @1295	0.54			699.3
Fish seed					
Prawn—PL * (no.)	Giant Freshwater Prawn @10000	0.03			300.0
Shrimp—PL (no.)	Giant Tiger Shrimp @3000	0.04			120.0
Carp seed (no.)	Rohu, catla, carpiao, and punti @2500	0.21			525.0
Drugs and chemicals					
Lime (kg)	White limestone @180	0.14			25.2
Disinfectant (50 g packs)	5	3.08			15.4

Table 4. Cont.

Input/Item/Produce	Description and Amount (Weight/No.)	Unit Price (USD/ha)	Cost/Revenue (USD/ha)		
			CRF		RPVF
			Boro	Aman	Boro
Probiotics (50 g packs)	7 (Basically, <i>Bacillus</i> group)	3.52			24.6
Labour	Harvesting cost (25-man days)	6.16			154.0
<b>Total cost from B</b>					2123.9
<b>C. Revenue</b>					
Revenue from rice					
Boro rice (kg)	CRF@6900; RPVF@ 6200	0.26	1794.0		1612.0
Straw from boro rice (kg)	2000	0.06	120.0		120.0
Aman rice (kg)	4200	0.23		966.0	
Straw from aman rice (kg)	1600	0.06		96.0	
Revenue from vegetables					
Bottle gourd (no.)	4205	0.23			967.2
Tomato (kg)	4500	0.15			675.0
Cucumber (kg)	1320	0.21			277.2
Bitter gourd (kg)	7000	0.18			1260.0
Revenue from fish					
Prawn and shrimp (kg)	310	6.46			2002.6
Carp (kg)	270	2.11			569.7
<b>D. Gross cost</b>	CRF: boro + aman; RPVF: total cost of A + B			2219.4	4741.0
<b>E. Gross revenue</b>	Revenue from rice + vegetables + fish			2976.0	7483.7
<b>F. Net revenue</b>	Total revenue—total cost			756.6	2742.7
<b>G. Undiscounted BCR</b>	Total revenue ÷ total cost			1.34	1.58

\* TSP—Triple Super Phosphate; MP—Muriate of Potash; DAP—Diammonium Phosphate; PL—Post-larvae.

### 3.4. Financial Viability Analysis

In terms of the financial viability of an investment over a long time period, by looking at net discounted cash inflows and discounted cash outflows that a farm will generate over five years, the results of this study show that the estimated net present values for CRF and integrated RPVF were USD 1917.1 and USD 8012.3, respectively (Table 5). Apart from the farm construction cost, the cash outflow and cash inflow were considered constant for the entire production periods of CRF and integrated RPVF. The discounted BCR for CRF and integrated RPVF were 1.19 and 1.38, respectively (Table 5). The discounted BCR for CRF and integrated RPVF was found to be lower (Table 5) than that of undiscounted BCR (Table 4).

**Table 5.** Analysis of financial viability in terms of net present value (NPV) and discounted BCR of CRF and integrated RPVF.

Cost and Benefits	FARMING TYPES	
	CRF	RPVF
Present value of cost (USD ha <sup>-1</sup> )	9658.5	21,096.6
Present value of the benefit (USD ha <sup>-1</sup> )	11,575.6	29,108.9
Net present value (USD ha <sup>-1</sup> )	1917.1	8012.3
Discounted BCR	1.19	1.38

Source: Derived from field survey data (2020); whereas the additional reconstruction cost for CRF (dike preparation) was USD 58.7 ha<sup>-1</sup>year<sup>-1</sup>, and RPVF (dike preparation, canal excavation, sludge removal, etc.) was USD 234.9 ha<sup>-1</sup>year<sup>-1</sup>.

### 3.5. Cash-Flow Analysis

The results of the cash-flow analysis are summarised in Table 6. The cash transfer rate is low in the CRF system. For rice production, a huge investment is needed to continue farming systems owing to the lease value of land, tillage, and transplantation of seeds; weeding; fertilizer application; use of insecticides, pesticides, and herbicides; irrigation; harvesting; and threshing of crops. However, the entire revenue comes at the end of the production period (USD 1914.0 from boro and USD 1262.0 from aman), and there is no opportunity for a revenue transfer system in the middle of production (Table 6).

On the other hand, RPVF has a continuous cash-flow system with a higher net revenue (USD 2742.7). In the dry season, although farmers first transplant boro rice and bottle gourd vegetables, the initial revenue is from vegetables, even before rice production, and this continues until the end of the production cycle (Table 6). This provides an opportunity to spend revenue from vegetables on rice cultivation, such as on irrigation, fertilizer applications, labour payments, etc., in the middle of the production cycle. In the wet season, farmers practice aquaculture and horticulture together, where there is more opportunity to transfer capital between the systems. This integration means that farmers begin receiving revenue from vegetables within 1.5 months, and from prawns within 3 months (Table 6). As shown in Table 6, the cash-flow is initially negative, but returns come over time, which helps the farmers operate without a large financial burden. Farmers spend this revenue on operational costs, mostly on the purchase of fish feed, drugs and chemicals, and labour payments.

**Table 6.** Cash-flow analysis between conventional rice farms (CRF) and rice–prawn–vegetable farms (RPVF) ( $\text{ha}^{-1}$  year $^{-1}$ ).

Category	Cost/ Revenue (USD)	January	February	March	April	May	June	July	August	September	October	November	December	Net Revenue
CRF	<i>Cost</i>	1216.5	236.4	56.4	52.9	188.3	-	-	154.4	154.9	19.5	-	140.2	(Total cost—total revenue) = 756.6 (USD)
	<i>Description</i>	Lease value; tillage; and seed cost of boro rice	Irrigation; weeding; and fertilizer cost	Irrigation; and fertilizer cost	Drugs and chemicals cost	Harvesting; and thrashing cost			Tillage; and seed cost of aman rice	Weeding; and fertilizer cost	Fertilizer cost	-	Harvesting; and threshing cost	
	<i>Revenue</i>	-	-	-	-	1914.0	-	-	-	-	-	-	1062.0	
	<i>Description</i>	-	-	-	-	Sale price of boro rice and straw	-	-	-	-	-	-	Sale price of aman rice and straw	
<i>Cash-flow</i>		-1216.5	-1452.9	-1509.3	-1562.2	163.5	163.5	163.5	9.1	-145.8	-165.3	-165.3	756.5	
RPVF	<i>Cost</i>	1221.6	423.4	54.3	103.5	276.4		1034.1	172.7	291.5	372.3	460.6	330.6	(Total cost – total revenue) = 2742.7 (USD)
	<i>Description</i>	Lease value; tillage; and seed cost of boro rice	Bottle gourd seed; and irrigation; weeding; and fertilizer cost for rice	Irrigation; and fertilizer cost	Drugs and chemicals cost	Harvesting and thrashing cost		Fish seed; feed; and drugs and chemicals cost	Fish feed; drugs and chem- icals; and vegetable seed cost	Fish feed; drugs and chem- icals; and harvest- ing cost	Fish feed; drugs and chem- icals; and harvest- ing cost	Fish feed; drugs and chemicals; and harvesting cost	Fish feed; harvesting; and marketing cost	
	<i>Revenue</i>	-	-	520.2	447.0	1732.0	-	-	10.0	665.6	1182.6	1570.8	1355.5	
	<i>Description</i>	-	-	Sale price of bottle gourd	Sale price of bottle gourd	Sale price of boro rice and straw	-	-	Sale price of bitter gourd; and cu- cumber	Sale price of prawn; cucum- ber; and bitter gourd	Sale price of prawn; tomato; cucum- ber; and bitter gourd	Sale price of prawn; carps; tomato; and bitter gourd	Sale price of prawn; carps; and tomato	
<i>Cash-flow</i>		-1221.6	-1645.0	-1179.0	-835.6	620	620	-414.1	-576.8	-202.7	607.6	1717.8	2742.7	

## 4. Discussion

### 4.1. Socio-Demographic Characteristics

It is projected that integrated aquaculture will continue to play an important role in supporting socioeconomic development and sustaining the livelihoods of rural communities in many Asian countries [31,32]. More specially, integrated rice–prawn farming is beneficial because its facilities multiple cropping, reduces fertilization costs, maintains soil fertility, prevents waste accumulation, accelerates pest control, improves livelihoods, and provides additional employment in farming households [22,33,34]. Numerous studies have identified the socioeconomic factors (e.g., age, education level, experience, etc.) that affect farm characteristics, the management system, and choices of technology adoption [15,35,36]. In this study, farmers of both CRF and integrated RPVF were middle-aged; however, relatively younger and less experienced farmers were engaged in integrated RPVF. Younger farmers were more likely to be interested in integrated RPVF because they tend to be technically efficient, have a higher willingness for change, and have quick decision-making capacities so as to adopt new ideas and technological innovations [37]. These results are consistent with previous findings that suggest traditional agriculture is becoming less attractive to younger farmers who have greater financial opportunities [4,38]. In contrast, older experienced farmers have less interest outside of their traditional farming system, indicating that they are unlikely to adopt RPVF technology owing to a lack of technical knowledge on productivity, profitability, and resource utilization [12,39]. In our study, educated farmers operated integrated RPVF systems, indicating their preferences for the integrated system, which performs better on statistical and economic issues in terms of input use, production methods, operational costs, and use of credit. This is in line with the earlier studies of Okoye et al. [40], Zulfiqar et al. [41], and Anwar et al. [42]. Education is instrumental in perceiving, interpreting, and increasing the managerial ability of farmers, which in turn helps them use agricultural inputs more efficiently [43]. Furthermore, education is positively changing attitudes and motivations, helping to make better managerial decisions on farming, and accelerating the adoption of new technology [36]. On the other hand, CRF farmers had a low level of education, indicating educated young people do not return to traditional farming because of the lower outputs and profit.

Alongside their primary occupation, the farmers of both CRF (80%) and integrated RPVF (60%) were involved in diverse alternative professions, including crop farming; land business; fishing; selling of livestock, poultry, and fish feed and chemicals; small private business; and teaching. This indicates that a considerable percentage of all farmers relied upon various alternative sources to meet their financial demands. Even though RPVF led to greater monetary returns [44], there was no difference in secondary occupation. There were no significant differences in household characteristics, such as size, gender composition (number of males and females), number of children, or number of school-going children, although this had a direct influence on the expenditure and income patterns of the family. The average household sizes were  $5.7 \pm 0.42$  and  $4.8 \pm 0.49$  for CRF and integrated RPVF, respectively, which was either larger or similar in comparison to the national average rural household size of 4.83 in Bangladesh [3]. There is a strong relationship between farm size, age, education, adoption techniques, and annual income. The mean farm size was  $0.7 \pm 0.12$  ha and  $2.2 \pm 0.46$  ha for CRF and integrated RPVF, respectively, which is 1.8 and 3.7 times larger than the national average of 0.59 ha [3]. These results indicate that farmers of integrated RPVF possess higher than average resources. RPVF farmers also tended to have a small land area, which encouraged them to intensify their land use towards integrated farming to increase productivity. Moreover, their leased land area was larger than CRF, indicating RPVF farmers tend to consolidate more land for integrated farming [29].

Similarly, the mean farm size and annual income from farms of integrated RPVF were 3.0 and 11.0 times higher than CRF farms, respectively, indicating that an integrated large farm is more profitable, which may be because educated and young farmers operated integrated RPVF. Furthermore, integrated RPVF had a greater number of hired labourers

because large farmers are more dependent on employees, which is consistent with previous studies [4]. This suggests that RPVF creates more employment opportunities for poor and landless people, which is an indication of the development of rural entrepreneurship in Bangladesh [22,29]. Another positive aspect is that educated youth are engaged in integrated RPVF, thus reducing the migration of rural people to urban areas for employment, which in turn will lessen excessive pressures on urban populations [45].

#### 4.2. Cropping Pattern and Seasonality

In Bangladesh, the CRF method is very similar across the country. Farmers cultivate two rice crops, such as boro and aman, once a year. Boro rice seed is transplanted between January and mid-February in the dry irrigated season. Boro is a winter season, photo-insensitive, transplanted rice cultivated on supplemental irrigation [46]. Before cultivation, farmers prepare the rice field by ploughing, laddering, and weeding in early winter. At around 40–45 days, seedlings are transplanted at a low water level to allow them to gradually grow new roots. Farmers transplant 2–4 plants per stand, with a distance of approximately 25 cm between stands, then fertilizers are used to increase soil fertility; chemicals and pesticides protect the crops from harmful insects, and irrigation to prepare the land effectively. Weeding begins 2–3 weeks after transplantation and is repeated 2–3 times, depending on the density and growth of weeds. Finally, harvesting and threshing are completed between April and May. Conversely, aman rice is cultivated during the early rainy season before the beginning of monsoon rain. After completing the boro rice cycle, farmers sow aman in July–August. The aman rice cycle is longer than that of boro rice at around 6 months. Compared with boro rice production, farmers use fewer chemicals and fertilizers and do not use any pesticides or irrigation. The aman cycle finishes in December, as harvesting and threshing end in the late autumn to early winter (November–December).

Farmers operate integrated RPVF in a rotational system, in line with the studies of Ahmed et al. [12], Belton [47], and Marques et al. [22]. Along with the economic benefits, integrated farming reduces the cost of pond fertilization, maintains soil fertility, avoids the accumulation of waste products, improves pest control, and allows farmers to produce significant quantities of rice, fish, and vegetables for subsistence consumption and local sales [22,47]. Prawns, shrimps, and carps are reared during the monsoon season, boro rice in the dry season, and vegetables throughout the year. In the integrated system, boro rice cultivation is similar to CRF; however, farmers grew vegetables on the gher embankment. Bottle gourd seed is sown along with transplanted boro rice, which increases household income and food production. Marques et al. [22] reported that vegetable cultivation on gher embankments ensures the maximum utilization of land and maintains an ecological balance, and it is also economically profitable since multiple crops are produced from a single piece of land. In the monsoon period (June–July), farmers initially stocked prawns and shrimp in the gher, followed 7–10 days later by the stocking of carp fingerlings. The simple procedure of fish stocking greatly reduces predation on juvenile prawns by fish [48]. Simultaneously, farmers started vegetable cultivation on the embankment with manmade bamboo-netting platforms. However, integrated gher farmers did not cultivate aman rice because the double cropping of rice may not always be feasible due to flooding during the monsoon season and the high cost of land and labour. In addition, farmers believe that the use of pesticides for rice negatively affects prawn growth [49].

#### 4.3. Economic and Cash-Flow Analysis

Analyzing economic benefits is important for evaluating profitability and determining the efficiency of resource allocation and management practices [50]. The net revenue of integrated gher farmers was 3.6 times higher than that of conventional rice farmers, which is consistent with the findings of Islam and Tabeta [29]. Moreover, the positive NPV implies that both CRF and integrated RPVF systems were financially viable; however, RPVF demonstrated higher financial viability as its value was over four times higher than that of CRF. Similarly, the discounted BCR was found to be higher in integrated RPVF (1.38)

compared to CRF (1.23), and this further confirms that investment in terms of financial viability is highly profitable in the integrated farming system. Recent studies of a similar pattern show that integrated agriculture–aquaculture–horticulture is more financially viable than conventional agriculture or aquaculture only systems [7,13,22,29]. If conventional RVPF in Bangladesh can be made more intensive as in Vietnam with increasing stocking density of prawn and fish, BCR will increase further [51]. Respondents of the current study reported that freshwater prawn and vegetables of gher dikes make integrated RPVF more profitable than CRF. Year-round vegetable production contributes a maximum of 42% of the total revenue that accounts for a remarkable difference in profitability between the two systems. Although it is a small, enclosed land, a lot of vegetables in the unutilised waterlogged area are produced, mainly on nets or bamboo scaffolds. Previous research suggests that integrated RPVF is a profitable and resource-saving model in the monsoon aquaculture phase because it uses low quantities of fertilizer, which is a major cost of vegetable farming [22,34]. Generally, farmers remove the bottom sediment every 1–2 years to repair the gher embankment, thus fertilizing the embankment land and reducing the need for inorganic fertilizers in vegetable cultivation. The pond sediment is a good quality organic fertilizer, and also has a high availability of essential soil nutrients and microbial activities that favour plant growth, as reported by Haque et al. [52]. Another related factor is that the market value of freshwater prawns, which contributes to about 27% of the gross revenue, is much higher than that of aman rice produced in CRF during the monsoon season. Along with prawns, whitefish species such as indigenous and exotic carp provide additional production and profit in RPVF system. The results of this study show that there is little difference between the yield and profit of boro rice in CRF and RPVF during the dry season; however, year-round vegetable cultivation and the higher price of prawn/shrimp production in the monsoon season led to a significant difference in the profitability between the two farming methods.

Economic benefits and financial viability analyses do not explain how a farming system spreads profits throughout the year, hence a cash-flow analysis was carried out. The cash-flow analysis revealed that an integrated RPVF system ensures that the cash-flow system functions year-round, thus reducing the financial burden on the farmers in terms of cost of feed, seed, drugs and chemicals, and labour investment. Vegetables play a key role in maintaining cash-flow in integrated RPVF. Therefore, many farmers grow vegetables all year round, which they can sell on a regular basis. The life cycle of most vegetables is usually 4 months; however, almost all the vegetables mature to marketable size in 1.5–2 months, and then production and sales continue until the completion of the whole cycle. William and Khan [53] reported that the vegetables from integrated RPVF enhance food security for the family, and income from the sale of the surplus crops can be used to finance feeding prawns, repair the gher, for loan repayments, and input requirements for the following year. Prawns and shrimp also play a major role in maintaining the cash-flow for operational costs. Generally, 2 months after the release of PL, farmers began the partial harvest of marketable size prawn/shrimp because of operational costs and to avoid cannibalism issues [54].

#### *4.4. Integrated Farming Effects on Sustainability*

Integrated aquaculture technologies consisting of different system components are reported to have various benefits [3,24,55] where the integrated RPVF system is linked to a series of benefits such as food supply, ecological improvement, and social welfare [56]. RPVF is a sustainable practice in Southwest Bangladesh that is helping farmers to achieve desirable farming efficiency, and to generate ecological and economic benefits. According to farmers interviewed in this study, an integrated RPVF system is easily adaptable and economically viable at the current prices and typical seasonal yields of the produce. Marques et al. [22] recognised that integrated RPVF systems contribute to increasing food security, improving the local and global economy, and enhancing the social, economic, and environmental sustainability of aquaculture systems in many countries. Ahmed et al. [57]



found that integrated RPVF offers diverse livelihood opportunities, including wild PL collectors and traders, snail harvesters and traders, feed traders, intermediaries, prawn traders, transporters, and day labourers. A network for seed, feed, fertilizer trading, and prawn marketing has been established, highlighting the positive benefits of social sustainability. Furthermore, the marketing of prawns/shrimps leads to the influx of money in the local economy [12]. In rural areas of Southeast Bangladesh, cash-flow has increased because various crops (rice, prawn, shrimp, and vegetables) are harvested in different seasons. As a result, along with diversified food production and income generation, the level of risk associated with the entire cropping system is relatively low. This increased income also offers many farmers the opportunity to engage in other income-generating activities, including agriculture, livestock rearing, and small businesses. Prior research identified that the average income of integrated gher farming is four times higher than conventional agriculture practices. It also increases the demand for labour, reduces food insecurity, and alleviates poverty, while providing education, protein, health care, and sanitation [58]. Integrated RPVF is not associated with any negative criticisms or environmental consequences of coastal shrimp production. The advantage of integrated farming is that production is attained without any additional land use, indicating that it helps reduce excess pressure on land and conserves the environment. Another positive aspect of prawn–rice farming is that, unlike shrimp farming, it does not require saline water; therefore, no conflict arises regarding the negative consequences related to salinity intrusion [29]. Despite the RPVF method being a highly profitable and sustainable technique for farmers, it has not yet been adopted across Bangladesh. The main constraints of the spread of the RPVF method are the insufficient supply of prawn PL and the lack of extension programs by the respective agencies individually or jointly [59]. The DoF only deals with capture fisheries and aquaculture while the DAE deals only with crops and horticulture. In these institutional settings, there is a complete lack of integrated agriculture–aquaculture–horticulture initiatives. Due to the absence of any joint initiatives between these two agencies, the RPVF system has not been promoted to the expected level in Bangladesh. Therefore, joint extension initiatives of these two government agencies in collaboration with NGOs and other development organizations are required to promote RPVF in parts of Bangladesh.

## 5. Conclusions

This study demonstrated that integrated RPVF is simple for young and educated small-scale farmers to adopt, and contributes to enhanced and diversified food production, as well as income generation. Crop seasonality is expanded in integrated RPVF, with prawns and other fish species being reared in the monsoon season from July to December. Farmers cultivated boro rice in the central plateau of the rice field during the dry season, which is transplanted in early January to mid-February and harvested in April–May. A variety of short-cycle vegetables were grown on dikes along with rice throughout the year. The economic and financial analyses such as that of net revenue, NPV, and undiscounted and discounted BCR demonstrate that integrated RPVF is highly profitable and more economically viable than CRF. Due to the production of a substantial amount of rice, prawn, fish, and dike crops (mainly vegetables) from the same land, RPVF generated a 3.6 times higher gross revenue (USD 7483.7/ha) than CRF (USD 2976.0). Freshwater prawns in RPVF accounted for a considerable share (27%) of the gross revenue. Vegetable production on dikes also plays a key role in RPVF contributing 42% of the total revenue. Although its market value is low, it maintains cash-flow through year-round production and sales. If the extension agencies DoF and DAE can jointly popularise the RPVF method in other parts of Bangladesh, farmers can benefit by investing in multi-crop production on the same farm year after year, and it will be a sustainable approach in the future to meet the food security challenges of large populations. However, further in-depth research is required to understand the impacts of RPVF on physicochemical and microbial soil and water quality parameters.

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