Environmental Research 180 (2020) 108879

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Assessment of organic shrimp farming sustainability from economic and environmental viewpoints in Bangladesh

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ARTICLE INFO

Keywords:
Organic shrimp
Profitability
Environment
Sustainability
Bangladesh

ABSTRACT

The study assessed the economic, environmental and sustainability issues of organic shrimp farming in Bangladesh. Following stratified random sampling technique, 60 farmers were interviewed from several villages of Assasuni upazila under Satkhira district. The study revealed that productivity of organic shrimp per hectare was 383 pound and benefit cost ratio was 1.91 which meant that organic shrimp farming was highly profitable. Educational level of household head, *gher* size and knowledge on organic shrimp production had positive and significant influence in adopting organic shrimp production by the farmers. Cause-effect-mitigation analysis pointed out that organic shrimp farming could mitigate the adverse effects on environment caused by traditional shrimp farming. Appropriate climate and environment for organic shrimp culture was found as major strength and comparative profitability than traditional shrimp production was found as major opportunity of organic shrimp production. The study confirmed sustainability of organic shrimp production from the standpoint of consuming energy, protecting environment, economic feasibility and social/political equity. The study recommends that farmers should be trained to follow the work instructions and principles of organic shrimp production and the application of good management practices (GMPs) should be ensured for reducing the disease outbreak risk.

1. Introduction

Shrimp plays an important role in the international trade as a part of fisheries commodity. Bangladesh is ranked as 5th largest aquaculture producing country in the world after China, India, Vietnam and Indonesia with a fish production of 41.34 lakh metric tonnes in 2015–16 (Uddin et al., 2019a, 2019b; BBS, 2017). Its coastal area in the southwest has a unique brackish water ecosystem. This region is recognized worldwide as one of the most suitable shrimp farming areas for resource abundance and favorable agro-climatic circumstances (Ahmed et al., 2008). Satkhira, Khulna and Bagerhat districts are the key areas for producing shrimp in the southwestern Bangladesh, which contribute 71.4% to the national total production (BBS, 2017). Due to the availability of wild shrimp fry, low lying agricultural land, warm climate and the high profit, more farmers started using their lands extensively for shrimp farming. In the last decades, the demand for shrimp from both local and overseas markets has been increasing and many countries, especially in the global north, depend on imports of fish and seafood (Morf, 2014).

Shrimp aquaculture has turned out to be one of the most significant sectors of Bangladesh's economy. According to BFFEA (2017) and WITS (2017), frozen seafood contributes 1.7% (US$ 535.8 million) of the total export earnings (US$ 31714.2 million) from Bangladesh in 2015–16. Every year, Bangladesh ships more than 0.8 lakh tons of shrimp from producing on 2.1 lakh hectares land in the southwestern saline area. In a production period, around 0.8 million shrimp growers get involved to produce and harvest 0.4–0.5 ton shrimp and prawn per hectare, the monetary value of which is US$ 6.5 per pound (16–20 pieces) (Akber et al., 2017). In the fiscal year 2015–16, Bangladesh exported 68,306 metric tonnes of fish and fish product, to which shrimp contributed about 58% with an export value of US$ 117 million. In 2017 from 2011, annual foreign currency earnings from shrimp export rose to US$ 124 million by 14.0% (UNB, 2016; DoF, 2017). The EU has emerged as the largest importer of shrimp from Bangladesh holding nearly 60% share of the total export (WorldFish, 2012).

Because of avoiding to use harmful chemical substances by most of the farmers in extensive shrimp production, the quality of Bangladeshi shrimp is still considered as quite high (Hensler, 2012). Yet, there are numerous shrimp producers who use synthetic stuffs. The quality of soil, ground as well as underground water, and ecosystem biodiversity

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https://doi.org/10.1016/j.envres.2019.108879
Received 3 August 2019; Received in revised form 25 October 2019; Accepted 29 October 2019
Available online 01 November 2019
0013-9351/

Abbreviations and Acronyms

BBS	Bangladesh Bureau of Statistics
BCR	Benefit Cost Ratio
BFFEA	Bangladesh Frozen Foods Exporters Association
CST	Closed System Technology
DoF	Department of Fisheries
et al.	et alia (L.) and Other
EIA	Environmental Impact Assessment
EU	European Union
FGD	Focus Group Discussion
GC	Gross Cost
GM	Gross Margin
GMP	Good Management Practice
GoB	Government of Bangladesh
GR	Gross Return
ha	Hectare
HACCP	Hazard Analysis and Critical Control Point
HIES	Household Income and Expenditure Survey
i.e.	id est (that is)
lb	Libra (Pound)
MoST	Ministry of Science and Technology
MTT	Modified Traditional Technology
NGO	Non-government Organization
NR	Net Return
SWOT	Strengths, Weaknesses, Opportunities and Threats
TC	Total Cost
TFC	Total Fixed Cost
TVC	Total Variable Cost
UNB	United News of Bangladesh
US$	United States Dollar
WI	Work Instructions
WITS	World Integrated Trade Solution
%	Percentage

are greatly affected by the detrimental use of agrochemicals, antibiotics, disinfectants, chemical fertilizers and insecticides in traditional shrimp farming (Gräslund et al., 2003). It is often said that shrimp culture in Bangladesh has been unplanned and led to environmental degradation such as lessened water and soil quality, reduced farm productivity as a result of land and soil fertility diminution, declined livestock production due to grazing land reduction, hazarded human health and destructed mangrove forest (Rahman et al., 2013).

Shrimp cultivation is contributing to increase salinity by constructing canals and flooding the earlier rice production fields with saline water (generally known as *gher*). *Gher* is an enclosure made for shrimp cultivation by modifying rice-fields through building higher dikes around the fields and excavating a canal several feet deep inside the periphery of the dikes to enter water during the dry season (Kendrick, 1994). This affects not only the soil salinity of the *gher* but also of the surrounding areas as salt water is channeled through neighboring land (Alam et al., 2017). Soil fertility declines and as a result, rice, vegetable or other crop production decreases. Shrimp farming damages the ecosystem of mangrove areas through converting mangrove wetlands to ponds or *ghers* for shrimp aquaculture. Since water exchange in shrimp aquaculture is needed, polluted effluents are often discharged into waterways which have resulted in widespread diarrhoea, dysentery and other water-borne diseases affecting humans (Hossain and Hasan, 2017).

Generally, in organic shrimp farming, no artificial feed is used, chemical use is prohibited and natural treatment is applied that cuts the effect of these substances causing environmental pollution compared to conventional shrimp farming (Rönnbäck, 2000). However, the basis of organic farming system is sustainable agricultural management considering environmental protection and social justification. Currently, local as well as foreign consumers pay attention to safe and quality shrimps and shrimp products which are produced in an organic manner. Across the whole of Bangladesh, there exist only a few organic shrimp farms, due to higher risk of disease infestation and higher production input cost (Marschke and Wilkings, 2014).

Presently, non-government organizations (NGOs) and several shrimp processing plants have undertaken initiatives to produce quality and safe shrimp through providing technological support and good management to the farmers. The consumers of international market seek for food quality and safety, hence it is crucial for respective public-private authorities to maintain the pertinent quality of the food items exported by the means of appropriate quality control and safety measures. The main goal of such programme is to produce shrimp in conformity with the HACCP (Hazard Analysis and Critical Control Point) guidelines and recommended codes of conduct by the import countries of European Union. Since the ending period of 19th century, HACCP approach was strongly followed by the developed nations to ensure food safety. Following HACCP principles, farms are accountable to analyze the way of entering the hazard like foodborne pathogens into the product, establishing and monitoring effective control points for assuring maximum food safety by checking those hazards at different point of production processes, and ensuring hygiene and good manufacturing practices (GMPs) (Cato, 1998). However, it is obvious to accomplish a performance study and based on economic, environment and sustainability issues of small-scale organic shrimp farming.

Modality of the present study has been portrayed in other few studies. Gambelli et al. (2019) assessed the economic performance of organic aquaculture and found that organic aquaculture might contribute to an improved livelihood and integrate effectively with local farming practices. As said by Jayasinghe et al. (2019), better management practices in site selection, pond construction and preparation, selection of post larvae for stocking, pond management, bottom sediment management and disease management together with reducing non-climate stressors such as pollution, conservation of sensitive ecosystems and adoption of dynamic management policies could contribute to combat climate change impacts for shrimp aquaculture. Rasha et al. (2019) identified the costs of shrimp fry, feed, fertilizer, human labour and water management having positive and significant effect, and the cost of lime having negative and insignificant effect on the profitability of shrimp farming in Bagerhat district of Bangladesh. Sivaraman et al. (2019) pointed on optimized input supply, improved management practices, routine maintenance, social responsibility, group approach and culture-system-related practices as key thematic factors of better management practices for sustainable small-scale shrimp farming.

Ahmed et al. (2018) opined that institutional support and technical assistance might enable prawn farmers to be engaged in fully organic culture that could bring widespread social, economic and environmental benefits in Bangladesh. Saha (2017) declared that elementary modifications in the organizing and regulatory process are needed to promote *Bagda* shrimp farming as an approach for poverty reduction and socioeconomic development in the southwestern saline region of Bangladesh. Kabir and Eva (2014) revealed that soil and water salinity of shrimp producing areas in Bangladesh were increasing as a result of weak drainage structure and long term shrimp farming. By analyzing the socioeconomic and environmental consequences of shrimp culture Mitra et al. (2014) concluded that though it had harmful impacts on water quality, it did not have any significant effect on soil quality in Bagerhat district of Bangladesh. According to Paul and Vogl (2012), though organic shrimp farming was high yielding in southwest Bangladesh, it was less productive than other shrimp producing countries. Uddin (2009) stated that the hygiene and sanitation condition of the buyer-driven shrimp value chain activities were scrutinized by the expert authority, whereas processors-cum-exporters executed HACCP measures about 85.0%–90.0%.

The above discussed literatures confirmed that till now, there is no in-depth empirical study combining economic, environmental and sustainability concerns of organic shrimp farming in Bangladesh. Considering such research gap, the study might help the policy makers to get some ideas for judicious planning to produce shrimp in organic manner based on eco-environmental perspectives of organic aquaculture production. Moreover, the findings of the study would recommend policy options for to produce organic shrimp in a sustainable way in Bangladesh. The specific objectives of the study were: i) to estimate the productivity and profitability of organic shrimp production; ii) to examine the factors affecting adoption of organic shrimp production by the farmers; iii) to assess the environmental impacts of organic shrimp farming in relation to traditional shrimp farming; and iv) to address the prospects and challenges as well as recommend policy options for sustainable organic shrimp production in Bangladesh.

2. Materials and methods

2.1. Study area and sample size

The study was carried out at five villages of Assasuni upazila under Satkhira district namely, Mohessorkati, Chapra (South), Chapra (North), Baliapur and Kalibari for collecting the required data. These villages were selected for the study based on availability of large number of organic shrimp farmers in these areas. A total of 60 sample farmers from a population of 200 farmers were interviewed through the following sampling technique (Arkin and Colton, 1963):

$$n = \frac{NZ^2P(1-P)}{ND^2 + Z^2P(1-P)}$$

where, n = Sample size; N = Population size; Z = Confidence level (at 95% level, Z = 1.96); P = Estimated population proportion (0.5 which maximizes the sample size); and D = Error limit of 10% (i.e., 0.1).

2.2. Collection of data and information

Data related to the study were collected through time to time visit in the study areas during November 2018 to February 2019. Primary data were collected through questionnaire survey from the farmers and focus group discussions (FGDs) with local stakeholders. In compliance with the objectives, a structured questionnaire was developed for collecting relevant primary data from the farmers. At first, the draft questionnaire was prepared and pre-tested on handful respondents for its validity and reliability. In the pre-test, concentration was given to identify and categorize information which was not included in the draft questionnaire. Then some parts of questionnaire were improved, rearranged and modified in light of the field experiences and FGDs. Lastly, the final questionnaire was prepared to collect information. The questions were properly structured so that even the most reluctant informant could have no hesitation in passing on the necessary information. Data were collected by the research assistant and enumerators on a time-to-time basis. FGDs were conducted in each study area to cross-check the data and information.

The sources of secondary data and information included government annual reports, official statistical abstracts and other different researches. Moreover, the data published in different books, handouts, publications, notifications, published and unpublished documents of Government of Bangladesh (GoB) and its different organizations and agencies such as Statistical Yearbook of Bangladesh, Bangladesh Economic Review, policy documents about agricultural development and national as well as international journals were also considered to accomplish the research.

2.3. Analytical techniques

After collecting necessary data and information, those were classified, edited and coded. For analyzing the data, an amalgam of descriptive, mathematical and statistical techniques were followed for achieving consequential results from the objectives.

To document the socioeconomic status of organic shrimp producers, descriptive statistics (i.e., sum, average, percentage, etc.) with the support of tables and figures were used. In order to calculate the organic shrimp productivity and profitability, profitability analysis was done from the viewpoint of individual farmers. The formula required for calculating profitability is as follows (Dillon and Hardaker, 1993):

$$GR = X_{mp}\,P_{mp} + X_{bp}\,P_{bp};\; GM = GR - \sum C_v;\; NR = GR - \sum C_v - \sum C_f;\; BCR = GR \div GC$$

where, GR = Gross return; GM = Gross margin; NR = Net return; BCR = Benefit cost ratio; X_{mp} = Yield of main product (i.e., productivity of the main product); P_{mp} = Price of main product; X_{bp} = Yield of by-product; P_{bp} = Price of by-product; ΣC_v = Total variable cost; ΣC_f = Total fixed cost; and GC = Gross cost.

For examining the factors affecting farmers' adoption of organic shrimp production, as there was variation in same location among the farmers in terms of adoption of organic shrimp production, the following dichotomous logit regression model was used to find out the determinants that affect the adoption of this farming manner (Gujarati, 2003):

$$Y_i = \ln\left(\frac{P_i}{1-P_i}\right) = \mu_0 + \mu_1K_1 + \mu_2K_2 + \mu_3K_3 + \mu_4K_4 + \mu_5K_5 + \mu_6K_6 + \mu_7D_1 + \mu_8D_2 + \varepsilon_i$$

where, P_i is the probability of adoption and non-adoption of organic shrimp production, $P_i = 1$ indicates adoption and $P_i = 0$ indicates non-adoption; Y_i = Probability of adoption of organic shrimp production; K_1 = Household size (no.); K_2 = Respondents' literacy level (years of schooling); K_3 = Age of household head (years); K_4 = *Gher* size (ha); K_5 = Household income (US$); K_6 = Shrimp production experience (years); D_1 = Extension contact ($P_i = 1$ indicates having extension contact and $P_i = 0$ indicates having no extension contact); D_2 = Knowledge on organic shrimp production ($P_i = 1$ indicates having knowledge on organic shrimp production and $P_i = 0$ indicates otherwise); μ_0 = Intercept; μ_1 to μ_8 = Regression coefficients of the dependent variables; and $\mathcal{E}_i$ = Error term.

The marginal probabilities of the key determinants of adopting organic shrimp production were estimated based on expressions derived from the marginal effect of the logit model which was as follows:

$$dY/dK = \mu_i\{P_i(1-P_i)\}$$

where, μ_i = Estimated logit regression coefficient with respect to the ith factor; and P_i = Estimated probability of farmers' adoption status.

Cause-effect-mitigation analysis was done to point out the environmental impacts of organic shrimp farming in relation to traditional shrimp farming. The analysis was done to conduct a proper analysis of the situation, establish the causes of the problem and subsequently developing a fitting solution for the situation (Páez-Osuna, 2001).

To address the prospects and challenges of sustainable organic shrimp production, SWOT (strengths-weaknesses-opportunities-threats) analysis and 4 E (energy, environment, economics and equity) sustainability analysis were used. In SWOT analysis, strengths (S) and weaknesses (W) were defined as the internal factors of organic shrimp production whereas opportunities (O) and threats (T) were defined as the external factors of organic shrimp production. SWOT analysis matrix was constructed to depict the constraints and prospective of organic shrimp production (Gürel and Tat, 2017).

Sustainability refers to the state in which both natural and social systems survive and thrive together for the foreseeable future by allowing individuals to meet their present needs without negotiating the capability of upcoming generations to meet their own needs. 4 E sustainability framework analysis assessed the sustainability of producing shrimp in organic manner from the viewpoints of energy, environment, economics and social/political equity (Uddin and Dhar, 2018).

3. Results and discussion

3.1. Socioeconomic status of the organic shrimp producers

3.1.1. Demographic characteristics of the organic shrimp producers

The demographic status of the organic shrimp producers depicted in Table 1 represented that average number of members in respondents' family was 6.0, which was almost 1.5 times higher compared to the country's average of 4.1 (HIES, 2016) whereas the proportion of male and female members was 66.7% and 33.3%, respectively. About 98.0% male and 2.0% female respondents were surveyed for the investigation, of which 49.1% were active and work capable as belonged to the age group of 15.01–55.00 years (lower than national average of 54.8% according to HIES, 2016). Most of the respondents (40.9%) attained primary educational level whereas 33.3% respondents were illiterate. In terms of occupation, 65.2% and 34.8% respondents were involved with shrimp production only, and shrimp production and other income generating activities (i.e., crop farming, livestock rearing, homestead gardening, etc.), respectively. It was found from the study that on an average, farmers' monetary income was US$ 1338 per year (Table 1).

3.1.2. Tenancy status of the organic shrimp producers

Table 2 reveals the land holding arrangements of the organic shrimp farmers. The farmers were categorized as small, medium and large based on their farm size. Most of the farmers (66.7%) were small farmers (lesser than the national mean value of 76.7%) (HIES, 2016). Average *gher* size of small, medium and large farmers was 0.33, 1.12 and 3.19 ha, respectively. The major share of the *gher* was own land (57.6%, 82.1% and 66.5% for small, medium and large farmers, respectively). Though medium and large farmers rented/leased-out a small portion of land (7.1% and 10.0%, respectively), the study found no evidence of that in case of small farmers. The findings are similar to the findings of Paul and Vogl (2012) where the authors explored that 78.5% farmers in Satkhira district of Bangladesh mainly used own land for shrimp farming whereas 21.5% farmers did not own any land but they leased-in land or participated in a jointly managed farm.

3.1.3. Productivity and profitability of organic shrimp production

Productivity of organic shrimp was estimated as the total output produced per unit of land. The calculation of GR, GM, NR and BCR was done to measure the profitability. For calculating the total production cost, variable costs (i.e., human labour; shrimp fry; feed; lime and medicine; manure; transportation; construction of water supplying canal, canal digging and dyke reconstruction; harvesting; and miscellaneous) and fixed costs (i.e., land use cost; depreciation cost; and interest on working capital) were taken into consideration.

By performing the profitability analysis, the study estimated TVC and TFC organic shrimp farming at US$ 1207 and US$ 196 per hectare, respectively resulting in TC as US$ 1403 per hectare (Table 3). It was experienced that 43.6%, 16.5% and 7.3% of TC were incurred as for shrimp fry purchasing, human labour hiring and land use cost, respectively. Productivity (i.e., total output) of organic shrimp was found as 383 lb/ha, the market price of which was 7 US$/lb. GR, GM and NR from organic shrimp production were estimated at US$ 2681, US$ 1474 and US$ 1278 per hectare, respectively. BCR for organic shrimp production was found as 1.91. The findings indicated that producers earned US$ 191/ha in return by spending US$ 100/ha in organic shrimp production. From the relevant studies (Shawon et al., 2018; Siddiqa et al., 2018; Karim et al., 2014), it was found that the average BCR for traditional shrimp production was 1.56, which was almost 22.4% lower than the BCR of organic shrimp production, and it indicated that producing shrimp in organic manner was relatively higher profitable than producing it in traditional way (Table 4).

3.1.4. Factors affecting adoption of organic shrimp production by the farmers

The logit model used to spot the determinants that influenced the farmers to adopt organic shrimp production in the study areas is represented in Table 5. Out of eight major determinants considered in the model, three had positive and significant influence in adopting organic shrimp production by the farmers which were: respondents' literacy level, *gher* size and knowledge on organic shrimp production. The estimated equation was as follows:

$$Y = 3.219 + 0.028K_1 + 0.007K_2 + 0.142K_3 + 0.206K_4 + 0.005K_5 + 1.603K_6 + 1.032D_1 + 0.004D_2$$

It is evident from Table 5 that farmers' adoption probability of organic shrimp production would be increased by 0.016 and 0.011 times with 1 unit increase in respondents' literacy level and *gher* size (significant at 5% and 10% level of probability, respectively). Also, the probability of adopting organic shrimp production for those farmers who had knowledge on organic shrimp production was 0.010 times higher compared to those farmers who did not have that (significant at 5% probability level). The findings were quite similar to Karim et al. (2014) where the authors identified farmers' age and access to training as the major determinants of both modified traditional technology (MTT) and a closed system technology (CST), and *gher* size and access to financing as the major determinants of the more intensive CST in Southwestern Bangladesh. In addition, Ullah et al. (2015) found land tenure status and farmers' awareness had significant influence on adoption of organic farming in Peshawar, Pakistan.

3.1.5. Consequences of organic shrimp farming on the environment in relation to traditional shrimp farming

Environmental impacts of shrimp farming can be evaluated from the standpoint of: (i) shrimp pond establishment areas; (ii) shrimp pond operation technology; (iii) scale and surface of production; and (iv) receiving waters' capacity. The cause-effect-mitigation analysis points out how these environmental facts might be adversely affected by traditional shrimp farming and how organic shrimp farming mitigated the effects which are represented in Table 6. Alike these findings, Paul and Vogl (2011) also declared that environmental shocks like demolition of mangrove area, increase in saline water, siltation, pollution and disease

Table 1
Socioeconomic characteristics of the organic shrimp producers.
Source: Field survey, 2018–19.

Particulars about the respondents		Percentages (%) of respondents
Family size (no.)		6.0 (Male: 66.7%; Female: 33.3%)
Sex	Male	98.3
	Female	1.7
Age	0.00–15.00 years	21.9
	15.01–55.00 years	49.1
	Above 55.00 years	29.0
Educational level attained	Illiterate	33.3
	Primary	40.9
	Secondary	20.0
	Higher secondary and above	5.8
Occupational status	Shrimp production only	65.2
	Shrimp production and others	34.8
Annual income (US$)		1338

Table 2
Land holdings of the organic shrimp farmers.
Source: Field survey, 2018–19.

Farmers' categories	% of farmers	Average gher size (i.e., farm size) (ha)	Land leasing arrangements (ha)		
			Own land	Rented/leased-in land	Rented/leased-out land
Small farmers (less than 1.00 ha	66.7	0.33	0.19 (57.6)	0.14 (42.4)	–
Medium farmers (1.01–2.99 ha)	25.8	1.12	0.92 (82.1)	0.12 (10.8)	0.08 (7.1)
Large farmers (3.00 ha and above)	7.5	3.19	2.12 (66.5)	0.75 (23.5)	0.32 (10.0)

Note: Figures in the parentheses indicate percentages of average farm size.

Table 3
Productivity and profitability of organic shrimp production.
Source: Authors' estimation, 2019.

Cost of organic shrimp production

Particulars	US$/ha	Percentage (%) of total cost
Variable costs		
Human labour	231	16.5
Shrimp fry	612	43.6
Feed	27	1.9
Lime and medicine	47	3.3
Manure (cowdung and compost)	43	3.1
Transportation	66	4.7
Construction of water supplying canal, canal digging and dyke reconstruction	73	5.2
Harvesting	60	4.3
Miscellaneous	48	3.4
i. Total variable cost	1207	86.0
Fixed costs		
Land use cost	103	7.3
Depreciation cost	54	3.9
Interest on working capital	39	2.8
ii. Total fixed cost	196	14.0
iii. Total cost	1403	100.0

Return from organic shrimp production

Particulars	Productivity (lb/ha)	Price (US $/lb)	Amount of return (US $/ha)
iv. Gross return	383	7	2681
v. Gross margin (iv - i)			1474
vi. Net return (iv - iii)			1278
vii. Benefit cost ratio (BCR) (iv ÷ iii)			1.91

infestation played defensive roles in developing sustainable shrimp production which could be resolved through adopting organic production strategies. According to Hossain et al. (2013), the major environmental impacts might include the conversion of mangroves and agricultural lands into *gher*, loss of capture fisheries and biodiversity, pollution and disease outbreak which can be mitigated through establishing procedures for environmental impact assessment (EIA) and minimizing the adverse ecological change resulting from water extraction, land use, effluent discharge, use of drug and other activities.

Table 5
Estimates of logistic regression model.
Source: Authors' estimation, 2019.

Variables	Coefficient (μ)	Standard Error	z	P > |z|	dY/dK
Constant	3.219	2.967	1.085	0.084	–
Household size (K_1)	0.028	1.003	0.028	0.153	0.030
Respondents' literacy level (K_2)	0.007**	0.682	0.010	0.043	0.016
Age of household head (K_3)	0.142	0.079	1.797	0.175	0.006
Gher size (K_4)	0.206*	2.146	0.096	0.153	0.011
Household income (K_5)	0.005	0.436	0.011	0.009	0.283
Shrimp production experience (K_6)	1.603	0.435	3.685	0.031	0.281
Extension contact (D_1)	1.032	0.801	1.288	0.093	0.074
Knowledge on organic shrimp production (D_2)	0.004**	0.278	0.014	0.047	0.010

Note: ** and * indicate significant at 5% and 10% probability level, respectively.

3.2. Prospects and challenges of sustainable organic shrimp production

3.2.1. SWOT analysis on organic shrimp production

Table 7 reflects the SWOT analysis on organic shrimp production. As strengths, 80.0% farmers opined that Bangladesh had appropriate climate and environment for organic shrimp culture in terms of good water quality conditions to support the production of two major shrimp commodities, i.e., White shrimp (*L. vannamei*) and Black Tiger shrimp (*L. monodon*) in organic matter. According to 78.3% farmers, geographically, Bangladesh had a strategic position in exporting organic shrimp. The production manner was also admired by 54.2% farmers because being highly labour intensive, many unemployed human resource of the country might be employed in organic shrimp production. The major weakness that farmers faced was their less knowledge on the production and maintenance procedure of organic shrimp (stated by 87.5% farmers). Another major weakness was limited monitoring and extension support from different government and non-government extension agents (according to 72.5% farmers). Almost 60.0% farmers objected that they had to face structural and institutional barriers for applying good management practices (GMPs) in producing organic shrimp (Table 7).

The biggest opportunity of organic shrimp farming was its higher

Table 4
Profitability of traditional shrimp production.
Source: Adopted from Shawon et al. (2018); Siddiqa et al. (2018); Karim et al. (2014).

Types of farming	Study areas	Gross cost (US$/ha)	Gross return (US$/ha)	Net return (US$/ha)	BCR
Small scale	Khulna	1701	2947	1246	1.73
Commercial	Satkhira, Khulna, Bagerhat and the southern part of Jessore	2857	4408	1551	1.54
Closed system technology	Satkhira, Khulna and Bagerhat	5803	8763	2960	1.51
Average profitability of traditional shrimp production		3454	5373	1919	1.56

Table 6
Cause-effect-mitigation analysis.
Source: Field survey, 2018–19.

Conditions	Causes	Effects of traditional shrimp farming	Mitigating actions by organic shrimp farming	% of farmers responded
Shrimp pond establishment areas	Mangrove forest destruction	Loss of habitats of local species and reduction in biodiversity	Acceptable balance of mangroves and shrimp pond area	72.5
	Conversion of agricultural land and salt-flats	Saline soil production and alteration of water drainage pattern	Consideration of socio-economic justification and ecological role of the ecosystems	54.2
Shrimp pond operation technology	Decline in water and soil quality	Water quality deterioration in the receiving waters eutrophication	Practicing polyculture and improving the composition of the feed	53.3
	Release and spread of diseases	Disease outbreaks and infection in the wild species	Ensuring good water quality and disease control with the use of probiotics	61.7
	Hazards in human health	Effect of drug resistance pathogens	Application of effective organic anti-bacterials	69.2
Scale and surface of production	Salt water intrusion	Contamination of ground water aquifers	Avoiding the use of fresh groundwater to shrimp ponds	73.3
	Sediment disposal	Release of nutrients, organic and inorganic matter and chemical substances	Using pond liners and probiotics, and utilizing sediment discarding areas	44.2
Receiving waters' capacity	Excessive water use	Competition with other users for water	Reduced or zero exchange rate	50.0

Table 7
SWOT analysis matrix.
Source: Field survey, 2018–19.

Statements			% of farmers	Statements			% of farmers
Strengths	i)	Appropriate climate and environment for organic shrimp culture	80.0	Weaknesses	i)	Lack of knowledge on organic shrimp production strategies	87.5
	ii)	Strategic position in exporting organic shrimp	78.3		ii)	Lack of support from local extension agents	72.5
	iii)	Abundance of human resource	54.2		iii)	Weak implementation of good management practices (GMPs)	59.7
Opportunities	i)	More profitable compared to traditional shrimp production	95.8	Threats	i)	Outbreak of virus and bacteria borne diseases	91.8
	ii)	High consumer demand for being organic shrimp	69.2		ii)	Trade barrier and highly quality shrimp requirement in export market	41.7
	iii)	Wide export market	82.5		iii)	Severe competition from other countries	61.7

profitability than traditional shrimp farming (opined by 69.2% farmers). The farmers stated that they experienced almost fifty percent higher gross return from organic shrimp farming in relation to traditional shrimp farming. 82.5% farmers encouraged organic shrimp farming for its wide open export market to be exported in Japan, Hong Kong and Singapore, European Union countries and United States. More than 91% farmers opined outbreak of virus and bacteria borne diseases in the shrimp farm as the major threat of organic shrimp production for which partly or sometimes the total production might be failed to be harvested. Another threat according to 61.7% respondents was the severe competition for organic shrimp export from other countries like China, Thailand, India and Vietnam (Table 7). Burneo (2017) supported the findings where the author identified disease resistant larvae as major strength, less implementation of GMPs as major weakness, worldwide growing market of shrimp as major opportunity and political instability as major threat for shrimp industry in Ecuador.

3.2.2. Sustainability of organic shrimp production

Organic shrimp production is declared as sustainable when the institutional development and production system of this farming practice satisfy the needs of current users while securing the ability of future generations to meet their own needs. Regarding this aspect, 4 E sustainability framework was developed to clarify whether producing shrimp in organic manner was sustainable from the perspectives of energy, environment, economics and social/political equity (Table 8).

The study revealed that both electricity and biofuel are used as sources of energy for hatching and processing of shrimp fry, but the use of electricity is more convenient for majority of the organic shrimp producers (53.3%). Dube and Chanu (2012) also stated that organic aquaculture can reduce the use of fossil energy in agricultural practice to a minimum. Producing shrimp in organic way prohibits the use of all chemical energy inputs and medicines, and encourages the usage of probiotics. Hence, 61.7% respondents opined that they found the production technology friendly to the environment and ecology, and safe to the consumers. The findings are similar to Cao (2012) where the author identified organic shrimp culture as a system which combines best environmental practices, high biodiversity level, conservation of natural resources and application of high animal welfare standards. From the perspective of economic profitability, this organic shrimp production technology is more profitable than traditional one (stated by 58.3% farmers) where the return is almost double in terms of investment. Alam et al. (2007) and Islam et al. (2005) disclosed the similar findings where the authors stated that due to higher yield and profit in organic shrimp production, farmers in Bangladesh are starting to switch from traditional production methods to organic production methods. As said by 65.0% respondents, women involvement in organic shrimp cultivation system can lessen gender inequality, and ensure scope for employment, income generation and poverty reduction of the farmers in some extent. The findings are faintly supported by Paul and Vogl (2013) where the authors stated that farmers' in southwestern Bangladesh secured sustainable livelihood through increasing their assets and mitigating vulnerability by getting involved in organic shrimp farming.

4. Conclusion

The study was conducted for evaluating the economic, environmental and sustainability issues of organic shrimp farming in Bangladesh. It was found that most of the organic shrimp producers were within small category having less than 1 ha of *gher* size. The study revealed that organic shrimp production was profitable by twice than the money invested. Respondents' literacy level, *gher* size and knowledge on organic shrimp production were the significant factors having impact on farmers' decision to adopt organic shrimp production technology. It was also experienced that organic shrimp production had positive impacts on the environment over traditional shrimp production. Appropriate climate and environment for organic shrimp culture was found as the major strength, lack of knowledge on organic shrimp production strategies was found as the major weakness, more profitable compared to traditional shrimp production was found as the major opportunity and outbreak of virus and bacteria borne diseases was found as the major threat of organic shrimp production. Finally, the study found organic shrimp production technology sustainable from the outlook of energy, environment, economics and equity. Because of time and financial constraints, the authors could not study on the traditional shrimp producing farms but considered the existing literature on different aspects of traditional shrimp production. Based on the findings, the study suggests a number of policy recommendations which are:

a) The principles of organic production standards should be followed

Table 8
4 E sustainability framework.
Source: Field survey, 2018–19.

Sustainability perspectives	Sustainability determinants	Determining responses	% of farmers responded
Energy	Which sources of energy does organic shrimp production use?	Generally, electricity is used to supply energy for heating in the shrimp hatcheries. Sometimes biofuel is also used for this purpose	53.3
	Are the energy sources polluting?	No, the energy source is not polluting	
	What is the impact of energy use?	The energy and fuel is used for the purpose of hatching and processing of shrimp fry	
Environment	Does organic shrimp production harm the environment?	No, the production technology is friendly to the environment and ecology	61.7
	Does the production technology or its applications impact negatively to the consumers?	Organic shrimp production prohibits the use of all chemical energy inputs and medicines, and encourages the use of probiotics. So, the consumption of shrimp produced in this way is safe to the consumers	
Economics	What are the inputs used in organic shrimp production? Are they available?	The major variable inputs are human labour, shrimp fry, feed, manure and water supplying canal. The major challenges in this case are the availability of quality shrimp fry and labour, as this is a highly labour intensive farming	58.3
	Is the production technology profitable?	Yes, this production technology is more profitable than traditional shrimp production technology	
	How much profit does the production technology gain?	The return is almost double in terms of investment	
Equity (social/political)	Who are the beneficiaries?	The producers, middlemen as well as the consumers	65.0
	How organic shrimp production can contribute to social or political inequalities?	Now-a-days, a number of women entrepreneurs are getting involved in this production technology. Thus, gender inequality is lessened	
	What is the impact of this production technology on stakeholders' livelihood?	Involvement in organic shrimp production creates scope for employment, income generation and poverty reduction in some extent	

by the stakeholders along with appropriate work instructions (WI);
b) Seedlings and feed compositions that are modified genetically should not be used in organic shrimp production;
c) Farm location should be selected based on availability of sufficient organic feed round the year;
d) Farmers should be furnished by appropriate knowledge on organic shrimp farming by the respective authorities;
e) Water quality of shrimp pond should be monitored time to time in order to check disease outbreak;
f) Precautionary actions should be in taken to control disease transmission from one pond to another; and
g) The application of good management practices (GMPs) should be ensured to reduce the risk of infection from pathogenic microorganisms as well as guidance for the organic shrimp larvae production.

Declaration of competing interest

Please check the following as appropriate:

- All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.
- This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.
- The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript
- The following authors have affiliations with organizations with direct or indirect financial interest in the subject matter discussed in the manuscript:

Acknowledgement

The authors are thankful to Ministry of Science and Technology (MoST), Government of the People's Republic of Bangladesh for funding to conduct this study.

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