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The current issue presents two research papers and a case study covering the important topics related to production and supply chain management. The first two papers discuss the challenges faced by aquaculture and the economic efficiency of Bulgarian farms, respectively, and suggest strategies that can improve the existing business model. The case study highlights the supply chain strategies adopted by Dell to move from make-to-order to make-to-stock business model.

The first paper, "Developing a Sustainable Coastal Aquaculture Value Chain for the Rural Communities of Bangladesh" by Prabal Barua, Md. Mazharul Islam and Anisa Mitra, highlights the importance of aquaculture and its role in the economic development of many nations. This study specifically focuses on the contribution of aquaculture to the economic development of Bangladesh and its role in improving the earnings of marginalized communities. The study was conducted to assess the development and adoption of sustainable value chain for aquaculture business in the southern coast of Bangladesh. The authors found that small-scale aquaculture and inland fisheries sectors are facing some environmental, technological and socioeconomic challenges that may lead to aquaculture production failure and make this subsector unstable in the near future. Additionally, farm-raised fish quality and their safety for human consumption are becoming a serious concern to local and international food markets. These challenges could have severe impacts on the earnings as well as the rural economy of the region. To overcome these challenges, adoption of sustainable and environment-friendly aquaculture practices are required. These practices can maximize environmental and economic sustainability as well as reduce the likelihood of outbreak of disease in the aquaculture farms. However, adapting Good Aquaculture Practices (GAPs) requires a combination of strategies and policies. The authors suggest that "top-down" and "bottom-up" holistic approach to aquaculture planning and management may help to sustain this sector.

The second paper, "How to Assess the Governance Efficiency of Farming Enterprises?" by Hrabrin Bachev, defines and assesses the economic efficiency of Bulgarian farms from the perspective of New Institutional Economics. The author points out that despite the fundamental progression of the theory of economic organizations, farm continues to be studied as a "production structure" and its efficiency is assessed using "factors productivity". Based on the new institution theory, a farm is considered to be efficient if inputs supply and marketing transactions of a farm are governed effectively. First-in-kind quantitative evaluation of governance efficiency of Bulgarian farms is made on the basis of assessments of managers of typical farms. "Nature of the problems in effective organization of major type of farm transactions for securing the needed factors of production and output realization" is used as an indicator for the comparative transaction costs. The study finds that the governance efficiency of farms in general is at a good level, but 60% of all farms have low efficiency and will likely cease to exist in the near future. The major factors behind the inferior governance efficiency of farms are unsatisfactory efficiency in the supply of necessary labor, innovations and know-how, and funding. There is a huge variation in the governance efficiency of farms with different specializations, as holdings in field crops, vegetables, flowers and mushrooms, and mixed livestock demonstrate the lowest levels. There is a big discrepancy between the new assessments and the traditional approach to farm efficiency. The suggested framework has to be improved and widely applied to economic analysis at various levels, which requires the collection of a novel type of microdata on farms' governance and transaction costs.

The case study, "Supply Chain Transformation at Dell", by Nikhat Afshan, presents the supply chain transformation strategy of Dell, which involved moving away from its legendry make-to-order model to make-to-stock model. It highlights why Dell decided to adopt the make-to-stock model from which it had distanced itself for decades. Once known for several benefits such as no finished goods or parts inventory, flexibility, and negative cash-to-cash cycle, it started adding great complexity and cost. Dell decided to move to make-to-stock model while operating the make-to-order model for the customers who value it, but at a reduced level.

Nikhat Afshan
Consulting Editor

Developing a Sustainable Coastal Aquaculture Value Chain for the Rural Communities of Bangladesh

Prabal Barua, Md. Mazharul Islam** and Anisa Mitra****

Over the last three decades, aquaculture production and technologies for culture system upgradation have become a revolutionary development in Bangladesh, especially in the coastal areas. The study was conducted to assess aquaculture development along with sustainable value chain for aquaculture business purposes in the southern coast of Bangladesh. The authors found that small-scale aquaculture and inland fisheries sector in the study areas is facing some environmental, technological and socioeconomic challenges that may lead to production failures and make it unstable in the near future. Additionally, farm-raised fish quality and their safety for human consumption are becoming a serious concern to local and international food markets. These challenges could have severe impacts on earnings and the rural economy of the southern coast of Bangladesh. To overcome the challenges, sustainable and environment-friendly aquaculture practices are required to be taken up to maximize environmental and economic sustainability and reduce the likelihood of outbreak of diseases in the aquaculture farms. However, adopting Good Aquaculture Practices (GAPs) requires a combination of strategies and policies. A top-down and bottom-up holistic approach to aquaculture planning and management may help to sustain this sector.

Introduction

Aquaculture is the fastest-growing food-production technology that contributes to food security directly through consumption or indirectly as a source of income for many countries in the world. Sustainable aquaculture has become a successful revitalizing economic force in a number of underprivileged rural and coastal areas where sustainable economic development is often difficult (Davenport *et al.*, 2003; and FAO, 2018). It incorporates both spatial and temporal dimensions of environmental, economic and social parameters that not only maximize economic benefits, but also minimize accumulation of detriments, and other types of negative impacts on the natural and social environment.

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Environmental issues along with corresponding implementation of practices designed to reduce the environmental footprint of aquaculture are a pressing concern and a vital focal point, whether academic, governmental, productive or market-based (Anderson *et al.*, 2017). In today's world, aquaculture production is kept in the forefront of the considerations that govern the management of aquaculture firms and their regulation, public perception and marketing of farm-raised products (Ackefors and Enell, 2016; and Engle and D'Abramo, 2018).

Over the last three decades, rural and coastal aquaculture has undergone a revolutionary development in Bangladesh, particularly in coastal areas, which has made the country rank fifth in fish production in the world. Thousands of farmers have converted their low-lying agriculture fields into aquaculture ponds (Uddin and Akter, 2019; Barua and Rahman, 2018; and Barua and Barua, 2021).

In fact, the practice of aquaculture in rice fields, along with the traditional fish culture in rural ponds, in addition to extensive and semi-intensive shrimp and prawn farming in large coastal areas, and increased household consumption have led to a rise in aquaculture sector in Bangladesh. Now, it has emerged as a potential source of employment for poor farmers and displaced capture fishermen. It has already generated considerable employment through aquaculture farm, feed, seed and supporting (i.e., aquatic health products) and industrial and marketing development (Castel and Tiews, 2015; Gari *et al.*, 2015; and Barua *et al.*, 2017).

The speedy expansion of coastal aquaculture production in Bangladesh through poor control and unsustainable alteration of wetlands, such as mangrove wetlands, into coastal aquaculture ponds in the current times, has raised concern among climate scientists, academicians, environmentalists and policymakers regarding the impact of coastal aquaculture systems on prevailing coastal ecosystems. The southeastern coast of Bangladesh has experienced destruction of mangroves because of the large-scale alteration to aquaculture ponds, as evident in the Chittagong coastal areas. In Bangladesh, approximately 600,000 people are engaged in coastal aquaculture, marketing and others linkage activities. Besides, 130,000 farmers are involved in small-scale coastal aquaculture activities, engaging nearly 300,000 farm laborers (Rahman *et al.*, 2014; and Das and Barua, 2020). Besides, expansion of aquaculture ponds in other potential areas along Bangladesh's coast toward coastal wetlands, deltas and estuaries is expected in future (Barua and Sarker, 2011; Islam *et al.*, 2014; and Mahmood, 2015).

Climate variables, including coastal flooding due to Sea Level Rise (SLR), cyclones, drought, rainfall variation, salinity intrusion, shifting monsoonal climate along with disease outbreak, have been considered as major challenges for sustaining coastal and rural aquaculture development. Additionally, farm-raised fish or shrimp quality and their safety for human consumption are becoming a serious concern to local and international food market (Shamsuzzaman *et al.*, 2017; and Zahangeer *et al.*, 2017). These challenges could have severe impacts on export earnings and the rural economy of Bangladesh. To tackle these challenges, Good Aquaculture Practices (GAPs) need to be adopted to maximize environment and economic sustainability and minimize the likelihood of a disease outbreak in the aquaculture farms. Adopting GAPs requires a combination of strategies and policies. A top-down and bottom-up holistic approach to aquaculture planning and management may help to sustain this sector (Mahmud, 2010; Barua and Chakraborty, 2011; and Meade, 2014).

This study conducted a survey to obtain a snapshot assessment of the current business, economic, environmental and climatic conditions of the Micro-Entrepreneurs (MEs) who are engaged in different aquaculture activities in the Sitakunda and Mirsharai areas and have the potential to participate in the sustainable entrepreneurship program activities as important stakeholders. The specific objectives of this survey are: (1) Assessing the current status of MEs, highlighting their existing aquaculture practices; (2) Generating baseline information on environmental and climatic conditions that is linked to sustainable aquaculture development; (3) Providing general information for understanding the role of MEs engaged in aquaculture venture in the local economy of the investigated areas; (4) Identifying the socioeconomic and environmental constraints and challenges involved in ME sector development through sustainable aquaculture practices; and (5) Providing benchmark information on socioeconomic and environmental factors and indicators that can be utilized for measuring project i.e., [Sustainable Entrepreneurship Program (SEP)] achievements and impact.

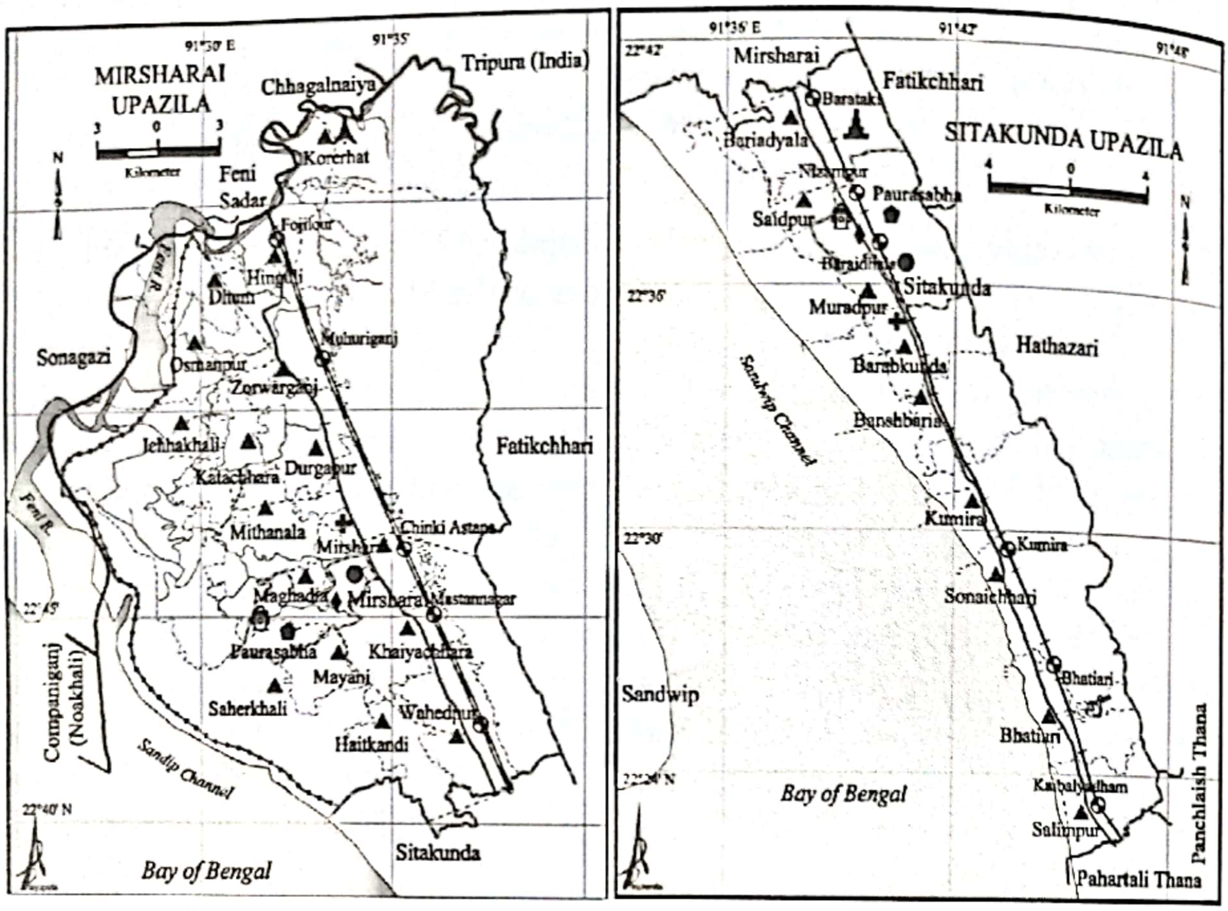
Data and Methodology

Study Area

The study was conducted in two coastal upazilas: (1) Mirsharai and (2) Sitakunda, which are almost equal in size (i.e., 482.88 km^2 and 483.97 km^2, respectively). These coastal upazilas are bounded by Tripura state of India, Chhagalnaiya and Feni Sadar upazilas on the north, Pahartali Thana on the south, Fatikchhari and Hathazari upazilas on the east, Sandwip Channel on the west. These two upazilas consisted of 16 and 9 unions, respectively (Figure 1). The survey covered 11 unions (Mirsharai 7; and Sitakunda 4), taking representative samples from each union, following adaptive mixed-method approach.

Considering the duration of the assignment and constraints related to availability of data, the study team employed an adaptive mixed-method approach, using both quantitative (including non-experimental design stakeholder surveys) and qualitative analysis (e.g., Focus Group Discussion (FGD), Key Informant Interviews (KII) and field visits). The mixed-method approach is well suited to the activity being evaluated and enabled the team to work efficiently in the field (Chambers 1980; and IIRR 1998). For example, this approach provided the flexibility to collect data from several locations concurrently. KIIs/Information Exchange Meetings (IEMs) with several individuals and FGD meetings with various resource users were carried out.

Figure 1: Union Boundaries in Mirsharai and Sitakunda Upazilas



Data Collection

The study was conducted through quantitative and qualitative survey methods and a deep knowledge of local factors that shape options for objective data collection on aquaculture production, processing and marketing with future potentials for supporting livelihood, food security and nutrition in Bangladesh. The mixed-method approach employed consisted of: (a) Document review, (b) Questionnaire survey, (c) KII, (d) FGDs, and (e) Participatory field investigation methods.

The sample comprised 200 Household Heads (HHs) or aquaculture practicing families in two upazilas. The HHs or MEs were selected from each union following a stratified random sampling procedure. The questionnaire is shown in Appendix.

The authors conducted FGD during fieldwork meetings with specific beneficiary groups, such as the aquaculture researchers, farmers, extension workers, harvesters and processors, traders and distributors, to enable open discussion to gather semi-structured qualitative data. The preselected participants (balanced to the extent feasible by gender, age, and any other relevant factors) discussed the issues and concerns based on the key themes mentioned in the objectives. These sessions encouraged free-flowing discussion on the present status of MEs and the people who engage in those enterprises as HHs.

The authors revisited key informants and resource persons (especially academics, researchers and entrepreneurs) to triangulate and validate the information obtained. The team members also met daily during fieldwork to review the progress and assess whether the steps taken to avoid bias are working and whether or not new sources emerge that need to be mitigated. Table 1 summarizes the number of participants in the survey activities and meetings.

Table 1: Participation in Surveys	
Type of Data Gathering Activity	**Participants**
Questionnaire Survey	200
KII/IEM	11
FGD	75
Total	**286**

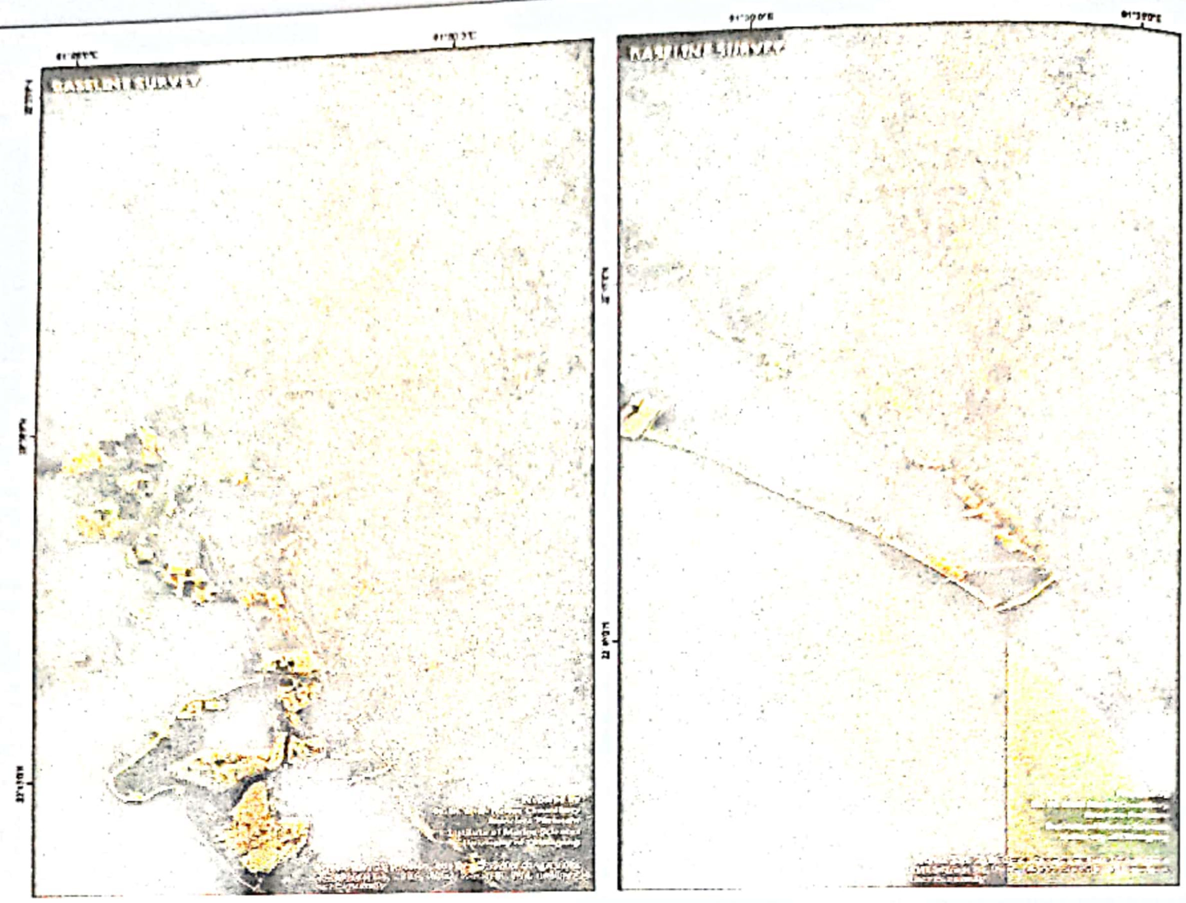
Results

Aquaculture is one of the main land-based economic activities in the Mirsharai coastal areas, whereas aquaculture is less prominent in Sitakunda coasts. Geospatial analysis of satellite images during this survey indicates that ~7,500 acre areas are being used for growing fishes in Mirsharai upazila. Most of those fish culture areas come under the Muhuri Irrigation Project, located at the western part of Mirsharai upazila. Muhuri Irrigation Project, consisting of five miles of coastal earthfill embankments and a dam of about 1.5 miles with a 20-vent regulator across the Feni River, was constructed in 1986 to provide irrigation facilities and to reduce the inflow of saline water into the Feni River from the northern Bay of Bengal. This project changed the geomorphology of the region through changing morph-dynamics in sediment transports and created opportunities for inland culture fishery development, which is playing a very important role in the local economy at Feni and Mirsharai regions. On the contrary, pond-based aquaculture is being practiced in Sitakunda region at subsistence level, which has occupied <550 acres, and those ponds are sporadically distributed throughout the western flat lands of Sitakunda upazila. Figure 2 shows the cluster of aquaculture farms along the Feni River at Mirsharai, whereas a large number of homestead aquaculture ponds are sporadically distributed along with a large mangrove area in Sitakunda upazila.

Current Status of Aquaculture-Based MEs

Construction of coastal earth-fill embankments and the dam across the Feni River offered opportunities for inland culture fishery development in the southern bank of Feni River. Aquaculture activities were initiated in 1990 with a limited number of farms, which got a boost during 2010-2020 with 300% growth rate. Presently, ~300 MEs are engaged in

Figure 2: Satellite Images Showing the Land Use Patterns in Mirsharai (Left) and Sitakunda (Right) Upazilas



aquaculture and the annual fish production is ~50,000 MT at an average production rate of 6.65 MT per year depending on the size and inputs of the farm. The size of the individual aquaculture farm largely varies (<1-200 acres) in Mirsharai upazila (Figure 3), whereas the farm size is restricted to <1-2 acres in Sitakunda upazila.

Aquaculture Practices

Polyculture is preferred (95%) over monoculture (5%) by the farmers or entrepreneurs. Common carps (40%) and tilapia (39%) are the dominant aquaculture species, followed by catfish (17%) and prawn (1.4%). Improved traditional culture method with low feed inputs was followed by 77% of the farms, while the rest followed semi-intensive culture system with better feeding inputs and water aeration system (Figure 4).

Socking density varied between 2-7 individuals/m^2 depending on culture methods and investment capacity of farmer or enterprise. Commercial hatchery-reared fish fry is usually stocked. None of the farmers are aware of the benefits of stocking 'Halda fry', which is known as the best quality natural seed in Chattogram region and has better growth performances in enhancing fish production. The number of production cycles depends on culture species. The farmers who are culturing tilapia, cat fishes and freshwater prawn, have 2-3 annual production cycles, while they harvest common carp annually. It is

Figure 3: Size (Acre) Variations of Aquaculture Farm in Mirsharai Areas

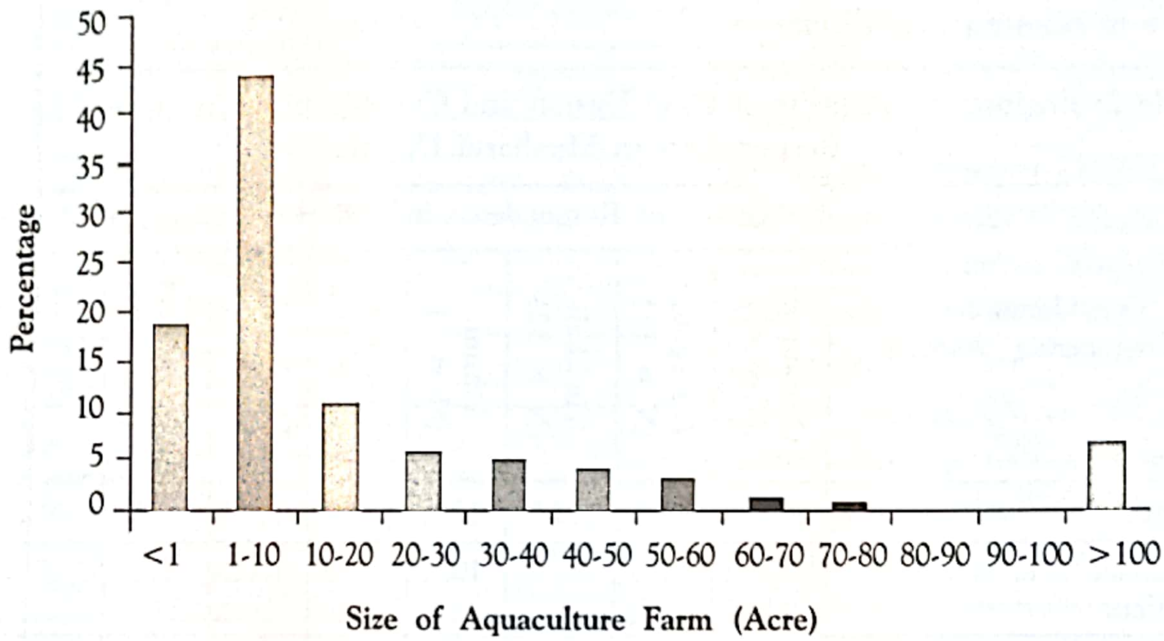
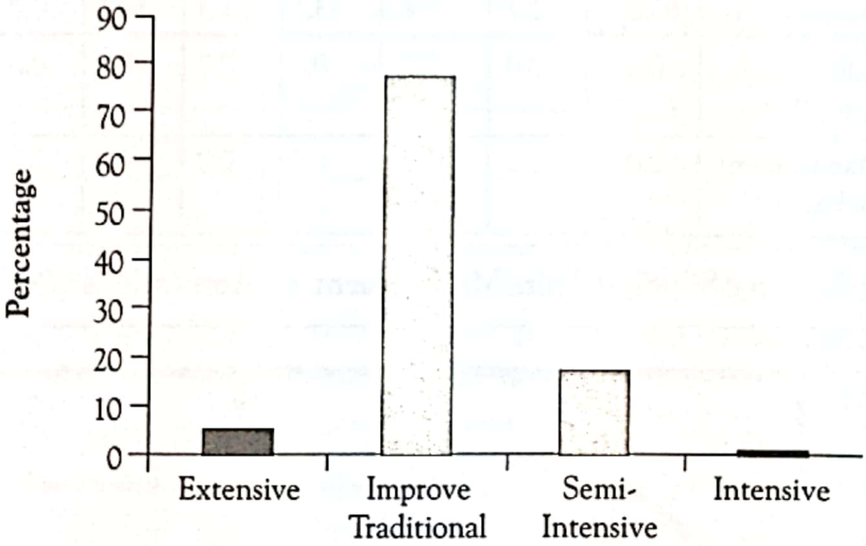


Figure 4: Different Aquaculture Systems and Their Relative Composition in Mirsharai and Sitakunda Areas

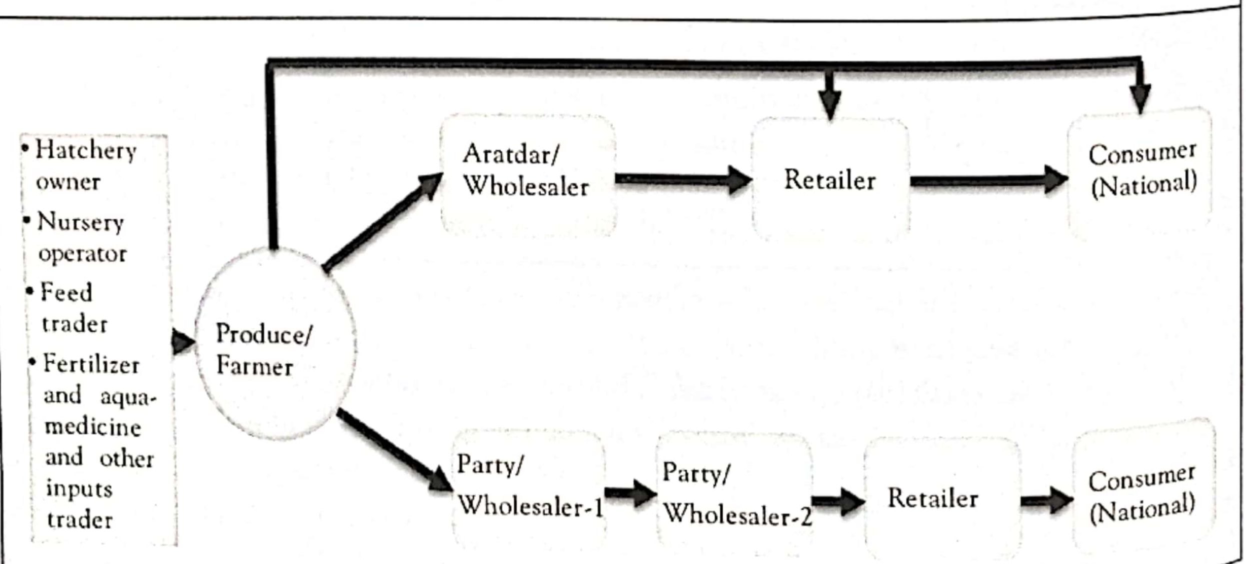


revealed that 96% of the farmers followed some criteria to select the culture species. These are: (i) good market price (rank score: 0.22); (ii) fast growth (rank score: 0.22); (iii) easy to culture (rank score: 0.19); (iv) seed availability (rank score: 0.12); (v) disease resistance (rank score: 0.12); and (vi) taste (rank score: 0.10). One-fourth of the farmers do not consider site suitability criteria (e.g., water quality, bottom soil characteristics, accessibility, availability of logistic supply, etc.) and engineering aspects (e.g., pond shape, depth, dike dimension, liner to prevent seepages, draining inlets and outlets, etc.) for selecting their culture sites and construction of their ponds respectively (Table 2). None of the aquaculture farmers in the Mirsharai and Sitakunda areas utilize extra ponds for water reservoir that are usually used for water stocking and treating culture/rearing water before intake to culture ponds (Figure 5).

Table 2: Engineering Aspects of Pond Design and Construction Considered by the Respondents in Mirsharai Upazila

Consideration of Engineering Aspects	Percentage of Respondents in Different Unions in Mirsharai							
	Osmanpur (N = 40)	Zorargonj (N = 11)	Ichakhali (N = 32)	Dhum (N = 3)	Katachora (N = 3)	Mirsharai Sadar (N = 4)	Khoiyachora (N = 0)	Total Respondents (%) (N = 93)
Depth	85.0	100.0	93.8	100.0	66.7	100.0	0.0	90.3
Drainage Inlet and Outlets	97.5	100.0	50.0	100.0	33.3	100.0	0.0	79.6
Pond Shape	57.5	81.8	93.8	100.0	66.7	100.0	0.0	76.3
Use of Liner to Prevent Seepage	77.5	54.5	68.8	100.0	66.7	50.0	0.0	71.0
Dike Slope	52.5	36.4	75.0	100.0	66.7	50.0	0.0	60.2
Dike Dimension	65.0	72.7	9.4	33.3	33.3	50.0	0.0	44.1
Water Reservoir for Treatment Culture Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste Water Management Unit Before Discharge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 5: Existing Supply Chain Management of Aquaculture Products



Commercial Feed Brand	Users Percentage
Nahar	19.7
Kaji	6.1
Ruposi Bangla	6.1
EON	1.5
Aftab	2.3
Quality	18.1
CP	15.9
Paragon	11.3
Provita	8.3
Globe	3.0
Aman	2.3
Asia	1.5
Pran	0.7
ACI	3.0
Total	100

Table 3: Commercial Feed Used in Aquaculture Farms in Mirsharai and Sitakunda Upazilas

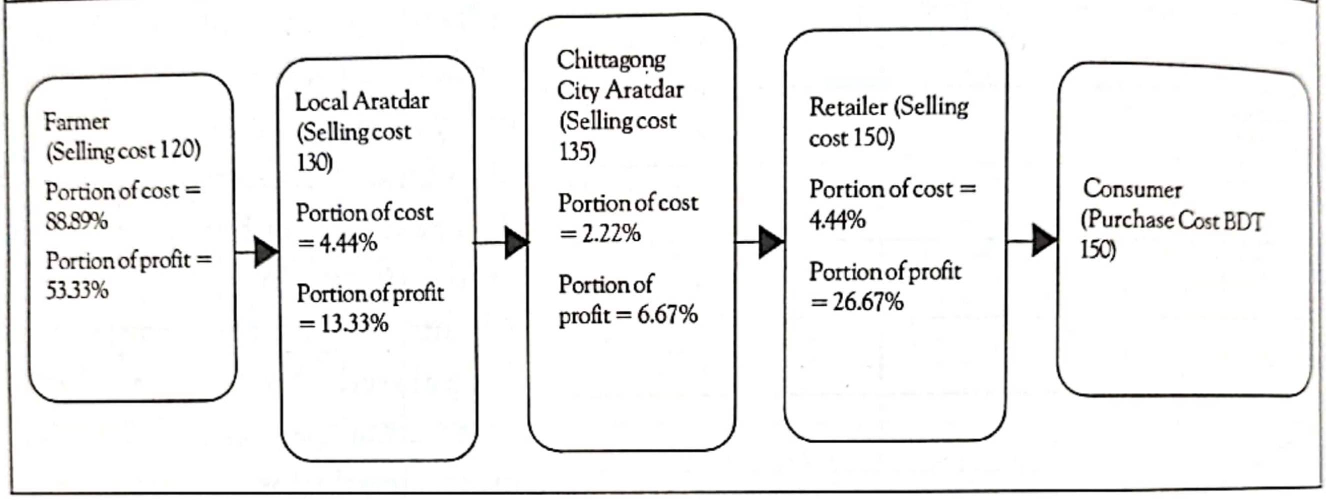
Annual pond drying is a common practice in the investigated areas. Farmers or entrepreneurs intake their culture waters from three different sources: rainwater (49%); surface water (46%); and underground water (5%). Among those who use surface water (i.e., river water), 65% do not treat the water before intake to culture ponds. Most of the farmers fertilize their pond water using lime, salts, and organic and inorganic fertilizers at varying dosages to enhance primary productivity in pond waters. About 83% of the farmers use formulated feeds (i.e., 98% commercial pellets and 2% farm mesh feed) for growing their fish, while 17% of the farmers rely on natural pond-based foods. Popular feed brands are shown in Table 3.

Most of the farmers check fish weight gain regularly taking fish samples using cast net. A large number of farmers (~86%) do not maintain register to record fish growth performances and health condition. About 59% farmers do not monitor water quality during fish culture periods. The farmers who monitor pond health, only check ammonia, water pH and soil pH. Only 31% farmers fertilize their pond water to ensure primary productivity during culture period. 69% of the farmers face ammonia problem and 97% of them use probiotics to eradicate this problem. 57% the farmers face disease outbreak in the ponds. Fungal infestation (49%) is considered a major problem after bacterial (30%) and parasite (21%) attacks. Use of antibiotics for treating fish disease was not evident during the survey period. There is no waste water management unit in any of the aquaculture farms, which is considered an important part in modern aquaculture practices. Usually, these facilities are used for treating the nutrient-rich pond effluent waters before discharging into natural system.

Current Value Chain

The average market value of 1 kg fish was found to be BDT 150 at the fish culturist level. The farmers spend 100 BDT for production of 1 kg fish, and the expenditure includes leasing cost of water body, feed price, purchase of fish fry, applied medicine, pond management, labor cost, etc. Local retailers purchase fish from farmers at a cost of BDT 120 per kg and sell fish to Aratdar in Chittagong city for BDT 130, and thus get a profit of BDT 10 (13.33% of total profit), including consideration of labor cost, utility bill and lease cost of aratdar (Figure 6).

Figure 6: Value Addition and Pricing Process per Kg of Carp-Tilapia Fish



Baseline Information on Environmental and Climatic Conditions

The climate of Mirsarai and Sitakunda areas is tropical, with a dry season and heavy monsoon, in the rest of year, and no cold season. These areas are situated in or near the tropical moist forest biome. Air temperature reaches a maximum of ~36 °C during March and April, while the lowest temperature can reach ~16 °C in December. The average temperature is ~25 °C. Humidity in those areas varies from 40% (February) to 90% (July and August). Rainy season is very prominent in this region like other coastal parts of the country. Droughts in winter months (i.e., November-February) cause aridity in the soils, whereas 80% of the total rainfall occurs in June to September due to northwest monsoonal winds. Average annual rainfall of the Mirsarai and Shitakunda regions is ~2500 mm. May is considered as the windiest month with an average wind speed of ~4 m/s and it drops to ~2 m/s in October. The soil characteristics in the investigated sites are sandy loam to clayey loam in some coastal areas. Most of the aquaculture ponds are on sandy loams with some black cotton soils in the lowlands. Non-calcareous dark gray floodplain soil is the only general soil type of the area. The land slopes from the northwest to southeast. Most of the coastal aquaculture ponds are just 10-20 m above the sea level. These areas are highly prone to tropical cyclone and storm surges. Surface water system of the Mirsarai area comprises Feni River, Isakhali Canal and Bamonsundar Canal, while small creeks entered Sitakunda coastal areas vegetated with mangroves. Feni River is considered as the main river system that flows between 20 m^3 (February) and 164 m^3 (August) with water level of 3.47 m to 4.15 m. This river is dominated by freshwater flows in upstream and becomes saline in downstream due to the influence of Bay of Bengal. Salinity drops to zero during the peak of monsoon and increases to 20 ppt in winter months. Ground water of shallow aquifers in Mirsarai and Sitakunda regions is slightly saline. Low saline fresh ground water is available at a depth of 700-900 ft.

Role of MEs in Local Economy

Aquaculture-based MEs have been playing an important role in local economy, particularly in the northwestern regions of Mirsharai upazila, whereas aquaculture practices in Sitakunda area are at small scale and supplementing family income. About 8,000 ha areas are now being used for aquaculture production in investigated areas, which are dominant in Mirsharai upazila (94%) than Sitakunda upazila (6%). At present, ~52,000 MT are harvested annually at an annual average 6.7 MT/acre and 4 MT/acre production rates in Mirsharai and Sitakunda upazilas, respectively, which contributes $970 mn annually. Approximately, 300 MEs are actively engaged in growing fish at Mirsharai upazila, where over 1,800 people are employed in aquaculture farm operation and management. Hundreds of people are indirectly involved in different value chain activities (i.e., fish harvesting, processing, seed and feed supply and their transportation, marketing, etc.) related to this sector. Furthermore, 700 families are involved in doing family-based pond aquaculture in Sitakunda upazila, which also contributes to supplementing their family incomes. Moreover, 46% of the respondents employed by MEs believe that the income from their jobs helps meet everyday needs and 24% employees can even save money for social security, whereas 29% respondents believe that their engagement in ME business has improved their living standards.

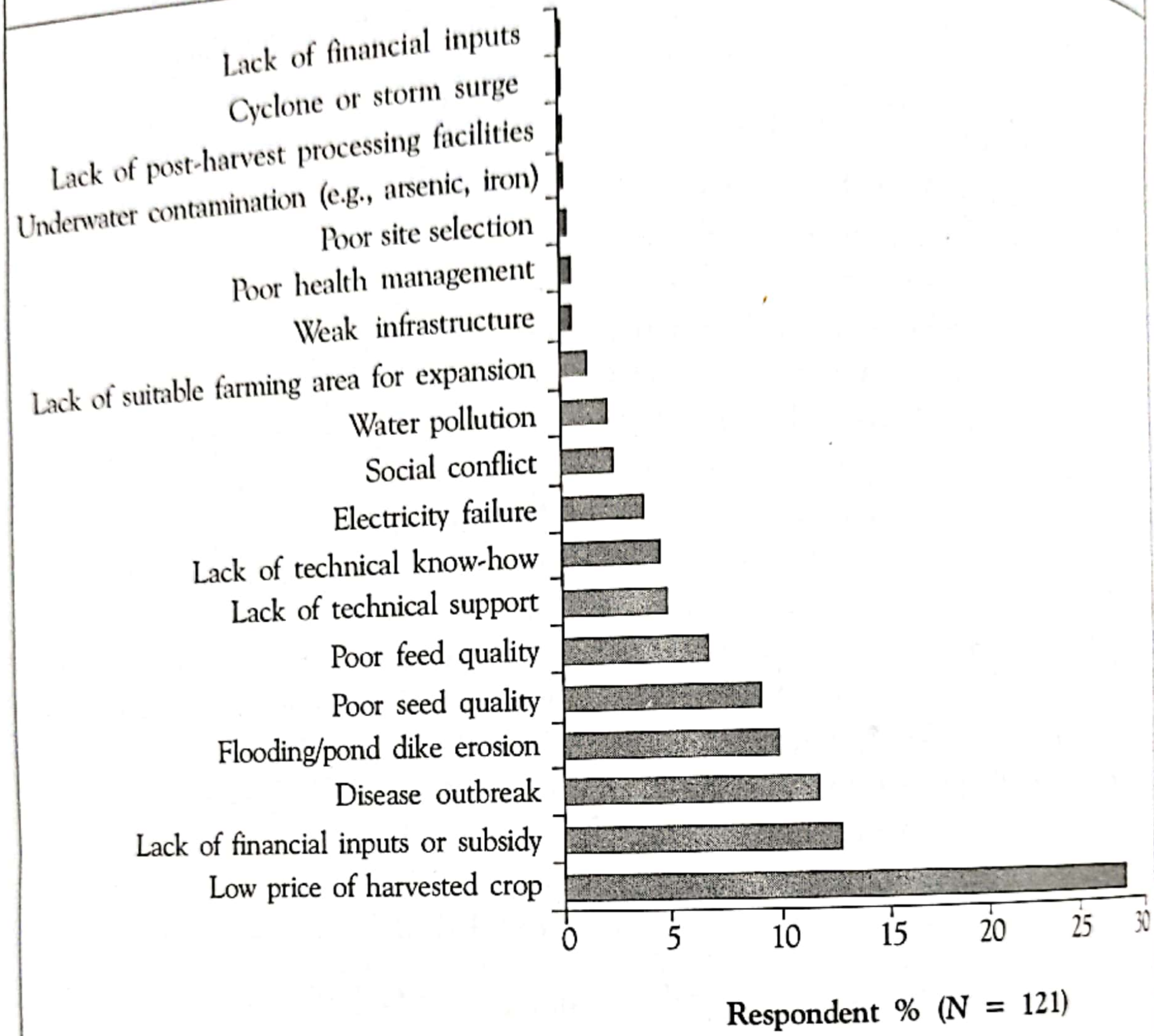
Socioeconomic and Environmental Constraints and Challenges

Fish production is undergoing global expansion and most of the financial profits came from the inland culture fisheries sector, but fish production has not achieved significant progress in investigated areas. The possible reasons of such poor growth are many and multiple issues have been identified as bottlenecks to enhancing fish production in Mirsharai and Sitakunda upazilas (Figure 7). These issues can be broadly categorized into: (1) environmental, (2) technological, (3) social and (4) economic, which are discussed below.

Environmental Challenges

Flooding in monsoon season has been identified as one of the serious environmental constraints in the investigated sites (Table 3). Particularly, cross-dam establishment across the Feni River in Mirsharai area had a negative impact and failure to drain the rainwater in monsoon season caused water logging and flash-flood in upstream areas. Aquaculture farmers lost their crops if the flood water level reached over their pond dikes, and the pond draining system failed due to the combined effects of tidal floods and upstream flashfloods.

Figure 7: Socioeconomic and Environmental Constraints and Challenges to Enhancing Fish Production in Northern Chattogram



Aquaculture farmers raise the height of pond dike for protection of the pond from flood water. The soil for the pond dike is taken from the pond bottom sediments, which helps to increase the pond depth (>2 m). Additionally, the farmers had to use geo-textile cloth over the dike to prevent erosion, which also increased the maintenance costs.

The effluents from aquaculture ponds are rich in nutrients, released from uneaten feed and fecal losses. The aquaculture plots in the investigated sites are not well organized and did not have effluents treatment system. The sharing of water intake and drainage systems by multiple farmers led to control water pollution and cross-contamination. As a result, disease outbreak (i.e., fungal and bacterial) is becoming a common problem in those areas, reducing fish production. Moreover, underground water contamination (e.g., arsenic and iron) is also a problem for those farmers who use bore well in ponds for raising fish. Both the Mirsharai and Sitakunda coasts are exposed to sea. Tropical cyclones and storm surges

Table 3: Rank of Environmental Threats That Hamper Aquaculture Production in Mirsharai Areas, Based on Scores Given by Respondents (N = 121)

Environmental Threats	Weight Scores Given by Respondents at Different Unions in Mirsharai								
	Osmanpur	Zorargonj	Ichakhali	Dhum	Katachora	Mirsharai Sadar	Khoiyachora	Total Scores	% Score
Excessive Rainfall/Flooding	33.2	10.9	40.8	6.7	6.0	4.8	1.9	104.3	45.6
Aridity/Drought	18.4	6.0	25.3	4.7	3.6	3.8	1.7	63.5	27.8
Eutrophication	5.5	1.9	11.4	2.5	1.6	2.4	2.7	28.0	12.3
High Temperature	23.1	2.6	0.0	0.0	0.0	0.0	0.0	25.7	11.2
Coastal Erosion	5.2	0.0	0.0	0.0	0.0	0.0	0.0	5.2	2.3
Flooding	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.4
Cyclone or Storm Surge	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8	0.4
Industrial Pollution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Salinity Intrusion	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fluctuation in Nutrient Flux	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sea Level Rise (SLR)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ground Water Extraction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Land Subsidence	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: Each respondent was asked to provide scores (0-1) to rank the environmental threats that hamper their aquaculture production from a given list.

along with SLR in changing climate are potential threats to these regions, which may also affect aquaculture activities.

Technological Challenges

Improved traditional methods are widely followed for growing fish in Mirsharai and Sitakunda areas. Farmers in those areas are not aware of applying semi-intensive farming technique that can increase the present production volume up to three times higher. Intensification in culture system rather than horizontal expansion can bring more profits to farmers. Intensification can be achieved by providing water aeration system with quality feeds for increasing the stocking density and their better growth. Bioremediation technology can be adopted for healthy pond ecosystem management that can reduce the dependency on aqua-drugs and chemicals for producing safe and healthy aqua-food. Poor site selection can be avoided by specifying an aquaculture practice zone after critical analysis of soil, water, and socioeconomic conditions through the development of species-wise aquaculture suitable maps. Seeds are one of the key inputs for fish farming. Many farmers are not happy with the present seed quality in terms of survival and growth performance, and thus faced mixed experiences. For instance, monosex tilapia are highly preferred species for their fast growth rates. Usually, methyltestosterone hormone is used for sex reversal in tilapia hatcheries. It needs specific dosages of hormones and special care for rearing tilapia fries in a control environment, which are absent in most tilapia hatcheries and hence they failed to produce quality seeds. Technological inputs related to post-harvest handling are absent in these areas, which causes post-harvest loss and reduces the fish quality during transportation. It is revealed that 89% of the farmers never received any sort of technical training that can help them to increase their technical know-how for operation and management of their aquaculture farm. Hence, necessary training related to production, harvesting, quality control, and processing technologies is necessary for improving the inland culture fishery sectors for these regions (Table 4).

Table 4: Suggestions Provided by the Respondents (N =121) to Improve the Aquaculture Production in a Sustainable Way

Suggestions	% of Respondents
Reduction of feed and medicine price	26.5
Ensuring good market price (sales)	22.4
Training and technical support	20.4
Easy loan and financial aid	20.4
Ensuring good quality seed	4.1
Drainage system development	4.1
Water quality testing support	2.0

Social Challenges

Half of the aquaculture farms were constructed in temporary leased land in Mirsharai upazila, which are allotted by the local land department. Land use conflicts exist among common interest groups to occupy those public lands, which are highly influenced by local politics. Power failure and weak road networks are also considered as constraints to aquaculture in Mirsharai and Sitakunda areas. Women are not allowed to work in aquaculture enterprises, i.e., half of the population is not connected yet with inland aquaculture production system in Mirsharai and Sitakunda areas. On the contrary, land use changes due to conversion of agriculture fields to aquaculture ponds reduce agriculture productivity and squeeze livestock grazing fields, putting pressure on agriculture farmers and other land user groups. Moreover, respondents listed some negative impacts of unplanned aquaculture development from Mirsharai area, which are presented in Table 5.

Table 5: Negative Impacts of Unplanned Aquaculture on the Environment in Mirsharai Upazila	
Negative Impacts of Unplanned Aquaculture Development	**% of Respondents (N = 26)**
Land use (e.g., agriculture field) alteration	38.5
Decline of SIS	34.6
Mangrove deforestation	15.4
Environmental pollution	7.7
Aquatic habitat or biodiversity loss	3.8
Pathogen contamination	0.0

Economic Challenges

Farm-raised fish prices are becoming very competitive in Bangladesh. Low farm gate price of harvested fish against production cost is identified as the most significant constraint for expansion of aquaculture activities in Mirsharai and Sitakunda areas. Rising feed and seed costs are reducing the profit margins for aquaculture farmers. 31 farmers out of 100 faced financial loss in the last five years. Multiple reasons have been given for the same during the social survey (Figure 8). Covid-19 pandemic situation, disease outbreaks, high feed cost and low fish price have been recognized as major reasons for the economic failure. Particularly, Covid-19 caused financial loss to the MEs in many ways (Figure 9). Goods transportation cost increased due to nonavailability of transport services, which disrupted the entire distribution channels and caused imbalance between input and output demands. To cope with these situations, consumers reduced their consumption, which ultimately forced the farmers to sell their products at low prices, thus incurring losses. As a result, farmers had to borrow money from different sources such as microfinance institution (62%), bank (29%), local money lenders (3%), friends and relatives (5%). 68% of the farmers faced difficulties in receiving the loan on time due to delay in processing. The farmers wanted input support in the form of: (i) financial aid (49%); (ii) technological assistance (44%); and (iii) managerial support (8%), i.e., training for reviving their aquaculture ventures. The social survey indicated that 60% of the MEs need financial support to overcome the economic, social, health and environmental consequences faced by them in their value chain network due to Covid-19.

Sustainable Aquaculture Practices: Socioeconomic and Environmental Factors

Most of the farmers or MEs in the investigated areas are not familiar with the Best Management Practice (BMP) and GAP practices, which are getting popular in other parts of the country. Different practices including, (1) effective biosecurity and disease

Figure 8: Major Challenges to the Economic Sustainability of Aquaculture Farms in the Investigated Areas

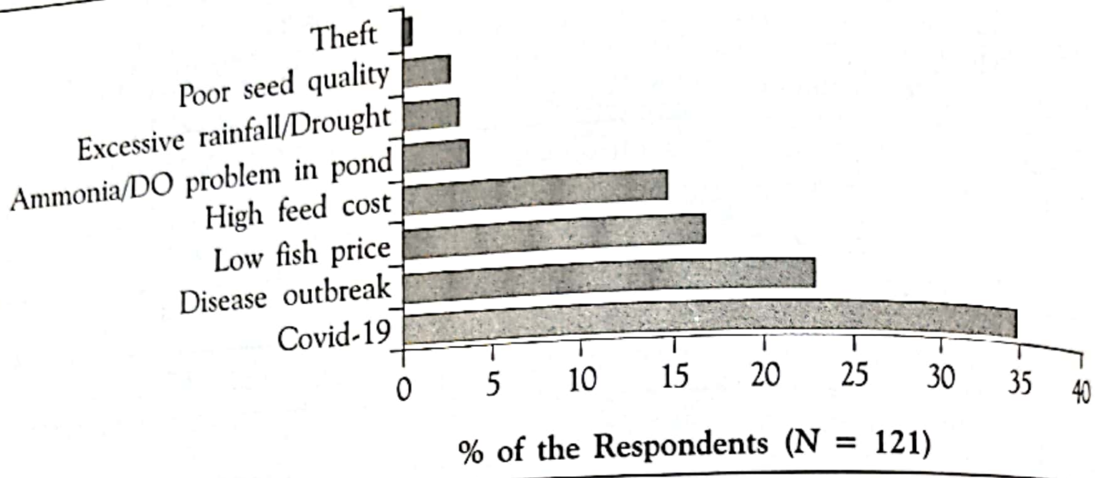
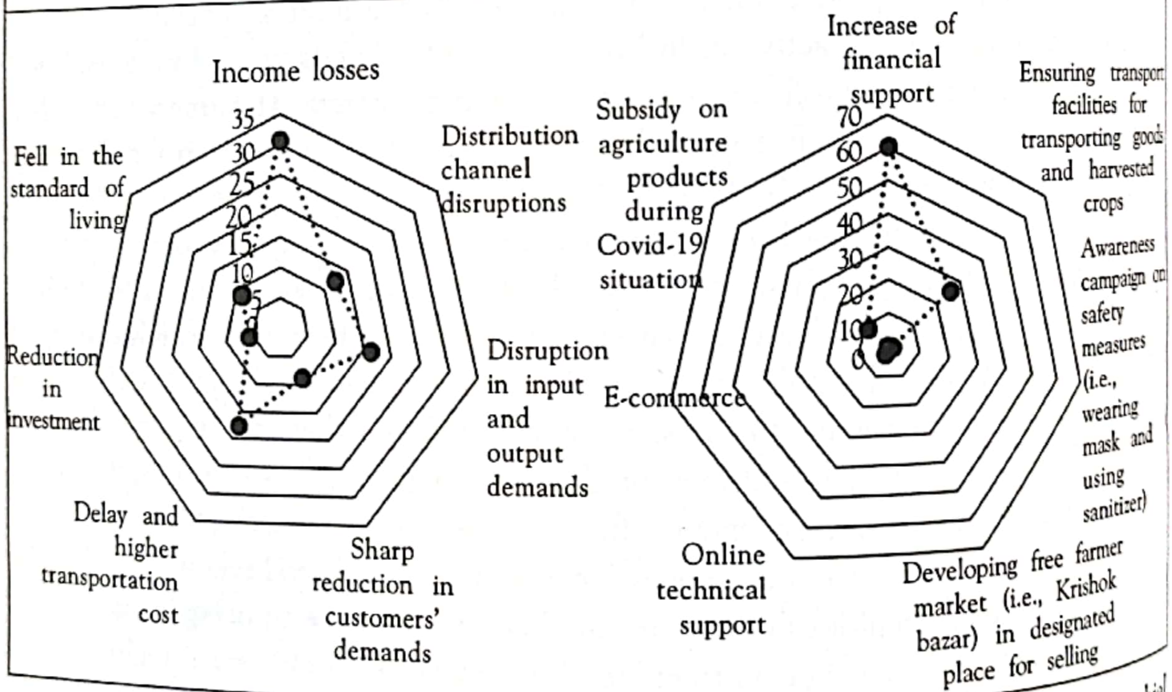


Figure 9: (a) Consequences of Covid-19 Faced by Aquaculture MEs; and (b) Possible Suggestions Provided by the Respondents (N = 121) to Improve the Situation



control systems; (2) minimal antibiotic and pharmaceutical use; (3) microbial sanitation; (4) maintaining HACCP standards for hygiene in all phases of production and post-harvest handling; (5) efficient processing and transport; (6) accountable record-keeping and traceability; and (7) profitability, can be achieved through multiple training and demonstration. SWOT analysis of aquaculture activities in the study areas is presented in Table 6.

The authors found that communities in the study areas are adopting indigenous knowledge for an effective value chain approach to selling their fish products in the

Table 6: SWOT Analysis of Fisheries Sector Value Chain	
Strengths • Small-scale village ponds exist in nearly 60% beneficiary households. • All the ponds could be developed and administered for fish culture. • Most of the beneficiaries have experience in aquaculture and in applying old techniques. • Good backward and forward linkages of aquaculture in the region.	**Opportunities** • Huge local and national demand. • Well-established linkage between the backward markets of inputs, feeds, aqua chemicals, etc. • Linkages between businessmen and forward market are strong in the study areas.
Weaknesses • Lack of information on pond development, and management and inadequate techniques for semi-intensive aquaculture practices in small ponds. • Wrong perception of the viability of commercial aquaculture in small ponds. • The habit of using caught fingerlings or poor quality inputs and habit of growing fish without investing in it. • Inputs are not quality-graded. • Accessibility to credit and loan facilities not sufficient.	**Threats** • Alkalinity, pH and salinity intrusion could impact water conditions and culture system in ponds. • Natural disaster-prone areas. • Limited access to finance for small-scale producers. • Dependence on loans limits business decisions and ownership.

Source: Modification of Barua et al. (2021)

commercial markets. The indigenous knowledge and techniques help them in obtaining significant profits within a short period of time. Inhabitants of the study areas are familiar with the transportation of their fish products to the markets (Figure 10).

Discussion

The study found most of the aquaculture farms clustered in the Ichhakhali, Osmanpur and Dhum unions of Mirsharai upazila and those were operated by commercial enterprises. In contrast, most of the aquaculture activities are pond-based in Sitakunda upazila at subsistence

Figure 10: Fish Marketing System: From Landing Center to Market

Fishermen/ fish farmers approach

- Rickshaw/Van: Three wheeler non-mechanized man-driven carrier for transporting the products
- CNG Taxi/*Nasimon*/Tampo/*Tamtam*: Used for transporting the product as cost is high
- Pickup: Small lorry

Approach of *Paiker*

- Bus: Used for quick and easy transport
- Truck: Used for long distance markets
- Pickup/Tampo/CNG: Used for low-cost marketing

Approach of Retailer

- Head load: Container, carry on head
- Rickshaw/Van: Three-wheeler non-mechanized carrier
- Bus: Passenger bus
- Truck: Cargo carrier
- *Nasimon*: Locally made mechanized small lorry/van
- Pickup/Tampo/CNG: Small lorry

Source: Modification of Barua et al. (2021)

level and operated by households. Half of the aquaculture areas in Mirsharai upazila are leased lands as these were the parts of old Feni River, which are newly accreted land due to sedimentation as a result of Muhuri cross-dam construction. All the aquaculture ponds in Sitakunda upazila are constructed in homestead family-owned properties.

From the study, it was found that sustainable community practices related to agribusiness are not evident in the investigated areas. Community practices such as—(1) well-defined rights to public land and water resources; (2) aquaculture zones and responsibilities for aquaculturists; (3) regulatory compliance and effective enforcement; (4) community involvement; (5) health safety; (6) fair labor practices; and (7) equitable compensation—were totally absent and those can be potential factors in the sustainable growth of aquaculture sector. Health issues for working community were becoming vital in the pandemic situation. Currently, protocols for health safety measures (i.e., wearing PPE including mask, using sanitizer, social distancing, etc.) were not followed at all. Development of health safety protocols and their common practices at enterprise level must be ensured. Moreover, competence in e-commerce and distance technical support to farmers through online can also be good community practices that can contribute to sustainable production and market development for healthy economic returns.

Present aquaculture practices in Mirsharai and Sitakunda areas are disorganized and disrupting to the surrounding ecosystem, along with substantial pollution impact due to lack of BMPs. Moreover, the present aquaculture production systems in the study areas are small in scale and might not be sustainable environmentally, economically and socially in the future. To address those issues, sustainable aquaculture development initiatives need to be taken and the following indicators can be helpful in understanding the progress after implementing those initiatives. Respondents in the social survey indicated that 89% of the farmers discharge their waste water directly into open water bodies, which is harmful to small indigenous fish species (SIS) and other aquatic biodiversity. Valuable mangroves were destroyed due to unplanned horizontal expansion of aquaculture in coastal sites and conversion of agriculture fields for aquaculture development in upstream areas. None of the enterprises or farmers are aware of environmental insurance, if their farming activities deteriorate the air, soil and waters of surrounding environment. Understanding the necessity of: (1) mangrove and wetland conservation; (2) effective effluent management and water quality control; (3) sediment control and sludge management; (4) soil and water conservation; (5) efficient fishmeal and fish oil use; (6) responsible sourcing of broodstock to combat inbreeding problem during seed production; and (7) control of escapes and minimizing biodiversity and wildlife impact can be the factors for SEP sub-project that might help in the improvement of the environment.

Conclusion

Flat lands in the northern Chattogram hold the potential for inland aquaculture development. Particularly, about 7,500 acres of flood plains in Mirsharai upazila along the Feni River are suitable for the aquaculture practice, which is considered one of the important agribusinesses in northern Chattogram region. Over 300 commercial MEs are engaged in the agribusiness and generating over $900 mn revenue annually. Additionally, family-based inland aquaculture practices (i.e., small-scale pond culture) in Sitakunda upazila are also contributing to local economy, supplying fish to local markets and meeting household demands. Of late, this regional inland fisheries sector is facing some environmental, technological and socioeconomic challenges that may lead to aquaculture production failure and make this subsector unstable in the near future. This baseline survey provided a general overview of this agriculture subsector (i.e., inland culture fishery) and tried to bring those challenges to the fore so that SEP sub-project can address them through different initiatives for sustainable fisheries production. The present aquaculture practices in Mirsharai and Sitakunda areas are becoming less sustainable and disrupting to the surrounding ecosystem, along with substantial pollution impact due to lack of BMPs and input supports. Success of the SEP sub-project towards the development of sustainable aquaculture for better fisheries production in northern Chattogram can be achieved through: (1) environment practices; (2) farm management practices; and (3) community practices, as discussed above. However, adapting GAPs requires a combination of strategies and policies. A top-down and bottom-up holistic approach to aquaculture planning and management may help to sustain this sector.

The study also highlights the opportunities for additional research in the field of agriculture product value chain and climate change adaptation options for profitability of coastal inhabitants in response to the problem of financial losses and opportunities for sustainable development.

Sustainable aquaculture development can bring real and lasting benefits to coastal communities. But the environmental consequences of inappropriate or excessive development will have an adverse impact on the wider communities and the farmers themselves. Therefore, there is an increasing need for good planning and management of aquaculture in Bangladesh. Environmental capacity is used in some developed countries to inform the management of aquaculture as it provides a more objective basis for planning and regulating aquaculture conditions, recognizing the cumulative impacts of resource users and the assimilative capacity of the environment.⌘

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