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Assessment of Tilapia Cage Culture and Disease Risk Factors in the Dakatia River, Bangladesh: Implications for Sustainable Aquaculture Development

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ABSTRACT

Tilapia (*Oreochromis niloticus*) cage aquaculture has expanded rapidly across Bangladesh as a feasible source of rural livelihoods and to meet national fish demand. The Dakatia River, particularly in Chandpur Sadar Upazila, is a prominent site for small- and medium-scale cage farming. This study assesses the operational characteristics, profitability, and disease risk factors associated with tilapia cage culture in the river system. A total of 50 respondents from eight villages were surveyed using a structured interview to capture data on cage construction, stocking density, feed management, and disease incidence with symptoms. The results revealed that a locally made cage with a stocking of 500-600 fish per cage (20 ft × 10 ft × 10 ft) yields an average of 400 kg per cycle, with a net profit margin of Tk. 15830, highlight the economic feasibility of the practices. However, the study also shows key vulnerabilities: 87.5% cage overcrowding within 5-10 m, poor pre-stocking hygiene, and an unknowingly excessive use of antibiotics. Seasonal disease outbreaks, especially during the monsoon, are associated with water turbidity, predator intrusion, and pathogen introduction from nearby sluice gates. These findings underscore the urgent need for spatial planning, improved biosecurity, reduced reliance on antimicrobials, and farmer training in water quality monitoring and disease detection. Accounting for those findings can help fill the knowledge gap on open-water cage farming in Bangladesh and offer policy-relevant insights to enhance health-resilient, sustainable aquaculture systems in the country.

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Introduction

Tilapia is among the most extensively farmed and consumed freshwater species worldwide, remarkable for its rapid growth, adaptation to varied environmental conditions, and cost-effective production, making it particularly appropriate for small- and medium-scale aquaculture systems (WorldFish, 2015; Bosu *et al.,* 2016). Widely produced across 150 countries, it ranks as the second-largest framed fish after carp, with cage aquaculture globally significantly driving its production (Roderick, 2025). For achieving huge productivity and profitability through cage culture in open water bodies, mostly in Asia, cultivating more than 72 suitable species, where Nile tilapia (*Oreochromis niloticus*) is among the top in these systems. The appeal of cage aquaculture lies in its efficient use of open waters and its high yield per unit area, making it a promising fish species for continuously boosting fish supply and farmers' livelihoods. Over the past two decades, Bangladesh has been in a notably consistent position, both sub-regionally and globally, due to the tilapia boom across its open-water areas and its status as a significant source of food and livelihoods for rural areas. In 1999, nationally, tilapia production was about 2140 metric tons, but in 2015 it skyrocketed to about 347800 metric tons, an 18-fold increase (Hussain *et al.,* 2017). By 2014, Bangladesh was ranked the third-largest tilapia producer in Asia, after China and Indonesia, and output has continued to climb, exceeding 370000 metric tons by 2021 (Roderick, 2025). This expansion is underpinned by widespread adoption among smallholders and entrepreneurs. By 2015, more than 15,000 commercial tilapia farms and 400 hatcheries had been established across the country to meet demand for sed and consumable market-size fish (Hussain *et al.,* 2017). For instance, the Chandpur Sadar region in the Dakatia River has emerged as a focal point of intensive cage culture, with numerous (approximately 1500 cages) small and medium farmers familiar with this practice (Belton *et al.,* 2011). Despite this positive development, concerns have been raised because its sustainability is increasingly threatened (Debnath *et al*., 2022).

Bosting of production in open waters, especially under low water flow, limited spatial planning, and seasonal hydrological changes, triggered outbreaks of disease (Bosu *et al.,* 2016). Particularly during the monsoon season, periodic mortality events have been linked to deteriorating water quality, suspended solids, and the spread of pathogenic-parasitic infections (Abdullah *et al.,* 2018). These challenges are often exacerbated by poor management compounded with overcrowding of the cage, unimplemented biosecurity, poor predator control, indiscriminate use of drugs, lack of knowledge of disease and treatment, improper pre-stocking, feeding, and harvesting, which elevate the risks of stock survival and lead to quick vulnerabilities (Subasinghe *et al.,* 2023). Although several studies have examined tilapia farming in ponds and hatcheries, a comprehensive site-specific assessment of cage aquaculture systems in open water (River ecosystem) remains limited in the Bangladeshi context (Hossain *et al.,* 2017). Most importantly, critical data are lacking on the interlinkage between farming practices, environmental stressors, and disease emergence in cage-based systems.

The Dakatia River, despite its growing importance as a cage-farming hotspot, remains underrepresented in academic and policy-oriented research (Belton *et al.,* 2011). To ensure its long-term viability and bridge knowledge gaps, this study assesses the current status of tilapia cage culture and identifies potential risk factors associated with disease, with insights expected to support more sustainable, health-resilient cage aquaculture development in Bangladesh.

Materials and Methods

Study Area and Sampling Framework

The study was conducted along the Dakatia River in the Chandpur Sadar Upazila of South-central Bangladesh. Between April and September 2022, data collection was implemented over six months. This region was chosen for its emerging significance as a focal point of freshwater-intensive cage aquaculture, particularly for Nile tilapia (Oreochromis niloticus), which is rapidly being adopted by small- and medium-scale farmers. The Dakatia River offers favorable hydro-ecological conditions for cage farming, including moderate current, accessible riverbank, and community reliance on aquaculture as a primary livelihood. However, increasing disease outbreaks, combined with deteriorating water quality and management inefficiencies, have raised concerns among practitioners and policymakers. To obtain a comprehensive understanding of current practices and health-related challenges in tilapia cage culture, the study employed a purposive sampling technique targeting only active cage operators with at least one year of continuous farming experience.

A total of 50 respondents were selected from eight river-adjacent villages, including Rogunathpur, Gunrazi, Islampur, Gucchogram, Puran Bazar, Dakkin Ichli, Tero Nong Goramara, and Gacchtola. These sites were selected to represent a diverse cross-section of socio-ecological variability along the river. The sampling ensured inclusion of both high- and low-density farming zones, allowing for spatial variation in practices, risk exposure, and health management strategies. These respondents provide a solid foundation for assessing operational status, disease prevalence, and potential risk factors influencing tilapia cage aquaculture in the Dakatia River system (Figure 1) (Table 1).

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Figure 1. Study Area (Chandpur Sadar Upazila, showing the Dakatia River)

Table 1. Number of respondents in the selected area

Name of Village	Number of Respondents
Rogunathpur	11
Gunrazi	6
Islampur	7
Gucchogram	5
Puran Bazar	5
Dakkin Ichli	7
Tero Nong Goramara	5
Gacchtola	4
	Total = 50

Data Collection Procedure

Before conducting fieldwork, a comprehensive questionnaire was designed to collect both qualitative and quantitative information in a sequential, systematic manner. Later, pretested and restructured the administration, which was under the direct leadership of the Bangladesh Agricultural University's lead researcher. Furthermore, to enhance the depth of the questionnaire, a semi-structured interview was carried out with local fisheries officers from the Department of Fisheries (DoF) and other relevant stakeholders. The questionnaire was constructed around the following factors: cage-making techniques, fingerling source and stocking density, types and frequency of feeds, inquiry into disease symptoms and treatment strategies, as well as water-quality management practices and overall biosecurity measures. Operational costs and income per cage are also estimated to assess the financial viability. Data collection was conducted through face-to-face interviews with 43 farmers across the study area, and an additional 7 were interviewed by telephone due to limited on-site accessibility or unavailability. This dual approach enhanced the flexibility of respondent engagement, ensuring real-time data.

Data Analysis

Following data collection, all responses were systematically cleaned, coded, and entered into Microsoft Excel, and then the descriptive statistics (means, frequencies, and percentages) were computed. To evaluate economic viability, a cost-return analysis was performed by dividing production expenses into variable costs (fingerlings, feed, labour, miscellaneous inputs) and fixed costs (cage construction and depreciation costs). Economic indicator calculated using the following formula:

- Gross Revenue (Tk/cage) = Average Yield (per cage) × Market Price (Tk/kg)
- Net Profit (Tk/cage) = Gross Revenue – Total Production Cost (Tk)

Later, to enhance interpretability, visual tools were used to highlight trends in production efficiency, cost structure, disease occurrence, and the distribution of risk factors, ensuring results aligned with the study's objectives.

Results

Construction Specifications of Tilapia Cage

The construction of a tilapia cage in the Dakatia River mirrors the practical, locally adapted techniques used in open-water aquaculture. Each cage measures 20 × 10 × 10 feet, covering a substantial nursing volume of 1400 cubic feet, with 1-1.5 feet above the water surface to ensure floatability and stability. Native and cost-effective materials have been used, such as bamboo, galvanized iron pipes, and plastic or metal drums to build cages, highlighting enriched sources of those materials (Table 2).

Table 3. Key considerations of a cage

Parameter	Specifications
Cage materials	Bamboo, galvanized iron pipes, and plastic or metal drums
Cage size (L × W × H)	20ft × 10ft × 10ft
Cage volume	1400 cubic feet
Floating height above water	1 – 1.5 feet
Net mesh size (feed net)	2 cm; Rachel's net: 0.5 m height
Cover net mesh size	5 cm

The primary net mesh size is 2 cm, sufficient to contain tilapia culture, allow adequate water exchange, and provide maximum oxygen and natural feeds. Additionally, a finer-mesh net (Rachel net, 0.5 m in height) is fitted inside the cage to minimize feed waste, improve feed efficiency, and reduce environmental pollution. A large secondary mesh (5 cm) is used to cover the top of the cage, providing protection from avian predators. This layered mesh system reflects a proactive approach to biosecurity and feed management. Overall, approximately 1550 cages were estimated in the Chandpur Sadar region, mirroring the widespread development of cage aquaculture and indicating the potential for a sustainable future of fish farming (Figure 2).

Figure 3. Cages in the study area

3.2 Stocking Management

Stocking management in tilapia demonstrates a strategic blend of commercial sourcing and self-rearing practices. Primary sources (60%) of the fry are from local hatcheries such as CP, Mega, and Nourish (local traders). However, approximately 40% farmers use their hatchery fry for cage cultivation and release into cages suitable size (3 – 5 inches). This practice considers both economic viability and an adaptive response to local availability and biosecurity concerns. The typical stocking size ranges from 20 – 50 g, with a density of 10 – 20 fingerlings per kg. Farmers generally stock 500–600 fingerlings per cage to reduce over-stocking and minimize the risk of disease outbreaks, optimize resources, and balance water quality (Table 3).

Table 4. Stocking practices and management of a cage

Parameter	Value/ Description
Fry sources	Hatcheries, self-reared
Percentage from hatcheries	60%
Percentage from self-reared	40%
Stocking size (length)	3-5 inches
Stocking size (weight)	20-50 g
Stocking size (count/kg)	10-20 pieces
Stocking density	500-600 fish/cage
Feeding method	Broadcasting
Supplementary feed source	Local producers
Stocking season	October – November
Harvesting season	May – July
Harvesting size	700 – 800 g

Generally, stocking release and harvesting depend on seasonal conditions. In favorable conditions (October – November), fry are introduced into a cage that provides efficient natural feed, water movement, and natural nourishment. Harvesting is typically done in May–July, when fish reach a marketable size (700 – 800 g). Feeds are delivered via broadcasting to ensure equitable distribution throughout the cage. Most farmers use locally produced commercial supplementary feed, indicating a shift towards standardized, efficient feeding protocols that reduce feed loss and improve growth performance (Figure 3).

Figure 4. Stocking and feeding of fish in a cage

Profitability Analysis of Cage Culture

An economic assessment was conducted to determine the cost structure and profitability per cage in the study area. The total cost per cage comprised both variable and fixed components. Variable cost estimated for 65.75%, amounting to Tk. 31670 per cage, where feed cost emerged as the most significant contributor, comprising 74% (Tk. 23400), reflecting the reliance on commercial feeds for overall profitability. Fish fingerling, another essential input, costs Tk. 4500 (14%), with prices varying based on sourcing from hatcheries. Combining both permanent and temporary workers, labour expenditure constituted 8% (Tk. 2520), while miscellaneous operational costs accounted for the remaining 4% (Tk. 1250) (Table 4) (Figure 4).

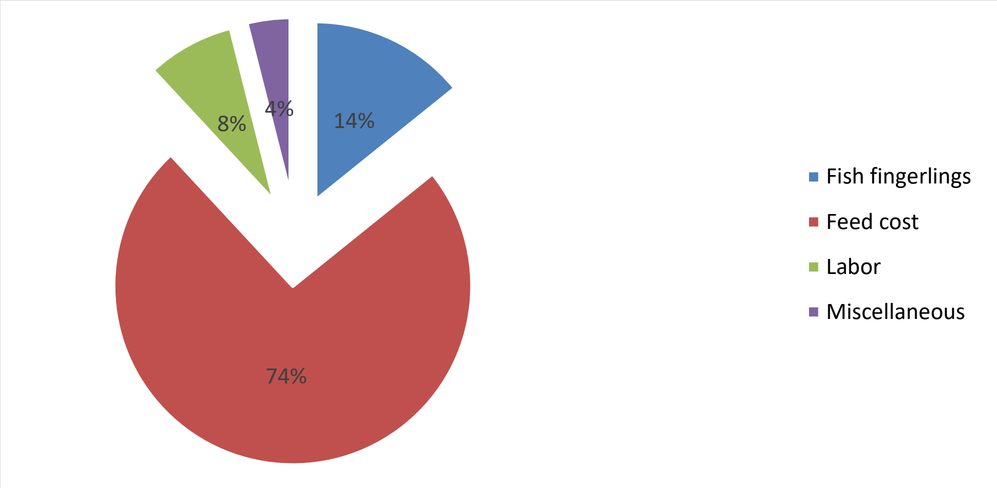

Figure 5. Variable cost percentage of a cage

Fixed costs were primarily contributed by cage construction, averaging Tk. 16500. This brought the total production cost per cage to about Tk. 48170. The average production yield was 400 kg per cage, with a prevailing market price of approximately Tk. 160. Then, the gross return was calculated in Tk. 64000, and the net return stood at Tk. 15830 per cage (Table 5). This positive margin underscores the profitability of the study area, given modest initial investment and potential yield optimization, indicating a strong future for cage aquaculture in Bangladesh overall.

Table 5. Cost-benefit analysis of a cage

Cost item	Cost (Tk/cage)	Percent of cost (%)
Variable Cost		
Fish fingerlings	4500	14
Feed cost	23000	74
Labour cost	2520	8
Miscellaneous	1250	4
Total Variable Cost	31670	100 (65.75)
Fixed Cost		
Cage construction cost	16500	100
Total Fixed Cost	16500	100 (34.25)
Total Cost	48170	100 (65.75+34.25)

Table 6. Economic Returns of a Cage

Economic Indicator	Value (Tk/cage)
Average Yield	400 kg
Market price	160 Tk/kg
Gross Return	64000
Total Cost	48170
Net Return	15830

Disease Problem and Management

Farmers monitor fish health and behavior during feeding and occasionally lift fish with a scoop net to check for signs of disease. Most farmers reported that disease outbreaks generally occurred between April and October (Baisakhi–Kartik), with the highest mortality rate in July–August (Ashar), attributed to increased water turbidity during the monsoon. In contrast, minimal or no mortality was observed during winter, which farmers associated with lower pathogenic activity. Although many farmers did not observe clinical signs and symptoms, some reported that the number of signs, such as scale loss, gill rot, mouth gaping, eye protrusion, blackening body coloration, hemorrhages around the fins and opercula, fin and tail rot, and erratic swimming (Table 6).

Table 7. Seasonal disease incidence and clinical signs

Parameter	Observation
Peak outbreak months	April – October (Baisakhi – Kartik)
High-risk months	July – August (Ashar)
Common (disease) signs	Scale loss, gill rot, mouth gaping, eye protrusion, black coloration, hemorrhages, fin/tail rot, erratic swimming

Regarding the treatment strategy, 54% of farmers administered antibiotics only, and another 20% combined antibiotics with aqua drugs to ensure recovery and optimal growth performance. Additionally, 26% supplemented integrated health treatments with growth boosters to enhance fish resilience and recovery (Figure 5).

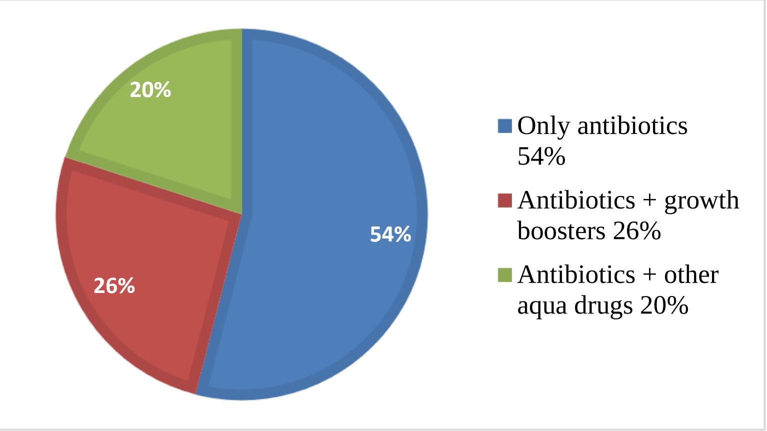

Figure 6. Drug use patterns among farmers

Risk Factors Associated with Diseases

Assessment of risk factors for diseases in the study area revealed interconnected vulnerabilities in farming systems, with 87.5% of cages located within 5-10m of adjacent farms, and only 12.3% maintaining specific separation. Another concerning issue is that many cages near sluice gates or drainage outlets were exposed to untreated effluents, leading to increased fish mortality. Pre-stocking management practices were also found to be weakened, with limited application of disinfectants, net drying, or hygienic measures. Additionally, the persistent presence of predatory birds and snakes poses a biological hazard, as they can serve as sources of pathogens. Furthermore, seasonal turbidity exacerbates stress and mortality, promoting early harvests to mitigate economic losses (Table 7).

Table 8. Disease risk factors identified in the study area

Risk Factors	Description
Cage proximity	87.5% within 5-10 m of the adjacent cage
Water source contamination	Cage near the sluice gate or the drain outlets
Pre-stocking management	Minimal disinfectant use and net drying
Predatory birds and animals	Frequent presence of birds/snake, viral deterrents
Monson turbidity	High-level suspended particles and plastics

Discussion

This study presents a comprehensive assessment of small-scale tilapia cage culture, revealing both promising practices and critical vulnerabilities. Farmers constructed a standardized, cost-effective cage using locally available materials such as bamboo, galvanized iron, and plastic drums for easy accessibility and flotation (Rojas & Wadsworth, 2007; Das et al., 2018), which aligns with the smallholder culture systems of other developing regions. The net layering system in the cage enhances feed retention and biosecurity, a design consistent with the international cage system aimed at predator exclusion and waste control, a biosecurity design also seen on the global stage (Rojas & Wadsworth, 2007). The prevalence of approximately 1,550 cages in the Chandpur Sadar area underscores the rapid adoption of this farming method, indicating its perceived viability and potential to enhance fish production in open waters. Although tilapia fingerlings stocking in the study area is like common intensive systems in Latin America and Southeast Asia, and reflects a strategic effort to prevent overcrowding and diseases (Rojas & Wadsworth, 2007). A previous investigation in the same region found that high stocking density and cage crowding were associated with tilapia epizootic diseases in the Dakatia River (Bosu *et al.,* 2016). But, despite keeping stocking rates in check, farms in Northern Thailand demonstrated higher densities (Chitmanat et al., 2016), indicating the need for efficient management to achieve greater productivity in intensified controlled-cage farming systems. The conservative stocking and water exchange in the culture area align with recommended best practices, since excessive densities and poor flow are well-known risk factors for stress and diseases in cage culture (Bosu *et al.,* 2016; Chitmanat *et al.,* 2016). Lessons from Africa, Southeast Asia, and Latin America underscore that optimizing stocking densities is crucial to improve water quality and pathogen proliferation, whereas moderate densities paired with good water exchange tend to support better survival and growth (Rojas & Wadsworth, 2007; Baqui & Bhujel, 2011; Kwikiriza *et al.,* 2025; Songe *et al.,* 2025). Feed, the single largest operating cost (74%) in the study area, closely mirrors reports from Asia and Africa, where commercial feed typically accounts for 60-70% of recurrent expenses (FAO, 2025), similar in China, Thailand, Latin America, and Brazil (K. J. Rana *et al.,* 2009). Despite this cost burden, farmers' shift towards quality commercial feed is positive, as proper feeding regimes are crucial for growth and feed conservation efficiency. The profit margin (15830 Tk, roughly 33% of the total cost) achieved over a grow-out season of 7-9 months is substantial for rural families and illustrates why cage aquaculture is gaining popularity. Moreover, the literature suggests that tilapia cage culture can be an effective income-generating tool for rural communities when managed cost-effectively (Rahman *et al.,* 2021; Obiero *et al.,* 2022). Rahman *et al.,* (2021) noted that the cage farming of Nile tilapia is being embraced as a strategy for poverty alleviation in Bangladeshi communities, with profitability hinging on inexpensive cage designs and adaptive management practices.

Notwithstanding these positive trends, the study highlights significant health challenges that threaten the sustainability of cage culture if left unaddressed. Seasonal variation and environmental stressors precipitate disease, as contributing heavy rainfall, flooding, introducing pathogens, organic load, and degrading water quality, a factor that has been similarly identified as the top risk factor for tilapia cage mortalities in other tropical regions (Lake Volta, Ghana; Philippines) (Baleta *et al.,* 2019; Zornu *et al.,* 2023; Lubembe *et al.,* 2024). Farmers noted many clinical signs (scale loss, gill rot, mouth gaping, eye protrusion, blackening body coloration, hemorrhages around the fins and opercula, fin and tail rot, and erratic swimming) which have been consistent with pathogenic bacteria, virus, and fungal infections (Abdel-Latif *et al.,* 2020; Islam, Rodkhum, *et al.,* 2024; Rao *et al.,* 2021), recently significantly outbreaks of mortality in Asia and Africa in the cage farming systems (Gupta & Acosta, 2004; Silva & Phillips, 2007). Additionally, the high-risk period in mid-monsoon also reflects a surge in pathogen levels and reduced fish immunity due to temperature fluctuations and suspended solids, as documented in analogous open-water farming systems (Rao *et al.,* 2021; Roh & Kannimuthu, 2023; Islam, Mahfuj, *et al.,* 2024). Besides, clustering of cages closely a rapid spread of pathogens in cage aquaculture. (Bosu *et al*., 2016) reported that Bangladesh's cage farms, tight spacing, and poor water flow around cages significantly increased disease incidence, a finding that strongly resonates with our results. Similarly, water exchange conditions in Dakatia sites are suboptimal, which causes the adjacent cage near the sluice gates or drainage outlets, leading to organic pollution and periodic influxes of pathogens. The lack of proper pre-stocking (inadequate disinfectants and insufficient drying of the net) weakens biosecurity measures, allowing pathogens to persist in the cage and infect each new batch of fish, as observed earlier in Bangladesh (Bosu *et al.,* 2016). While most studies have looked at wildlife interactions, have been flagged in other studies as contributing to pathogens transfer in the aquaculture environment (Bouwmeester *et al.,* 2021; Mordecai *et al.,* 2021). Taken together, these findings highlight that the current management regime has a vulnerable point at multiple levels.

Farmers documented that the disease outbreak is heavily reliant on chemical interventions, particularly antibiotics. Most farmers use integrated pest management to combat diseases and reduce production losses. Studies have found that most tilapia farmers in Bangladesh and neighboring countries resort to antimicrobials when faced with disease, often without veterinary oversight (Chowdhury *et al.,* 2022; Moffo *et al.,* 2024; Dandi *et al.,* 2025). For instance, a survey of cage tilapia farming on Lake Volta showed over 55% use of antibiotics or chemicals to treat outbreaks (ED, 2023), and similarly high rates of antibiotic use (up to 80% of tilapia growers) have been reported in parts of Asia (Haenen *et al.,* 2023; Schar *et al.,* 2021). This indiscriminate use of antibiotics leads to resistant pathogen strains and residue accumulation in the ecosystem, undermining both fish and public health (Pepi & Focardi, 2021; Ljubojević Pelić *et al.,* 2024). These findings imply an urgent need for improved health management strategies, such as enhanced vaccination, the use of probiotics, and more robust preventive measures, to support sustainable aquaculture.

Conclusion

The study demonstrates that the small-scale tilapia cage culture in the Dakatia River offers a viable aquaculture strategy for rural livelihoods in Bangladesh. Farmers employed cost-effective cages made from locally available materials and adopted moderate stocking densities (500-600 fish per cage), thereby establishing a stable production system. With an average yield of 400 kg per cage and a net profit of Tk. At 15830 per cycle, the economic analysis confirms the model's profitability. However, feed cost, which covers 74% of variable costs, is the most significant financial burden, underscoring the need for improved feed efficiency. Despite its financial potential, it faces considerable disease risks, particularly during the monsoon season (April-October), driven by environmental stressors. Notably, inadequate space among the cages (87% cages), pre-stocking biosecurity, and widespread antibiotic use (more than 74%) further compound these vulnerabilities, raising concerns over antimicrobial resistance in the ecosystem, public health, and long-term ecological sustainability.

Considering these findings, the following recommendations are proposed to ensure the sustainable expansion of tilapia cage culture:

- Designate appropriate cage spacing guidelines to improve water flow and reduce pathogen transmission risks
- Promote consistent pre-stocking measures, including net disinfection, drying, and predator exclusion, to minimize disease introduction.
- Introduce farmer-level training on assessing turbidity, dissolved oxygen, and pH, overall water quality parameters, especially in the high-risk monsoon season.
- Encourage the minimum use of antibiotics; maximize use of probiotics, immune enhancers, and selectively permitted aqua drugs.
- Strengthen extension and capacity-building services for sustainable aquaculture.

Competing interest

The authors declare that they have no competing interests.

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