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From monoculture to polyculture: Assessing the economics of integrated fish-makhana (Euryale ferox) farming in Kishanganj's wetlands

Ravi Shankar Kumar

Assistant Professor, College of Fisheries, Kishanganj, Bihar, India

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Corresponding Author: Ravi Shankar Kumar

Abstract

This study assesses the economic parameters of integrated fish cum makhana culture versus makhana monoculture in Kishanganj district, Bihar, based on a survey of 80 farmers using stratified random sampling. Results indicate that while integrated fish cum makhana culture involves higher production costs (₹72,456/ha) compared to makhana monoculture (₹39972/ha), it delivers significantly greater gross income (₹227,640/ha) and net income (₹155,184/ha). The system also demonstrates superior profitability, with a cost-income ratio (CIR) of 0.23 and a benefit-cost ratio (BCR) of 3.14, outperforming makhana monoculture (gross income: ₹112140/ha; net income: ₹72168/ha; BCR: 2.80). Major constraints include illegal fishing, floods, water scarcity, high labor costs, and a shortage of skilled labor. The study strongly recommends adopting integrated fish-makhana farming over monoculture in the wetlands of Kishanganj district. Policy measures should include leveraging MGNREGA for wetland maintenance, promoting community-based management, and investing in skill development to advance integrated aquaculture in the region.

Keywords: Fish cum makhana, integrated farming systems and economic analysis

Introduction

"Fish cum makhana culture" refers to an integrated farming system where fish decomposing makhana plant matter releases nutrients into the water, enhancing plankton growth. The resulting organic detritus supports zooplankton, insect larvae, nematodes, and gastropods, serving as food for bottom-feeding fish like mrigal and common carp. Meanwhile, fish help control makhana pests, and their excrement acts as organic fertilizer for the crop.

Fig 1: Makhana farming in Kishanganj's wetlands

Among the various integrated farming systems, fish-cum-makhana (Euryale ferox) culture has gained attention as a sustainable and economically viable practice that enhances productivity, optimizes resource use, and improves farmers' income (Yadav *et al*, 2020) [10]. Makhana, a highly nutritious aquatic cash crop, is traditionally cultivated in stagnant water bodies, while fish farming complements this system by utilizing the same water body for dual production. This holistic strategy enhances both land and water efficiency while supporting food security and creating rural job opportunities.

Agriculture and aquaculture are critical to rural livelihoods, particularly in regions with abundant wetland resources like Kishanganj, Bihar. Wetlands in this region support diverse ecosystems and provide a foundation for traditional farming systems (Prasad & Sinha, 2020) [7]. However, the dominance of monoculture practices—whether in pisciculture or Makhana (Euryale ferox) cultivation—has led to ecological degradation, economic instability, and inefficient resource use (Kumar *et al*., 2019) [5].

Integrated farming systems, particularly polyculture of fish and Makhana, present a sustainable alternative by maximizing productivity while maintaining ecological balance (Jha *et al*., 2021) [4]. Makhana, a high-value aquatic cash crop, is primarily cultivated in stagnant water bodies and holds significant nutritional, medicinal, and economic importance (Singh & Das, 2018) [9]. Bihar accounts for more than 80% of the world's Makhana (fox nut) output, playing a vital role in the livelihoods of local farmers (Dutta & Pandey, 2022) [2]. Meanwhile, fish farming, especially species like Rohu (Labeo rohita), Catla (Catla catla), and Mrigal (Cirrhinus mrigala), is well-established in Kishanganj's wetlands (Das & Sahoo, 2020) [1].

Despite their coexistence potential, fish-Makhana integrated farming remains underexplored, with limited research on its economic feasibility and ecological benefits (Ghosh & Mandal, 2021) [3]. This study aims to bridge this gap by assessing whether polyculture systems can enhance profitability, optimize land use, and reduce environmental risks compared to traditional monoculture (Mishra and

Mohanty, 2019) [6].
Integrated aquaculture-agriculture systems (IAAS) offer a sustainable solution by combining fish farming with floating crops like Makhana (Prein, 2002) [8]. Key advantages include:

- **Resource Efficiency:** Fish excreta act as natural fertilizer for Makhana, reducing the need for chemical inputs (Das & Sahoo, 2020) [1].
- **Increased Productivity:** Studies suggest that polyculture systems can enhance yield by 20-30% compared to monoculture (Ghosh & Mandal, 2021) [3].
- **Risk Diversification:** Farmers gain multiple income streams from fish and Makhana, reducing economic vulnerability (Kumar *et al*., 2019) [5].

This study will provide empirical evidence on the profitability and sustainability of fish-Makhana integration. The study will also suggest policy interventions to support farmers in adopting polyculture of fish cum Makhana.

Location of study
Kishanganj is considered as economically distressed district of Bihar, where majority of population depends upon agriculture and allied activities. The district of Kishanganj boasts a rich network of rivers, such as the Mahananda, Kankai, Mechi, and Donk, enhancing livelihood opportunities. Beyond these rivers, Kishanganj district has a lot of small and medium natural water bodies or Wetlands. These Wetlands provide opportunities for fisheries as well as makhana culture in the district.

Sampling Methods
Multistage stratified random sampling method has been used to study the economic assessment of fish cum makhana culture in Kishanganj. A total sample of 80 farmers of Kishanganj district were collected by using multistage stratified random sampling.

Methodology
1. Cost and Income Analysis
Cost-Income Analysis is a financial assessment tool used by businesses to evaluate the relationship between operational costs and income generated. It helps organizations measure efficiency, profitability, and financial health by comparing expenses to revenue.

Component of Cost- Income Analysis

- **Cost:** Includes Fixed Cost and Variable cost. Fixed Costs (FC) are expenses that remain constant regardless of changes in production or sales volume in the short term. Variable Costs (VC), on the other hand, fluctuate in direct proportion to the level of production or sales.
- **Income:** Includes total earnings from sales of produce.
- **Gross Income:** The total revenue a company/ farm earns from sales before deducting costs like production, operating expenses, or taxes.
- **Net Income:** Net Income (also called net profit or bottom line) is a key financial metric that represents the amount of profit a company/ farm has earned after subtracting all expenses, taxes, and costs from its total revenue.
- **Cost- Income ratio:** The Cost-Income Ratio (CIR) is a key financial metric used primarily in the banking and financial services sector to measure efficiency. It compares a farm's operating costs to its income, indicating how much it costs to generate each unit of revenue.

Cost-Income ratio is estimated as-

CIR= $\left(\frac{Operating\ costs}{Operating\ Income}\right)$ * 100

- A lower CIR indicates higher efficiency.
- A higher CIR suggests inefficiency.

2. Benefit- Cost Analysis
Benefit-Cost Analysis (BCA) is a systematic approach to evaluating the economic feasibility of a business, policy, or investment by comparing its benefits and costs. It helps decision-makers determine whether the benefits outweigh the costs and whether a business is worth pursuing. It is estimate as-

Benefit- Cost Ratio (BCR) = $\frac{Gross\ Income}{Total\ Cost}$

3. Constraint Analysis
Constraint faced by farmers involve in Fish cum makhana culture is analyzed by Rank Based Quotient (RBQ) methods.
The Rank-Based Quotient (RBQ) is a statistical metric that evaluates constraints using a ranking approach.

$$RBQ = \frac{\Sigma f_i (n + 1 - i) \times 100}{N \times n}.$$

where,
f_i= No. of wholesaler reporting a particular constraint under ith rank.
n= No. of constraints identified
N= Total No. of wholesaler
r = No. of Rank

- Higher RBQ (closer to 1) → More severe constraint (needs urgent attention).
- A lower RBQ (closer to zero) indicates a less critical constraint.

Results and Discussion
Benefit-Cost Analysis
Benefit-cost analysis has been used to find out the performance of fish cum makhana culture with respect to makhana culture in Kishanganj's Wetlands. Costs and Income were separately estimated for fish cum makhana culture and monoculture of makhana in Kishanganj district of Bihar.

Benefit-Cost analysis of Fish cum makhana culture in Kishanganj's Wetlands
Cost structure for fish cum makhana culture in Kishanganj district can be seen in table1:

Table 1: Cost involve in monoculture of Makhana in Kishanganj's Wetlands

Fixed Cost		
Sl. No.	**Particulars**	**Cost/ha/year (In rupees)**
1.	Lease amount for Jalkar	2464/-
2.	Maintenance cost of Jalkar	12558/-
3.	Gear	2218/-
4.	Interest (12%)	2069/-
Total Fixed Cost (A)		19309/-
Variable Cost		
1.	Seed Cost	22583/-
2.	Feed Cost	6259/-
3.	Labour Cost	12659/-
4.	Fertilizer cost	11646/-
Total Variable Cost (B)		53147/-
Total Cost (A+B)		72456/-

From the table, it is clear that per hectare fixed cost, variable cost and total cost for fish cum makhana culture in Kishanganj's wetlands was found to be rupees 19309/-, 53147/- and 72456/- respectively.

Income Statement for Fish Cum Makhana Culture in Kishanganj's wetlands

Income for fish cum makhana culture for one hectare of wetland in Kishanganj can be seen in table-2.

Table 2: Benefit-cost ratio for monoculture of makhana in Kishanganj's wetlands

Sl. No.	Particulars	Quantity (Kg)	Price (Rs/Kg	Income (In rupees)
1.	Makhana	218	180	39240/-
2.	Fish	942	200	188400/-
Gross Income (G)				227640/-
Net Income= G- (A+B)				155184--
Benefit-Cost ratio				3.14

The integrated fish cum makhana farming system in Kishanganj's wetland demonstrated strong economic viability, with an estimated gross income of ₹227,640 per hectare per year and a net income of ₹155,184 per hectare per year. The benefit-cost ratio (BCR) for fish cum makhana culture in Kishanganj was found to be 3.14 which strongly indicates that integrating makhana cultivation with fisheries is an economically viable and highly profitable venture for farmers, as it demonstrates that for every 1 rupee invested, farmers can expect a return of 3.14 rupees, significantly exceeding the initial costs and ensuring substantial financial gains. The result is very much similar to study carried out by Sahoo *et al*. (2022) on "Cost-benefit analysis of integrated aquaculture-agriculture systems in Eastern India" highlighted that the Benefit-Cost Ratio (BCR) for this system ranges between 2.8 and 3.2, indicating high profitability.

Benefit- Cost analysis for monoculture of Makhana in Kishanganj's Wetlands

Cost structure involve with monoculture of makhana was estimated and it is shown in table-3:

Table 3: Cost for Fish cum Makhana culture in Kishanganj's wetlands

Fixed Cost		
Sl. No.	**Particulars**	**Cost/Ha/Year**
1.	Lease amount of Jalkar	11767.0/-
2.	Maintainance of Jalkar	12459.0/-
3.	Interest (12%)	2907.0/-
Total Fixed Cost (A)		27133/-
Variable Cost		
1.	Labour	9247/-
2.	Fertilizer	3592/-
Total variable cost (B)		12839/-
Total Cost (A+B)		39972/-

Per hectare per year Total fixed cost, Total variable and Total cost for monoculture of makhana in Kishanganj's wetlands were estimate as 27133/-, 12839/- and 39972/- rupees respectively.

Income Statement for Monoculture of Makhana in Kishanganj's wetlands

Income statement for monoculture of makhana in Kishanganj's wetlands is shown in table-4.

Table 4: Benefit- Cost ratio for Fish cum Makhana culture in Kishanganj's wetlands

Sl. No.	Particulars	Quantity (Kg)	Price (Rs/Kg)	Income (In Rupees)
1.	Makhana	623	180	112140/-
Gross Income (G)				112140/-
Net Income= G- (A+B)				72168/-
Benefit- Cost ratio				2.80

From the detailed data presented in the table above, it is evident that the Gross Income generated per hectare from the monoculture cultivation of Makhana (a cash crop) in Kishanganj district amounts to ₹112140, while the Net Income (after accounting for all production costs) stands at ₹72168. The Benefit-Cost Ratio (BCR) for Makhana monoculture in Kishanganj was calculated to be 2.80, signifying that for every ₹1 invested in cultivation, farmers gain a return of ₹2.80.

The benefit-cost ratio (BCR) analysis revealed that integrated fish cum makhana culture yielded a significantly higher BCR of 3.14 compared to makhana monoculture, which had a BCR of 2.80. This demonstrates that the integrated system is more economically advantageous than makhana monoculture, offering greater profitability and resource efficiency.

Cost-Income Ratio (CIR) for Fish cum Makhana integration and monoculture of Makhana

The Cost-Income Ratio (CIR) for fish cum makhana culture in Kishanganj was found to be 0.23 which signifies an exceptionally profitable and highly efficient farming system, as it demonstrates that for every 1 rupee spent on production costs, the farmer earns approximately 4.35 rupees in revenue, highlighting strong financial viability and optimal resource utilization in this integrated aquaculture-agriculture model.

The detailed analysis revealed that the Cost-Income Ratio (CIR) for monoculture cultivation of Makhana (Euryale ferox) in the Kishanganj district of Bihar, India, was calculated to be 0.35, indicating that the total production costs accounted for only 35% of the gross income generated from the crop, thereby reflecting a highly profitable agricultural enterprise with a favorable economic return for farmers in the region.

The Cost-Income Ratio (CIR) for fish cum makhana culture in Kishanganj was 0.23, indicating an exceptionally profitable and highly efficient farming system. In contrast, the CIR for monoculture makhana cultivation was 0.35, suggesting that while it remains highly efficient, it is slightly less profitable than the integrated fish cum makhana system.

Constraints faced by farmers involve in Fish cum Makhana culture in Kishanganj:

Constraint Analysis was done to know the constraints faced by fish cum makhana culture which is summarized in table-5.

Table 5: Constraints faced by farmers involved in fish cum makhana culture in Kishanganj's Wetlands

Sl. No.	Constraints	Rank
1.	Pouching/ Illegal fishing by unauthorised person.	I.
2.	Floods	II.
3.	Insufficient Water depth in dry season	III.
4.	High labour cost	IV.
5.	Insufficient skilled labour for Makhana Harvesting & Processing	V.

All constraints faced by farmers involve in fish cum makhana culture are described below:

1. **Pouching/ Illegal fishing by unauthorized person:** The most pressing issue faced by fish-cum-makhana farmers in Kishanganj's wetlands is the illegal harvesting of fish by unauthorized individuals during night time. Under the integrated fish and makhana farming system in wetland, farmers not only lose their cultured fish to these thefts but also suffer damage to their makhana plants due to the intruders' disruptive activities. Such illegal practices result in significant economic losses for the farmers, compelling many in Kishanganj to abandon integrated farming and shift exclusively to makhana monoculture in their wetlands.
2. **Floods:** Flooding is identified as second most serious problem affecting fish-cum-Makhana culture in Kishanganj district, Bihar. The district is classified as a flood-prone area, making it highly vulnerable to inundation during the monsoon season. Floodwaters submerge Makhana fields, damaging the floating leaves and rhizomes of the plant. During floods, water bodies overflow, allowing fish to escape and depleting fish stocks.
3. **Insufficient Water depth in dry season:** The third most significant problem affecting fish-cum-makhana culture in Kishanganj is the reduction in water depth during the dry season. The wetland experiences a drastic decline in water levels, leading to extensive drying of large portions of the water body. This phenomenon severely restricts the available culture area, directly impacting fish and makhana (foxnut) production.
4. **High labour cost:** High labour cost ranks as the fourth most significant problem in fish-cum-makhana culture in Kishanganj, primarily because this integrated farming system is highly labor-intensive, Labor costs account for the highest proportion of total input expenses. As a result, the increased expenditure on manpower substantially reduces the profit margins for farmers engaged in fish-cum-makhana cultivation, making it a critical economic constraint in the region.
5. **Insufficient skilled labour for Makhana Harvesting & Processing:** In Kishanganj district, there is a significant shortage of skilled labourers proficient in makhana harvesting and processing, forcing farmers to rely on workers brought in from distant regions such as Darbhanga, Katihar, and other areas. Since local expertise is limited, these migrant labourers are in high demand, leading to increased labour costs. As a result, makhana farmers in Kishanganj must pay substantially higher wages to secure the necessary workforce, which in turn raises production expenses and reduces profitability. This labour shortage not only impacts the economic viability of makhana cultivation but also highlights the need for skill development initiatives within the district to create a sustainable local workforce.

Policy Recommendations

- **Promote Integrated Farming Systems:** Encourage fish-cum-makhana co-cultivation to maximize profitability compared to makhana monoculture.
- **Enhance Wetland Management:** Utilize MGNREGA labor to maintain and deepen the outer sections of wetlands, supporting sustainable fish-makhana farming.
- **Combat Illegal Fishing:** Implement community-led surveillance and awareness programs to prevent poaching.
- **Develop Skilled Labor:** Provide localized training programs for makhana cultivation, harvesting, and processing.
- **Expand Market Linkages:** Foster integrated farming adoption to meet rising domestic and global demand for makhana products.

Conclusion

The research underscores the greater economic benefits of integrated fish and makhana farming in Kishanganj district, Bihar, over conventional makhana monoculture. The analysis reveals that the integrated system generates substantially higher income, with a gross income of ₹227,640/ha and a net income of ₹155,184/ha, far surpassing makhana monoculture (₹112140/ha gross income and ₹72168/ha net income). The Cost-Income Ratio (CIR) of 0.23 and Benefit-Cost Ratio (BCR) of 3.14 for fish-cum-makhana culture indicate superior profitability and resource efficiency, making it a more sustainable and economically viable farming system. Despite its advantages, several constraints hinder its expansion, including illegal fishing, seasonal floods, inadequate water depth, high labor costs, and a shortage of skilled workers for makhana processing. It

is recommendation to use MGNREGA labor to maintain and deepen outer part of wetlands to support fish-cum-makhana farming. It is also recommended to encourage fish-cum-makhana cultivation for higher profits over monoculture of Makhana.

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JEL codes: Q12, Q16 and Q22

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