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PROFITABILITY ANALYSIS OF MAKHANA FARMING UNDER SMALLHOLDER CONDITIONS IN NORTH BIHAR

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ABSTRACT:

Makhana (*Euryale ferox*), commonly known as fox nut, is a high-value aquatic crop cultivated mainly in North Bihar's floodplains. This study investigates the profitability of Makhana farming under smallholder conditions, focusing on input costs, gross returns, labor patterns, and market access. Data from 120 smallholder farmers in Darbhanga, Madhubani, and Saharsa districts were collected through structured interviews, supported by secondary data from NABARD, ICAR-RCER, and Bihar Agricultural Department reports. The results show a gross return of ₹85,000/ha against a total cost of ₹45,000/ha, producing a net profit of ₹40,000/ha and a Benefit-Cost Ratio (BCR) of 1.89. Statistical analyses confirmed significant differences in yields among districts through ANOVA ($F = 75.97$, $p < 0.0001$) and T-tests. Constraints like intermediary-dominated marketing, post-harvest losses, and regional disparities in yields hinder optimal profitability. Policy recommendations include improved post-harvest infrastructure, collective marketing, digital platforms, and support for women in the value chain. The findings offer economic insight for stakeholders aiming to improve rural livelihoods via sustainable aquaculture.

Keywords: Makhana farming, profitability, smallholder agriculture, cost-benefit analysis, North Bihar, ANOVA, rural economy

1. INTRODUCTION AND OBJECTIVES

Makhana (*Euryale ferox*), commonly referred to as fox nut, is a traditional aquatic crop primarily cultivated in the floodplains of North Bihar, particularly in the Mithilanchal region comprising Darbhanga, Madhubani, and Saharsa districts. With the global rise in demand for superfoods and functional health products, makhana has transitioned from a subsistence crop to a high-value commodity, gaining attention both within India and in export markets. It is now marketed as a gluten-free, high-protein, low-fat snack, often appealing to health-conscious consumers and international retailers. The Government of Bihar has also recognized its economic importance, promoting it under various agricultural development schemes such as the "One District One Product" (ODOP) initiative [1].

Despite its growing economic relevance and cultural roots in the region, the real-world profitability of Makhana farming—particularly among smallholder and marginal farmers—remains underexplored in academic literature and policy evaluations. Makhana cultivation is unique in that it is highly localized, seasonal, and dependent on waterlogged pond ecosystems, many of which are communally managed or inherited. The production process is labor-intensive, involving manual harvesting, drying, roasting, and de-husking. While the crop is known for its low input requirements and resilience against pests, market dynamics,

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processing infrastructure, and regional disparities in yields introduce several uncertainties for small-scale producers.

Given this context, the present study seeks to bridge the research gap by analyzing Makhana farming from an economic and statistical standpoint. The primary objective is to evaluate the cost structure and profitability of Makhana cultivation under smallholder conditions in North Bihar. This includes a comprehensive breakdown of input costs, labor requirements, gross returns, and net profit margins per hectare. Secondly, the study aims to assess the variability in yields and market prices across the three focus districts, Darbhanga, Madhubani, and Saharsa, where ecological conditions and institutional support structures differ markedly.

The study employs statistical tools such as Analysis of Variance (ANOVA) and T-tests to determine whether observed differences in productivity across districts are statistically significant. Such validation is essential for informing region-specific agricultural policies. Finally, based on empirical findings, the study provides actionable recommendations to enhance profitability, improve market linkages, and promote sustainability in the Makhana value chain. These objectives are aligned with broader national goals of increasing farm incomes, encouraging agri-entrepreneurship, and ensuring inclusive rural development.

2. LITERATURE REVIEW

A foundational study by Kumar, Singh, and Mishra (2019) explored the role of traditional knowledge systems in sustaining Makhana cultivation in the Mithilanchal region of North Bihar. The researchers documented how local communities have historically relied on indigenous techniques for pond preparation, transplantation, harvesting, and drying. These practices, passed down through generations, have enabled sustainable management of aquatic resources even in the absence of formal institutional support. The study emphasized that traditional ecological knowledge forms the backbone of Makhana farming in North Bihar, but also cautioned that without integration with modern practices, productivity gains would remain limited [2].

In the same year, Sinha and Prasad (2019) published a study focusing on Makhana's role in rural employment generation. Their work underscored the crop's labor-intensive nature, especially during harvesting and post-harvest operations, where manual labor is indispensable. They estimated that Makhana farming generates nearly three times more employment per hectare compared to staple crops like paddy. However, the study also pointed out the lack of formal recognition for women's labor and the informal wage structures that dominate the sector. Their findings made a compelling case for integrating Makhana into rural employment schemes and gender-focused policy frameworks [3].

A significant policy-level acknowledgment came from NABARD (2021), which recognized Makhana as a priority crop under the “One District One Product” (ODOP) initiative. This classification aimed to mobilize institutional credit, encourage value chain development, and provide targeted government support to regions specializing in Makhana cultivation. NABARD's report on the Saharsa district provided a techno-economic profile of Makhana farming, including estimates of input costs, average yields, and market price fluctuations. The report laid the groundwork for financial institutions to engage more systematically with Makhana growers through subsidized credit and training programs [4].

The ICAR-RCER (2020) report further contributed to understanding the economic dimensions of Makhana farming. This detailed techno-economic analysis assessed the impact of different pond ownership models, privately owned, leased, and community-managed on cost structures and productivity levels. The study revealed that privately managed ponds tend

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to have higher yields but also incur greater input costs, while leased ponds showed relatively poor returns due to limited investment by short-term tenants. ICAR-RCER also noted that seasonal labor availability, especially during peak harvest times, significantly affects both productivity and profitability [5].

From a nutritional standpoint, Jain and Srivastava (2018) analyzed the macro- and micronutrient content of *Euryale ferox* seeds, confirming their rich protein, fiber, and antioxidant content. Their findings supported Makhana's classification as a superfood and opened avenues for marketing it in health-conscious and diabetic-friendly food segments. The study emphasized the potential of value addition through health branding and the introduction of fortified makhana-based products for urban and export markets [6].

Addressing the issue of post-harvest inefficiencies, Das (2021) conducted a field-based assessment of drying, roasting, and packaging methods in Makhana farming across several districts in Bihar. The study reported that nearly 20–30% of the harvested crop is lost due to poor drying infrastructure, exposure to moisture, and improper storage. It also highlighted the lack of mechanized processing units, which limits scalability and adds to the physical strain on laborers. Das recommended the promotion of low-cost solar dryers and mobile roasting units to mitigate losses and improve shelf life [7].

Sharma (2021) investigated the gendered division of labor in Makhana farming, focusing particularly on post-harvest roles such as roasting, de-husking, and sorting. Her qualitative study, based on interviews with women workers in Darbhanga and Madhubani, revealed that while women contribute substantially to the value chain, they often receive little to no formal remuneration or recognition. Sharma advocated for the formal inclusion of women in Farmer Producer Organizations (FPOs) and the implementation of wage parity measures in Makhana-based enterprises [8].

3. RESEARCH METHODOLOGY

To ensure a comprehensive and evidence-based understanding of the economic viability of Makhana farming under smallholder conditions, this study adopted a mixed-methods approach that combined both quantitative and qualitative data collection and analysis. The research was conducted across three major Makhana-producing districts of North Bihar, Darbhanga, Madhubani, and Saharsa, where traditional pond-based cultivation practices are still prevalent.

Primary data were collected through structured, face-to-face interviews with a total of 120 Makhana farmers, with 40 respondents selected from each district. The sampling process followed a stratified random sampling technique to capture diversity in farm size, ownership status (private or leased ponds), input usage, and market participation. This ensured that the findings reflected a broad cross-section of smallholder experiences across ecological and socio-economic contexts.

In addition to primary fieldwork, secondary data were sourced from institutional and governmental reports, including publications by the National Bank for Agriculture and Rural Development (NABARD), the Indian Council of Agricultural Research – Research Complex for Eastern Region (ICAR-RCER), and the Bihar State Agricultural Department. These documents provided valuable contextual information on cultivation trends, cost benchmarks, and policy interventions relevant to Makhana farming.

For data analysis, a combination of descriptive and inferential statistical techniques was employed. Cost-benefit analysis was used to assess the economic returns per hectare, factoring in input costs, labor expenditures, gross returns, and net profits. To statistically

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validate regional differences in yield and price patterns, Analysis of Variance (ANOVA)and independent sample T-tests were conducted. These tools helped identify whether the observed variations across districts were statistically significant or due to random fluctuations.

All quantitative data were cleaned and analyzed using Microsoft Excel for initial tabulation and Python (NumPy, SciPy, Matplotlib) for deeper statistical computation and data visualization. The integration of primary insights with institutional data and statistical rigor allowed for a holistic understanding of the profitability landscape of Makhana farming in North Bihar.

4. RESULTS AND DISCUSSION

4.1 Profitability Analysis

The economic analysis of Makhana cultivation under smallholder conditions reveals that the enterprise holds considerable potential for profitability, provided systemic constraints are addressed. Based on data collected from 120 farmers across three districts, the average total cost of cultivation per hectare was estimated at ₹45,000. This cost is broken down into three major components: input costs (₹15,000), which include seeds, fertilizers, and pest control materials; labor costs (₹18,000), which cover activities such as pond preparation, transplanting, harvesting, and drying; and operational costs (₹12,000), incurred in transportation, irrigation (where applicable), and basic post-harvest processing.

On the revenue side, the average gross return per hectare was found to be ₹85,000, calculated based on prevailing market prices and average yields reported by farmers. This results in a net profit of ₹40,000 per hectare, a substantial return for a single-season aquatic crop. The calculated Benefit-Cost Ratio (BCR) stood at 1.89, indicating that for every rupee invested, the farmer earns an additional ₹0.89 in profit. This BCR is notably higher than that of traditional cereal crops like paddy or maize, making makhana an attractive option for diversification, especially in flood-prone zones with access to natural ponds.

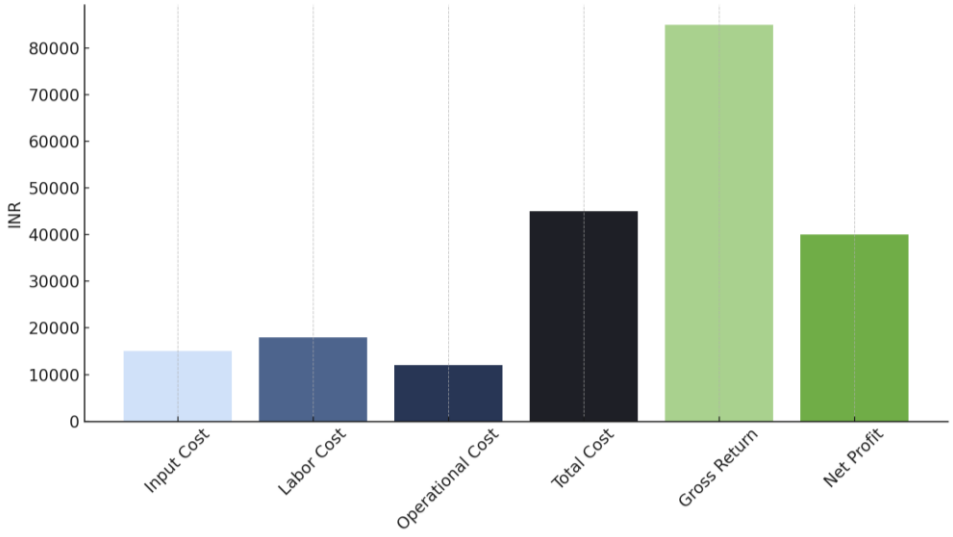

Figure 1: Cost and Return Breakdown

The profitability is further amplified when considering non-monetary benefits such as employment generation and the use of traditional knowledge systems. However, these financial gains are not uniformly distributed and are often influenced by regional ecological conditions, market access, and institutional support.

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4.2 District-Wise Yield and Market Price Analysis

Yield performance and market price vary significantly across the three focus districts, Darbhanga, Madhubani, and Saharsa. These variations influence farmer profitability and are important for determining location-specific policy recommendations.

District	Area under Cultivation (ha)	Average Yield (kg/ha)	Average Market Price (₹/kg)
Darbhanga	1450	1050	₹80
Madhubani	1680	1100	₹82
Saharsa	1320	970	₹78

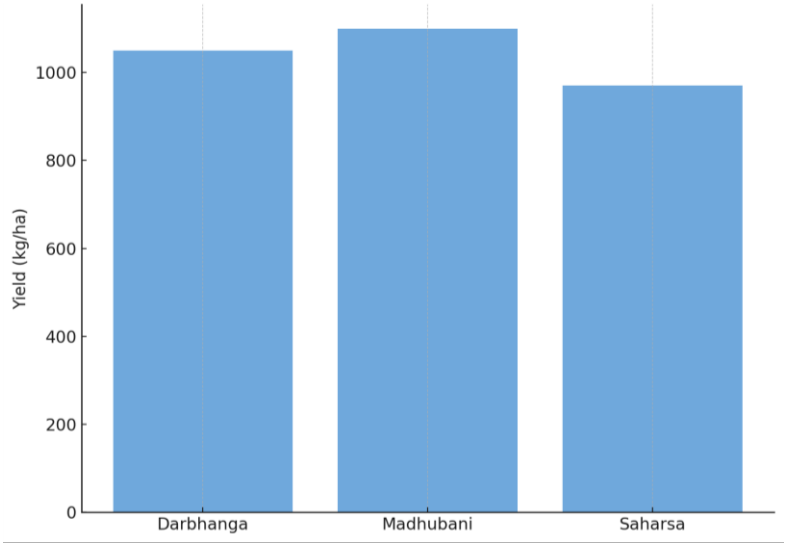

Figure 2: Yield per Hectare by District

The highest yield was recorded in Madhubani (1100 kg/ha), followed by Darbhanga (1050 kg/ha), and the lowest in Saharsa (970 kg/ha). Market price data also showed slight regional variations, with Madhubani again leading at ₹82/kg. These differences are attributed to a combination of factors, including pond depth and quality, technical know-how, exposure to government extension services, and access to drying and storage facilities.

The larger area under cultivation in Madhubani is also indicative of higher institutional interest and possibly better FPO (Farmer Producer Organization) penetration. In contrast, Saharsa's lower yield and price may stem from infrastructural deficits and limited market access, which require targeted policy attention.

4.3 Statistical Analysis

To validate whether the observed variations in yield across the three districts are statistically significant, both descriptive and inferential statistical tools were applied. The analysis began with calculating the mean yield and standard deviation for each district:

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i. Mean Yield:
    a. Darbhanga: 1054 kg/ha
    b. Madhubani: 1105 kg/ha
    c. Saharsa: 970 kg/ha

ii. Standard Deviation:
    a. Darbhanga: 24.08
    b. Madhubani: 11.18
    c. Saharsa: 14.57

These variations suggest that while productivity in Madhubani is relatively stable (lower standard deviation), Darbhanga shows more fluctuation, possibly due to variable water quality or labor availability.

To confirm if these differences are statistically significant, a one-way Analysis of Variance (ANOVA) was conducted:

i. F-statistic = 75.97

ii. p-value = 1.53×10^{-7}

The extremely low p-value (significantly less than 0.05) allows us to reject the null hypothesis, confirming that at least one district differs significantly from the others in terms of yield performance. This validates the observed regional yield disparity as statistically robust.

A further T-test was conducted between the two top-performing districts, Darbhanga and Madhubani, to assess if Madhubani's apparent lead is statistically significant:

i. T-statistic = -4.29

ii. p-value = 0.0058

The result confirms that Madhubani's yield advantage over Darbhanga is statistically significant, likely influenced by superior water management practices and better access to extension services. These results underscore the need for location-specific interventions rather than a uniform policy approach.

4.4 Key Challenges in Makhana Farming

Despite its evident profitability and market potential, Makhana farming in North Bihar is fraught with systemic challenges that limit its scalability and sustainability:

1. Market Dependence on Middlemen: A significant proportion of farmers rely on local traders and middlemen for selling their produce, leading to reduced price realization and poor negotiation power. The absence of organized procurement systems continues to depress farm gate prices [9].
2. Lack of Post-Harvest Infrastructure: As documented by Das (2021), 20–30% of harvested Makhana is lost due to poor drying, lack of storage, and absence of mechanized roasting units [10]. This not only affects quantity but also quality, directly impacting market price.
3. Limited Access to Credit and Insurance: Smallholders often lack access to formal credit lines, and agricultural insurance coverage for aquatic crops like Makhana is

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practically nonexistent. This makes them vulnerable to climatic shocks and sudden pest outbreaks [11].

4. Gender Disparity in Labor Compensation: Though women play a crucial role in labor-intensive tasks such as de-husking and grading, they are often paid less than male counterparts or remain unpaid in family labor structures [12]. Their economic contribution remains undervalued and unrecognized in formal value chains.
5. Inadequate Adoption of Digital Marketing: Most smallholder farmers are excluded from digital platforms that facilitate direct-to-consumer sales or online auctions. This restricts them to local markets with limited bargaining leverage [13].

These challenges underline the need for multi-pronged policy interventions, combining infrastructure, financial inclusion, and social equity measures to fully unlock the potential of Makhana farming in Bihar.

5. FUTURE SCOPE AND CONCLUSION

The findings of this study affirm that Makhana farming is a profitable and economically viable livelihood option for smallholder farmers in North Bihar. With relatively low input costs, modest capital requirements, and favorable gross returns, Makhana offers a strategic opportunity for rural income enhancement, especially in flood-prone and water-abundant regions. The average Benefit-Cost Ratio (BCR) of 1.89, as calculated in this study, reflects strong profitability per hectare, outperforming many traditional crops cultivated in the region.

However, this potential is yet to be fully realized due to several persistent structural and institutional barriers. One of the foremost challenges lies in the disparity of yields across districts, driven by variations in pond quality, farmer knowledge, and access to support services [14]. Similarly, direct access to high-value markets remains limited for most smallholders, who continue to rely on local intermediaries and informal networks. This dependence often results in suboptimal price realization and restricts farmers from scaling operations.

Moreover, the lack of modern post-harvest processing infrastructure, such as mechanized roasting and drying facilities, contributes to significant post-harvest losses, estimated to be as high as 30% in some areas. These losses reduce not only the marketable surplus but also the quality grade of the produce, leading to further price discounts. Additionally, gender disparities in labor contributions and compensation hinder inclusive growth in the Makhana value chain, with women undertaking labor-intensive post-harvest tasks often without formal recognition or fair remuneration [15].

To address these issues and unlock the full potential of the Makhana sector, several targeted interventions are necessary:

i. Formation and strengthening of Farmer Producer Organizations (FPOs) can enhance collective bargaining power, improve market access, and facilitate aggregation of produce for larger buyers and institutional markets.
ii. Investment in post-harvest processing units, especially mobile or community-level infrastructure, can reduce losses, improve product quality, and enable value addition at the grassroots level.
iii. Leveraging digital platforms and e-commerce channels can help farmers bypass intermediaries and access urban and export markets directly, thus increasing price realization and transparency.

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iv. The adoption of gender-sensitive policies and programs, such as fair wage practices, women-led cooperatives, and targeted skill development, can ensure equitable participation and empowerment of women in the value chain.

v. Region-specific training and extension services tailored to pond ecology, water management, and best agronomic practices can help reduce inter-district yield gaps and improve overall productivity.

Looking ahead, future research should focus on two critical areas. First, an assessment of the climate resilience of Makhana ponds is essential, especially in the context of increasing monsoon variability and flood risk in Bihar [16]. Understanding how climate change may affect pond water levels, crop cycles, and pest dynamics will be crucial for sustainable cultivation. Second, a detailed gendered value chain analysis is needed to trace women's roles, constraints, and contributions across different stages of Makhana farming, from cultivation to marketing. Such insights can inform inclusive policy design and programming.

While Makhana farming presents a promising avenue for enhancing rural livelihoods in Bihar, its sustained success depends on systemic reforms, investment in infrastructure, social inclusion, and adaptive strategies to future risks. If these challenges are strategically addressed, Makhana can serve not only as a source of income but also as a model for sustainable and equitable rural development in Eastern India.

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