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SMALLHOLDERS IN A HIGH-VALUE AQUATIC CROP SYSTEM: SOCIOECONOMIC PROFILE OF MAKHANA FARMERS IN NORTH BIHAR

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ABSTRACT

Makhana (Euryale ferox) is a distinctive high-value aquatic crop system that links wetland ecology, labour-intensive harvesting, and processing into an increasingly commercial value chain. Yet the socioeconomic base of the sector remains predominantly smallholder, shaped by land fragmentation, dependence on leased ponds/wetlands, informal marketing, and high exposure to flood risk. This study develops an empirical and transparent socioeconomic profile of makhana farmers in North Bihar by synthesising verifiable secondary sources and peer-reviewed field studies concentrated in the core producing belt. The analysis treats makhana cultivators as "smallholders embedded in a high-value aquatic system" and structures evidence on demographics, education, landholding and pond tenure, occupational diversification, labour organisation, institutional access (credit, cooperatives, extension), marketing channels and price realisation, assets and basic services, and risk and coping. Because district-level microdata for makhana households are not available in official public-use datasets, the study is explicitly a secondary-data profile; it does not estimate household regressions and documents limitations throughout. The results highlight a sector where small-owned land is commonly complemented by leased aquatic areas, where household labour availability interacts with drudgery-intensive operations, where collective institutions mediate access to ponds and marketing, and where market participation is constrained by informational asymmetry and price volatility. Policy implications emphasise tenure and water-body governance that protects small lessees, mechanisation and safety in processing to reduce drudgery, market infrastructure and price discovery, and risk-management packages aligned with the flood-prone ecology of North Bihar.

Keywords: Makhana; Euryale ferox; smallholders; pond leasing; North Bihar; Mithila; Kosi; value chain; rural institutions; flood risk

INTRODUCTION

Makhana, popped seeds of *Euryale ferox*, has shifted from a culturally embedded wetland food to a high-value commercial commodity, driven by urban demand for "healthy snacks", expanding retail channels, and export-orientated narratives. Bihar is consistently documented as India's dominant makhana producer, and official horticulture planning materials explicitly report that Bihar accounts for more than 85% of India's makhana production. [1] The same planning document identifies a cluster of North Bihar districts as major producers: Madhubani, Darbhanga, Sitamarhi, Saharsa, Katihar, Purnia, Supaul, Kishanganj and Araria, which provides a verifiable administrative basis for defining a "makhana belt" in the north floodplain. [1] The crop's distinctiveness is not merely botanical; it is systemic, relying on shallow standing-water ecologies (ponds, oxbow-like wetlands, seasonal waterlogged land), skill-intensive harvesting and processing stages (drying, grading, roasting, popping) that have historically relied on manual labour and specialised aquatic skills, making socioeconomic outcomes strongly dependent on labour organisation and tenure access rather than owned land alone. [1]

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This context has become more policy-salient as the Government of India has operationalised a National Makhana Board and rolled out a ₹476.03 crore Central Sector Scheme covering 2025–26 to 2030–31, with an explicit roadmap for research, quality seed production, value addition, branding, and export promotion. [2] At the same time, a major joint institutional report on makhana emphasises that the domestic value chain is largely unorganised, that reliable market data are limited, and that price realisation and farmer share vary across channels, raising a distributional question: can a high-value commodity boom translate into broad-based welfare gains when producers remain smallholders operating through leased aquatic tenure and intermediary-dominated marketing? [3] A district-anchored socioeconomic profile is therefore essential for policy design because "makhana farmer" is not a homogeneous category; it is shaped by local hydrology, institutions governing pond leasing, household labour availability, and market access.

This study answers a development-economics question: who are makhana farmers in North Bihar, socioeconomically, and what does "smallholder commercialisation" mean in an aquatic crop system where access to ponds and processing capacity may matter as much as owned land? The contribution is a structured, empirical profile integrating district-level production geography with household-level distributions from published field surveys in core producing areas, interpreted through the lens of smallholder constraints, commercialisation pathways, and vulnerability. Because publicly available official microdata do not identify makhana households as a crop-specific group at the district scale, the study is explicitly a secondary-data profile and does not claim to estimate econometric models from unavailable microdata; limitations are stated where household-level inference cannot be supported.

STUDY CONTEXT (MAKHANA SYSTEM IN NORTH BIHAR)

North Bihar's makhana system is best understood as an interaction between floodplain hydrology and rural institutions. A peer-reviewed ICAR-linked extension study using Bihar district production figures reports that makhana plays a pivotal role in Bihar's rural economy, "particularly in the Mithilanchal and Kosi regions," and provides district production values for major producing districts that include Darbhanga, Madhubani, Saharsa, Supaul, Purnia and Katihar. [4] This evidence is consistent with Bihar's horticulture planning document that defines a major-producer cluster in precisely these north floodplain districts (along with a few neighbouring districts), reinforcing the belt-like geography rather than a single-district specialisation. [1]

The ecology is also coherent with flood-hazard evidence. A Flood Hazard Atlas for Bihar prepared by NRSC/ISRO describes flood hazard mapping and monitoring for Bihar and is produced in association with national and state disaster management authorities, situating much of North Bihar as structurally exposed to flood risk. [5] In such settings, makhana is simultaneously an opportunity and a risk-amplifying livelihood: it needs standing water, but extreme floods and strong currents can disrupt harvesting and damage the crop.

Horticulture outreach material hosted on ICAR e-Pubs discusses makhana's relevance to flood-prone and waterlogged regions while framing its performance as contingent on climatic and hydrological conditions rather than unconditional "resilience". [6] The broader institutional context also matters. Bihar's makhana DPR emphasises the crop's labour intensity, the centrality of processing and value addition, and the way markets extend beyond Bihar, implying a long chain where local price discovery can be weak and intermediation substantial. [1]

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LITERATURE REVIEW

Research on makhana has long emphasised agronomy, processing technology, and cost–return economics, with a smaller but policy-relevant body documenting farmer socioeconomic conditions and value-chain performance. A consistent theme is drudgery and health risk in processing, motivating mechanisation and improved post-harvest engineering. ICAR's public documentation on mechanising makhana popping explicitly frames mechanisation as a way to save health and improve livelihoods, signalling that technology access is not only about efficiency but also about distributional welfare for labour-intensive households. [7]

At the farm level, field-based economic studies show that labour and rent are central cost drivers. A Darbhanga economic analysis reports a total cost of cultivation of about Rs. 63,211/ha for pond systems and Rs. 76,356/ha for field systems; it reports that variable cost shares are high and that manpower costs exceed Rs. 33,000/ha, highlighting labour as the binding input. [8] These findings align with a smallholder commercialisation framing where profitability can be high, but liquidity needs and labour bottlenecks can constrain expansion and upgrading.

Socioeconomic profiling evidence, though still limited in district-comparable form, is available from published field surveys in core hubs. A Darbhanga survey study reports an age profile skewed older, low formal education, large household sizes and high joint-family prevalence, and a production structure where small owned land is complemented by leased ponds accessed through cooperative arrangements. [9] This strengthens the conceptualisation of makhana farmers as smallholders whose binding constraints are tenure access to water bodies, working capital for labour-intensive operations, and bargaining power in unorganised markets. Value-chain and export strategy evidence further highlights limited market data, unorganised marketing, and channel-dependent farmer shares. [3]

Institutional changes have become salient in recent years through GI branding and national schemes; the GI Registry records "Mithila Makhana" as a geographical indication, providing a verifiable anchor for place-based branding and potential price premia, though distribution of premia within the chain remains an empirical question. [10] The National Makhana Board scheme further formalises a pathway for coordinated investment in seed, training, and post-harvest infrastructure. [2]

Finally, vulnerability is inseparable from this system. Flood hazard documentation for Bihar indicates structural exposure that can create covariate shocks across villages, limiting informal insurance and amplifying the importance of formal risk-management instruments and resilient infrastructure. [5]

Data & Sampling Design

This study is designed as a secondary-data socioeconomic profile combining two evidence layers. The first layer is district-anchored production geography used to justify the makhana belt and provide a concentration lens. For this, the study uses an ICAR-linked peer-reviewed extension study that provides production values for major producing districts and explicitly situates makhana in the Mithilanchal and Kosi regions. [4] This layer is cross-validated with Bihar's horticulture DPR, which names the major producing districts and reports Bihar's national dominance in production. [1]

The second layer is household-level socioeconomic distributions drawn from published field surveys in the core belt. The principal household-profile evidence is from a published Darbhanga survey that reports categorical distributions for age, education, family size and

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structure, landholding categories, leased pond/land categories, and broad income-portfolio categories, including cooperative-mediated pond leasing. [9] Cost and labour indicators are taken from the Darbhanga economic analysis that reports per-hectare costs, labour costs, rent components, yields, and gross returns for pond and field systems. [8] Market structure and price-realisation evidence is taken from the ICRIER–APEDA report that synthesises secondary research and field visits, describing the value chain as largely unorganised and summarising channel-dependent farmer shares. [3]

Because official public-use microdata do not identify makhana growers as a crop household group at the district scale, the study does not claim statistical representativeness for all makhana farmers in Bihar. Instead, the inference is explicitly contextual: it documents what is supported by published evidence for core producing districts and uses state-level rural indicators only as contextual proxies for services and digital access. For that contextual layer, the study uses the NFHS-5 Bihar fact sheet compendium for rural infrastructure, insurance coverage, and internet use. [11]

VARIABLES & MEASUREMENT

The profile variables are organised into eight domains aligned with the "smallholders in a high-value aquatic crop system" framing. Demographic variables include the age-group distribution of farmers, education categories, household size distribution, and household structure (joint vs nuclear) as reported in the Darbhanga survey. [9] Dependency ratio is not reported directly in the household surveys used here; where demographic pressure context is needed, the study uses rural Bihar child-population shares and related household indicators from NFHS-5 as a proxy for the broader rural environment rather than as a makhana-household estimate. [11]

Social structure is handled cautiously. The Darbhanga survey discusses the involvement of the Mallah (fishermen) community in the study area; this is treated as localised evidence rather than a statewide caste-composition statistic because comparable district-wise distributions are not available in the cited sources. [9]

Landholding and aquatic access variables include owned land categories (hectares) and leased pond/land categories (hectares) from the Darbhanga survey, interpreted jointly as the relevant resource constraint set. [9] Tenure arrangement is captured qualitatively via the reported role of Fisherman Cooperative Societies in mediating pond leasing at the block level. [9]

Occupational structure and diversification are measured using the Darbhanga survey's portfolio categories (agriculture only; agriculture + aquaculture; agriculture + aquaculture + other jobs/business/labour). [9] Production ecology and labour organisation are proxied through cost structure and labour cost data from the Darbhanga economic analysis, including total cost, variable/fixed shares, manpower costs, rent components, yields, and gross returns. [8] Institutional access variables include cooperative-mediated leasing in the Darbhanga evidence and the broader policy architecture of the National Makhana Board scheme and export strategy emphasis on upgrading and market linkages. [2], [3]

Marketing and price realisation are measured using the ICRIER–APEDA report's evidence on market organisation and its compiled channel-wise farmer share ranges (treated explicitly as compiled/synthesised evidence). [3] Assets and basic services are proxied by NFHS-5 Bihar rural indicators on electricity, water, sanitation, clean fuel, health insurance coverage, and internet use to describe the enabling environment for formal finance and digital market

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information. [11] Risk and vulnerability are characterised using Bihar's flood hazard atlas to anchor the structural flood-risk setting of North Bihar districts. [5]

METHODS OF ANALYSIS

Because a publicly accessible microdataset that identifies makhana households across districts is not available in the sources used, the analysis is deliberately descriptive, comparative, and transparent. District production values are used to compute shares and a Gini coefficient as a spatial concentration proxy for production across listed producing districts, explicitly not as a household-inequality estimate. [4] Household-profile distributions are synthesised into cross-tab-style tables for demographics, education, household structure, owned land, leased pond access, and income diversification, interpreted as evidence on smallholder constraints and commercialisation conditions in a traditional hub. [9] Cost/labour indicators are extracted from the field-based economic analysis and interpreted in relation to labour organisation and capital constraints. [8] Infrastructure, services, insurance, and digital exposure are summarised using NFHS-5 Bihar rural indicators as contextual proxies for the environment in which makhana households operate. [11] The study does not estimate regressions or logits because the required household-level microdata with makhana identifiers are not available in these sources, and it avoids implying inferential strength beyond what secondary evidence can support.

RESULTS

Table 1. Study area and key agro-ecological/market features (North Bihar makhana belt)

District (North Bihar)	Reported makhana production (t)	Agro-ecological feature relevant to makhana	Market/institutional feature highlighted in sources
Darbhanga	7421.4	Floodplain/waterlogged ecology supports pond-based cultivation	Traditional hub; field studies and policy focus
Madhubani	7280.7	Mithila wetlands/ponds; traditional knowledge systems	GI-linked branding context ("Mithila Makhana")
Saharsa	5267.0	Kosi-linked floodplain; water variability	Flood exposure shapes risk and timing
Supaul	5182.8	Kosi basin; high flood/waterlogging incidence	Basin-linked vulnerability and market disruptions
Purnia	11652.9	Lowland waterlogged fields; reported commercializing zone	High-output district in production statistics
Katihar	11759.0	Mahananda/Kosi-linked lowlands; waterlogged pockets	High-output district in production statistics

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Study: District production values and "major producing districts" from ICAR-linked peer-reviewed extension study; district cluster and Bihar's national production dominance from Bihar Horticulture DPR; market structure context from ICRIER–APEDA export strategy. [1], [3], [4]

The district anchoring confirms that the makhana belt spans Mithila (Darbhanga–Madhubani) and Kosi/Seemanchal lowlands (Saharsa–Supaul–Purnia–Katihar), consistent across independent sources. [1], [4] This spatial clustering matters for smallholder commercialisation because tenure, labour requirements, and flood exposure can differ across sub-regions even within "North Bihar", implying that a single intervention template is unlikely to be distributionally efficient. [3], [5]

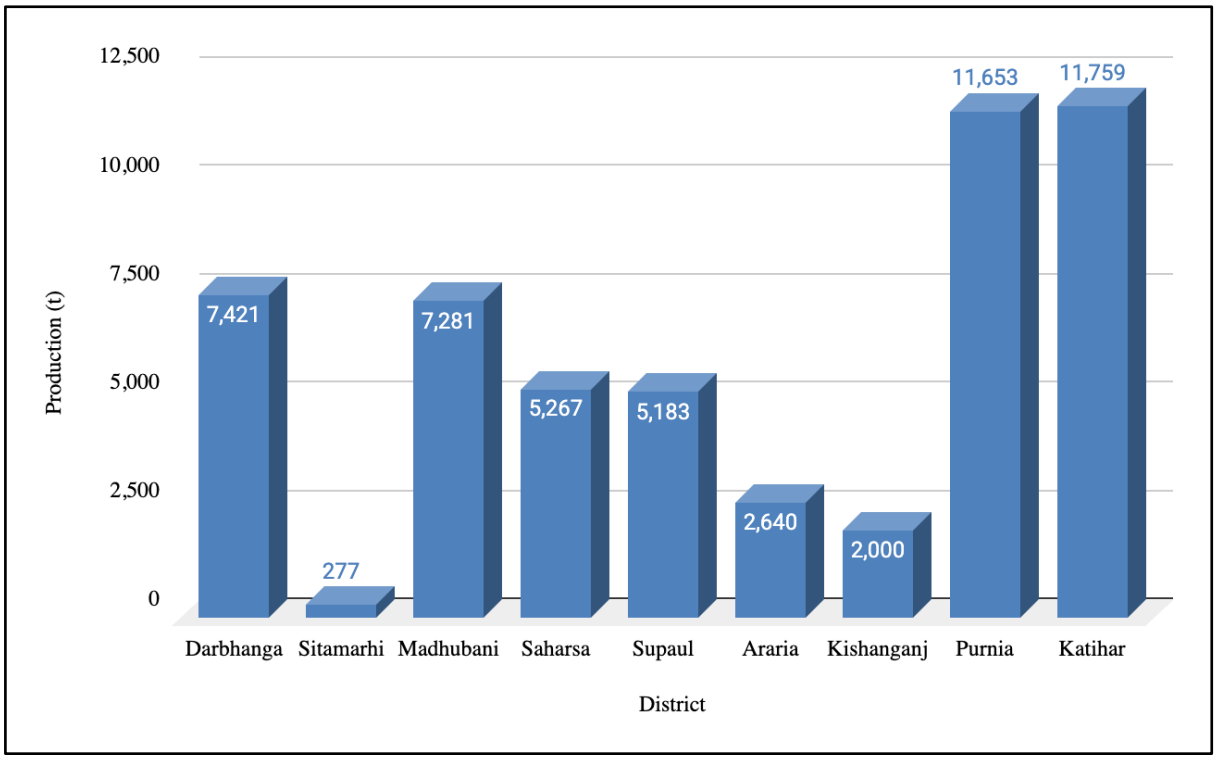

Figure 1. District distribution of makhana production in major producing districts of Bihar (t)

The production distribution is strongly concentrated at the upper end, with Katihar and Purnia at the top among the listed producing districts. [4] Treating these district totals as a spatial proxy yields a moderate concentration (Gini ≈ 0.36 across these nine districts), implying that value-chain investments that focus only on the most visible hubs risk leaving substantial producer mass outside the main infrastructure corridor. [4] This provides a structural rationale for profiling and policy targeting by district within the belt.

Table 2. Demographic and education profile (Darbhanga makhana farmer survey)

Indicator	Category	Share (%)
Age of farmer	20–29	8
	30–39	18
	40–49	20

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	50–59	22
	60+	32
Education	Illiterate	40
	Primary (up to class V)	46
	Secondary (VI–X)	12
	Intermediate (XI–XII)	2
	Graduate and above	0
Household size	1–5 members	4
	6–10 members	60
	11–15 members	30
	16–20 members	4
	21+ members	2
Household structure	Joint family	88
	Nuclear family	12

Source: Household survey distributions reported in the published Darbhanga study. [9]

The surveyed profile reflects binding human-capital constraints for smallholder commercialisation: the farmer age distribution is skewed older, and education is concentrated in illiterate/primary categories. [9] This pattern implies higher reliance on inherited local knowledge and networks but potentially weaker ability to engage with documentation-heavy formal credit, digital market information, and standardised grading/quality systems that increasingly shape high-value value chains. [3], [11] Large household sizes and joint-family prevalence can supply labour for drudgery-intensive operations, but they can also tighten liquidity by increasing consumption needs and dependency burdens, especially under covariate flood shocks. [5], [9]

Table 3. Landholding + pond access/tenure structure (Darbhanga makhana farmer survey)

Indicator	**Category**	**Share (%)**
Owned land (ha)	Up to 0.5	68
	0.5–1.0	30
	1–2	2
Leased pond/land for makhana (ha)	Up to 2	82
	2–4	16

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	Above 8	2
Tenure mediation (qualitative)	Leasing via Fisherman Cooperative Society (block level)	Reported mechanism

Source: Owned land and leased pond/land categories reported in the Darbhanga study; cooperative-mediated leasing mechanism reported in the same study. [9]

The core smallholder insight is that owned land is overwhelmingly marginal, but cultivation depends critically on leased aquatic areas, and that access is institutionally mediated. [9] This implies that land-based farm-size categories alone understate effective production capacity, and that pond leasing governance becomes a de facto land policy for the makhana economy, affecting entry barriers, rent extraction, and distribution of gains from commercialisation. [1], [9]

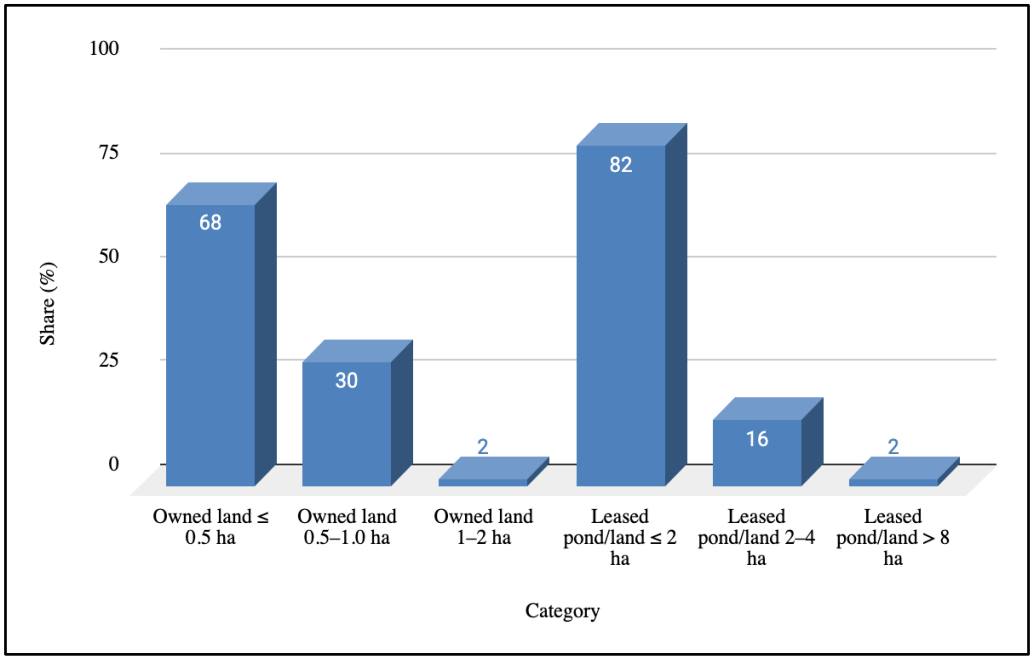

Figure 2. Smallholder structure in Darbhanga survey: owned land vs leased pond/land (share of farmers, %)

The duality shown here is fundamental to "smallholders embedded in an aquatic crop system": extremely small owned landholdings coexist with economically meaningful leased aquatic access. [9] Because leasing is mediated and rents are part of the cost structure, a rise in output prices can translate into rent increases rather than net welfare gains unless tenure arrangements protect small lessees and enable collective bargaining. [1], [8], [9]

Table 4. Income composition and diversification (Darbhanga makhana farmer survey)

Source-of-income portfolio	**Share of farmers (%)**
Agriculture only	4
Agriculture + aquaculture	34
Agriculture + aquaculture + other (job/business/labour work)	62

Source: Source-of-income portfolio categories from the Darbhanga study. [9]

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The majority of surveyed households combine agriculture and aquaculture with additional non-farm work, consistent with the idea that even in a high-value commodity system, liquidity needs and risk exposure generate diversification. [9] In development-economics terms, diversification can stabilise consumption but may reduce investable surplus for upgrading quality seed, better tools, and improved post-harvest practices, especially when markets are unorganised and price volatility is substantial. [3], [8]

Table 5. Cost/labour organization indicators (Darbhanga economics study; pond vs field system)

Indicator (per ha)	Pond system	Field system
Total cost of cultivation (Rs./ha)	63,211.09	76,356.53
Variable cost share of total (%)	79.73	62.81
Fixed cost share of total (%)	20.26	30.90
Manpower cost (Rs./ha)	33,107.11	32,333.33
Pond/land rent component (Rs./ha)	7,499	17,577
Production (raw makhana, quintal/ha)	19.60	24.21
Gross return (Rs./ha)	294,000	363,150

Source: Field-based economic analysis reporting costs, cost shares, manpower costs, rent components, yields and gross returns. [8]

Labour is a dominant cost driver in both systems, confirming that makhana is labour-absorbing but also vulnerable to labour scarcity, wage inflation, and the physical limits of an ageing workforce documented in the socioeconomic survey. [8], [9] The presence of sizeable rent components reinforces that tenure and rental markets directly affect cost competitiveness and net returns, making pond leasing governance a distributional determinant. [8], [9] The gross return figures explain why the crop is attractive, but the welfare question is how much net gain remains after labour and rent costs, and how that net gain is affected by market structure and bargaining power. [3], [8]

Table 6. Credit, extension, and institutional access

Dimension	Indicator (what is verifiably documented)	Evidence
Cooperative role in access	Pond leasing mediated through Fisherman Cooperative Society (block level)	Reported in Darbhanga survey
Upgrading agenda	Emphasis on interventions to address value chain inefficiencies, quality, and market linkages	ICRIER–APEDA report
Public investment pathway	₹476.03 crore scheme, 2025–26 to 2030–31, focusing on research, seed, value addition, branding, export promotion	PIB release
Digital information environment (proxy)	Rural Bihar: men who ever used internet 39.4%; women 17.0%	NFHS-5 Bihar fact sheet
Insurance coverage (proxy)	Rural households with any usual member covered under a health insurance/financing scheme: 15.1%	NFHS-5 Bihar fact sheet

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Source: Cooperative-mediated pond leasing from the Darbhanga survey; market/institution upgrading agenda from ICRIER–APEDA; national scheme architecture from PIB; rural internet use and insurance coverage context from NFHS-5 Bihar fact sheet. [2], [3], [9], [11]

Institutional pathways for improving smallholder outcomes exist through cooperative-mediated access and through national schemes emphasising training and post-harvest modernisation, but the enabling environment indicates constraints: digital exposure is limited, with a pronounced gender gap, and insurance coverage is low, which can reduce uptake of formal finance and market services. [2], [11] Where markets are unorganised and price discovery weak, these constraints can reinforce dependence on traders and informal credit, limiting smallholder share in the consumer rupee. [3], [11]

Table 7. Marketing channels and price realization indicators (secondary evidence; North Bihar focus)

Indicator	What the evidence indicates	Quantitative / qualitative value
Market structure	Largely unorganized; limited reliable market data	Qualitative summary
Price volatility	Volatility linked to supply shocks and market cycles	Qualitative summary
Farmer's share in consumer rupee (compiled range)	Farmer share varies across channels; one reported range is 34.20%–40.58% across three channels	Range reported in compiled evidence
Logistics and margins	Transport and logistics conditions affect realized margins across channels	Qualitative/illustrative evidence

Source: Market organisation, market data constraints, and channel-dependent farmer share ranges summarised in ICRIER–APEDA report. [3]

Commercialisation constraints are not only on-farm. Even when production economics are favourable, an unorganised market structure can weaken price discovery and bargaining power, and channel choice becomes a distributional mechanism because farmer shares vary across marketing pathways. [3] The policy implication is that strengthening aggregation, grading, and transparent market intelligence, often through FPOs and common facilities, can plausibly shift farmer shares upward, complementing production-side improvements. [2], [3]

Table 8. Risk/vulnerability indicators and coping (North Bihar floodplain system)

Risk dimension	What is verifiably documented for the region/system	Implication for makhana smallholders
Flood exposure (structural)	Flood hazard mapping indicates widespread flood-prone areas in Bihar, with major implications for North Bihar floodplains	Covariate shocks; production and harvest disruptions
Water-regime	Makhana is associated with standing-water ecologies; performance depends	"Too much" water in extreme

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sensitivity	on manageable hydrological conditions	events can be harmful
Market risk	Unorganized markets and market data gaps documented	Price shocks translate into income shocks, especially with debt
Services/insurance context (proxy)	Low rural insurance coverage	Weak formal shock buffering

Source: Structural flood risk from Bihar Flood Hazard Atlas; system context from Bihar horticulture DPR and ICAR outreach framing. [1], [5], [6]

Risk in this system is structural rather than idiosyncratic, and flood exposure implies covariate shocks that limit informal risk-sharing. [5] Because makhana depends on a manageable water regime, extreme events can create nonlinear losses even in a water-based system, and low insurance coverage in the rural environment suggests limited formal buffering. [6], [11] In such a setting, commercialisation can increase both upside and downside unless risk management (resilient storage, advisories, insurance/social protection linkages) is integrated into sector strategy. [2], [5]

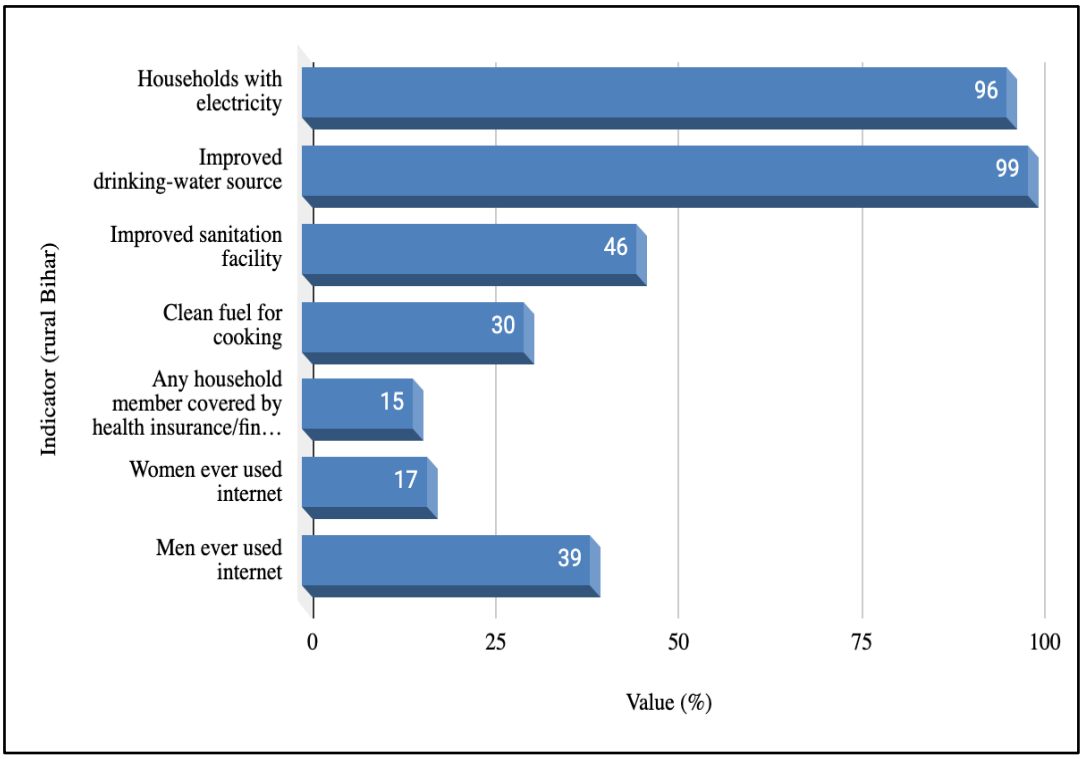

Figure 3. Basic services and digital exposure context for rural Bihar (NFHS-5; %)

Commercialisation in makhana occurs in a rural infrastructure setting with near-universal electricity and very high improved water access, but relatively weak sanitation and clean-fuel access, along with limited insurance coverage and substantial digital gender gaps. [11] These conditions matter for smallholders because they shape health burdens, time allocation (especially for women), and transaction costs for engaging with formal institutions and digital market information—factors that can determine who benefits from high-value value chain growth. [3], [11]

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DISCUSSION

The results support a coherent characterisation of makhana farmers in North Bihar as smallholders whose commercialisation prospects are governed by an interaction of tenure, labour, and market structure rather than by owned land alone. Household survey evidence from a traditional hub shows that owned land is typically very small, while cultivation depends on leased aquatic access, and that cooperatives can mediate the leasing process. [9] This dependence can be efficiency-enhancing if it reduces search costs and coordinates access, but it can also reproduce inequality if leasing is rationed, rents rise with commodity booms, or cooperative governance is not accountable to the smallest producers. [1], [9]

Labour organisation is the second central axis. Cost evidence shows that manpower is a dominant component of cultivation costs, and the profile evidence indicates an ageing farmer base and low education in the traditional hub. [8], [9] These patterns are consistent with ICAR's emphasis on mechanisation and improved processing technologies to reduce drudgery and health risks, which is inherently distributional: if smallholders cannot access equipment through common facilities, the benefits of mechanisation can be captured by better-capitalised actors, potentially widening inequality within the belt. [7], [8]

The third axis is market power and information. The ICRIER–APEDA report describes the makhana value chain as largely unorganised and highlights limited reliable market data, conditions that structurally shift bargaining power toward intermediaries and make farmer shares channel-dependent. [3] In such contexts, even high gross returns can translate into low and volatile net returns for smallholders, and the observed livelihood diversification patterns are consistent with households hedging risk and liquidity constraints. [9] The institutional response implied by current policy architecture—investment in seed systems, training, value addition, branding, and exports under the National Makhana Board—targets these bottlenecks, but distributional success depends on whether smallholders can access collective grading, processing, and market intelligence services rather than remaining price-takers. [2], [3]

Risk and vulnerability are structural in the floodplain ecology. Flood hazard mapping for Bihar situates North Bihar as chronically exposed to floods, and the crop's performance depends on a manageable hydrological regime rather than simply "more water". [5], [6] Low baseline insurance coverage and uneven digital access in rural Bihar can reduce the effectiveness of formal shock-buffering and information systems, intensifying reliance on informal coping and trader-linked credit after shocks. [11] This creates a classic smallholder risk trap in a high-value system: commercialisation increases exposure to price and production shocks unless risk management instruments are integrated into value chain upgrading. [2], [3], [5]

Inequality in the makhana system is therefore best conceptualised along three lines supported by available evidence: small owned land size in hub surveys; differential leased pond access mediated by institutions; and district-level variation in commercialisation intensity evident in production concentration. [4], [9]

CONCLUSION & POLICY IMPLICATIONS

This study provides an evidence-based socioeconomic profile of makhana farmers in North Bihar as smallholders embedded in a high-value aquatic crop system. The profile is grounded in verifiable district production evidence for the belt and in published household survey distributions from a traditional hub, complemented by field-based cost structures and contextual service and digital-access indicators. The central conclusion is that makhana

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commercialisation is shaped less by owned land expansion and more by access to leased aquatic tenure, drudgery-intensive labour organisation, market structure and price transparency, and floodplain risk exposure.

Policy implications follow directly from these mechanisms. Equitable growth requires transparent and accountable governance of pond and wetland leasing so that rising makhana demand does not translate primarily into rent extraction that squeezes small lessees. [9] Because labour costs dominate and the farmer base in traditional hubs is ageing and low-education, mechanisation and safety-focused post-harvest infrastructure should be deployed through common facility centres and producer collectives, aligning with national scheme priorities, rather than being left to private capture. [2], [7] Since the value chain is described as largely unorganised with limited market data, investments in transparent grading, aggregation, and price discovery are essential to raise farmer shares and reduce informational asymmetry. [3] Finally, because flood risk is structural in the belt, commercialisation strategies should integrate risk management—resilient storage, advisories keyed to hydrological thresholds, and insurance/social protection linkages designed for low digital access and low baseline coverage—to prevent widening inequality through asymmetric shock absorption. [5], [11]

A final implication concerns research infrastructure. The absence of open crop-identified microdata for makhana households at the district scale limits robust welfare evaluation and inequality monitoring as the sector scales. A statistically designed, publicly documented makhana household survey across the Mithila–Kosi–Seemanchal belt would materially strengthen evidence-based policy by enabling measurement of inclusion, gendered labour burdens, tenure security, market participation, and the distribution of gains from value chain upgrading. [2], [3]

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