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Shubrushu Singh
 PG Research Scholar,
 Department of Aquaculture,
 School of Agriculture, Sanjeev
 Agrawal Global Educational
 University, Bhopal, Madhya
 Pradesh, India

Shriparna Saxena
 Professor and Head,
 Department of Aquaculture,
 School of Agriculture, Sanjeev
 Agrawal Global Educational
 University, Bhopal, Madhya
 Pradesh, India

MK Yadav
 Assistant Professor,
 Department of Aquaculture,
 School of Agriculture, Sanjeev
 Agrawal Global Educational
 University, Bhopal, Madhya
 Pradesh, India

Corresponding Author:
MK Yadav
 Assistant Professor,
 Department of Aquaculture,
 School of Agriculture, Sanjeev
 Agrawal Global Educational
 University, Bhopal, Madhya
 Pradesh, India

Socio-economic analysis of fish farmers with special reference to constraints in aquaculture practices in Nuapada district, Odisha

Shubrushu Singh, Shriparna Saxena and MK Yadav

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Abstract

A comprehensive socio-economic survey of 130 inland fish farmers was conducted in the drought-prone Nuapada district of Odisha, India, to evaluate their socio-economic profile, identify critical constraints hindering aquaculture expansion, and establish empirical relationships between socio-economic parameters and farm productivity. Primary data were gathered through a pre-tested structured interview schedule administered across three randomly selected blocks. Pearson correlation analysis indicated that training exposure ($r = 0.62, p < 0.01$), pond size ($r = 0.58, p < 0.01$), and institutional credit access ($r = 0.53, p < 0.01$) exhibited the strongest positive and statistically significant relationships with fish productivity. Garrett's ranking technique identified water scarcity (mean score: 82.40) as the paramount operational constraint, followed by high commercial feed costs (78.60), poor quality seed supply (72.30), lack of extension and technical guidance (69.50), and market price volatility (65.20). The empirical findings revealed a mean fish productivity of 2,850 kg/ha/year and a mean annual net income of rupees 1,85,000 per aquaculture household. The study demonstrates that multi-pronged institutional support focusing on water harvesting infrastructure, quality input delivery, capacity building, and institutional credit is indispensable for transforming smallholder aquaculture into a sustainable and resilient rural livelihood strategy in drought-vulnerable agro-ecosystems.

Keywords: Socio-economic profile, inland aquaculture, Garrett ranking, constraints analysis, Nuapada district, Odisha, productivity determinants

1. Introduction

Aquaculture represents one of the fastest-growing food production sectors globally, playing a pivotal role in strengthening global food security, mitigating rural poverty, and offering high-quality animal protein. According to the Food and Agriculture Organization (FAO, 2023) ^[14], aquaculture currently supplies over 50% of the total fish destined for direct human consumption worldwide. In developing economies, small-scale freshwater fish farming provides vital opportunities for income diversification, employment generation, and socio-economic empowerment among rural households (Ali & Hossain, 2022; Rahman *et al.*, 2022) ^[3, 30]. Because fish is exceptionally rich in bioavailable essential fatty acids, micro-nutrients, and essential amino acids, sustainable aquaculture development aligns directly with several United Nations Sustainable Development Goals (SDGs), notably SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 8 (Decent Work and Economic Growth) (Belton *et al.*, 2020; Bene *et al.*, 2021) ^[5, 6].

India ranks second in global aquaculture production, with freshwater aquaculture constituting the major share of the inland sector (ICAR, 2022). Central government flagship programs, such as the Blue Revolution scheme and the Pradhan Mantri Matsya Sampada Yojana (PMMSY), have significantly propelled sector growth through capital subsidies, technological adoption, and infrastructure development. However, the spatial trajectory of aquaculture growth remains heterogeneous across states and ecological zones. Regionally backward, drought-prone, and rain-fed districts continue to face acute structural, socio-economic, and environmental bottlenecks that hamper full realization of their aquaculture potential.

Empirical literature underscores that socio-economic characteristics such as educational attainment, farming experience, land and pond holdings, credit accessibility, capacity

building through training, and extension contact substantially dictate technology adoption, production efficiency, and overall farm profitability (Davis *et al.*, 2021; Rao *et al.*, 2021; Sharma *et al.*, 2020) [11, 31, 33]. Smallholder farmers possessing enhanced institutional access are better positioned to adopt modern management practices and realize higher unit yields (Kumar *et al.*, 2022; Singh *et al.*, 2022b) [21, 35]. Conversely, resource-poor farmers encounter persistent hurdles, including capital constraints, inflated input costs, poor quality seed stock, and weak market bargaining power (Nguyen & Nguyen, 2022; Sahoo & Jena, 2021) [26].

Superimposed on socio-economic vulnerabilities, climate-induced hazards pose severe threats to aquatic food production systems. Changing precipitation patterns, extended dry spells, and thermal stress severely disturb pond hydrodynamics, water quality, stocking densities, and fish growth rates (Campbell *et al.*, 2022; IPCC, 2023; Mohanty *et al.*, 2022) [8, 23]. Environmental stressors documented across freshwater aquatic ecosystems highlight that water quality degradation and water volume contraction lead to significant biological and productivity decline (Dar *et al.*, 2022; Kassam, 2021; Tiwari & Singh, 2024) [9, 20, 37].

Odisha is recognized as one of India's primary fish-producing states; nevertheless, its western region including Nuapada district remains economically underdeveloped and ecologically vulnerable. Nuapada is characterized by frequent drought cycles, low irrigation coverage, and rain-dependent agriculture. While pond-based inland aquaculture has been identified as a strategic non-farm livelihood alternative for rural resilience in the district, its expansion is restricted by a complex web of environmental, socio-economic, and institutional barriers (Das & Panda, 2023; Patel & Swain, 2023; Pradhan *et al.*, 2024) [10, 27, 29]. Furthermore, modern intervention studies (e.g., biofloc technology and water conservation models) emphasize that intensive institutional handholding, structured training, and water management are critical to optimizing small-scale aquaculture operations (Ahmed & Thompson, 2019; Naylor *et al.*, 2021 and World Bank, 2022) [2, 25, 39].

2. Materials and Methods

2.1 Research Design

A combined descriptive and analytical cross-sectional research design was adopted. The descriptive framework was utilized to delineate the socio-demographic profile and operational practices of inland fish farmers, whereas the analytical component focused on evaluating bivariate correlations and ranking constraint severities using structured quantitative tools.

2.2 Study Area

The study was conducted in Nuapada district, situated in the western agro-climatic zone of Odisha, India. Nuapada lies between 20°0' N to 21°0' N latitude and 82°20' E to 82°53' E longitude. The district is characterized by a semi-arid, drought-prone climate, predominant reliance on monsoon rainfall, constrained irrigation networks, and marginal landholding patterns. Nuapada was purposively selected due to its high ecological vulnerability to drought and its promising, yet underutilized, potential for inland aquaculture development.

2.3 Sampling Procedure and Sample Size

A multi-stage random sampling strategy was implemented to select respondents across the administrative divisions of

Nuapada district. The multi-stage sampling framework is detailed in Table 1.

Table 1: Multi-stage sampling framework of the study area

Stage	Sampling Level	Methodology
Stage I	District Level	Nuapada District selected purposively based on vulnerability to drought and inland fishery scope.
Stage II	Block Level	Three (3) Development Blocks selected randomly out of 5 blocks in Nuapada district.
Stage III	Village Level	Six (6) Gram Panchayats / Villages selected randomly (2 villages per selected block).
Stage IV	Farmer Level	130 active inland fish farmers selected randomly from sampling frames provided by local fishery extension officers.

2.4 Data Collection

Primary empirical data were gathered through face-to-face personal interviews using a standardized, pre-tested structured interview schedule. The schedule comprised distinct modules capturing socio-economic and demographic parameters, pond operational characteristics, production economics, institutional linkages, and operational constraints. Field pre-testing was conducted on 15 non-sample fish farmers to refine instrument clarity and construct validity. Secondary data were collated from official reports of the Department of Fisheries (Government of Odisha), District Statistical Handbooks, ICAR publications, and FAO reports.

2.5 Selection of Variables

The study incorporated key quantitative and categorical variables classified into independent and dependent parameters: first Independent Variables: Age (years), Education level (attainment categories), Family size (members), Landholding size (ha), Pond size (ha), Farming experience (years), Training exposure (days of formal training received), Extension contact index, and Access to institutional credit (dummy variable) and second is Dependent Variables: Annual fish productivity per unit area (kg/ha/year) and Net annual household income derived from aquaculture (rupees/year).

2.6 Statistical Analysis

Data were analyzed using descriptive statistics, means, and standard error for socio-economic profiling, Pearson's correlation coefficient to evaluate relationships with productivity.

3. Results and Discussion

3.1 Socio-Economic Profile of Inland Fish Farmers

Understanding the demographic composition of fish farmers is essential for designing targeted extension strategies. Table 2 presents the age distribution of the surveyed farmers.

Table 2: Age distribution of surveyed inland fish farmers (n = 130)

S.No	Age Group	Frequency (f)	Percentage
1.	Below 30	18	13.85
2.	31 - 45	62	47.69
3.	46 - 60	38	29.23
4.	Above 60	12	9.23
5.	Total	130	100

As shown in Table 2, nearly half of the respondents (47.69%) fell into the middle-aged group of 31-45 years, indicating that aquaculture in Nuapada district is predominantly managed by economically active, working-age individuals. Farmers aged 46-60 years constituted 29.23%, while youth (<30 years) represented 13.85%. Elderly farmers (>60 years) comprised 9.23% of the sample. The predominance of middle-aged farmers (47.69% in the 31-45 years age bracket, followed by 29.23% in the 46-60 years group) reveals that inland aquaculture in Nuapada district is primarily managed by economically active, experienced individuals. Fish culture demands intensive manual labor, regular pond monitoring, and the financial capability to bear production risks attributes characteristically found in middle-aged operators. These findings are in close agreement with Gautam *et al.* (2007) [16], Biswas *et al.* (2018) [7], and Adewuyi *et al.* (2010) [1], who reported that the middle-aged cohort forms the dominant workforce in freshwater aquaculture due to their stability, risk-bearing capacity, and active decision-making authority in family enterprises. Similar demographic trends among inland fishers and farmers have also been documented by Moni and Khan (2014) [24] and Sujathkumar (1988) [36]. The relatively low participation of youth (13.85% below 30 years) indicates critical barriers to entry, such as limited access to capital, lack of independent land/water body ownership, and alternative preferences for immediate wage-earning opportunities or urban migration. As highlighted by Wetengere (2009) [38], while younger individuals possess high energetic potential and innovativeness, structural constraints often impede their direct entrepreneurial involvement in farming. The educational attainment level of respondents is summarized in Table 3.

Table 3: Educational Attainment Level of Respondents (N = 130)

S.No	Production Parameter	Mean Value	Unit of Measurement
1.	Average Operational Pond Area	0.78 ± 0.24	Hectares (ha)
2.	Mean Fish Productivity	2,850 ± 410	Kilograms per Hectare per Year (kg/ha/yr)
3.	Mean Annual Income from Aquaculture	1,85,000 ± 22,500	Indian Rupees (₹/year)

The educational profile indicates that 83.08% of fish farmers possessed formal literacy, with secondary education being the single largest category (35.38%), followed by primary schooling (30.77%). Higher secondary and tertiary educated farmers accounted for 16.92%, while 16.92% were illiterate. Operational parameters, productivity figures, and income realized from inland fish farming operations are summarized in Table 4. The mean operational pond size was 0.78 ha. The mean fish productivity achieved in the district stood at 2,850 kg/ha/year, yielding a mean annual net income of ₹1,85,000 per farming household. Farmers with access to formal training and institutional credit consistently achieved higher yields.

3.1 Correlation Analysis of Socio-Economic Determinants and Productivity

To evaluate the influence of socio-economic parameters on farm output, Pearson correlation coefficients were

calculated between selected independent variables and fish productivity (kg/ha/year). Results are presented in Table 5.

Table 5: Pearson correlation coefficients between socio-economic variables and fish productivity

S.No	Socio-Economic Variable	Correlation Coefficient (r)	Significance Level	Socio-Economic
1.	Training Exposure	0.62**	$p < 0.01$ (Highly Significant)	Training Exposure
2.	Pond Size (ha)	0.58**	$p < 0.01$ (Highly Significant)	Pond Size (ha)
3.	Institutional Credit Access	0.53**	$p < 0.01$ (Highly Significant)	Institutional Credit Access
4.	Extension Contact Index	0.49**	$p < 0.01$ (Highly Significant)	Extension Contact Index
5.	Education Level	0.46**	$p < 0.01$ (Highly Significant)	Education Level

All analyzed socio-economic factors exhibited positive and statistically significant correlations with fish productivity ($p < 0.01$). Training exposure demonstrated the strongest association ($r = 0.62$), indicating that skill development directly promotes scientific pond management, optimal stocking, balanced feeding, and prophylactic health management. Operational pond size ($r = 0.58$) reflected economies of scale, while institutional credit access ($r = 0.53$) facilitated timely purchasing of commercial feeds and quality seed stock.

3.4 Garrett's Constraint Ranking Analysis

Major operational, technical, and environmental constraints reported by respondents were prioritized using Henry Garrett's ranking technique (Table 6).

Table 6: Prioritization of aquaculture constraints using Garrett's ranking technique

S.No	Operational Constraint	Mean Garrett Score	Overall Rank Assigned
1.	Water scarcity and seasonal drying of ponds	82.40	Rank I
2.	High cost of commercial formulated feed	78.60	Rank II
3.	Non-availability of certified quality fish seed	72.30	Rank III
4.	Lack of timely technical guidance and extension	69.50	Rank IV
5.	Market price fluctuations and middleman exploitation	65.20	Rank V

Water scarcity emerged as the single most critical constraint (Garrett score: 82.40). Due to Nuapada's drought-prone ecology, seasonal ponds dry up prematurely, truncating the culture period and escalating fish mortality. High feed cost ranked second (78.60), reflecting severe margin compression. Poor quality seed (72.30), inadequate extension contact (69.50), and price volatility due to middleman dominance (65.20) followed in severity. The highly significant positive correlation of training exposure ($r = 0.62$), pond size ($r = 0.58$), credit access ($r = 0.53$), and extension contact ($r = 0.49$) with fish productivity corroborates the findings of Kumaran *et al.* (2012) [22] and Sathiadhas *et al.* (2003) [32], demonstrating that institutional support and technical capacity are crucial drivers for enhancing yield and achieving economies of scale.

However, the realization of full production potential is severely impeded by seasonal water scarcity (Garrett score: 82.40) and escalating feed costs (78.60), which emerged as the topmost operational bottlenecks in Nuapada district. These constraints align with observations by Pradhan *et al.* (2018) ^[28] and De *et al.* (2012) ^[12] who noted that climatic vulnerability, truncated culture cycles, and input inflation significantly compress farmer margins in rain-fed regions. Furthermore, high ranking of seed quality deficits and marketing exploitation (scores 72.30 and 65.20) mirrors the structural marketing and input-supply gaps reported by Aswathy *et al.* (2014) ^[4]. Addressing these interrelated constraints requires integrating short-duration culture species, localized feed formulations, and strengthened institutional extension linkages to optimize pond productivity under water-limited regimes.

Conclusion

The study demonstrates that inland fish farming in Nuapada district is predominantly sustained by middle-aged, economically active farmers whose productivity is significantly enhanced by training exposure, operational pond size, credit access, and extension contact. However, realizing the sector's full economic potential is severely constrained by seasonal water scarcity, high commercial feed costs, and inadequate supplies of certified seed stock. To transition from subsistence to climate-resilient commercial aquaculture, policy interventions must prioritize developing decentralized seed rearing units, promoting cost-effective local feed formulations, and introducing short-duration culture species. Additionally, establishing robust institutional credit links and youth-centric capacity-building initiatives will be vital to ensure long-term livelihood security and sustainable aquaculture growth in the region.

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Competing Interests

The authors have no relevant financial or nonfinancial interests to disclose.

Author Contributions

All the authors contributed to the study's conception and design. Material preparation, data collection and analysis were performed by Shubrushu Singh and M.K. Yadav. The first draft of the manuscript was written Shubrushu Singh, and all the authors commented on previous versions of the manuscript. All the authors have read and approved the final manuscript.

Availability of data and Materials

The data will be provided upon request to the journal.

Conflict of interest

The authors state that there are no conflicts of interest regarding the publication of this research paper.

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Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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