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Composite fish culture for strengthening income of fish farmers: Micro-economic evidence from West Bengal, India

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Abstract

This study examined the economic aspects of composite fish farming with Indian major carps using cost concepts and the Cobb-Douglas production function. The study also highlights and elaborates on various aspects of resource use efficiency in West Bengal. The entire cost of setting up a fish pond in the region was estimated to be roughly ₹1,92,168 ha^{-1}. Variable costs and fixed costs accounted for approximately 95.07 and 4.92% of the total cost respectively. The return on investment per rupee was roughly ₹1.24, which suggests for opting fish farming as a profitable livelihood enterprise in the study area. The resource use efficiency demonstrated that the resources in fish production were not being used to their full potential. It has been observed that the production of fish can be increased significantly by involving more human labour and feed management. Loss of products owing to perishability, water scarcity during summer season and non-availability of labour were the key challenges experienced during the production of fish. Post-harvest management facilities like proper storage structure and cold chain need to be developed to overcome the problem of perishability. As the cost of feed and labour are increasing significantly over the years, it is essential to calculate projected profit before initiating a fish farming venture.

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Introduction

India is the third largest fish producing country in the world, with a total production of 14.164 million t in the year 2019-20, comprising 3.727 million t from marine fisheries and 10.437 million t from inland fisheries. Fisheries sector contributes about 1.07% to the overall GDP and 4.85% of the agricultural GDP in India (NFDB, 2019). Fish is a good source of animal protein and has long been considered a great source of minerals. Small fish with bones are especially high in calcium (Kaur *et al.*, 2014). Fish is high in vitamin A and B, as well as oils containing poly-unsaturated fatty acids, which can aid to lower blood cholesterol levels (Singh, 2005).

West Bengal is India's sixth largest economy and one of the wealthiest states, with inland water resources of various forms accounting for 23.09% of the country's total inland water resources (Roy, 2017). After Andhra Pradesh which contributed 3.61 million t, West Bengal ranks second in inland fish production with a contribution of 1.62 million t (DoF, 2020). With rising incomes, the demand for fish products has been growing in West Bengal as well as across India. Fish farmers of this state are quite enthusiastic towards fish farming and further the. climatic conditions of the state are also ideal for fish farming. However, input prices have grown quickly in recent years, as has the wage rate, resulting in a fall in income from fish production (Mishra *et al.*, 2021). In terms of pond preparation, stocking, supplementary feeding, post stocking management and harvesting, the input costs are high. The initial costs are the most significant impediment to resource-poor farmers participating in commercial aquaculture in rural locations (Obiero *et al.*, 2019; Mulokozi *et al.*, 2020; Uddin *et al*., 2021). Apart from the aforementioned issues, overfishing, lack of high-quality fish seeds, lack of market infrastructure and numerous socio-economic and environmental constraints have impacts on fish production (Biswas *et al*., 2019). The three Indian major carps (IMCs) *viz.*, catla (*Labeo catla*), rohu (*Labeo rohita*), and mrigal (*Cirrhinus mrigala*), account for majority of the country's carp production. Economic analysis of aquaculture using the IMCs, catla, rohu and mrigal was undertaken in this study.

Materials and methods

Description of study area and sampling design

The current study was conducted in Birbhum and Murshidabad districts of West Bengal. These districts, like much of the state, have high inland fish production. Out of the 23 districts in West Bengal, 12 districts contribute significantly to the state's inland fish production. In light of the Covid-19 situation, two districts were picked at random from among these 12 districts. One block from each district and then three villages from each block were chosen randomly (Fig. 1). Subsequently, 10 fish farmers were picked at random from each village. The study had a total sample size of 60 fish farmers. According to the size of their land holdings, these respondents were grouped into three categories *viz,* marginal (less than 1 ha), small (1-2 ha) and semi-medium (more than 2 ha). The study's primary data was obtained from fish-producing farms *via* personal interviews, using a pre-tested well-structured survey schedule pertaining to the year 2020-21. However, as the respondents did not maintain records of their farming operations, data from previous years were obtained based on their recall.

Economic analysis

Different economic parameters *viz.*, Labour man days, fixed cost, variable cost, depreciation, gross return, net return, return per rupee investment, cost of production and cost of production over variable cost were calculated for per hectare of pond area.

Gross return (₹) = Total production (kg) x Price (per kg)

Net returns (profit) = Gross returns - Total cost

$$\text{Benefit Cost Ratio} = \frac{\text{Net return}}{\text{Total cost}}$$

$$\text{Depreciation} = \frac{\text{Original value - Salvage value}}{\text{Economic life period (years)}}$$

Labour man days: (No. of working days x No. of working hours per days x No. of labour working per day)/ 8 h.

Functional analysis

Resource use efficiency in fish production was estimated by fitting the Cob-Douglas production function to the farm level data.

The equation was specified as follows:

log Y = log a+b1 log X1 + b2 log X2 + b3 log X3 + b4 log X4 + b5 log X5 + b6 log X6 + u

where, u stands for error term; Y=Return (₹ ha^{-1}), X_1= Labour cost (₹ ha^{-1}), X_2= Feed cost (₹ ha^{-1}), X_3= Fertiliser cost (₹ ha^{-1}), X_4 = Lime cost (₹ ha^{-1}), X_5 = Manure-mix cost (₹ ha^{-1}), X_6 = Seed cost (₹ ha^{-1}), a=Constant; b1 to b6 are elasticity coefficients of respective inputs.

Garrett's ranking technique was used to analyse the constraints faced by the fish farmers.

Percentage position = 100 (Rij−0.50)/Nj

where, Rij = Rank given for the i^{th} item by the j^{th} individual; Nj = Number of items ranked by the j^{th} individual.

Results and discussion

A farmer's socio-economic standing is a measure of his or her social position. It has an impact on the adoption of suggested

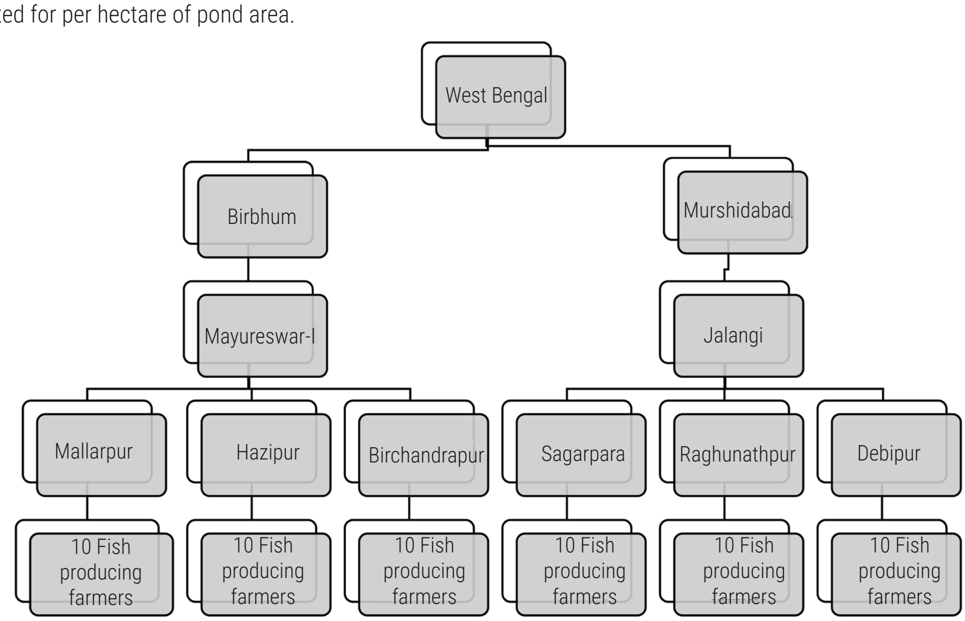

Fig. 1. Sampling design

farming methods and, as a result, on capital creation. Evidence reveals that farm size, pond size, education, age, family size, livestock distribution, cropping intensity and area under crops are all inextricably linked to income and capital creation. Farmers that perform both crop farming and fish production are examples of fish producers. Fish producing farmers are categorised according to classification of farm categories (Department of Agriculture, Govt. of West Bengal). They are divided into three categories *viz.,* marginal (less than 1 ha), small (1-2 ha) and semi-medium (2-4 ha). The average age of household heads in the marginal, small and semi-medium farm categories was 44, 48 and 53 years, respectively (Table 1). The majority of household heads in the marginal and small farm categories were between the ages of 36 and 50, whereas those in the semi-medium farm group were older than 50. In the marginal, small and semi-medium farm categories of fish producing farmers, majority of fish producers were educated up to primary level with 50.00, 51.61 and 63.63% respectively. The average land holding for marginal, small and semi-medium farms, were 0.69, 1.39 and 2.00 ha, respectively (Table 1). Semi-medium farms (63.50%) had the most irrigated land, followed by small (61.87%) and marginal farms (60.86%). For marginal, small and semi-medium farms, the average pond area was 0.35, 0.76 and 1.32 ha, respectively. Smaller farms had the highest number of livestock, followed by semi-medium and marginal farms.

Nature and type of crops grown predominantly determines the income of farmer. It can be seen from Table 2 that the existing cropping pattern followed by sample farmers in West Bengal. During kharif season respondents in the study area cultivated rice. The cropping intensity was found higher for semi-medium farms (168.00%) followed by small (166.18%) and marginal (160.86%) in the study area. Similar studies also support the fact that the farmers mostly grew crops like rice, jute, potato, vegetable, oilseed and pulse (Pal *et al.,* 2017; Roy, 2017).

Table 3 shows that farmers' annual income from combined farm and non-farm sources was ₹8,51,670.73. Fish farming appears to be the most important source of income, accounting for ₹5,70,817.93, *i.e.,* 67.02% of total annual income, followed by crop production at ₹2,08,175.50 (24.44%) and livestock at ₹19977.30 (2.34%). Other sources of income for fish producers in the target region were government and private jobs, which contributed ₹20,200.00 (2.37%), business at ₹20,000.00 (2.34%) and remittance at ₹12,500.00 (1.46%).

Table 2. Cropping pattern of sample farms in West Bengal

Crops	Farm categories		
	Marginal (<1 ha)	Small (1-2 ha)	Semi-medium (2-4 ha)
Rice	0.56	1.07	1.46
Potato	0.30	0.56	0.71
Jute	-	0.21	0.35
Vegetables	0.05	0.09	0.14
Oilseed	0.08	0.13	0.35
Pulses	0.11	0.21	0.35
Others including fallow	0.01	0.04	0.04
Gross cropped area	1.11	2.31	3.36
Net cropped area	0.69	1.39	2.00
Cropping intensity (%)	160.86	166.18	168.00

Table 1. Socio - economic feature of the sample farmers in the study area

Particulars		Farm category of fish farmers			Total (n=60)
		Marginal (<1 ha)	Small (1-2 ha)	Semi-medium (2-4 ha)	
Number of fish farmers		18	31	11	60
Age group (Nos.)	25-35 years	6 (33.33)	7 (22.58)	0 (0.00)	13 (21.66)
	36-50 years	9 (50.00)	16 (51.61)	4 (36.36)	29 (48.33)
	>50 years	3 (16.66)	8 (25.80)	7 (63.63)	18 (30.00)
	Total	18 (100.00)	31 (100.00)	11 (100.00)	60 (100.00)
	Average age	43.85	48.32	53.20	47.87
Educational level (Nos.)	Illiterate	5.00 (27.77)	9.00 (29.03)	0.00 (0.00)	14.00 (23.33)
	Primary	9.00 (50.00)	16.00 (51.61)	7.00 (63.63)	32.00 (53.33)
	Secondary	3.00 (16.66)	4.00 (12.90)	2.00 (18.18)	9.00 (15.00)
	Higher secondary	1.00 (5.55)	2.00 (6.45)	2.00 (18.18)	5.00 (8.33)
	Total	18.00 (100.00)	31.00 (100.00)	11.00 (100.00)	60.00 (100.00)
Family size (Nos.)	Male	3.21	3.44	3.63	3.40
	Female	2.13	2.24	2.39	2.23
	Average	5.34	5.68	6.02	5.63
Land holding pattern (ha)	Average land holding	0.69 (100.00)	1.39 (100.00)	2.00 (100.00)	1.29 (100.00)
	Irrigated area	0.42 (60.86)	0.86 (61.87)	1.27 (63.50)	0.80 (62.01)
	Un-irrigated area	0.27 (39.13)	0.53 (38.12)	0.73 (36.50)	0.48 (37.20)
Average area of pond (ha)		0.35	0.76	1.32	0.73
Livestock (Nos.)	Cattle	5.34	12.35	11.76	10.13
	Birds	8.75	11.37	10.43	10.41

Figures in parentheses indicate percentage of respective value

Table 3. Sources of annual income of sample fish producing farmers

Source of income	Overall average	%
Farm income		
Crop production	2,08,175.50	24.44
Livestock	19,977.30	2.34
Fisheries	5,70,817.93	67.02
Non-farm income		
Govt/Private job	20,200.00	2.37
Business	20,000.00	2.34
Remittance	12,500.00	1.46
Total	8,51,670.73	100.00

Cost and returns of inland fish farming in the study area

Fixed cost involved in fish farming

Table 4 shows the fixed costs necessary for fish farming on a per hectare basis. The overall cost of constructing a fish pond was ₹1,92,168.00. The major item of investment in the establishment cost was ₹65,738 for renovation and maintenance of the pond and pump house building, accounting for 34.19% of the overall investment cost. Other items comprised a submersible pump (₹3,134.00), cast net (₹28,118.00), boat (₹30,255.00), fencing (₹12,241.00), plastic crates (₹6,084.00), weighing machine (₹6,273.00), input-output pipe line (₹19,266.00), bore well (₹5,435.00) and feed room (₹15,624).

Table 5 shows the input use pattern in inland fish production in the study region, which shows that 191.70, 272.80, 5000.00, 480.00 and 3809.22 kg of fertiliser, lime, manures, fingerlings and feed were used on an average per hectare, respectively. The input use pattern of sample farms revealed fertiliser cost of ₹51.12 per kg, followed by lime (₹25.00), manure (₹1.00), fingerlings (₹200.00) and feed (₹52.11). The average number of labour man days per ha in the study region was 304, at a rate of ₹250.00 per man day. The average number of labours involved in pre-stocking, stocking and post-stocking management activities was 125.00, 63.00 and 116.00, respectively.

Table 6 shows the level of fish output in the study area. It means that the average number of rohu, catla and mrigal productions per ha were 1,227, 2,786 and 1,071 respectively. The average fish weights at harvest were highest for catla (1.40 kg fish^{-1}) followed by rohu (1.10 kg fish^{-1}) and mrigal (0.70 kg fish^{-1}). The average production of composite fish culture in inland fisheries was 6,000.00 kg ha^{-1}, with rohu, catla and mrigal production averaging 1,350.00; 3,900.00 and 750 kg ha^{-1}, respectively. In the study region, the sale (farm-gate) price of rohu, catla and mrigal was ₹170.00, ₹ 180.00, and ₹130.00 per kg respectively.

Table 4. Fixed cost of fish farming in the study area (₹ ha^{-1})

Particulars	Fixed cost (₹)	Share (%)
Renovation and maintenance of pond*	40,412.00	21.02
Pump house	25,326.00	13.17
Motors/Pump	3,134.00	1.63
Net	28,118.00	14.63
Boat	30,255.00	15.74
Fencing	12,241.00	6.36
Crates	6,084.00	3.16
Weighing machine	6,273.00	3.26
Input-output pipe line	19,266.00	10.02
Bore well	5,435.00	2.82
Feed room	15,624.00	8.13
Total	1,92,168.00	100.00

*Ponds are quite old (even two to three generations old) in West Bengal.

Table 5. Input use pattern in inland fish production in sample farm

Particular of input	Quantity or Nos. ha^{-1}	Rate (₹ kg^{-1})
Material		
Fertiliser (kg ha^{-1})	191.70	51.12
Lime (kg ha^{-1})	272.80	25.00
Manure (kg ha^{-1})	5000.00	1.00
Fingerlings (kg ha^{-1})	480.00	200.00
Feed (kg ha^{-1})	3809.22	52.11
Labour use (man days ha^{-1}) by activity		₹ per man-day
Pre-stocking	125.00	250.00
Stocking	63.00	250.00
Post-stocking	116.00	250.00
Total	304.00	

Costs and return analysis

The details on time-wise cost incurred in inland fish production on per hectare basis are presented in Table 7. The overall cost of producing inland fish was around ₹4,58,182.07 per ha, according to fish producers. The variable cost accounted for 95.07% of the overall cost (₹4,35,618.40), while the fixed cost accounted for 4.92% (₹22,563.67). The expenditure on feed products was the largest item of expenditure under variable expenses, accounting for ₹1,98,500.00 or 43.32% of the overall cost. On sample farms, this was followed by seed/fingerlings costs of ₹96,000.00 (20.95%) and maintenance costs of ₹10,000.00 (2.18%). Singh (2007) and Goswami *et al*. (2013), have shown that cost of fish fingerlings is a significant part of the expense in pond fish cultivation. The cost of labour accounted for ₹76,000.00, or 16.58% of the overall cost. Manure, fertiliser and lime costs formed 1.09% (₹5,000.00), 2.13% (₹9,800.00) and 1.48% (₹6,820.00), respectively, of the overall cost. The cost of medicine was ₹5,000.00 (1.09%). The overall variable cost of fish production, which was 6.21% of the total cost, includes interest on working capital (₹28,498.40).

Table 7 presents the gross and net returns received from fish production. The return realised by the producers was calculated by multiplying their average productivity by average price. The gross return from inland fish production was ₹10,29,000.00 per ha. In the study region, the equivalent numbers for rohu, catla and mrigal

Table 6. Levels of output in inland fish (composite) production

Fish species	Average no. of fish per ha	Average weight of fish (kg)	Average production (kg ha^{-1})	Average sales price (₹ kg^{-1})
Rohu	1227	1.10	1350.00	170.00
Catla	2786	1.40	3900.00	180.00
Mrigal	1071	0.70	750.00	130.00

were ₹2,29,500.00 (22.20%), ₹7,02,000.00 (68.22%) and ₹ 97,500.00 (9.47%), respectively.

Overall, net return of ₹5,70,817.93 ha^{-1} was obtained from fish production. Fish production costs were estimated to be about ₹76.36 kg^{-1}. Inland fish production earned a net return of ₹1.24 for every rupee invested, proving that it is financially viable. This suggests for opting fish farming as profitable livelihood enterprise in the study area. Fig. 2 depicts various cost components and returns. Debnath *et al.* (2014) reported the cost of construction of one kani pond under MNREGA scheme in Tripura is ₹3,00,000.00. Shiva *et al*. (2014) also reported ₹22,400.00 ha^{-1} for the same in Karnataka.

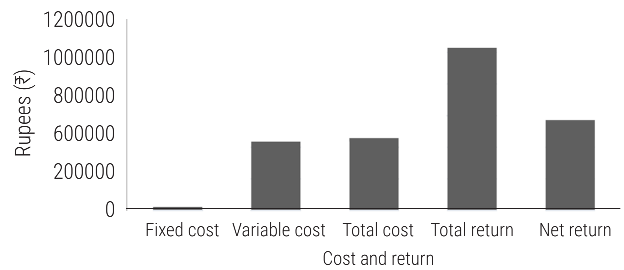

Fig. 2. Different cost components and returns

Resource use efficiency of inland fish production

The analysis was conducted to determine whether the production variables were being utilised to their full potential. Table 8 shows the Cobb-Douglas production function that was used to analyse resource use efficiency in fish production in the sampled farms. Before fitting the function to the data, a zero-order correlation matrix was used to resolve the multicollinearity.

The coefficient of multiple determination (R^2) of 71.50% meant that the several independent variables included in the model in Inland fish production in the target region explained 71% of the variations in return. Human labour (0.273) and feed (0.270) were found to be positive and significant at 5% probability level, whereas manures (0.113) were found to be significant at 1% level. This means that for every one percent increase in human labour, feed and manure expense, the gross return is likely to increase by 0.273, 0.270 and 0.113%, respectively. Similar findings were reported by Singh and Devi (2021).

Table 7. Costs and return analysis of Inland fish production in the surveyed farms

Particular/Items	Cost (₹ ha^{-1})	Share (%)
Variable costs:		
Labour charges	76,000.00	16.58
Material cost		
Seed	96,000.00	20.95
Feed	1,98,500.00	43.32
Manures	5,000.00	1.09
Fertiliser	9,800.00	2.13
Lime	6,820.00	1.48
Maintenance	10,000.00	2.18
Health care and medicine	5,000.00	1.09
Interest on working capital (@7%)	28,498.40	6.21
Sub total	4,35,618.40	95.07
Fixed cost		
Depreciation (@5%)	5,268.55	1.14
Interest on fixed cost (@9%)	17,295.12	3.77
Sub total	22,563.67	4.92
Total cost	4,58,182.07	100.00
Analysis of return		
Average fish production	6,000.00 kg/ha	
Rohu	2,29,500.00	22.30
Catla	7,02,000.00	68.22
Mrigal	97,500.00	9.47
Gross return	10,29,000.00	100.00
Net return	5,70,817.93	
Net return per rupees invested	1.24	
Cost of production (₹ kg^{-1})	76.36	
Cost of production over variable cost (₹ kg^{-1})	72.60	

Problems and constraints faced by the farmers

Table 9 summarises the issues that the farmers confront during the production process. The main issue that producers faced was loss of produce due to its perishable nature, which received an average score of 74.13, followed by a lack of sufficient water during the summer and non-availability of labour during various activities. Loss due to predators (57.53), non-availability of fingerlings at required location (50.03), lack of knowledge about source of feed and feeding practices (43.80), heavy investment (41.00) and non-availability of quality seeds (39.60) were the other major problems faced by the farmers in the order of importance. Producers noted that fish production in the inlands necessitated significant investment. As a result, shortage of cash was one of the primary issues in the study region. Other issues raised by fish producers were the lack of appropriate breeds of fingerlings (34.70) and the inability to get fingerlings in a timely manner (25.70). Several investigations in West Bengal and Rajasthan came up with similar results (Kumar *et al*., 2013; Rahaman *et al*., 2013).

Fish farming is an important economic activity for farmers in West Bengal, contributing roughly 67% of their yearly income. However, the initial financial investment required to commence fish production in the study area is substantial. Therefore, it is recommended that the government provide subsidies to fish farmers, particularly

Table 8. Estimated production function of inland fish production in the study area

Independent variables	Regression coefficients	Standard error	t stat	p value
Intercept	0.317	3.893	-0.294	0.769
Human labour (₹ ha^{-1})	0.273**	0.105	2.592	0.012
Fertiliser (₹)	0.144	0.120	1.191	0.238
Lime (₹)	-0.051	0.045	-1.122	0.266
Manure (₹)	0.113*	0.019	5.839	3.25E-07
Seed/fingerling (₹)	0.631	0.492	1.280	0.205
Feed (₹)	0.270**	0.103	2.618	0.011
R^2	0.715		-	-

*, ** indicates significant difference at 1% and 5 % probability level, respectively.

Table 9. Problems faced by fish producers in the study area

Problem	Avg. score	Rank
Loss of produce due to perishability	74.13	I
Shortage of water during summer	63.66	II
Non-availability of labour in time	62.73	III
Loss of produce due to predators	57.53	IV
Non-availability of fingerlings at required place	50.03	V
Lack of knowledge about source of feed and feeding procedure	43.80	VI
Requires heavy investment	41.00	VII
Non-availability of quality seeds	39.60	VIII
Non-availability of required breed of fingerlings	34.70	IX
Non- availability of fingerlings in time	25.70	X

small and marginal farmers, for the procurement of capital assets such as boats, cast nets, and pump house infrastructure, as well as for feed and fingerling, which account for the bulk of variable costs. The study also revealed that key inputs such as human labour, feed and manure, were underutilised despite their positive impact on productivity. Additionally, farmers demonstrated limited awareness regarding the availability of high-quality feed and appropriate feeding practices. This highlights the need for well-designed training and extension programmes through relevant line departments and agencies, focusing on production technologies, input and output marketing and post-harvest management. Furthermore, infrastructure such as proper storage facilities and cold chain systems need to be developed to address the issue of fish perishability.

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