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Economics & Technical Efficiency in Carp Culture

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Introduction

The fisheries sub-sector plays a significant role in Indian economic development. The estimated annual fish production rose from 0.752 million tonnes (mt) in 1950-51 to 4.949 mt in 1995-96, comprising 2.707 mt of marine fish and 2.242 mt of freshwater fish. It provides fulltime employment to 17,41,265 persons, part time employment to 13,26,983 persons and occasional employment to 22,89,010 persons in marine fishing. (Anon, 1991) Besides, hundreds of thousands of people are employed in fisheries related auxillary activites. In 1997-98, about 0.3 million tonnes of fish and fishery products were exported, fetching foreign exchange worth Rs 48,000 millions (1US$: Rs 42 approx), contributing about 4% of the country's total foreign exchange earnings. The sub-sector currently contributes 4.12% to the total GDP from agriculture.

Demand for fish in the Indian domestic market has been estimated at 12.5-20.0 mt. Out of India's total inland capture fish production of 2.24 mt in 1995-96, freshwater fish culture provided 1.38 mt of fish worth over Rs 40,000 millions. Carps form the main stay of Indian freshwater fish culture. Composite culture of three Indian major carps Catla (*Catla catla*), Rohu (*Labeo rohita*) and Mrigal (*Cirrhinus mrigala*) and three exotic carps, Common carp (*Cyprinus carpio*), Silver carp (*Hypophthalmicthys molitrix*) and Grass carp (*Ctenopharyncodon idella*) is the single technology most widely adopted in the country. The technology yielded 8-10 tonnes/ha/yr (hectare (ha)=10000m^2) However, the average yield realised by the farmers was reported to be about 15% of the highest yield obtained, indicating a widespread yield gap (Gupta. 1984). It is argued that bridging the gap between the maximum possible yield and the average yield realised by the fish farmers would help boost inland fish production significantly. (Jayaraman. 1995,1997 and 1998). The present study analysed the economics of carp culture, yield, yield variations and the causes of yield variations. and scope for enhancing carp production.

Materials and Methods

Forty fish farmers having fish ponds with a total area of 26.59 ha were randomly selected in the Thanjavur district, Tamil Nadu State. (India). The district was chosen purposively since it is the only district in which carp culture in owned, dug-out ponds is widely adopted. Further, homogenity in terms of aqua-ecological, soil and climatic conditions, and others were available in the district. A pre-tested enquiry schedule was used to collect information on status of technology followed, economics, yield, yield variations, marketing and constraints in carp culture.

Total Variable Cost (TVC) included all items of variable costs like inputs, and interest on variable cost at 4.5% p.a. Total Fixed Cost (TFC) included interest on capital costs at 10% p.a. and depreciation at 10-15% p.a. of various farm implements. Total income included sale proceeds of fish and other farm income. Total income minus total cost gave net income. Percentage and budgeting analyses were employed to analyze the data. The data collected covered the period from July 96 to June 97.

Analytical model

Economic efficiency is a combination of technical and allocative efficiencies. The study of technical efficiency, as to how carp farmers can maximize production with the existing production technology, and without additional cost, is of vital importance to planners, administrators and scientists. The frontier model provides adequate economic rationale to measure technical efficiency which refers to the proper choice of production function among those actively in use by farms. Allocative efficiency refers to the proper choice of input combinations. The widely used Cobb-Douglas production function assumes that all farms are technically efficient, and derives maximum output from any chosen level of inputs. The production function assumes constant returns to scale and a perfect competitive market. It neglects differences in the environments of farms compared. These assumptions are unrealistic because the optimum utilization of inputs depends on the farmers' level of knowledge about the chosen technology.

As the objectivity of the analysis is to measure yield gaps and explore the scope for enhancing farmed carp production, the Probabilistic Frontier Production Function (PFPF) model was used and is briefly explained below. Let the production function be:

$$\ln Y = \ln f(X) + W$$

where

Y is an (n x l) vector of observed outputs

X is a (n x k) matrix of inputs

W is the error term subject to the restriction, $0 \# e^{w} \# 1$

Suppose, the maximum yield-producing farm is observed to have a production plan (X^o, Y^o), such a plan is said to be technically efficient if $Y^o = f(X^o)$, and inefficient if $Y^o < f(X^o)$ and implies that there is still scope to raise production with the given technology bridging the gap in technology adoption. Its assumption of deterministic relationship is, however, a major limitation. Aigner et al. (1977) introduced a stochastic disturbance variable which had two components, a stochastic disturbance term, V_i and a one-sided efficiency disturbance, W_i and set a joint density function of U_i (error term):

$$\ln Y = \ln f(X) + (V+U)$$
$$U_i = V_i + W_i,\ W_i \# 0$$
$$\text{for all } i.$$

They named it Stochastic Frontier Production Function (SFPF). However, its estimation involved an iterative procedure and hence was not widely accepted. Farrel (1957) suggested a programming technique that minimizes the sum of absolute residuals or the sum of squared residuals under the constraint that all residuals be non-positive. However, this model is extremely sensitive to outliers. To overcome this, Aigner and Chu (1968) expressed the equation in probability form:

$$\text{Prob}\ \{3B_j X_{ij} \$ Y_i\} > P,$$
$$i = 1,2,3,.....n$$

where P is a specified probability within which the above statement holds. Essentially, this approach consists of estimating the frontier by using all observations and re-estimating the frontier by discarding first 100% efficient farms until the predetermined level of P is obtained. Timmer (1971) called this Probablistic Frontier Production Function and used it to measure technical efficiency. The frontier production function analysis helps to estimate bridgeable potential yield gaps in farming systems.

Results

Distribution Pattern of Ponds

Ponds measuring 0.40-0.80 ha each were dominant followed by those of less than o.40 ha each. (Table.1). The ponds of less than 0.80 he each accounted for 77.50% of the total number of ponds and 58.63% of the total fish pond area. The mean area of the ponds was about 0.67 ha.

Economics of carp culture

The respondents reported that carp culture was profitable. The average total cost was Rs.77,950/ha/ consisting of the total variable cost of Rs. 52,223 and the total fixed cost of Rs 25,727. The Total income and Net income were Rs. 1,45,824 and Rs. 67,874, respectively. (Table.2)

Mean yield and net income were found to be inversely proportional to the pond area. The mean yield varied from 2,364 kg /ha/ crop in the pond category 0.81-1.20 ha to 3,111 kg /ha/ crop in the case of ponds of less than 0.40 ha, each. A similar trend was observed in the case of net income as well . (Table-3).

Yield variations and its causes:

The mean yeild realised by the carp farmers was 4,317kg /ha/ yr. However, it ranged from 1,100 to 7,000 kg/ha/ yr. Inadequate use of the inputs recommended was observed to have largely caused the variations in the yield of farmed carps. Gaps in the input application, at average levels, were 22.33%, 20.00%, 22.00%, 5% for organic manure, urea, super phosphate and potash, respectively (Table-4). In the case of other inputs - ricebran, groundnet oilcake and stocking density - the levels of adoption were found to be more than that recommended.

The ponds were classified into five categories on the basis of yield and the pattern of input use on this basis. It revealed that yield variations were influenced to a great extent by the levels of input use. About 63.00% of the ponds had yields between 2,000 and 4,000 kg/ha/yr. Labour use did not vary much. Mean yield and net income seemed to be directly proportionate to the levels of input use. (Table-5).

The ponds were also categorised into six groups based on net income obtained by the respondents. The pattern of input use, net income groupwise, showed, once again, that as the levels of input use rose,the net income also went up. About 60.00% of the ponds had an average net income of upto Rs. 40,000 /ha/yr, while 7 ponds had net income between Rs. 40,000 and Rs. 60,000 /ha/yr. Only 7 ponds had income from 60,000 to Rs. 1,00,000 /ha/yr. (Table-6).

Production Function Estimates

An yield gap arises from technical inefficiency which marks failure to realise possible maximum yield. As described earlier, the PFPF measures the bridgeable yield gap for a specified level of probability. As it is difficult to aim at 100% efficiency atleast in the short run, an ad - hoc target of 60% efficiency was set, and that defined the probability level (P = 0.60). For this, the average production fuction was estimated and the PFPF was run in linear programming format that minimised total absolute deviation (MOTAD) by running the program in stages until the required probability was achieved (Table-7).

The results showed that all the functions had good fit and were valid for interpretation with the expected positive for all co-efficients having an R2 value of 0.87. All the functions showed increasing returns to scales. For the specified level of probability (0.60), the co-efficients stabilized. The technical efficiency of each pond was measured by the ratio of actual (observed) values of the regress and value of the fish produced to its estimated value in the equation that showed stability. The frequency distribution of technical efficiency index of the sample ponds is presented in (Table-8).

Discussion

Economics of carp culture

Carp culture was found to be profitable. The average total cost, total income and net income were Rs.77,950, Rs. 1,48,824 and Rs. 67,874, respectively. Among the various items of variable cost, feed topped (63,46%), followed by labour (11.10%), fingerlings (8.41%) and organic manures (6.53%) besides others. In the case of fixed cost, interest accounted for

79.50% of the total fixed cost, followed by repairs and maintenance (12.03%) and depreciation (8.47%).

The net income of Rs. 67,874 reported in the present study was over five times higher than the farm business income reported in carp culture in leased - out ponds in the same district during 1992-93 (Jayaraman, 1997) and 1993-94 (Jayaraman, 1995). The enhanced net income was caused by increase in the levels of adoption of the inputs recommended and appropriate adoption of the technology (Jayaraman, 1998).

The pattern of input use show a trend of inadequate use of some inputs and excess use of other inputs like fingerlings and feed. The farmers seemed to consider the number of fish fingerlings stocked. Many opined that stocking in excess of the recommended level of 6,000 number /ha could help tham to enhance yield. The mean stocking rate of 9,356 numbers /ha underscores this fact. Instead, the carp farmers could follow not only the recommended stocking rate but also the stocking size. Farmers stock seeds of varying sizes, mostly fry which could often result in low survival rate. Stocking of carp fingerlings at 6,000 numbers /ha with an average length of 50-60mm would help to achieve better survival, good growth and enhance yield.

A similar trend was seen in feed use also. While the recommended levels of ricebran (deoiled also) and groundnut oil cake were 1,500 kg/ha each, farmers use more of the former than of the latter input. Because, rice bran costs Rs. 2 per kg while groundnet oil cake costs Rs. 5-10 per kg. Use of pettet feeds could also be advantageous. Feed is the single most important production variable in carp culture which accounted for 63.46% of the total variable cost in the present study. Hence, the appropriate use of feed could aid in optimising its use in terms of cost incurred and yield realised.

The production function analysis showed that a 100% increase in the application of groundnut oil cake and fingerlings stocked would enhance the yield by 51.32% and 1.63%, respectively. The R2 value was 0.87 which implied that about 87% of the yield variations were explained.

Technical Efficiency

PFPF analysis revealed that already 21 ponds (52.50%) realised the maximum possible yield obtained by the most progressive farmer in the study sample. The remaining 19 ponds could enhance their yield, and technical efficiency by increasing appropriate use of the inputs recommended in due course of time. It may not be possible for them in the short run unless farm specific constrains, if any, were removed, and the technology was adopted fully. Regular contact with extension agencies and participation in training programmes would benefit the carp farmers in rationalising input so as to minimise inputs and thereby reduce costs. It would also help farmers to optimise net income from carp culture so that the farming operations become economically sustainable.

Globally, marine fish landings show a trend of stagnation whereas aquaculture production is steadily increasing. It has increased from 12.109 mt (1994) to 17.13 mt (1997) in inland and from 8.6 mt (1994) to 11.14 mt (1997) in marine sectors. Fish production in India is consistent with the global trend. Though the annual fish production has increased from 0.752 mt in 1950-51 to 4.949 mt in 1995-96, marine landings have not shown any substantial increase since 1990. Aquaculture seems to hold the key to augment fish production for domestic and export markets. FAO recently projected that the world fish production would go up by 2.69 times in 2025, growing from 122 mt in 1997 to 175 mt in 2025. Based on this projection, aquaculture should provide 53 mt to bridge the widening gulf between demand for and supply of fish, particularly where it is needed most.

India, as a leading country in Asia in aquaculture production, should be able to achieve at least 4 mt through aquaculture by the year 2025, i.e. 8% of the projected global aquaculture production of 51.8 mt. Besides, with the improvements in the domestic marketing, diversification of marine products exports, availability of a large number of culture technologies and different hydroclimatic zones for carpculture and seafarming, India could become a major player in world aquaculture production. Formulation and adoption of optional farm production plans would immensely benefit the carp farmers to optimise production on a sustainable basis.

Table 1. Distribution pattern of ponds (ha)

Pond Category	Area range (ha)	Total area (ha)	Average area (ha)	Number of ponds
I	0.01-0.40	4.29	0.31	14
II	0.41-0.80	11.30	0.67	17
III	0.81-120	6.40	1.07	6
IV	Over 1.20	4.60	1.53	3
	Total	26.59	0.67	40

Table 2. Economics of carp culture

Input	Quantity (kg)	Cost (Rs)	%
A.Total Variable Cost (TVC)			
Lime	506	1,249	2.39
(RCD) Raw Cow Dung	11650	3,410	6.53
Urea	160	661	1.27
Superphosphate	195	805	1.54
Muriate of Potash	38	200	0.38
Seed (Number/ha)	9356	4,392	8.41
Rice bran	9419		
Groundnut Oil cake	1996	33,139	63.46
Other feeds	816		
Labour (mandays)	145	5,792	11.10
Others		2,575	4.92
Total		52,223	100.00
B. Total Fixed Cost (TFC)			
Interest		20,454	79.50
Depreciation		2,178	8.47
Repairs & Maintenance		3,095	12.03
Total		25,727	100.00
C. Total cost (TC)		77,950	
Total Income (TI)		1,45,824	
Total Cost (TC)		77,950	
Net Income (NI)		67,874	
Yield (kg)		4,317	
Price(Rs/kg)		33.78	
Cost		18.06	
D. Cost - benefit ratio			
On TVC ratio		2.79	
On TC ratio		1.87	

Table 3. Economics of Carp Culture

(Rs / ha / Crop)

Pond category	Area range (ha)	No. of Ponds	Total Income	Total Cost	Net Income	Yield	Total	Area (ha) Average
		14	14,11,	6,83,7	7,27,9	43,5	4.29	0.31
I	up to 0.40	A	1,00,8	48,842	51,998	3,11		
		17	16,97,	8,72,8	8,24,1	48,7	11.3	0.67
II	0.41 - 0.80	A	99,828	51,346	48,482	2,86		
		6	4,62,5	2,98,0	1,64,4	14,9	6.40	1.07
III	0.81 - 1.20	A	77,083	49,670	27,413	2,36		
		3	2,52,4	1,65,3	87,030	7,60	4.6	1.53
IV	1.21	A	84,133	55,123	29,010	2,53		
		40	38,23,	20,20,	18,03,	1,14,	26.5	0.67

A = Average

Table 4. Average level of input gap

	Input	Kg/No	Adoption gap (%)
1	**Organic Manure**		
	Recommended	15,000	100
	Adopted	11,650	77.67
	Gap	3,350	22.33
2	**Lime**		
	Recommended	250	100
	Adopted	506	
	Gap	-	
3	**Urea**		
	Recommended	200	100
	Adopted	160	80
	Gap	40	20
4	**Super Phosphate**		
	Recommended	250	100
	Adopted	195	78
	Gap	55	22
5	**Muriate of Potash**		
	Recommended	40	100
	Adopted	38	95
	Gap	2	5
6	**Rice bran**		
	Recommended	1,500	100
	Adopted	9,419	
	Gap		
7	**Groundnut Oilcake**		
	Recommended	1,500	100
	Adopted	1,996	
	Gap		
8	**Stocking density (Number/ha)**		
	Recommended	6,000	
	Adopted	9,356	
	Gap	-	
	Mean Yield(kg/ha)	4,317	

Table 5. Yield wise gaps in input use

(kg / ha / crop)

Sl. No	Yield range	Lime	RCD	U	S	P	Seed	RB	GNOC	Other	Yield	Net In - come
	Recommended level of the inputs	250	15000	200	250	40	6000	1500	1500			
I	1000 to	141	5795	111	122	24	5596	3163	517	118	1645	22542
	2000 A%	43.60	61.37	44.50	51.20	40.00	6.73		65.53			
II	2001 to	385	8996	104	126	20	5711	7669	1072	122	2429	34039
	3000 A%		40.03	48.00	49.60	50.00	4.82		28.53			
III	3001 to	458	5756	70	132	24	5788	3918	1059	1939	3663	52514
	4000 A%		61.63	65.00	47.20	40.00	3.53		29.40			
IV	4001 to	393	8617	33	100	10	9917	12167	3250	451	4833	91808
	5000 A%		42.55	83.50	33.33	75.00						
V	5001	338	13500	354	234	105	9843	10300	1432	788	6625	152572
	A%		10.00		6.40				4.53			

U : Urea S : Super Phosphate P : Muriate of Potash RB : Ricebran
GNOC : Groundnut Oil Cake RCD : Organic Manure Seed = Numbers in ha/yr A = Adoption gap (%)

Table 6. Net income groupwise gaps in input use

(kg / ha / crop)

Sl. No	Net income Range	Lime	RCD	U	S	P	Seed	RB	GNOC	Other	Yield	Net Income
	Recommended Input levels	200	15000	200	250	40	6000	1500	1500			
I	up to 20,000	239	5918	72	103	26	5494	3571	704	95	1638	11359
	A%		60.55	64.00	58.80	35.00	8.43		53.07			
II	20,001	393	8491	113	103	15	5057	6982	870	654	2459	32479
	40,000 A%		43.39	43.50	58.80	62.50	15.72		42.00			
III	40,001	307	6990	100	143	29	7164	5609	1319	522	3157	45930
	60,000 A%		53.40	50.00	42.80	27.50			12.07			
IV	60,001	383	6200	91	130	25	7275	6550	969	548	3375	70463
	80,000 A%		58.69	54.50	48.00	37.50			35.40			
V	80,001	428	8083	145	94	42	9083	10083	2750	1542	4917	91215
	1,00,000 A%		46.11	27.50	62.40							
VI	> 1,00,001	150	14300	195	202	65	8593	7300	2088		6000	158613
	A%	40.00	4.67	2.50	19.20							

RCD : Organic Manure U : Urea S : Super Phosphate P : Muriate of Potash

RB : Rice bran GNOC : Groundnut Oil Cake Seed = Number of fingerlings / ha

A = Adoption gap (%)

Table 7. Estimated Multiple Linear Production Function

Variable	Co-efficient	Value	SE	't' Values
Y	a0	425.1672	86.5167	2.6521
M	a1	0.0816	0.0712	1.6562
U	a2	0.3121	1.6153	0.1065*
S	a3	1.0623	1.7125	0.4862
F	a4	0.0163	0.0123	0.1095*
R	a5	0.0156	0.0165	0.1076*
G	a6	0.5132	0.3169	0.1622*
L	a7	0.3157	0.5655	0.6158

Y = Yield (kg/ha/yr)

M = Manures (kg/ha)

U = Urea (kg/ha)

F = Fingerlings Stocked (Numbers / ha)

S = Super phosphate (kg / ha)

R = Rice bran (kg / ha)

G = Groundnut Oil cake (kg /ha)

L = Labour (mandays)

R^2 = 0.8761

n = 40

F = 19.6125

* significant at 1% level of significance

Table 8 Frequency distribution of ponds by their technical efficiency

Probability levels (class interval)	Ponds		
	Number	% to Total	Cumulative frequency
0.00 - 0.10	-		
0.11 - 0.20	2	5.00	5.00
0.21 - 0.30	2	5.00	10.00
0.31 - 0.40	3	7.50	17.50
0.41 - 0.50	2	5.00	22.50
0.51 - 0.60	2	5.00	27.50
0.61 - 0.70	2	5.00	32.50
0.71 - 0.80	3	7.50	40.00
0.81 - 0.90	2	5.00	45.00
0.91 - 1.00	1	2.50	47.50
	19	-	47.50

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