

Profitability and technical efficiency of aquaculture in Punjab, India

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ABSTRACT

The profitability and technical efficiency aspects of aquaculture in Punjab were examined using primary data pertaining to the year 2007-08 using cost and return concepts and stochastic frontier production function, respectively. Study showed that only two-fifth of the farms were using nursery ponds for fingerlings in early stages and few farmers were using branded feed. Application of chemical fertilisers and manures were directly and inversely related to farm size. Differences between observed and frontier output is attributed mainly to the inefficient use of resources which are under the control of fish farmers. Use of nursery, high proportion of rohu and training received by fish farmers were significantly affecting the technical efficiency. Aquaculture in Punjab is high yielding and profitable despite certain constraints. High cost of feed, low dissolved oxygen, poor availability of electricity, inadequate seed supply and poor quality of seed were perceived as the major constraints to aquaculture. The findings indicated that the farmers need to be trained for use of nursery ponds and optimum mix of resources to increase profitability in fish production. Further there is urgent need for development of low cost feed and establishment of more hatcheries to meet the demand of disease free and disease resistant fish/shrimp seed with strict quarantine measures.

Keywords: Constraints, Costs, Determinants, Frontier production function, Profitability, Returns, Technical efficiency

Introduction

Fisheries sector occupies an important place in the socio-economic development of the country. The sector generates income and employment and provides livelihood to a large section of economically backward population. Government is giving importance to fishery sector and investment in this sector has been increasing all through the plan periods (Vasisht and Singh, 2009). Inland fish production has shown remarkable increase from 0.22 million t in 1950-51 to about 4.93 million t in 2009-10 and its contribution to total fish production increased from 29% in 1950-51 to 40, 50 and 62% in 1990-91, 2000-01 and 2009-10, respectively. Freshwater aquaculture sector in India is growing at an impressive rate. Contribution of freshwater aquaculture to inland fish production increased from less than a half during eighties to nearly four-fifths in 2009-10. In Punjab State, water resources are scarce and its share in total inland fish production in the country was only around 2% in 2010-11 with a production of around 97000 t. However, the state topped the country in fish productivity for the seventh year in a row and produced around 6.56 t ha⁻¹, which is more than double the national average of 3 t ha⁻¹ in 2012-13. Kumar *et al.* (2008) reported that Punjab State has achieved the highest growth (14%) in inland fish

production in the country from 1990-81 to 2005-06. Fish production in the state has also recorded an impressive growth of 6.9% from 2006-07 to 2010-11 mainly due to an impressive increase in productivity. Improvement in farm efficiency is an important factor for productivity growth. However, selected studies analysed the farm level technical efficiency and its determinants in freshwater aquaculture in India (Sharma and Leung, 2000; Dey *et al.*, 2005, Singh, 2008; Singh *et al.*, 2009). Studies also showed that fish farming practices in Punjab were profitable (Debnath *et al.*, 2007). But, so far no such studies have been undertaken to study the technical efficiency of aquafarms in Punjab. In this backdrop, the present study was undertaken to analyse the resource use, profitability and farm specific technical efficiency as well as its determinants herein to suggest some policy measures for improving efficiency and profitability of freshwater aquaculture in Punjab.

Materials and methods

In Punjab State, three districts, *viz*; Ludhiana, Firozpur and Sangrur were purposively selected on the basis of maximum acreage under aquaculture. A sampling frame of small (less than 2.5 ha⁻¹), medium (2.5-5.0 ha⁻¹) and large (greater than 5.0 ha⁻¹) fish farms was designed and the required information collected from

the fisheries departments of selected districts. A total number of 120 fish farms were randomly selected from selected districts on the basis of proportion of farms in each category pertaining to the year 2007-08. Differences in the economic results are widely attributed to the differences in management forms (Kumar *et al.*, 2007). Therefore, information on all the inputs along with management practices and other socio-economic variables involved in aquaculture were collected with the help of structured schedule and subjected to functional and tabular analysis.

In order to analyse the profitability of aquaculture business, the cost incurred on different inputs as well as fixed costs and gross as well as net returns were calculated on per hectare basis. The straight line method was used to calculate the depreciation on fixed capital. Interest on fixed capital and variable cost was also computed and the present rental value of leased-in pond was used to compute the rental value of owned pond. These costs were added to the input cost to compute the cost of cultivation and in computing the benefit to cost ratio for the estimation of profitability of aquaculture. Further, to ascertain the return per rupee of investment, the net benefit cost ratio was obtained by dividing the net benefits with the given cost of cultivation.

Estimation of technical efficiency

The stochastic frontier production function, popularly known as ‘composed error model’, was employed to measure the fish farm specific technical efficiency. The function with Cobb-Douglas functional form propounded simultaneously by Aigner *et al.* (1977) and Meeusen and van Den Broeck (1977) was specified as below:

$$Y = (X; \beta). \exp \epsilon \quad (1)$$

where Y is $(n \times 1)$ column vector of output, X represents $(n \times k)$ matrix of input observations including ones for the intercept term, β is $(k \times 1)$ column vector of unknown coefficients and ϵ is $(n \times 1)$ vector of disturbance term. The model is such that the possible production Y is bounded above by the stochastic quantity of $(X\beta). \exp(V)$, hence the term stochastic frontier (Jondrow *et al.*, 1982). Here the error term ϵ is composed of two independent error components as: $\epsilon = V-U$.

This error term $V \sim N(0, \sigma_v^2)$ is a two-sided error term symmetrically distributed $(-\infty < V_i < \infty)$ and it captures the effects of random shocks outside the firm (farm) control, observation and measurement error on independent variables, and usual statistical ‘noise’ generally found in an empirical relationship. The other independent error component (U) is assumed to be non-negative and represents technical efficiency. This error term is one - sided and is a truncation of the $N(0, \sigma_u^2)$ distribution

(*i.e.*, half normal distribution or having exponential distribution). The economic interpretation of this error term U is that each farm production must be either on or below the production frontier. The source of the difference between the farmer’s yield and that estimated by the frontier production function is examined by calculating the variance ratio parameter. The variance ratio parameter (γ), which can be attributed to technical efficiency, is the proportion of total variation of output from the frontier which is given by:

$$\gamma = \sigma_u^2 / \sigma_v^2 \quad (2)$$

Based on the value of γ , one can infer whether the differences between a firm’s output and efficient output is basically due to statistical errors or because of the less efficient use of inputs and technology by the firm. The measurement of firm specific technical efficiency is based on deviations of observed output from the best production or efficient production frontier. It refers to the comparison of mean production for given realised farm effect to the corresponding frontier mean production, if the farm effect was zero. Thus, the technical efficiency of a farm is given by:

$$\text{Exp}(-U_i) = \frac{Y_i}{Y_i^*} = \frac{\text{Actual output}}{\text{Maximum possible output}} \quad (3)$$

If a firm’s actual production point lies on the frontier, it is perfectly efficient. If it lies below the frontier, then it is technically inefficient. For the frontier production function analysis, the fish yield (q per ha^{-1}) was considered as the exogenous variable and stocking density/fingerlings used (nos. per ha^{-1}), human labour (man days per ha^{-1}), manure and fertilisers (kg per ha^{-1}) and feed (q per ha^{-1}) were endogenous variables.

Determinants of technical efficiency

The technical efficiency of farmers is determined by socio-economic and demographic factors. Multiple linear regression was modeled to identify the factors that were influencing the technical efficiency of the fish farmers. The determinants of technical efficiency was estimated using the following equation:

$$TE = \alpha + \beta_1 \text{NUR} + \beta_2 \text{EXP} + \beta_3 \text{EDU} + \beta_4 \text{ROHU} + \beta_5 \text{POND} + \beta_6 \text{TRNG} + v \quad (4)$$

where, TE represents technical efficiency (in percentage) of farms, NUR is nursery code (‘1’ if fingerlings kept in the nursery and ‘0’ otherwise), EXP is farmers’ experience in fish farming in number of years, EDU is education of the farmer (number of years of schooling), $ROHU$ is percentage of Rohu in total number of fingerlings, $POND$ is pond size in ha and $TRNG$ = formal training received in fish farming (‘1’ if the farmer is trained and ‘0’ otherwise).

Results and discussions

The size of the pond plays a major role in aquaculture. It influences the input use, technology adoption, level of production and the income generation for the farmers. Further, leasing of ponds gives an opportunity to farmers to realise the benefit of economies of scale by increasing the average size of the ponds. However, a majority of the sample farmers had less than 2.5 ha, *i.e.*, small (57%) and 2.5-5 ha, *i.e.*, medium (20%) having average pond size of 1.4 and 3.9 ha, respectively (Table 1). There were only 23% large farmers (more than 5 ha) who had an average pond size of 9.1 ha. Leased-in activity of pond is very common among the fish farmers in Punjab. Nearly one-third of the farmers were involved in leased-in activity of ponds. It was also observed that around two-fifths of the total pond size was leased-in by the fish farmers and it ranged from 18% on small farms to 54% on large farms. The practice of keeping fingerlings in the nursery ponds in the early stage results in low cost and better management. Although, most of the farmers reported to have nursery ponds, yet only around 43% of the sampled farms were using nursery ponds for fingerlings in early stages.

The socio-economic variables like, age and education of the farmers, experience in farming, endowment of resources and related parameters influence the decision making and selection of enterprises of the farmers in general. Distribution of age of the selected aqua-farmers in Punjab reveals that the respondents of all age groups were involved in aquaculture (Table 2). However, young farmers (less than 30 years) were less interested in aquaculture compared to old age groups. It is interesting to note that about 35% of the farmers belong to above 50 years age group.

Table 1. General details of sample aquaculture farms in Punjab

Particulars	Small	Medium	Large	Total
Sample farms (no.)	68	24	28	120
Sample farms (%)	56.7	20.0	23.3	100.0
Average size of pond (ha)	1.38	3.90	9.06	3.68
Average size of leased-in pond (ha)	0.25	0.83	4.91	1.45
Leased-in pond to total pond (%)	17.9	21.3	54.2	39.5
Lessee farmers to total farmers (%)	16.2	29.2	71.4	31.7
Farms with nursery ponds (%)	39.7	45.8	46.4	42.5

Source: Primary survey data, 2007-08.

Table 2. Age, education, experience and occupation of the aqua-farmers

Age group		Education		Experience in fisheries		Occupation	
Years	%	Group	%	Years	%	Name	%
Less than 30	5.8	Primary & below	14.2	Less than 5	20.0	Fisheries & agriculture	63.3
30-40	20.8	Secondary	21.7	5-10	38.3	Fisheries only	14.2
40-50	38.3	Senior secondary	38.3	More than 10	41.7	Fisheries & business	11.7
More than 50	35.0	Graduate & above	25.8	-	-	Fisheries & others	10.8

Source: Primary survey data, 2007-08.

For any occupation, knowledge is necessary as it helps to improve the technical efficiency and maximise the production and profit in a sustainable manner. The educated, experienced and trained farmers take sound logical decisions regarding farming practices such as stocking density, composition of the fingerlings, feeding of concentrates and application of right amount of manures and fertilisers at right time. The analysis reveals that a good proportion of aqua-farmers had graduate and post graduate (26%), senior secondary (38%) and secondary (22%) education. Further, four-fifths of the farmers had experience in fish farming. Most of the farmers had also undertaken formal trainings (83%) and received technical guidance from department of fisheries (80%). Further, to get subsidy and financial assistance from government, most of them (89%) were registered with government department. In addition to aquaculture, the farmers also owned other business to enhance their income. Other occupations also supported the infrastructure and resources required for aquaculture. It was found that majority of the farmers were involved in fisheries plus agriculture (63%) followed by fisheries only (14%) and fisheries plus business (12%).

Stocking density and fish species

Maintaining fingerling density in the ponds is very much necessary to reap the benefits of healthy and good crop. Small farmers stocked highest number of fingerlings per ha (37035 nos.) followed by medium and large farmers (Table 3). Thirty seven percent of the selected farmers obtained fingerlings from both private and government hatcheries, 33% from only private hatcheries and 28% from only government hatcheries. Further, polyculture or mixed culture is practiced to increase the returns and reduce risk. Indian major carps, rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*) and catla (*Catla catla*) were the most preferred species and their proportion to the total were 35, 24 and 16%, respectively. Overall share of common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*) and silver carp (*Hypophthalmichthys molitrix*) were 11, 9 and 6%, respectively. The medium category of farmers preferred rohu and mrigal, while small farmers preferred catla and grass carp.

Input use

Details regarding use of different types of feeds, manures and fertilisers by the fish farmers are presented

Table 3. Fish species preferred by aqua-farmers in Punjab

Particulars	Small	Medium	Large	Overall
Average stocking density (no. ha ⁻¹)	37035	32044	32045	33107
Proportion of fish species				
Rohu	29.5	39.3	35.8	35.0
Catla	18.4	14.8	14.4	15.5
Mrigal	24.7	25.5	23.7	24.3
Common carp	10.3	9.2	11.3	10.6
Silver carp	6.6	4.4	6.7	6.2
Grass carp	11.0	6.8	8.1	8.5

Source: Primary survey data, 2007-08.

in Table 4. It is interesting to note that only 16% of the farmers use branded feed. This could be attributed to high cost of branded feed in comparison to mustard oil cake and rice deoiled cake. The data revealed that proportion of farmers using branded feed and mustard oil cake had direct relationship with farm size whereas the farmers who used rice deoiled cake, a comparatively cheaper and low-nutrient feed, had inverse relationship with farm size.

Table 4. Proportion of fish farms using feed and fertilisers (%)

Particulars	Small	Medium	Large	Overall
Feed				
Branded feed	13.2	16.7	21.4	15.8
Mustard oil cake	82.4	91.7	82.1	84.2
Rice de oiled cake	92.6	79.2	75.0	85.8
Manures and fertilisers				
Urea	14.7	25.0	39.3	22.5
Single super phosphate	35.3	33.3	25.0	32.5
Di ammonium phosphate	51.5	54.2	67.9	55.8
Dung	54.4	29.2	21.4	41.7
Poultry waste	22.1	25.0	35.7	25.8
Others: Lime	94.1	91.7	92.9	93.3

Source: Primary survey data, 2007-08.

Table 5. Quantity of input use in aquaculture

Particulars	Small	Medium	Large	Overall
Fingerlings (no. ha ⁻¹)	37035	32044	32045	33107
Human labour (Mandays ha ⁻¹)	229	102	79	116
Feed (kg ha ⁻¹)				
Branded feed	558(4.4)	766(6.0)	1436(10.9)	1106(8.5)
Mustard oil cake	4954(39.0)	5256(41.0)	5885(44.8)	5553(42.8)
Rice deoiled cake	6945(54.6)	6563(51.2)	5705(43.4)	6151(47.4)
Other feed	254(2.0)	234(1.8)	120(0.9)	173(1.3)
Total feed	12710(100)	12818(100)	13146(100)	12983(100)
Fertilisers (kg ha ⁻¹)				
Urea	40(12.0)	40(9.3)	72(13.9)	58(12.7)
Single super phosphate	156(46.8)	228(53.7)	265(51.5)	234(51.2)
Di ammonium phosphate	137(41.2)	157(37.0)	179(34.7)	165(36.1)
Total fertilizers	333(100)	425(100)	515(100)	457(100)
Manures (kg ha ⁻¹)				
Dung	3547(72.8)	2525(70.1)	2082(56.0)	2352(63.6)
Poultry waste	1141(23.4)	919(25.5)	1281(34.4)	1069(28.9)
Other manures	183(3.8)	160(4.4)	355(9.5)	277(7.5)
Total manures	4871(100)	3604(100)	3718(100)	3698(100)
Others (kg ha ⁻¹): Lime	280	271	335	310

Source: Primary survey data, 2007-08.

Note: Figures in parentheses are % to total.

The use of diammonium phosphate and urea was reported by 56 and 23% of the fish farmers and the proportion of farmers using these fertilizers increased as farm size increased. Farmers are well aware of the utility of lime in aquaculture as is reflected by the usage of good proportion of farmers. On an average around 42% of the farmers use dung. However, the proportion of large farmers using dung was very low (21%) in comparison to small farmers (54%). Surprisingly a good number (26%) of farmers were using poultry waste as fish feed in Punjab. It may be due to availability of large poultry waste as poultry industry is well developed in the state.

Human labour employed were quite high (229 man days ha⁻¹) in small farms in comparison to 79 man days ha⁻¹ in large farms (Table 5). Total feed quantity used in farms was 130 quintals ha⁻¹. The share of rice deoiled cake and mustard oil cake in the total feed was found to be 47 and 43%, respectively. Quantity of branded feed used by farmers was very low. However, the use of branded feed and mustard oil cake as feed increased with farm size. On the other hand, use of rice deoiled cake was very high in small farms in comparison to large category of farms.

The total use of fertilisers namely urea, single super phosphate and diammonium phosphate ranged between 333 kg ha⁻¹ in small farms to 515 kg ha⁻¹ in large farms. Among these fertilisers, the use of single super phosphate was almost a half of the total fertilisers used by all the category of farmers. As expected, maximum use of dung was observed in small farms. On the other hand, use of poultry waste in total manure was higher (34%) in large farms and lower (23%) in small farms.

Cost of cultivation and returns

Economic performance of aquaculture farms are presented in Table 6. The cost incurred on different input items as well as returns were calculated on per hectare basis. Further, net return per rupee of investment was obtained by dividing the net benefits with the calculated cost of cultivation. Average cost of cultivation was ₹1,28,124/- per ha. It was ₹1,47,728/- per ha for small farms and ₹1,21,802/- per ha for large farms, which indicates inverse relationship between cost of cultivation and farm size. Feed cost, rental value of pond and wages of human labour are the most important cost items in aquaculture. Their share in average cost of cultivation were found to be 52, 27 and 8%, respectively. Further, rental value of pond and wages were found to impressively decrease with farm size. Small farms were also incurring higher cost on fingerlings, manure and fertilisers, irrigation and drugs, except feed in comparison to medium and large farms. This discerns a sign of occurrence of diseconomies of scale on the small farms.

The overall yield of fish was 54.2 quintal ha⁻¹ with small variation among the various farm categories (Table 6). Thus, the gross income realised per ha was of the same order for all the category of farms. However, the net income per ha were low for small farms in comparison to large farms because of high cost of cultivation. The net return per rupee of investment was impressive for large farms (₹0.62), whereas it was ₹0.31 for small farms and ₹0.52 for medium farms. The results indicate that there is still ample scope to increase the profitability of small and medium category of farms.

Farm specific technical efficiency in aquaculture

The fundamental concept of frontier function analysis is that the most efficient farm in terms of input use will

be identified and rest of the farms will be compared with the best farm and the efficiency will be declared with respect to that best farmer. It is the estimation of technical efficiency which denotes how much the farms are efficient in converting the incurred inputs into physical output. The maximum likelihood estimates are comparable to the ordinary least squares (OLS) estimates of Cobb-Douglas production function (Table 7). However, there are a few minor changes in the magnitude of the elasticity coefficients. As expected the constant term in stochastic frontier function was higher than that of the OLS method. Thus, compared to the OLS model, the frontier production could shift vertically upwards. In case of coefficients of inputs used, the OLS and the frontier were different indicating that the frontier function was different from OLS in terms of slopes too.

The results reveal that among all the variables included in the model, only stocking density and feed were significant at 1% level, indicating that 1% increase in stocking density would result in change in output by 0.24%, keeping all other variables constant. Similarly, a 1% increase in feed would result in change in output by 0.08%. 'λ' which is the ratio of the variance of the farm specific production behaviour $\sigma^2_{(u)}$ to the variance of the statistical noise $\sigma^2_{(v)}$ was 4.65 and was significant indicating that one-sided error component had dominated relatively to symmetric error component. The estimate γ which is the ratio of the variance of the farm specific performance indicates the presence of significant inefficiencies in the production of fish. In other words, about 96% of the difference between the observed and the frontier output was mainly due to the inefficient use of resources which are under the control of fish farmers.

Table 6. Cost of cultivation and returns in aquaculture (₹ ha⁻¹)

Particulars	Small	Medium	Large	Overall
Costs				
Human labour	17252 (11.7)	8948 (7.1)	7030 (5.8)	9612 (7.5)
Fingerlings	3454 (2.3)	2926 (2.3)	2842 (2.3)	2990 (2.3)
Feed	63760 (43.2)	64142 (51.1)	69195 (56.8)	66967 (52.3)
Manures and fertilisers	6177 (4.2)	5672 (4.5)	5988 (4.9)	5961 (4.7)
Irrigation	5342 (3.6)	4827 (3.8)	2268 (1.9)	3465 (2.7)
Medicines	815 (0.6)	183 (0.1)	57 (0.05)	245 (0.2)
Rental value of pond	44723 (30.3)	33504 (26.7)	29686 (24.4)	34395 (26.8)
Interest on working capital	3565 (2.4)	2988 (2.4)	2945 (2.4)	3086 (2.4)
Depreciation on fixed capital	1090 (0.7)	1016 (0.8)	745 (0.6)	876 (0.7)
Interest on fixed capital	1550 (1.0)	1401 (1.1)	1045 (0.9)	1228 (1.0)
Total cost of cultivation	147728 (100)	125607 (100)	121801 (100)	128124 (100)
Returns				
Yield (q ha ⁻¹)	53.8	52.6	55.0	54.2
Gross income (₹)	193820	187980	197134	194487
Net income (₹)	46092	62373	75333	66363
Net income per rupee of cost	0.31	0.50	0.62	0.52

Source: Primary survey data, 2007-08.

Note: Figures in parentheses are percentages to total.

Table 7. Coefficients of Cobb-Douglas and Frontier production function

Variables	Cobb-Douglas production function		Frontier production function	
	Coefficients	Standard error	Coefficients	Standard error
Constant	0.51		0.85	
Stocking density	0.22***	0.052	0.24***	0.048
Human labour	-0.014	0.037	-0.014	0.037
Manures and fertilisers	0.038	0.026	0.017	0.025
Feed	0.066***	0.012	0.078***	0.010
R ² / Log likelihood	0.33		15.11	
Sigma-squared (u) and sigma-squared (v)			0.1278 and 0.0059	
λ and γ			4.65 and 0.96	
Technical Efficiency			77.5	

Note: *** Significant at 1% level.

The average technical efficiency of the aquafarms was 78% compared to the best frontier whereas the allocative efficiency was 58%. The economic efficiency of Punjab farmers in aquaculture was recorded around 45%. Although the farms are somewhat technically sound, the economic efficiency is low. This low value of economic efficiency in aquaculture for Punjab farmers might be due to various factors like, inefficient use of resources, low price of output or high cost of inputs. Despite this, there is a tremendous scope to increase technical, allocative and economic efficiencies of fish farmers. The distribution of farms according to technical efficiency showed that nearly two-fifths and one-fifth of aquafarms had less than 70% and between 70 - 80% technical efficiency, respectively (Table 8). Contrary to it, 41% farms had shown more than 80% efficiency when compared with the best frontier. Moreover, small fish farmers were managing their resources better than the other category of farmers.

Determinants of technical efficiency in aquaculture

Technical efficiency of farmers is determined by socio-economic and demographic factors (Timmer, 1971;

Table 8. Classification of aqua-farms based on technical efficiency (%)

Efficiency category	Small	Medium	Large	All
Less than 70%	32	50	43	39
70-80%	24	13	18	20
80-90%	18	13	25	18
More than 90%	26	25	14	23

Muller, 1974; Kalirajan and Shand, 1989; Bhende and Kalirajan, 2007). Multiple linear regression was modelled to know the factors that are influencing the technical efficiency of the fish farmers. A perusal of Table 9 clearly indicates that the model explained the variation in technical efficiency in the sample fish farms to the extent of 34%. The use of nursery for fish farming, proportion of rohu in total fingerling density and formal training received by fish farmers were found to be significantly affecting the technical efficiency. It is expected that the experience in fish farming and level of education helps in

Table 9. Estimates of the factors affecting technical efficiency in Punjab aquaculture

Variable	Coefficients	Standard error
Intercept	63.60	4.95
Use of nursery	9.70***	1.88
Farmers' experience in fish farming	-0.37	0.22
Education of the fish farmer	0.17	0.28
Proportion of Rohu in total fingerling	0.23**	0.10
Pond size	-0.21	0.28
Formal training received by fish farmers	5.97**	2.45
R-square	0.34	

***and **: Significant at 1 and 5% levels.

adoption of improved management practices and access to latest information. Though, these variables may be crucial in determining the technical efficiency, they had no role in increasing the efficiency in aquaculture in Punjab. Further the coefficient of size of pond was negative and non-significant. This deciphers the fact that some of the fish farming operations at critical stages were increasingly difficult to accomplish as farm size increased.

Constraints to aquaculture in Punjab

There are a number of constraints which affect aquafarming in the study area. It is inferred from the analysis that high cost of feed is the major constraint reported by 52% of the fish farmers followed by low dissolved oxygen (36%), poor availability of electricity (28%), inadequate seed supply (28%) and poor quality of seed (22%). The respondents reported that financial assistance and subsidy, disease, vandalism, flood, seepage of water, poaching and plankton bloom were not serious constraints to aquaculture in Punjab.

As aquaculture is capital intensive, farmers need help from financial institutions. Around 71% of the farmers availed loan facility from banks. Further, about 89% of the farmers who availed institutional loan got subsidy from Department of Fisheries, Government of Punjab. Although, about 62% of the farmers reported disease occurrence in farms, only 11% suffered from crop loss in aquaculture. With regard to marketing of the aquaculture

produce, majority (89%) of the farmers in Punjab sell their produce to wholesalers and only a limited number of farmers prefer retailers.

From the policy perspective, very large difference between the observed and the frontier output in aquaculture sector in Punjab, indicated inefficient use of resources which were under the control of fish farmers. The economic efficiency of aquafarms was low despite being technically sound to some extent, which offers a tremendous scope to increase technical, allocative and economic efficiencies in aquaculture in Punjab. Use of nursery for fish farming, proportion of rohu in total fingerling stocking and formal training received by fish farmers were found to be important factors significantly affecting technical efficiency of fish farms. High cost of feed, poor availability of electricity, inadequate seed supply and poor quality of seed were identified as major constraints to aquaculture in the state. Despite all this, there is still scope in Punjab aquaculture to increase the profitability of farmers in general and small and medium farmers in particular by improving the technical efficiency and mitigating the constraints to the extent possible. Hence, it becomes imperative to train fish farmers for use of nursery ponds and optimum mix of resources in fish production. Urgent need is also felt for the development of low cost feed and establishment of more hatcheries to meet the demand of disease-free and disease-resistant fish/shrimp seed with strict quarantine measures.

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