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Determination of Efficiency of Fish Farms in North-East India Using Data Envelopment Approach

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Abstract

North-East (NE) India produced about 3.38 lakh tonnes of fish from the total inland water bodies of 5.63 lakh ha during the year 2012-13 with productivity of about 600 kg/ha and it also sources about 90,000 tonnes of fish per year from other states of India. This study has estimated the efficiency levels of fish farms and has identified the fish production potential by improving the efficiency level of underperforming units. The variables, viz. fish farm area and occupation and fish farming with agriculture have been found to significantly influence the efficiency level of fish farms in this area. The study has found that larger farms were more efficient. The average efficiency levels of fish farms in the study area being low, the scope for improvement in fish farming is immense in North-East India and Manipur through adoption of better production practices.

Key words: Technical efficiency, allocative efficiency, cost efficiency, fisheries, North-East India

JEL Classification: Q22, Q140, O32, O33

Introduction

In North-East India, fish production was 3.59 lakh tonnes in 2013-14, while the Government of India aims to produce 7 lakh tonnes of fish in this area by 2020 and has also planned to double the per capita fish availability in NE India to 15 kg (ToI, 2013). Among North-East states, Assam registered the highest fish production, 254.27 thousand tonnes, followed by Tripura, Manipur, Nagaland, Meghalaya, Arunachal Pradesh, Mizoram, and Sikkim. In 2012-13, the total inland fish production in India was 56.32 lakh tonnes to which the contribution of NE India was 3.38 lakh tonnes only. Based on the respective fish production in India and NE India for the period 2004-2013, the compound growth rate of fish production was 4.67 per cent in India and 5.10 per cent in NE India. The annual growth rate of fish production in NE India has registered a positive growth over the years, indicating a healthy trend (Baik *et al*., 2009). Despite the fact that NE India has enormous common use resources for fish production, the growth, of late, has been emanating from the private capital investment in fish farming. Hence, it is important to study the efficiencies of different fish farms which would reveal the potential that could be achieved by adopting improved fish production processes in NE India.

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Data and Methodology

Amongst the states in North-East India, Manipur was selected for the study and in Manipur, the district of Bishnupur having the highest fish production, was selected. A sample of 150 fish farmers, constituting 50 fish farmers from each category, namely, marginal (< 1 ha), small (1-2 ha) and large (> 2 ha) was selected.

Table 1. Annual rate of growth of fish production in North-East region and India

(in per cent)

Year	States in NE India								North-East region	India
	Arunachal Pradesh	Assam	Manipur	Meghalaya	Mizoram	Nagaland	Sikkim	Tripura		
2005-06	1.85	0.57	2.36	-26.95	1.90	12.24	7.14	20.31	1.96	4.23
2006-07	0.73	-3.15	2.09	33.25	0.27	5.45	0.00	19.94	0.38	4.52
2007-08	2.17	4.87	0.27	-27.14	0.00	0.00	20.00	26.62	6.13	3.76
2008-09	1.77	8.61	0.80	-1.00	-23.14	6.55	-11.11	-0.69	6.03	6.86
2009-10	-7.99	5.47	2.13	9.34	12.11	2.91	0.00	17.44	6.72	5.02
2010-11	18.87	6.58	5.31	5.31	-10.49	3.62	12.50	16.44	7.75	2.91
2011-12	4.76	4.96	9.89	4.61	1.03	3.79	55.56	8.35	5.76	5.28
2012-13	12.42	4.26	12.47	13.63	85.32	4.24	75.00	7.72	6.32	4.57
Compound growth rate	3.41	4.54	3.65	-0.02	0.25	4.26	12.62	14.08	5.10	4.67

Data source: www.dahd.nic.in/dahd

To estimate the technical, scale and returns to scale, the data envelopment analysis (DEA) was used (Charnes and Cooper, 1978). Assuming constant returns to scale, the following input-oriented linear programming model was used to measure the overall technical efficiency of farms (Dantzig, 1955; Umanath and Rajasekar, 2013):

$$\text{Min}_{\theta,\lambda}\ \theta$$

Subject to

$$-y_i + Y\lambda \geq 0$$

$$\theta x_i - X\lambda \geq 0$$

$$\lambda \geq 0 \qquad \ldots(1)$$

where,

y_i is a m × 1 vector matrix of output for the i^{th} farm, and m = 1, as only one output, namely fish production is considered in the study,

x_i is a k × 1 vector matrix of inputs for the i^{th} farm, k = 5 as five inputs, namely seed, feed, fertilizer, lime and person-day labour were considered for the study,[1]

Y is a n × 1 output matrix for 'n' number of farms,

X is a n × k input matrix for 'n' number of farms,

θ is an efficiency score, it is a scalar whose value would be the efficiency measure for each 'i' farm and it ranges from 0 to 1. If θ = 1, then the farm would be efficient; otherwise, the farm would be below the effi-cient level, and

λ is a n × 1 vector of matrix which provides the opti-mum solution. The λ values are used as weights in the linear combination of other efficient farms for an inefficient farm, which influences the projection of the inefficient farms on the calculated frontier.

Results and Discussion

Table 1 depicts the annual growth rates of fish production for different states of NE India, North-East region and India for the period 2005-06 to 2012-13. It reveals that except Meghalaya, all other states recorded positive growth rate during this period. The growth rate was highest in Tripura (14.08%), followed by Sikkim (12.62%), Assam (4.54%) and Nagaland (4.26%). The growth rate in Mizoram was barely 0.25 per cent and in Meghalaya, it was marginally negative. Despite being large states, the performance of Assam and Arunachal Pradesh leaves much to be desired.

Table 2 enlists the district-wise fisheries resources in Manipur. The total fisheries resources in terms of

[1] To develop the DEA matrix, only those variables which could be directly quantified were taken since one of the objectives was to determine the cost efficiency which would be revealed only when those cost elements are included in the model that could be captured either in terms of value or quantity.

Table 2. Common water resources in Manipur

(water spread area in ha)

Name of district	Ponds/Tanks	Lakes/Beels	Rivers/ Streams	Paddy Fields	Reservoirs	Total
			Valley Districts			
Imphal West	2869	8125	2186	1125	216	14521
Imphal East	825	237	859	697	251	2869
Thoubal	2016	6728	1987	1168	268	12167
Bishnupur	2356	8016	2789	1286	0	14447
Total for valley districts	8066	23106	7821	4276	735	44004
			Hill Districts			
Chandel	869	362	806	494	0	2531
Churanchandpur	864	384	1289	256	100	2893
Senapati	532	186	1457	315	0	2490
Tamenglong	258	187	1608	268	125	2446
Ukhrul	853	208	907	129	0	2097
Total for hill districts	3376	1327	6067	1462	225	12457
Grand total	11442	24433	13888	5738	960	56461

Source: DoF (2012)

water spread area for the valley districts extend to 44,000 ha. Both Bishnupur as well as Imphal West have resources of more than 14,000 ha each. Imphal East has the smallest resource of less than 3,000 ha. Therefore, factor endowments in terms of fisheries water spread area are inequitably distributed among the valley districts of Manipur. The hill districts enjoy a little over 12,000 ha of fisheries water spread area of Manipur (Table 2) and these resources are more or less evenly spread. The total water spread area of fisheries resources in Manipur extends to about 56,500 ha. There is abundance of lakes in the valley districts as they cover 23,000 ha area in the total of 24,500 ha of lakes and beels in the state. The lakes and beels constitute almost 50 per cent of the total fisheries resources of Manipur.

Figure 1 shows the district-wise fish production in the Manipur valley for the period 2003-04 to 2012-13.

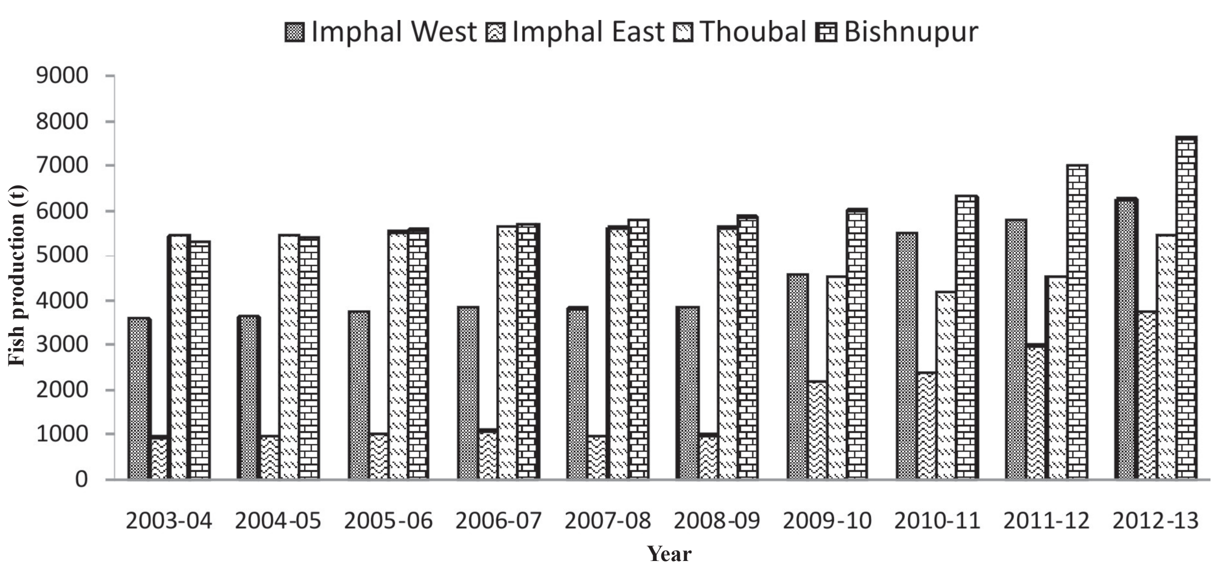

Figure 1. Districts-wise fish production in Manipur valley during 2003-04 to 2012-13

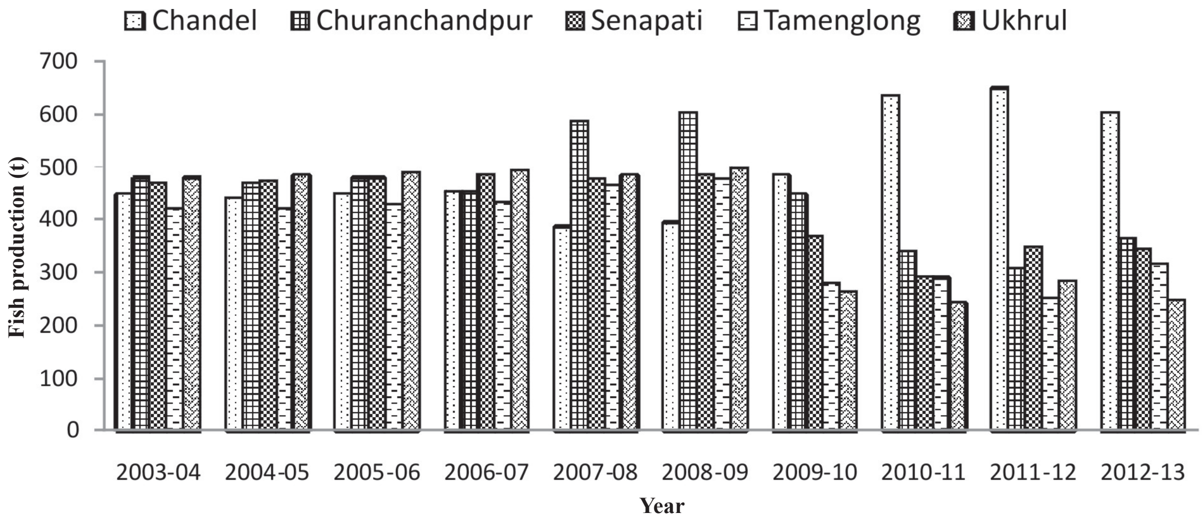

Figure 2. Districts-wise fish production in Manipur hills during 2003-04 to 2012-13

The Bishnupur district has registered the highest fish production, followed by Imphal West, Thoubal and Imphal East in 2012-13 in absolute terms. But, the compound growth rates of these districts for the period 2003-04 to 2012-13 show that the growth rate was highest in Imphal East (17.43%), followed by Imphal West (6.68%), Bishnupur (3.66%) and Thoubal (–2%).

Figure 2 shows fish production in the hill districts of Manipur during 2003-04 to 2012-13. In absolute terms, Chandel district has registered the highest fish production followed by districts of Churanchandpur, Senapati, Tamenglong and Ukhrul. But in terms of compound growth rate, district of Chandel has registered the highest growth rate of 4.52 per cent in fish production during this period. The other districts have all registered negative compound growth rates.

The performance of valley districts of Manipur in fish production has been substantially better than of the hill districts. The fish production in all the hill districts was almost equal till the year 2007-08, but thereafter, it declined in all the hill districts, except Chandel. This decline may be attributed to overexploitation of the existing natural resources and an inherent aversion to new technologies in aquaculture and the increasing fish production in the Chandel district may be attributed to amenable climatic conditions, better communication and road facilities and its proximity to the international border of Myanmar.

Economics of Fish Farming in Bishnupur District, Manipur

In Bishnupur district, the average landholding size was 1.87 ha, which ranged from 4.03 ha on large farms to 0.51 ha on marginal farms (Table 3). The average imputed leased value of land was ₹ 31,380/ha, which

Table 3. Basic cost details of fish farming in Bishnupur district of Manipur

Particulars	Marginal farms	Small farms	Large farms	All farms
Sample farms (No.)	50	50	50	150
Area (ha)	25.63	54.00	201.50	281.13
Average landholding (ha/farmer)	0.51	1.08	4.03	1.87
Imputed leased value of land (₹ /ha)	45,759	34,400	13,980	31,380
Amortized annual cost of farm machinery/ nets/traps, etc. (₹ /ha)	10,122	4,235	1,538	2,839
Cost on feed (₹ /ha)	2,428	8,217	10,657	9,438
Cost on fertilizer (₹ /ha)	615	165	1,296	1,016
Cost on lime (₹ /ha)	737	347	45	166

Table 4. Resource-use pattern across fish farms in Bishnupur district of Manipur

(kg/ha)

Farm input	Marginal farms	Small farms	Large farms	All farms
Quantity of mustard oil cake	39	77	124	107
Quantity of rice bran	168	462	538	490
Quantity of composite feed	0	0	42	42
Quantity of other supplementary feed	0	0	4	4
Organic manure	334	36	323	269
Inorganic fertilizer	0.2	3	11	8
Quantity of lime	49	23	3	11

ranged from ₹ 13,980/ ha on large farms to ₹ 45,759/ ha on marginal farms.

The average amortized annual cost of farm machinery, nets, traps, etc. was ₹ 2,839/ha. The capital cost was generally low for large farms because the use of capital assets such as boats, nets, pumps, etc. was spread over a large farm area. The marginal farmers were not utilizing the farm machineries to the full extent. The overall cost on feed, fertilizer, lime was found to be ₹ 9438/ha, ₹ 1016/ha and ₹ 166/ha, respectively.

The management practices across farm-size groups do not appear to be consistent with the size of their operational water spread area. The budget for feed was negligible in the case of marginal farmers as compared to the other farm-size groups. Similarly, the budget for fertilizer in marginal and small farms was also much lesser than that of large farms. The expenditure on lime was very low in case of large farms compared to marginal farms.

The use of resources by the farmers in a fish production cycles is shown in Table 4. It can be noted that only large farms used composite feed as well as supplementary feeds. The use of organic manure was low by small fish farms. The practice of liming was minimal in large farms.

The average fish production in Bishnupur district, Manipur, was 1640.84 kg/ha, which ranged from 1372.50 kg/ha on large farms to 2187.22 kg/ha on small farms and 2599.30 kg/ha on marginal farms. Fish production is higher in case of marginal fish farms than in small and large farms. Obviously, the productivity of large farms is much lower compared to small and marginal farms. This may be due to the fact that large farms need better management. It also appears that large farms follow extensive fish culture in the farms, while the marginal and small farms practice fish farming at higher stocking densities, resulting in higher productivity.

The cost of cultivation of fish was ₹ 1,73,470/ha in Bishnupur district of Manipur (Table 5). It was higher in marginal fish farms than small and large fish farms due to increased cost of capital assets such as imputed leased value of land, amortized annual cost of farm machinery, nets, traps, etc. The overall gross income was ₹ 2,72,190/ha.

The net returns (₹ /ha) was higher in marginal than small and large fish farms. This can be attributed to proper management and full utilization of available resources. The overall net return over cost was ₹ 98,720/ha.

Technical Efficiency using DEA

The data envelopment analysis was carried out to obtain the efficiency levels of each of the fish farms under assumption of constant returns to scale (CRS). After estimating the technical efficiency and cost efficiency, the allocative efficiency of each fish farm was computed and the results are given in the Tables 9, 10 and 11, respectively. The cut-off score for efficient farms was decided on the basis of Ferreira (2005) criterion. Fish farms operating at score of 0.90 or more (TE, AE, CE) were considered as efficient farms.

The data envelopment analysis enables the classification of farms on the basis of their technical, allocative and cost efficiencies (Wadud and White, 2000). The technical, allocative and cost efficiencies have been classified into five ranges, viz. 0-25; 25-50; 50-75; 75-90; and 90-100.

Table 5. Economics of fish farming in Bishnupur district of Manipur

Particulars	Marginal farms	Small farms	Large farms	All farms
Total FF area (ha)	25.63	54.00	201.50	281.13
No. of sample fish farmers	50	50	50	150
Fish production (kg/ha)	2599	2187	1372	1640
Cost of cultivation (₹ /ha)	240050	219910	152550	173470
Cost of production (₹ /kg)	92	101	111	106
Price realization (₹ /kg)	163	165	167	166
Gross income (₹ /ha)	423920	360990	229100	272190
Net return over cost (₹ /ha)	183870	141080	76550	98720
Net return over cost (₹ /kg)	71	65	56	60
B:C ratio	1.77	1.64	1.50	1.57
Credit requirement (₹ /ha)	216040	197920	137300	156120

Table 6. Technical efficiency of fish farms at Bishnupur district of Manipur

Technical	Marginal farms		Small farms		Large farms		All farms	
efficiency	No.	%	No.	%	No.	%	No.	%
0-25	0	0	0	0	1	2	1	0.67
25-50	11	22	29	58	13	26	53	35.33
50-75	28	56	17	34	16	32	61	40.67
75-90	5	10	1	2	8	16	14	9.33
90-100	6	12	3	6	12	24	21	14.00

Table 7. Allocative efficiency of fish farms at Bishnupur district of Manipur

Allocative	Marginal farms		Small farms		Large farms		All farms	
efficiency	No.	%	No.	%	No.	%	No.	%
0-25	9	18	9	18	13	26	31	20.67
25-50	23	46	12	24	9	18	44	29.33
50-75	17	34	17	34	9	18	43	28.67
75-90	0	0	8	16	11	22	19	12.67
90-100	1	2	4	8	8	16	13	8.67

It can be seen from Table 6 that 12 per cent (6 Nos.) of the marginal farms, 6 per cent (3 Nos.) of small farms and 24 per cent (12 Nos.) or 14 per cent (21 Nos.) of the sample farms were technically efficient.

Table 7 shows that 2 per cent (1 No.) of marginal farms; 8 per cent (4 Nos.) of small farms and 16 per cent (8 Nos.) of large farms or 8.67 per cent (13 Nos.) of total number of farms surveyed were found efficient in terms of allocation of resources among the fish farms at Bishnupur district of Manipur.

Table 8 shows that only a small fraction, viz. 2 per cent (1 No.) of marginal farms; and 4 per cent (2 Nos.) of large or 2 per cent (3 Nos.) of the total farms sample were efficient in terms of budget used for purchasing of inputs in Bishnupur district of Manipur.

Marginal Farms — Assuming constant returns to scale (CRS), only about 12 per cent of the sample farms were found efficient (above 90%) and 22 per cent were found in the TE range of 25-50 per cent. The highest number of farms (28) was in the TE range of 50-75 per cent. It could be inferred that 44 fish farms (88%) did not

Table 8. Cost efficiency of fish farms at Bishnupur district of Manipur

Cost efficiency	Marginal farms		Small farms		Large farms		All farms	
	No.	%	No.	%	No.	%	No.	%
0-25	22	44	24	48	21	42	67	44.67
25-50	27	54	25	50	6	12	58	38.67
50-75	0	0	1	2	16	32	17	11.33
75-90	0	0	0	0	5	10	5	3.33
90-100	1	2	0	0	2	4	3	2.00

Table 9. Efficiency measures and descriptive statistics for fish farmers according to scale of operations in Bishnupur of Manipur

Scale of operation	Efficient farm (≥ 0.90)		Efficiency measures	
	No.	%	Mean	Standard deviation
		Marginal farms		
Technical efficiency	6	12	0.62	0.18
Allocative efficiency	1	2	0.40	0.19
Cost efficiency	1	2	0.25	0.15
		Small farms		
Technical efficiency	3	6	0.52	0.16
Allocative efficiency	4	8	0.56	0.26
Cost efficiency	0	0	0.28	0.14
		Large farms		
Technical efficiency	12	24	0.69	0.23
Allocative efficiency	8	16	0.53	0.33
Cost efficiency	2	4	0.39	0.29
		All farms		
Technical efficiency	21	14	0.61	0.20
Allocative efficiency	13	8.67	0.50	0.27
Cost efficiency	3	2	0.31	0.21

operate at the maximum efficiency level and these could increase the fish production level by 38 per cent (Table 9).

The marginal fish farms efficient in terms of allocation and cost efficiency, were only 2 per cent in each. These efficiency levels may be attributed to the use of family labour in fish production by the marginal farms. The average allocative and cost efficiency scores were 0.40 and 0.25, respectively for the sample 50 marginal farms (Singh, 2014) .

Small Farms — Under the assumption of constant returns to scale, only 6 per cent of the small fish farms were found efficient. The average efficiency score was lower than that of marginal fish farms. The average allocative and cost efficiency scores for the sample small farms were 0.56 and 0.28, respectively and there exists ample scope for increasing the productivity of these farms by following better technological and managerial practices.

In terms of allocative efficiency score, small fish farms were found more efficient than marginal fish farms. But, none of these fish farms was performing at cost efficient levels, may be due to a high use of family labour in these farms.

Large Farms — Assuming constant returns to scale, 24 per cent of large fish farms performed well in terms of technical efficiency; however, the allocative efficiency was just 16 per cent which resulted in low

Table 10. Factors determining cost efficiency in fish farming among large farmers in Manipur

Factors	Coefficients	Standard error	P-value
Intercept	0.26	0.08	0.002
Occupation			
Fish farming and agriculture	-0.20	0.09	0.031
Fish farming and business	-0.30	0.24	0.214
Fish farming and service	0.20	0.14	0.171
Fish farming and other occupation	-0.87	0.23	0.001
Fish farm area (ha)	0.05	0.02	0.004
Credit availed	-0.11	0.12	0.366
Sample size (No.)	50		
R - square	0.4182		

level of economic and cost efficiency (4%). Twelve out of the 50 large fish farms were efficient, indicating that the level of efficiency was higher in large farms than in marginal and small fish farms. The average technical, allocative and cost efficiency scores were 0.69, 0.53 and 0.39, respectively for the sample 50 large farms. The allocative and cost efficiency levels have also been found to be higher in these farms compared to marginal and small fish farms.

In nutshell, since the majority of farms irrespective of size, operate at low efficiency levels in the North-Eastern states, there is an urgent need for technology transfer and better extension efforts to improve their managerial skills for enhancing their profitability in fish farming.

Determinants of Cost Efficiency

To estimate factors determining cost efficiency, the efficiency scores were regressed against education, occupation, experience, area of fish farms and credit availed by large farms (n = 50) using a simple linear regression. Since occupation is multinomial (5 level), four dummies were used with only fish farming as base. The stepwise regression procedure was used. Since the two variables education and experience were insignificant, they were dropped from the model. The credit variable was also a dummy with '1' for those availing credit and '0' otherwise.

The fish farm area and fish farming and other occupation and fish farming with agriculture were found to be significantly influencing the efficiency level of fish farms (Table 10). The variations in cost efficiency among large farmers were explained to the extent of 40 per cent by the independent variables. Since the dependent variable (inefficiency scores) is a part of the error component, the coefficients of regression are expected to be less significant or insignificant as in error correction models of time-series analysis. With the larger sample size, the same model is expected to yield a higher value for the coefficient of multiple regressions (Gujarati, 2003). The fish farm area was positive which showed that larger farms were more efficient.

Concluding Remarks

Fish farming is one of the important economic activities in the state of Manipur. However, the majority of fish farms operate at a very low level of economic efficiency. Weak management practices coupled with obsolete techniques of production have resulted in low efficiency scores w.r.t. usage of important inputs like feed, fertilizers and liming. Despite fact that 66 per cent of fish farmers in Manipur belonged to the large farms category, the inefficiencies were the least in this category.

Nevertheless, the scope for improvement of fish farming is immense in North-East India, and especially in Manipur. With the establishment of a regional office of the National Fisheries Development Board at Guwahati and also special programs for NE India by the NABARD, the potential of fisheries in Manipur is being explored in earnest. The Tribal Support Plan as well as NE India specific development plans are also being handled by central fisheries research institutions in collaboration with the state DoF. Therefore, the future of fisheries in Manipur appears to be bright in the light of concerted efforts to increase fish production and improve per capita consumption of fish in these states.

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