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Evaluation of Different Trout Farming Systems and Some Policy Issues in the Black Sea Region, Turkey

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Abstract: The main objective of this research was to evaluate different trout farming system in terms of their social, bio-technical and economical aspects in the Black Sea region, Turkey. Data were collected from 75 trout pond farms which were randomly selected and determined by the exact counting method 6 dam farms and 3 sea farms. The farm characteristics were defined in terms of culture systems. One-Way Analysis of Variance and the Chi-Square test were used to test means and frequencies. Data Envelopment Analysis was used to calculate efficiency measures. Results showed that there were differences between culture systems in terms of their social, bio-technical and economical aspects. Most of the social characteristics of the sea farms were more advanced when compared to the others. However, the smaller farms, especially pond farms, were relatively more technically and economically efficient. The costs of production in the pond, dam and sea farms would be reduced by 32, 39 and 50%, respectively, if these farms were managed efficiently. Provision of infrastructure, optimal input use and modern fish farming techniques are crucial to improve farm performance. State intervention on externalities, coordination among related sites and incentives might help to solve current farm problems and to develop the aquaculture sector in the region.

Key words: Comparison of culture system, trout farming, black sea region, Turkey

INTRODUCTION

Aquaculture is a socially and economically important sector in the developing countries. Growth in aquaculture can play a major role in helping to improve food security and to increase or diversify economic opportunities at both local and national level in Turkey. Increased employment in aquaculture can help to reduce migration and help to maintain the quality of life for rural populations (Burbridge *et al*., 2001). The availability of high quality protein sources in light of declining wild fish stocks and continued population growth are crucial. Aquaculture is ideally suited to meet these needs. Nowadays, aquaculture is practiced worldwide and involves the farming of many species. Over the last decade, world aquaculture production has grown from 11 to 38 million tones (Yıldız, 2005). Turkey is one of the countries having many favorable sites for aquaculture. The inland water resources in Turkey are suitable for culturing different freshwater fishes, especially 'rainbow trout *Onchhorynchus mykis* (Walbaum).

There has been noticeable development in Turkey's aquaculture since the 1980's. Marine aquaculture production increased from 1.514 tons in 1989 to about 40 thousand tons in 2003. Similarly, fish production in freshwater has grown from 4.237 tons to 40 thousand tons (Yıldız, 2005). Trout production is 57% of the total fish production obtained from aquaculture (Bozoğlu *et al*., 2005). The rainbow trout is the main freshwater species cultured in Turkey. Cage farming of rainbow trout is widespread in lakes and reservoirs and has gained popularity over the last decade. Sea bass and sea bream dominate marine species production in the Aegean and Mediterranean regions in Turkey. In contrast, trout production, especially of rainbow trout, has increased considerably in the last decade in the Black Sea region. Increasing interest in aquaculture techniques has encouraged farmers and researchers to evaluate the feasibility of pond and cage culture in recent years.

To date, there has been a wide range of research to explore bio-technical characteristics and performance of aquaculture farms and their economic aspects worldwide (Shang, 1973; Naylor *et al*., 1998; Sharma *et al*., 1999; Paul, 2000; Orea, 2002; Wedekind *et al*., 2001). However, studies evaluating different trout production systems globally are limited (Rifai, 2000; Lever *et al*., 2004), including Turkey. Different culture systems have different effects on the socio-economic and environmental viability

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of fish farms (Shang *et al.*, 1998). The objectives of this study were (i) to examine some social, bio-technical and economic characteristics of different systems of trout farming and (ii) to propose some policy issues for the specific improvement of farms and the overall improvement of the aquaculture sector in the region.

MATERIALS AND METHODS

The study was based on primary data gathered from aquaculture farms in the Black Sea region. The research area covered 10 selected provinces where trout farming is most common, namely Samsun, Ordu, Trabzon, Rize, Sinop, Artvin, Düzce, Giresun, Bolu and Kastamonu. Farms in this region constitute 87% of the total physical capacity and 86% of the total aquaculture farms in Turkey (Bozoğlu *et al.*, 2005).

Most of the data were gathered from 75 randomly selected trout pond farms out of a total 301 farms and also from all of the farms which raise rainbow trout in dams (6 dam farms) and the sea (3 sea farms). The information was gathered using a structured questionnaire. To enhance validity and reliability of the survey, the primary data was supplemented by focus group interviews. Face and content validity were established by convening a focus group that included beneficiaries and individuals with relevant expertise. Reliability was assessed using the test-retest method in which the survey was administered to the same group at two different times. Cronbach (1951) alpha was used as an index of internal reliability or consistency for the set of questions and an alpha of 0.80 or higher was considered an acceptable level of internal reliability (Cramer, 1998).

The variables analyzed in this study can be divided into three broad groups: social characteristics of the farms (education and experience of the respondents, labour profile, type of ownership, participation in extension courses and information sources, insurance and collaboration level of farmers); Bio-technical characteristics and performance (stocking density, productivity, survival ratio, harvest density, feed conversion ratio, fattening period and technical efficiency) and economic characteristics (production capacity, capacity use ratio, credit use, production costs, distance to markets, marketing period, fish marketing size, fish price, total assets, liquidity and solvency, return on equity, return on asset and economic efficiency). Data were numerically coded, entered into a database (SPSS for Windows) and analyzed. Descriptive statistics were used to describe the sample farms.

Data Envelopment Analysis (DEA) was used to calculate efficiency measures. DEA is one of several techniques that can be used to calculate a best practice production frontier (Coelli *et al.*, 1998; Kumbhakar and Lovel, 2000). Farrell (1957) proposed that the efficiency of a firm consists of two components: technical efficiency, which reflects the ability of a firm to obtain maximal output from a given set of inputs and allocative efficiency, which reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices and the production technology. These two measures are then combined to provide a measure of economic efficiency. The Farrell measure equals 1 for efficient farms on the frontier and then decreases with inefficiency.

Based on the suggestion by Charnes *et al.* (1978), it was assumed that each trout farm produces a quantity of live trout (Y_i) using multiple inputs (x_i*) and that each farm (i) was allowed to determine its own set of weights for both inputs and output. The input based cost efficiency for the ith farm can be obtained by solving the following Linear Programming (LP) problem:

$$\begin{aligned} &\text{Minimize}_{\lambda, xi*} w_i^T x_i^* \\ &\text{Subjectto} -y_i + Y\lambda \geq 0 \\ &\qquad x_i^* - X\lambda \geq 0 \\ &\qquad \lambda \geq 0 \end{aligned} \quad (1)$$

where w_i is a vector of input prices for the ith trout farm, superscript T is the transposed function and x_i* is the cost-minimizing vector of input quantities for the *i*-th trout farm calculated by the LP, given the input prices w_i and output level Y_i (Coelli *et al.*, 1998). In this study, two inputs were employed: Feed (tons per year) and labour (thousands of hours per year) and one output. Equation 1 represents cost minimization under Constant Returns to Scale (CRS) technology. Constant return to scale means that trout farmers are able to linearly scale inputs and outputs, without increasing or decreasing efficiency. The total cost efficiency, or Economic Efficiency (EE), of the ith trout farm is calculated as $EE = w_i^T x_i^* / w_i^T x_i$ (2). That is, EE is the ratio of minimum cost to observed cost, for the ith trout farm, given input prices and CRS technology. The allocative efficiency was calculated residually by AE = CE/TE (3) (Coelli *et al.*, 1998).

Coelli *et al.* (1998) pointed out that the CRS model is only appropriate when the farm is operating at an optimal scale. Some factors such as imperfect competition and constraints on finance may cause a firm to be not operating at the optimal level. Since trout farms conducted their activities under imperfect competition and the size of many farms was below the borrowing limits set by financial institutions in the research area, Eq. (1) was transformed to Variable Returns to the Scale (VRS) technology model by adding the convexity constraint:

N1λ = 1. The restriction eliminates scale effects from the analysis (Banker *et al.*, 1984). In that case, efficiency of the farm was calculated by using Eq. (2), replacing the numerator with the minimum costs of the farm under VRS technology (Banker *et al.*, 1984). Efficiency measures under CRS and VRS were calculated by using DEAP 2.1 which was developed by Coelli (1996).

One-way analysis of variance (ANOVA) was used to test the hypothesis that means were equal when comparing the 3 different culture systems in terms of non-categorical scale variables. Once it was determined that differences existed among the means, pair wise multiple comparisons were made using Duncan's Multiple Range Test. Since some variables included in this study were categorized, the Chi-Square Test was used to compare the observed and expected frequencies in each category.

RESULTS AND DISCUSSION

Social characteristics: In the research area, the education level of the respondents at the sea farms was higher than for the other systems (χ^2 = 6.37, p<0.05). Since the sea cage system requires relatively more technical knowledge, the result was as expected. Two thirds of the respondents at the sea farms had a university degree, while the pond and dam farms were 15 and 17%, respectively. For the pond farms, 68% of the respondents had only primary school education, while it was 33% for the dam farms. The low educational level and insufficient technical knowledge of the respondents were the main social constraints for both pond and dam farms (Table 1). On the other hand, respondents at sea farms had greater experience in aquaculture than at pond and dam farms. However, the difference was very low due to the high standard error of coefficients (p>0.05).

The main workforce was family members at the pond and dam farms, while it was based on hired labour for the sea farms. High levels of family members employed by the pond and dam farms decrease disputes between employers and workers and all allow the farms to withstand financial difficulties and economic risks.

Table 1: Some social characteristics of the farms*

Variables	Pond farms	Dam farms	Sea farms
Education level of the respondents (years)	3.24	4.00	4.67
Experience of the respondents (years)	8.61[a]	7.17[a]	10.50[a]
Family labour (persons)	2.18[a]	2.60[a]	1.00[b]
Hired labour (persons)	3.21[a]	2.50[a]	19.64[b]
Technical persons	0.09[a]	0.00[a]	1.67[b]
Family farm (%)	78.70	66.7	33.3
Farmers having participated in extension course (%)	62.70	50.0	100.0
Farms insured (%)	18.7	16.6	33.0
Fisheries cooperative membership (%)	37.0	50.0	100.0

* Farming systems with same letter(s) are not significantly different

Only 8% of the pond farms and one sea farm of 3 employed a fisheries technician. However, there were no technicians employed at the dam farms. This might be consequence of the small-scale of the farms and unsuitable social conditions in rural areas. Absence of a technician on the farms caused technical problems and increased deaths of eggs, fingerlings and fish.

While family ownership characterized pond and dam farms (χ^2 = 4.69, p<0.05), most of the sea farms were company owned. The labour and farm ownership profile indicated that the sea farms were more professional and market oriented than the others.

All farmers at the sea farms participated in at least extension courses on aquaculture, while half at the dam farms and 37% at the pond farms had not attended any course. Participation of pond and dam farm employees at extension courses was low. The reasons for the low participation may be insufficient publicity on the availability of extension courses, time and financial limitations, long distance to extension services and absence of extension courses. The information sources for farming systems were statistically different (χ^2 = 4.71, p<0.05). For the pond and dam farms, farmers generally tended to try to solve their problems themselves, in spite of the fact that they did not have sufficient knowledge on aquaculture, especially on growing and disease control. Trying to solve their problems themselves exacerbated the problems. Some of the previous studies in Turkey produced similar findings (Sayılı *et al.*, 1999; Karli, 2000; Atay and Korkmaz, 2001; Kocaman *et al.*, 2002). In contrast, the sea farms opted to employ a technical person on their farms to solve problems.

Insurance against any negative impacts on fish stocks or the aquatic environment from bird predation, tourism, maritime activities and other industries was not common. Thirty three percent of the sea farms preferred to insure their farms against risks, while only 19% of the pond farms and 17% of the dam farms had insurance. This situation could adversely affect the sustainability of the farms. There was no statistical difference between the farming systems with regard to insurance (χ^2 = 0.510, p>0.05).

While the sea farmers were all members of a cooperative or an association, only half of the dam farmers and 37% of the pond farmers worked with a cooperative or an association. The pond and dam farmers were not well organized at managing inputs and at the marketing stage. Similarly, Elbek (1993) suggested that farmer organizations were not good at supplying services such as inputs, credit and marketing to their members in Turkey. Tendency to cooperate within culture systems was also statistically different (χ^2 = 6.32, p<0.05) and willingness to be organized was very high among the farmers.

Bio-technical characteristics and performance: Based on research results, (Table 2) the survival ratio in the pond farms was higher than in dam and sea farms ($p<0.05$). A possible reason for the higher survival ratio in the pond farms might be the more intensive care on the smaller scale. The average survival ratios on the farms were lower than the acceptable level (65.3%) suggested by Logan and Johnston (1992). This may be attributable to a high level of temperature variations at the sea and dam farms.

Regarding stocking density, the number of fish per m^3 in pond farms was higher than for dam and sea farms ($p<0.05$). The stocking density in the sea farms was lower than dam farms. A similar picture emerged for harvest density ($p<0.05$). Therefore, some farmers increased stocking rates to combat this problem. This practice leads to low profitability in the farms at greater than optimal stocking density. The highest harvest density was observed in the pond farms with 9.91 kg m^{-3}. The dam farms and the sea farms followed with 4.75 kg m^{-3} and 2.83 kg m^{-3}, respectively.

Feed conversion ratios for pond, sea and dam farms were 1.3, 1.25 and 1.23, respectively. In comparison, Rad and Köksal (2001) stated that the average feed conversion ratio was 1.57 for trout farms in Turkey.

The fattening periods for the pond, sea and dam farms were 13.7, 8.5 and 6.5 months, respectively. The pond farms tended to raise fish from eggs, while the sea and dam farms started fattening from the fingerling stage.

The estimated technical efficiency measures for pond, dam and sea farms were 0.82, 0.76 and 0.62, respectively. Interestingly, the pond farms were more technically efficient than the sea farms, despite the employment of technicians. There was no statistical difference between the dam and sea farms in terms of technical efficiency ($p>0.05$).

Use of stream and well water by the pond farms, even if they were not suitable for aquaculture (Rad and Köksal, 2001), intensive establishment of farms in some locations (Uzungöl, Firtina stream, Perşembe inlet), absence of sedimentation ponds and use of uncovered canals for supplying water to the farms may have adversely affected the bio-technical performance of the farms and consequently the development of the aquaculture sector in the region. In addition, inappropriate feeding, diseases, not measuring oxygen levels and microbiological characteristics of water and buying eggs and fingerlings from other farms without controlled conditions are obstacles for the farms. Rad and Köksal (2001) also stressed that the absence of equipment and incorrect design of ponds negatively affected their bio-technical performance. In addition, inappropriate feeding causes management problems such as water pollution, loss of nursery stock and low yield. These externalities can cause significant social costs, which may hinder development of aquaculture in the region.

Table 2: Some bio-technical characteristics and performances of the farms*

Variables	Pond farms	Dam farms	Sea farms
Stocking density (unit m^{-3})	54.8[a]	18.40[b]	4.86[c]
Productivity (kg m^{-3})	9.91[a]	4.75[b]	2.83[c]
Survival ratio (%)	47.70[a]	36.80[b]	38.60[b]
Harvest density (kg m^{-3})	9.91[a]	4.75[b]	2.83[c]
Feed conversion ratio	1.30[a]	1.23[b]	1.25[b]
Fattening period (months)	13.72	6.50	8.50
Technical efficiency	0.82[a]	0.76[ab]	0.62[b]

* Farming systems with same letter(s) are not significantly different

Economic characteristics: The production capacity for the sea, dam and pond farms were about 129 thousand m^{-3}, 8 thousand m^{-3} and 1 thousand m^{-3}, respectively (Table 3). The production capacities were statistically different among the farms ($p<0.05$). The average capacity use ratio of the farms was relatively low. That can be traced to a number of obstacles, including bureaucratic 'red tape', which makes fish production difficult and increases costs. Other obstacles were high feed prices, diseases, high fish losses, inadequate demand and excess capacity.

Analysis of distance to markets revealed that pond and dam farms preferred local retail markets, while sea farms preferred wholesale markets ($p<0.05$). As a result of their high production, sea farms supplied their fish to wholesale markets in big cities. Their marketing period was shorter ($p<0.05$), as expected. By tradition, there isn't a strong seasonality in live fish sales from pond and dam farms. Marketing period for pond and dam farms extended approximately 10-12 months, while that of the sea farms was only two months. The sea farms marketed their fish with an average size of 583 g, while that of the dam farms and the pond farms were 258 and 213 g, respectively. Marketing size of fish in the sea farms were statistically different from the pond farms ($p<0.05$).

Table 3: Some economic characteristics of the farms*

Variables	Pond farms	Dam farms	Sea farms
Production capacity (m^3)	1074.10[a]	7812.70[b]	129421.00[c]
Capacity use ratio (%)	0.64[a]	0.42[a]	0.65[a]
Distance to market (km)	36.10[a]	42.67[a]	70.00[b]
Marketing period (months)	10.60[a]	11.60[a]	2.00[b]
Fish marketing size (g)	213.11[a]	258.33[ab]	583.33[b]
Production cost (TL kg^{-1})	3.75[a]	0.90[b]	0.89[c]
Fish price (TL kg^{-1})	3.73[a]	2.62[a]	2.37[b]
Total assets (TL)	112357.00[a]	68237.00[b]	500509.00[c]
Liquidity of farms (current ratio)	3.16[a]	2.79[b]	0.78[c]
Solvency of farms (Debt $asset^{-1}$)	0.05[a]	0.03[b]	0.55[c]
Amount of credit (TL)	5327.23[a]	7000.00[b]	275659.50[c]
Return on equity (%)	10.53[a]	99.62[b]	262.97[c]
Return on asset (%)	12.17[a]	98.14[b]	141.80[c]
Economic efficiency	0.68[a]	0.61[ab]	0.50[b]
Allocative efficiency	0.83[a]	0.80[ab]	0.81[b]

* Farming systems with same letter(s) are not significantly different

The difference in marketing size among the farms can be attributed to marketing requirements. The sea farms marketed their fish fresh to wholesalers and the pond and dam farms generally marketed fresh or cooked directly to consumers. The percentages of farms with graded fish packing and cold shocking were 67% for sea farms and 17% for dam farms. There was no diversification of fish species and income sources in the pond farms. The pond farms preferred to sell fish directly to consumers without packing or grading. Production costs for pond farms were higher than for dam and sea farms. Sale prices were different for the farm systems. Due to direct marketing, the pond farms received higher prices than the sea farms ($p<0.05$).

Analysis showed that pond farms used more capital m^{-3} than the others ($p<0.05$). However, the returns on equity and total assets were lower for the pond farms ($p<0.05$). This may be attributed to the high level of fixed assets of the pond farms. For the sea and dam farms, return on equity exceeded return on assets. Namely, farms gained more than interest payments on debt, while the opposite was true for the pond farms. Liquidity and solvency of the pond and dam farms was higher than sea farms ($p<0.05$). This can be attributed to the amount of credit used by those farms. The differences between the farm systems in terms of credit use were significant ($p<0.05$). It might be inferred that sea farms are more professional and market oriented. However, they are faced with serious liquidity and solvency problems and their economic efficiency is lower than the others.

The estimated economic efficiency scores for the pond, dam and sea farms were 0.68, 0.61 and 0.50, respectively. The pond farms were more efficient economically than sea farms ($p<0.05$). This could be attributed to the intensive use of their scare production factors. In addition, pond farms had a greater opportunity cost of labour. The difference among production systems in terms of economic efficiency is attributable to the scale of the farms. Small-scale farms tended to be more efficient economically. This supported the hypothesis of small but efficient advanced by Schultz (1964). Some management problems resulting from the scale of farms led to decreased technical and economic efficiencies. The technical efficiency scores indicated that farmers could reduce their inputs by 18% in inefficient pond farms, 24% in inefficient dam farms and 38% in inefficient sea farms, without reducing production. Based on the estimated allocative efficiency scores, sea farms were inefficient allocatively compared to the pond farms ($p<0.05$).

Policy issues relevant to the farms and aquaculture development in the region: Research results revealed that the three farming systems differed significantly in terms of social, bio-technical and economic aspects. Results also indicated that farms faced similar and different constraints related to sub-structural, human resources and administrative, technical and economic aspects in the research area. When externalities exist, public intervention is often needed to reduce them, if such action is socio-economically justifiable.

The provision of infrastructure, adequate inputs and modern fish farming techniques are crucial to improving the productive performances of farms. Pilot farms should be established by the government as centers for producing technical information and disseminating it. In the future, farms will only be competitive if they successfully deal with issues such as disease control, feeding strategies and marketing.

Technical assistance and extension programs on feeding, control of diseases and hygiene may be useful in solving technical problems and improving technical efficiency. Future programs for farmer training and extension activities should focus on human resource development and assist farmers to be more market oriented. Nevertheless, encouraging big farms to employ a technical expert might be beneficial. This is impossible for the small and medium scale farms in the region. In their case, farmers' organizations should employ a technical expert to give advice to their members.

State support for self-help among farmers might increase cooperation among farmers and the efficiency of farmer organizations. Close co-operation among farms is essential to overcoming crucial problems. The further development of cooperatives or associations may also increase marketing efficiency and decrease marketing costs.

Sea farms are better positioned for development in the Black Sea region when their returns on assets, feed conversion ratio and production costs are considered. Despite the fact that pond farms were well placed regarding liquidity, solvency, efficiency measures, survival ratio and fish prices, their returns on assets and equity were low and production costs were very high. Simply by having substantial opportunities to reduce unit production costs and increase efficiency of input use in cage culture, sea and dam farms are most likely to more profitable in the near future.

Despite the difficulties in overcoming sub-structural deficiencies and inefficiencies on farms, government should plan and start a program to remove deficiencies and increase support at the regional level. The sustainable utilization of limited farming areas and potential overcrowding might be resolved by limiting farm numbers and production capacity by regulation. Improvement of feed quality and extension programs for farmers on feeding would enhance current feed conversion ratios. In addition, Rad and Köksal (2001) proposed that a health certificate should be obligatory when selling eggs and fingerlings and that the flow of eggs and fingerlings among farms should be tightly controlled. This proposal might increase the survival of stock on farms.

Reductions in production costs and negative environmental impacts through bio-technical improvement and efficient management are all important for sustainable development of aquaculture. By operating at full efficiency, the sampled farms would substantially increase their output and revenue, reduce costs and raise profitability. Compared to the efficient farms, production costs of inefficient pond, dam and sea farms would be reduced by 32, 39 and 50%, respectively, by operating at full efficiency. These cost reductions would result from the elimination of inefficient input use in production. As a result, farmers would increase their profits.

Restructuring debts of sea farms and supporting them with soft loans might enhance the development of this type of farm in the region. Shang *et al.* (1998) stated that improving production efficiency and minimizing negative environmental impacts requires farms to coordinate their production and marketing, diversify markets and products and improve product quality. Vertical integration by farmers would increase the value of their fish, resulting in increased income. Diversification in presentation and supply of value-added products (fillets, precooked, etc.), increased size range, improvement of product quality image (quality certification, designation of origin, organic, etc.), creation of new markets and development of current markets may increase sustainability. In addition, combining pond farms with restaurants and sites suitable for rural tourism might accelerate the transformation from family pond farms to more market based production.

The main hope for the farms lies in an increase in production efficiency. This involves a reduction in costs, an increase in the scale of operation, disease control and a significant investment in modern technology. However, high production costs, unsatisfactory marketing opportunities and the constraints obliged by nature conservation and the environment render trout farming extremely difficult in the region. To facilitate sustainable and equitable development of aquaculture, there also need to be major improvements in the provision of scientific information and advice in forms that can be effectively utilized by policy makers, spatial planners and resource managers. Aquaculture development is constrained by the absence of integrated development planning frameworks and the predominance of sector-based planning and management. There is a need for special development strategies for aquaculture farms in the region and, well-designed strategies should be implemented continuously. Such regional strategies could be included in a national aquaculture development strategy. A national strategy has the potential to deliver major economic and social benefits at national, regional and local levels in Turkey.

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