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Economic analysis of family trout farming in Southern Brazil

Andressa Steffen Barbosa[1] · Raquel Grande Pereira[2] · Laurindo André Rodrigues[3] · Jorge de Matos Casaca[4] · Wagner Cotroni Valenti[5] · Thiago El Hadi Perez Fabregat[1]

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Abstract
This study aimed to evaluate the economic feasibility of family trout farming in the Serra Catarinense, a temperate region in South Brazil. Two properties characterized as small (production = 10.8 t/yr) and medium (production = 32.4 t/yr) scale, respectively, were evaluated. The investment costs were US$ 20,780.53 for the small-scale farm and US$ 92,677.03 for the medium-scale farm. Operating expenses were US$ 17,920.40/yr for the small-scale and US$ 45,876.24/yr for the medium-scale farms. Feed was the main cost. In the small-scale farm, both fixed and variable costs were higher. While feed costs per kg of fish produced were similar between the two production scales, for the medium-scale farm, the larger production scale decreases the significance of the remaining costs, resulting in higher profitability. Still, the economic analysis showed that the two scales of farming are economically feasible with IRR values of 18 and 19% for the small and medium scales, respectively, and the payback period is less than 6 years for both scales of farming. The medium-scale producer had higher income and higher net present value, but the results of the other economic indicators were similar to the small-scale producer. We conclude that the family farming of trout in small and medium scales is economically feasible. The small-scale production requires complete dedication from the owner. For the medium-scale farm, it is feasible to hire a technician without compromising economic outcomes. Finally, based on the sensitivity analyses, it was shown that improper feed management can render the activity economically unfeasible.

Keywords Aquaculture economics · Family farm · Rainbow trout · Sustainability

Introduction

The state of Santa Catarina has a special niche in Brazilian aquaculture, which is characterized by the predominance of small family-owned farms. Currently, the cultivation of rainbow trout

✉ Thiago El Hadi Perez Fabregat
thiagofabregat@hotmail.com

Extended author information available on the last page of the article

(*Oncorhynchus mykiss*) is becoming developed in the region. The rainbow trout is a salmonid native to North America, which requires low temperatures and clean and abundant water for its culture (FAO 2020). This fish was introduced in Brazil as an alternative for fishing. Nevertheless, it became intensively cultivated for commercial purposes because of its excellent quality meat, high commercial value, and the possibility of domestication.

Trout farming in Brazil is mainly carried out by small family farms. The majority of these farms have not been producing more than 20 t per year (Amaral 2007) and the activity is the main source of revenue for many of them. In Santa Catarina, there are 90 producers (IBGE 2020) producing a total of 694 t per year (EPAGRI/CEDAP 2020). This is in contrast to the primary production areas in Europe, North America, Chile, Japan, and Australia, where production is industrialized and on a large scale (FAO 2020).

Currently, a trend of intensification exists for aquatic products, increasing competition for resources and water. It is essential that the three components of sustainable aquaculture are respected to maintain viability in trout farming. These components are lucrative production, environmental conservation, and social development. These are considered to be indissociable for the activity to be sustainable (Valenti et al. 2018). The development of well-designed, productive projects and a strong supply chain are necessary to attain economic sustainability (Valenti and Moraes-Valenti 2010). A well-designed project should have a realistic business plan and should be based on using the most adequate technology for the local conditions and for the investor. Projects executed without proper economic analysis constitute a short path to failure.

Thus, the objective of the present study was to analyze the economic feasibility of trout farming on family farms in the Serra Catarinense region, SC, Brazil, comparing two profiles of farming by characterizing their different scales of production.

Materials and methods

A list of trout farmers in the Serra Catarinense region, obtained from EPAGRI (Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina/Agricultural Research and Rural Extension of Santa Catarina) in the city of Lages (27° 49′ 0″ South, 50° 19′ 35″ West), was made publicly available for selecting representative farmers. Two representative trout farmers operating on small and medium scales of production were selected. The main criteria used in this selection were the wet area, infrastructure available, annual production, and income. The properties were visited between July 2012 and July 2013 for obtaining the economic data. We also obtain data on labor and feed conversion rate on other similar farms of the region and the mean value was used for analysis. All monetary data, including cited data from previous studies, were updated using the Brazilian General Index of Prices for Internal Market (IGP-DI) in February 2020. Thus, data were converted into US dollars based on the mean currency value in Feb 2020 (US$ 1.00 = R$ 4.48), and based on the information obtained, the economic analyses were performed.

The property chosen to represent a small-scale farm had the capability of producing 10.8 t/yr. It has 16 raceway tanks in concrete, with 21 m^2 each, and totaling 336 m^2 of wet area. The tanks are organized in a single array with a continuous water flow with 1-h turnover. The water is treated in a decantation pond of 100 m^2 before being returned to the river. The feed is stored in a concrete shed of 24 m^2, which is located close to the tanks. The production cycle lasts about 10 months, and the fish are harvested with a weight of 400 g. The production was 32.14 kg of fish per cubic meter, which was chilled after slaughter.

The management in small-scale farms begins with the acquisition of fingerlings (2 g), which are stocked in a density of 89.3 fish/m^2. The fish are fed commercial diet for carnivorous fish with 45% crude protein and 14% fat. The fingerlings are fed 4 times a day for 30 days in a proportion of 10% of their body weight. Larger fish are fed 2 times per day at a proportion of 3% of their body weight. The pellet size of the food increases with the growth of fish, with powder for the fingerlings and pellets of 1 cm for the larger fish. The average feed conversion ratio is 1.54 kg feed/kg of fish produced. The highest mortality rates were 10%. Fish were classified and re-stocked in the tanks according to size each month. Also once a month, the tanks are partially emptied to be cleaned with a brush and high-pressure water. This practice is fundamental to disease prevention to avoid sanitary problems. The owner performs all management and does not have a contracted worker. Overtime work comes from the owner's family.

A property with the capability of producing 36 t per cycle was selected to represent family production from a medium-scale farm. The facility is allocated on a total area of 3.2 ha. The constructed area occupies 2 ha and contains 22 raceway tanks for grow-out (21 being rectangular and 1 larger irregular tank divided into smaller subsections). The wet area totals 946 m^2, and the decanting pond is 200 m^2. Water is completely renewed every hour. The tanks are arranged in three arrays in which the water is reused between the tanks for 3 times. The property has an area with a tiled zinc roof of 140 m^2 to store the inputs such as fish feed. This pavilion shelters the feed supplies, which occupy 24 m^2. Overtime is provided by the family. The production technology is basically the same as the small-scale farm but with small differences in feed management and productivity.

The fingerlings are stocked in a density of 95.1 fish/m^2. During the first month, the fingerlings are fed 6 times per day at a ratio of 10% of body weight. In the next phase, the fish receive 2 feedings per day. The amount of feed provided can decrease to 3% of the fish's body weight according to the fishes' responses in this phase. Productivity is 38.05 kg/m^2. Temporary workers are contracted for the harvest and the fish to be marketed after slaughter is only chilled.

The analyses of cost-return and financial feasibility were determined according to Shang (1990), Jolly and Clonts (1993), and Engle (2010). The fixed costs included were depreciation and the opportunity costs (payment for the owner and interest on initial investment). The land lease was disregarded because the land area is very small. Variable costs were the fingerlings, diet, labor, maintenance of facilities, and interest on working capital. The indicators of financial feasibility determined were annual income (IA), payback period (PP), net present value (NPV), benefit-cost ratio (BCR), internal rate of return (IRR), and the revenue/investment ratio (RRI). The life of the project was 20 years. This period was defined based on the useful life of the ponds and the raceway tanks, which were the structures that had the most significance in the investments. We assumed that the inflation of production costs will be compensated by inflation in the prices obtained for the production. The minimum attractive rate of return (MARR) and the discount rate were both set at 10.75% per year, due to interest on initial capital in Brazil.

Simulations were performed by creating different scenarios using the data obtained from the economic analyses. These scenarios evaluated the sensitivities of indicators of financial feasibility, which were derived from situations in the investment risk—Scenario 1, an increase in feed conversion of 1.54 to 2.0; Scenario 2, 15% increase in the price of the diet of US$ 0.67

to 0.82; Scenario 3, reduced fish survival from 90% to 70%; and Scenario 4, trout farming ceases to be the owner's primary activity—and thus a manager must be hired to keep up with production.

Results

Investments are listed in Table 1. If one considers the proportion between the costs of grow-out structures and the quantity produced, the facilities were proportionally cheaper for small-scale production (US$ 1515.67 per tonne/yr) than those observed for the medium-scale farm (US$ 2273.51 per tonne/yr). The investments in the construction had greater significance than other investments in both the small- and medium-scale farms. The costs of construction for the grow-out facility were somewhat proportionally lower for the small-scale farm (78.8%) compared with the medium-scale farm (88.3%). In contrast, the investment for the storage shed (feed storage) from the small-scale farm was proportionally larger.

The most important items in the operating costs were the feed and fingerlings (Table 2). Expenses with the feed and fingerlings were the major variable costs (Table 2). In general, the percentages represented for the different investments were similar for the two scales of trout farms.

Production costs, gross revenue, and profit are shown in Table 3. On the smaller-scale farm, both the fixed and variable costs per kilogram produced were higher.

The economic analysis showed that the two properties evaluated are economically feasible (Table 4). The medium-scale producer obtained higher annual income and higher net present value, but the results of the other indicators were very similar between the two scales of farms.

IA annual income, *PP* payback period, *NPV* net present value, *BCR* benefit-cost ratio, *IRR* internal rate of return, *RRI* revenue investment ratio

The results of the sensitivity analyses are presented in Table 5. For the small-scale farm, the reduction in feed conversion and the contracting of a manager makes the activity economically unfeasible. Both situations decrease the BCR to less than 1 and reduces the IRR to 10%. The rising price of feed and the reduction of survival did not show the activity to be unfeasible. The producer from the medium-scale farm showed a higher capacity of resilience against negative scenarios.

Scenario 1, increasing feed conversion (2:1); Scenario 2, price of feed 15% higher; Scenario 3, lower survival rate (70%); and Scenario 4, contracting of a manager

PP payback period, *NPV* net present value, *BCR* benefit-cost ratio, *IRR* internal rate of return

Discussion

The results obtained with the economic analyses demonstrated that family-operated trout farming in the Serra Catarinense is an economically feasible activity for the two scales of production evaluated. In the medium-scale farm, the costs with facilities were less significant when coupled with a greater quantity produced, resulting in slightly better profitability. Regardless of the scale of farms, the total cost per kilogram of trout produced was greater than the cost of other fish farmed in the same region. In the polyculture of Chinese carps in ponds in Santa Catarina, the cost of production ranged between US$ 0.71 and 0.74/kg

Table 1 Investments for implementation of trout farming in small and medium scales and the useful life of each investment

Items	Total value (US$)	(%)	Useful life (years)
Small-scale			
Functional structures			
Grow-out structures	16,360.11	78.77	20
Office/storage	3272.00	15.75	20
Equipment and utensils			
Plastic box	32.73	0.16	5
Weighing scale	327.38	1.58	10
Thermometers	16.30	0.08	1
Other items	327.38	1.58	1
Project planning and regulation			
License and permit	16.36	0.08	4
Formulation of the project plan	420.56	2.01	20
Medium-scale			
Functional structures			
Grow-out structures	81,846.45	88.31	20
Office/house	6547.71	7.07	20
Electrical infrastructure	327.38	0.35	20
Equipment and utensils			
Plastic box	65.47	0.07	5
Seine net	409.22	0.44	10
Weighing scale	327.38	0.35	10
Pump	327.38	0.35	10
Thermometer	16.36	0.01	1
Other items	327.38	0.35	1
Project planning and regulation			
License and permit	654.76	0.71	4
Formulation of the project plan	1827.47	1.97	20
Small-scale farm total (US$)		**20,781.14**	
Medium-scale farm total (US$)		92,677.03	

US$ 1.00 = R$ 4.48

depending on the density used (Graeff 2004; monetary values were updated to February 2020). For the production of Nile tilapia in ponds in Western Parana, the total production cost ranged from US$ 0.87 to 1.17/kg (Andrade et al. 2005; monetary values were updated to February 2020). Although the trout production costs were higher, the high selling price of trout meat carried the economic indicators to be positive.

The internal rate of return (IRR), which indicates the approximate profitability, payback period (PP), and the benefit-cost ratio (BCR) were similar in the two scales of farming. The capital invested had a return of 18–19% per year. This value is higher than the income obtained from the financial market in 2013 in Brazil and higher than the minimum attractive rate of return that was 10.75. The PP was less than 6 years for the two scales of farms, a relatively short period for the recovery of investment. Similar results to the present study were obtained by Mwangi (2007), which evaluated the production of trout in Kenya and found a PP of 5.3 years in an 18-month cycle and an IRR of 16%. Nile tilapia production in netted cages in Zacarias, São Paulo, South Brazil, obtained an IRR of 57% per year, PP of 1.71 years, and BCR of 3.34 (Campos et al. 2007). These values are more attractive than the trout farming in the present study, but the tilapia study showed that tilapia reared in netted cages was

Table 2 Operational costs of trout farming in the small- and medium-scale farms

Items	Total value (US$)		(%)	
	Small-scale	Medium-scale	Small-scale	Medium-scale
Variable costs				
Inputs				
Fingerlings	1669.66	5565.14	8.44	8.75
Grow-out feed 45% CP	11,979.17	39,930.59	60.61	62.80
*Labor**				
Hired labor	–	98.21	–	0.15
Maintenance	610.40	2705.83	3.08	4.25
Other investments				
Taxes	609.91	2033.06	3.08	3.19
Fish farmer registry	163.69	163.69	0.82	0.25
Interest on working capital	428.98	1422.59		
Medicines	196.42	147.32	0.99	0.23
Electrical energy	137.49	314.29	0.69	0.49
Fixed costs				
Depreciation	1014.00	4578.69	5.13	7.20
Owner payment (includes family labor)	4804.63	7983.08	11.85	6.12
Interest on capital invested	610.51	2721.69	3.08	4.28
Total variable costs	**15,795.79**	**52,381.17**	**79.92**	**82.39**
Total fixed costs	**3968.24**	**11,195.57**	**20.08**	**17.61**
Total costs	**19,764.03**	**63,576.77**	**100.00**	**100.00**

*The major labor comes from the owners' families

US$ 1.00 = R$ 4.48

economically unfeasible when considering a 20% fall in the sale price. Therefore, trout farming is more resilient.

The trout needs clean water and the tanks must be made of concrete. These two conditions increase the investments for facilities, demanding high investment in proportion to a small area constructed. In the present study, the cost of grow-out structures varied from US$ 1515.67 to 2273.51 per tonne produced by year. This could have occurred because of the differences in property characteristics (topography, distance to a water source, etc.) and materials used in construction. The information also varied widely in the literature, confirming this trend. Higher values were found for trout producers in the State of Rio de Janeiro, US$ 5668.88 per tonne, as an example (Amaral 2007; the monetary value was updated to February 2020). Graeff (2004)

Table 3 Gross revenue, average costs of production, and net profit from the two scales of trout farming

	Small-scale	Medium-scale
Gross revenue (US$)	26,518.24	88,394.17
Selling price (US$/kg)	2.45	2.45
Variable cost average (US$/kg)	1.46	1.38
Fixed cost average (US$/kg)	0.36	0.30
Break-even price (US$/kg)	1.82	1.71
Unit cost with fish feed (US$/kg)	1.11	1.11
Net profit (R$/kg)	0.62	0.75

US$ 1.00 = R$ 4.48

Table 4 Indicators of economic feasibility in trout farming for the two scales

	Small-scale	Medium-scale
IA (US$)	7848.93	31,346.20
PP (years)	5.66	5.33
NPV (US$)	98,432.01	389,170.40
BCR	1.54	1.63
IRR (%)	18	19
RRI	0.377	0.338

US$ 1.00 = R$ 4.48

reported that the cost was US$ 3568.46 (updated to February 2020) for the construction of 1 ha of ponds to produce 1882 kg/yr of Chinese carps.

The costs of the grow-out structures were shown to have greater significance in both scales of farming. These results are also consistent with the data from previous studies (Amaral 2007). For the medium-scale farm, the significance of the facilities' costs was larger when compared with the small-scale farm. This was probably due to a higher cost of structure required per tonne produced. In this context, strategies to reduce the costs of construction are important for this activity. The search for new techniques and materials in construction can improve economic outcomes and render the activity more accessible to new producers who do not possess investment capabilities. An alternative is the covering of tanks' bottom and bunds with plastic or other specialized membranes. Although these alternatives have a shorter useful life than the concrete tanks, their costs are lower.

The feed is the primary item of cost in production and has a great impact on the economic outcomes. The main factors affecting the costs of feeding are feed conversion and feed prices. The average feed conversion obtained on properties in Santa Catarina is 1.54:1. The trout is considered to be an efficient fish that can attain a feed conversion ratio of 1:1 in ideal conditions (Webster and Lim 2002). However, the feed manufactured in Brazil does not have the same qualities as found in other countries, making it impossible to obtain similar results.

The feed management affects feed conversion (Webster and Lim 2002). If the producer does not adopt simple measures such as controlling the quantity of feed supplied and decreasing waste, conversion can easily get above 2.0. The sensitivity analysis showed that such a scenario makes the activity economically unfeasible. d'Orbcastel et al. (2009) compared a trout farming in Europe operating in the traditional flow-through system with a farming using

Table 5 Economic sensitivities of trout farming for the two scales of production

	Original	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Small-scale					
PP (years)	5.66	10.83	7.51	8.17	8.83
NPV (US$)	98,432.01	73,043.63	85,682.63	72,121.16	79,834.90
BCR	1.54	0.73	1.12	1.01	0.92
IRR (%)	18.0	7.0	12.0	11.0	10.0
Medium-scale					
PP (years)	5.33	8.97	6.74	7.10	5.89
NPV (US$)	389,170.43	304,542.54	346,672.51	301,467.53	370,271.40
BCR	1.63	0.91	1.25	1.18	1.46
IRR (%)	19.0	9.0	14.0	13.0	18.0

US$ 1.00 = R$ 4.48

recirculating water, both having the same production capacity. Their study concluded that the feed is the key indicator to determine the environmental balance and improve production costs regardless of production system.

The price of feed is also highlighted to have a great influence on the economic outcome. Different from the feed conversion, which can be improved with management techniques, the value of the feed depends solely on the market because the price is subject to cost and availability. Trout are carnivorous fish and must be fed a diet rich in animal protein. In Santa Catarina, the feeds are based on fishmeal, the ingredient that provides the best results and is still widely available in the state. However, the trend in the medium and long term is the rise in demand and price of fishmeal. Alternative ingredients still need to be better evaluated as substitutes for fishmeal in trout farming. The sensitivity analysis showed that a rise of up to 15% of the feed costs affect economic outcomes but is not enough to make the activity unfeasible. Larger increases may compromise the situation of producers. In this sense, the development of homemade diets using residues from production or using live foods would be an alternative to reduce the dependence of fishmeal. The idea of alternatives would lower prices considering that the supply of food is limited to a few companies. Developing options would avoid dependence on the few corporate sources of fishmeal and can improve economic sustainability.

Another relevant item of operating expenses is the costs with labor. Although labor can come from family, it has an economic value, classified as non-cash expense (Shang 1990). In the present analysis, we assumed that all family labor was an opportunity cost, included in the owner payment. Nevertheless, in the medium-scale farm, it is feasible to contract a technician responsible for managing production. On the other hand, contracting a technician for the small-scale farm makes the activity economically unfeasible; thus, the owner must be responsible for production.

A risk factor for culture is an increase in mortality. A mortality of 10% is expected mainly in the fingerling phase because of the higher sensitivity to adapting to a new habitat. However, mortality of around 30% can occur since trout farming is an activity mostly dependent of cold water. Cold water may not be available during a drought and summer. In addition, there is a risk of disease. Intensive production increases the possibility of a disease to spread rapidly. In other countries, problems with viral illnesses are common (Dixon et al. 2016). However, this study showed that a mortality of 30% would not make the activity economically unfeasible. The sensitivity analysis of this scenario demonstrated that the costs are still covered even for the small-scale farmers.

This study concludes that family-operated trout farming in small- and medium-scale farms are both economically feasible. The small-scale farm requires complete dedication from the owner, whereas the medium-scale allows the contract of a technician. Some fixed costs may be higher in medium-scale farms, but it is compensated by the effect of the economies of scale, which proportionally reduces the variable costs. On the other hand, inadequate feed management can render the activity economically unfeasible regardless of the farm scale. Further studies based on a larger number of enterprises may reinforce the present conclusions. Although the family income, employment, and opportunity costs were addressed in the present study, the assessment of social sustainability dimension is desired in future studies.

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Compliance with ethical standards

Conflict of interests The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with animals performed by any of the authors.

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Affiliations

Andressa Steffen Barbosa[1] • Raquel Grande Pereira[2] • Laurindo André Rodrigues[3] • Jorge de Matos Casaca[4] • Wagner Cotroni Valenti[5] • Thiago El Hadi Perez Fabregat[1]

[1] College of Agriculture and Veterinary, Santa Catarina State University, Lages, SC, Brazil

[2] College of the West, Chapecó, Santa Catarina State University, Chapeco, SC, Brazil

[3] Embrapa Meio-Norte, Teresina, PI, Brazil

[4] Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina, Chapeco, SC, Brazil

[5] UNESP Innovation Agency – AUIN, São Paulo State University, São Paulo, Brazil