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BIOECONOMIC APPROACH TO TILAPIA (*Oreochromis spp.*) FOR A SUSTAINABLE AND RESILIENT AQUACULTURE IN LAKE ILOPANGO, EL SALVADOR

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ABSTRACT

Fisheries and aquaculture management in El Salvador dates back to 1955. The case of aquaculture in Lake Ilopango serves as a notable example of how fisheries and aquaculture have been managed in the country. However, by 2017, there was the need to regulate the aquaculture activities in the lake, due to the increase in cages and production. The aim of this work was to conduct a bioeconomic approach on tilapia (*Oreochromis spp.*) farms in Lake Ilopango, in the central region of El Salvador, for sustainable and resilient activity. Financial analysis of Internal Rate of Return (IRR), Net Present Value (NPV) and Benefit–Cost Ratio (BCR) were utilized to evaluate the production of tilapia, by department, municipalities, and cantons. Tilapia farming was concentrated in 3 departments of El Salvador: San Salvador (29%), Cuscatlán (65%), and La Paz with (5%). San Agustin, a canton from San Pedro Perulapán Municipality and the department of Cuscatlán presented nearly 40% of the total production of tilapia in the whole lake. For the bioeconomic analysis, CBR, IRR and NPV were above 0 values in all farms, suggesting that all of them were producing revenue from tilapia farming. The more profitable farms where those in category C (21-30 cages), followed by categories B (11 – 20 cages) and A (1 – 10 cages). It is recommended to establish a coordination mechanism between the municipalities involved in this productive activity, in collaboration with the national fisheries and aquaculture authority, as well as the environmental authority, to develop comprehensive and sustainable long-term management strategies. It is also important for the organization of the producers and authorities involved, to coordinate the financial support for farmers with private financial institutions and the Ministry of Economy of El Salvador.

Key words: Tilapia farming, bioecomonic analysis, Lake Ilopango, El Salvador

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1 INTRODUCTION

1.1 Background

The history of aquaculture in El Salvador begins in 1962, with a program in freshwater aquaculture from FAO, which introduced the first specimens of carp and tilapia. Following in 1967, a program from the USAID (United States Agency for International Development) trained people in freshwater aquaculture practices. By 1976, the Canadian International Cooperation had conducted an evaluation about the social aspects of fisheries and aquaculture. In 1984, the first three shrimp farms were built in the western part of El Salvador, Jiquilisco Bay. The Japan International Cooperation Agency contributed in 1999 to the implementation of the Master Plan in Fisheries, and by 2001, the development of mollusc aquaculture started, with support for over 15 years until 2015.

Nowadays, the General Directorate of Fisheries and Aquaculture (CENDEPESCA) is part of the Ministry of Agriculture and Livestock in El Salvador (MAG). CENDEPESCA is the national institution responsible for applying laws and regulations concerning Fisheries and Aquaculture in El Salvador. The institute is divided in three main divisions: Policy and Administration, Encouragement and Development, and Fisheries and Aquaculture Research (CENDEPESCA, 2020).

1.2 Study case: The management of tilapia farming in Ilopango Lake

The management of fisheries in El Salvador goes back to 1955, when the 204 Act was approved (Fisheries and Marine Hunting) in the Congress of El Salvador, followed in 1981 by the 799 Act the Fisheries Activities General Law. By 2001, the General Law of Fisheries and Aquaculture Promotion and Ordination (637 Act) entered into force, and since 2015, there has been discussion about a new law in the Congress of El Salvador. The management of fisheries and aquaculture is conducted by the coordination of the three divisions. The Fisheries and Aquaculture Research and the Development and Promotion Divisions functions as a support for the General Direction of the institution and decisions are taken in coordination with the Management and Administration Division in charge of creating new regulations, surveillance and monitoring, and enforcement, among other related activities (CENDEPESCA, Ley General de Ordenacion y Promocion de Pesca y Acuicultura y su Reglamento (Fisheries and Aquaculture Law and Regulation, 2001).

The Ilopango Lake aquaculture case is an example of how management of fisheries and aquaculture have been carried out in El Salvador. This lake is in the central part of the country, and is shared by eleven municipalities, suggesting a co-management approach of the water body. It covers an area of 72 Km^2, with a depth of 230 m, and is considered the largest lake in El Salvador from volcanic origin. *O. niloticus* is the only species cultured there in cages, with sizes of 103 m^3 and density of forty-five fingerlings per cubic meter. The market is focused mostly in producing fillets for the supermarket chains.

By 2017, there was the need to regulate the aquaculture activities in the lake, due to the increase in cages and production (CENDEPESCA, 2017). By 2012, 353 tons of production was reported in nearly 200 cages. This increased by 2015, with 1,025 tons cultured in 498 cages. From 2017 to 2018, a study of the lake was conducted with the aim to supply methodological elements to establish sustainable capacity. In this study ten monitoring stages were implemented to measure chemical and physical variables of the water, to ascertain its quality and analyse the status of the environment, but also to establish the quantity of the cages that can be allowed for *O. niloticus.* culture. In 2018 a law for aquaculture regulation in the lake was implemented, setting the number of cages at no more than six hundred (Hernandez & Cardenas, 2018).

The management of the Ilopango lake is challenging for CENDEPESCA, but also for other ministries like tourism, health and for the municipalities. Since the lake is a shared water body with 11 municipalities (Hernandez & Cardenas, 2018), it has been suggested that a holistic approach for its management should be implemented. Some of the challenges can be classified as economic, social, and scientific. The situation was challenged by the effects of COVID-19 at the global, national, and local level, reducing income for families, reducing jobs, and increasing need for food.

After CENDEPESCA conducted another study on the number of cages in Ilopango lake in 2021, the number of cages was increased to a total of 900 cages, which represents an increment of 100% in only 3 years. This behaviour could be explained as the fish farms are bringing jobs and protein availability to surrounding municipalities of the lake, and these farms are viewed by the inhabitants as opportunities for their family economy.

It needs to be clarified that not all the farmers have aquaculture authorization, and most of the cages installed in the last years are not allowed by the CENDEPESCA. In 2022, at the initiative of the General Direction, in order to conduct proper management based on scientific data, planning for a new study and monitoring of the conditions of the lake started. This study collaborated with the Instituto Nacional de la Pesca y la Aquaculture, National Institute of Fisheries and Aquaculture (INAPESCA) from Mexico, who sent experts to give advice on the implementation of the new study regarding the carrying capacity in Ilopango lake.

1.3 **Research problem**

Aquaculture activity in El Salvador has increased in the last twenty years from 500 tons cultured annually in 2001, to 11,000 tons by 2020. The two main cultured species are tilapia (*Oreochromis spp.*) and white leg shrimp (*Penaeus vannamei*), with tilapia the most cultured nowadays. Tilapia production is focused in three main nucleuses, in Guija lake with eighteen cultured farms, in the east part of El Salvador, Atiocoyo irrigation district, with 160 tilapia farms, in the central east part of the country, and the Ilopango lake farms, in the central part of the country, with over one hundred farms operating by 2022. The most important production nucleus is Atiocoyo Irrigation District, in terms of production, number of farms and processing facilities, followed by Ilopango lake and Guija lake (CENDEPESCA, 2020).

Due to the COVID-19 situation, in the last three years, there has been an increase in the number of farms in Ilopango Lake. In 2019 there were only forty-six farms, and by 2022, the number of farms has risen to over one hundred. The culture system consists of cages, with a density of forty-five fingerlings per cubic meter, the size of the cage is, 6x6x3 m, giving 108 cubic meters per cage, and in some farms, this could reach up to 30 cages per farm.

The Ministry of Economics of El Salvador has conducted two studies in recent years related to fisheries and aquaculture. One of the studies is about the value chain of seafood and aquaculture products at national level, and the other one concerned the value chain of the three main nuclei of tilapia farm production in the country (Machuca, 2019; Ministry of Economics, 2021) This information, cost of production, culture methods, among others variables, are necessary for the cost benefit analysis in Ilopango Lake for the tilapia farms.

The key issue to address in Lake Ilopango is its carrying capacity, relating to the human activities conducted there, with tilapia farming being the most important activity in terms of jobs, family income and its contribution to the regional economy.

In this study, the cost benefit analysis of tilapia farming in Lake Ilopango will be assessed. To set the base line for the proposal of management based on income, feasibility of the farms, and the payment of permits by the farmers in accordance with their activity. The final goal of the study is to give advice for proper management of the lake, based on the importance of the economic activity that tilapia farms represent for this region and make it sustainable for future generations.

1.4 **General objective**

Determine the cost-benefit analysis of the tilapia (*Oreochromis spp*.) farms in Lake Ilopango, in the central region of El Salvador, since this analysis could contribute to a better management and policies for more sustainable and resilient activities.

1.4.1 *Specific objectives*

- Identify the production of tilapia by cycle in Ilopango Lake farms, determined by department, municipalities, and cantons.
- Determine the production cost and benefits of the tilapia production in the farms found in Ilopango Lake.
- Conduct bioeconomic analysis to determine the feasibility of the tilapia farms in Ilopango lake, using the financial tools of Internal Rate of Return (IRR) and Net Present Value (NPV) and cost-benefit (C/B) analysis.

2 LITERATURE REVIEW

2.1 Status of aquaculture in El Salvador

The main species cultured are tilapia (*Oreochromis spp.*) and white-leg shrimp (*Penaeus vannamei*), with nearly 11,000 metric tonnes produced for tilapia, and 2,000 MT for white-leg shrimp (Figure 1), (FAO, 2020; CENDEPESCA, 2020). Since 2010, mollusc aquaculture has been developing, producing species such as the Pacific Oyster (*Crassostrea gigas*), and native marine cockles (*Anadara spp.*).

Freshwater aquaculture is geographically found in the mainland, specifically in the lakes Guija and Ilopango, but also in an irrigation district called Atiocoyo, marine and brackish water aquaculture is in the western part of El Salvador, in Jiquilisco Bay and Fonseca Gulf.

Currently, there are 9 farms for mollusc aquaculture, 44 for white shrimps and 286 farms for tilapia culture, making a total of 339 farms in 2020 spread all over the country.

The production system used in those farms are cages, ponds, long lines, and nurseries, which might vary from semi-intensive to intensive culturing (CENDEPESCA, 2020).

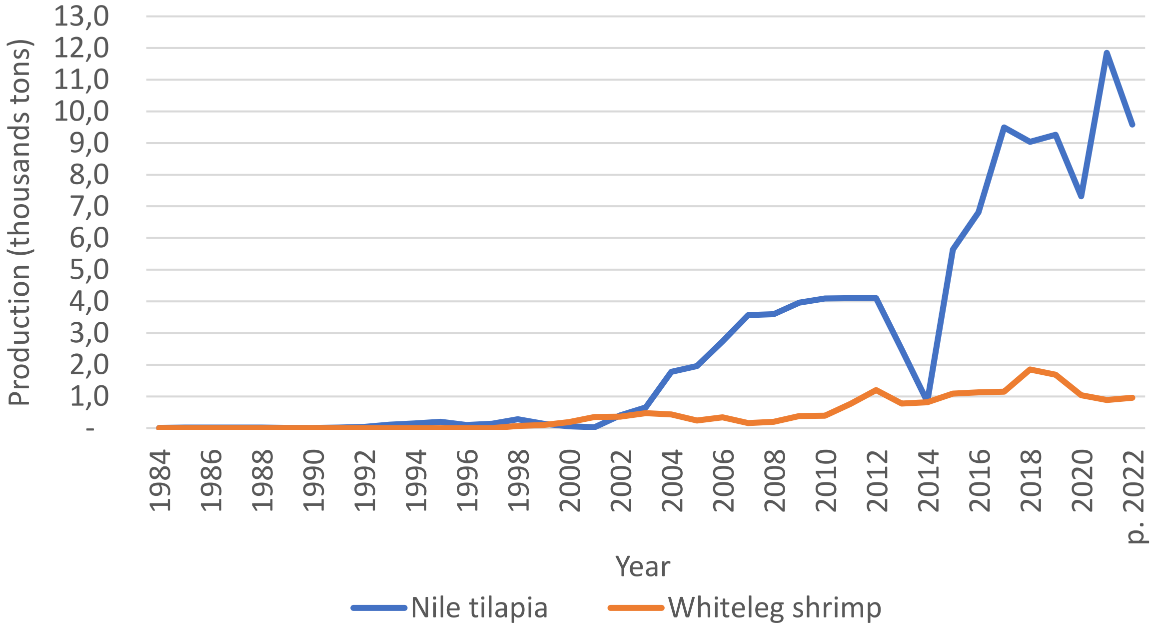

Figure 1. Production trend for tilapia (*Oreochromis spp.*) and white-leg shrimp (*Pennaeus vannamei*), from 1984 to 2020 and 2022 (p=projection) (CENDEPESCA, 2022).

2.2 Tilapia culture status in El Salvador

Tilapia is the second most important group of aquaculture fish in the world; it is grown in at least eighty-five countries, with most production coming from Asia and Latin America. The world supply of tilapia increased in the 1990s and early 2000s, due to genetic improvements through the widespread introduction of improved varieties, availability of feed supply, effective management of reproduction and expansion of consumer markets.

According to preliminary figures from the Central Bank of El Salvador (BCR) at the end of 2018, the country exported $319 thousand worth of fresh and refrigerated filleted tilapia; a figure well below what was exported in the past five years, which exceeded $2 million. The main target market is Guatemala, however, previously it was the United States.

Currently, there is only one plant in El Salvador that meets the required standards by the US Food and Drug Administration (FDA) with the admissibility to export fresh and chilled tilapia fillets to said market; almost one hundred percent of what was exported, was destined for the United States, the world's leading buyer of tilapia (Machuca, 2019).

By virtue of diversifying export destinations, it is important to consider other markets with growing imports and consumption of this tropical fish, such as the European Union, according to data from the Food and Agriculture Organization of the United Nations Agriculture (FAO). In this context, it is worth noting that some markets, such as the European one, demand more sustainable and ethical production conditions, which can be a success factor if El Salvador wants to position itself in this market. China is the main supplier to this region, followed by Indonesia, Thailand, Ecuador, Colombia, and Brazil.

One of the suggestions that various studies related to national aquaculture provide is to encourage the consumption of seafood nationwide. With a consumption of only 6 kilograms of fish meat per capita per year, El Salvador is considered as one of the Central American countries with the lowest per capita consumption of fish compared with other countries, such as Panama, Costa Rica, and Honduras. Thus, the country occupies the sixth place in the region, only before Belize that occupies the last position.

The increase in local consumption is an important factor for the growth of industry. For example, in Asian producing countries such as Indonesia, the Philippines, and Malaysia, the domestic market absorbs an important part of the production, thanks to the fact that the governments have implemented strategies to promote national demand (Machuca, 2019).

2.3 Tilapia production techniques

Four cultivation systems were identified in the country:

1) extensive cultivation in continental waters,
2) culture in ponds (the most used),
3) intensive systems, and
4) cage culture, whose stocking density is 45 fingerlings per cubic meter and the main places of cultivation are found in Ilopango Lake and Guija Lake.

Among the species with greatest commercial value in El Salvador are the Nile tilapia (*Oreochromis niloticus*), golden tilapia (*Oreochromis aureus*), and red tilapia (*Oreochromis sp*.) (Machuca, 2019).

2.4 **Commercialization of tilapia in El Salvador**

Tilapia wholesale prices fluctuate between $1.23 - $1.70 average per pound, as expressed by cooperatives interviewed. A maximum price of $2.00 per pound is reported (Machuca, 2019).

Currently the cooperatives have a stable market, thanks to the purchase volumes from some of its main wholesale and intermediary clients. The presentation they offer to their clients is fresh on board, and they sell it in most cases directly in the cooperatives to customers. Only one cooperative stated that they place orders at home at their clients' request, since they have a pickup (small truck) and coolers, with the capacity to transport up to 1,000 pounds (450 Kg.).

One of the main reasons why cooperatives fail, to market directly to the institutional market (hotels, restaurants, and banquets) and/or retailers, is the lack of financial resources to invest in processing plants, supply chains, cold, storage, technologies, and transport. Many also lack the health and quality certifications required by institutional markets, as well as the limited professional and technical competencies for the management of production and marketing activities (Machuca, 2019).

3 MATERIALS AND METHODS

3.1 Location of the study

El Salvador is in Central America, the land territory is 21,000 km^2, it is surrounded by Honduras to the north, Guatemala in the East, Nicaragua to the west, and the Pacific Ocean to the south.

Lake Ilopango is a crater lake which fills an 8 by 11 km (72 km^2) volcanic area in central El Salvador, on the borders of the San Salvador, La Paz, and Cuscatlán departments.

Figure 2. Location of Ilopango lake in El Salvador, where tilapia (*Oreochromis spp.*) farms are located.

3.2 Data collection

For this study, the statistical reports from CENDEPESCA and FAO for the last 20 years were used. The data provided information about the background, the development, and the growth of the aquaculture production in the country.

A data base for the aquaculture farms in Lake Ilopango, and statistical reports generated by the Department of Statistics of CENDEPESCA from 2000 to 2022 was used to support to the summarized information collected.

For the cost-benefit analysis data used in this study, the documents published by Ministry of Economics of El Salvador carried out 2 studies related to value chain analysis of seafood and aquaculture products (Machuca, 2019, 2021) for the value chain analysis of the tilapia in the three main production nuclei (Ministry of Economics, 2021).

The information needed for the Benefit-Cost Analysis (BCA) was obtained from these documents, which assessed a total of 112 farms. A cash flow model was designed for a 7-year assessment, and a bioeconomic feasibility analysis was conducted.

Information on the cost of materials, the local prices, were obtained from the studies conducted in the last three years by the Ministry of Economics for El Salvador, and related unpublished reports, produced by the Division of Encouragement and Development of Fisheries and Aquaculture from CENDEPESCA (General Directorate of Fisheries and Aquaculture, Ministry of Agriculture and Livestock of El Salvador).

For the numerical, statistical, and financial analysis Microsoft excel was used.

3.3 **Criteria for evaluation in a cost benefit analysis**

3.3.1 *Net Present Value (NPV)*

This measures the present value of the net benefits of the development project. It will be calculated according to the Eq. 1:

$$NPV = \sum_{t=0}^{n} \frac{Rt}{(1+i)^t}$$

where:

R_t=Net cash inflow-outflows during a single period, t

i=Discount rate or return that could be earned in alternative investments

t=Number of timer periods

The project period or terminal year is *t* which can equal infinity, the start time *t0,* while the discount rate is *R*. For a project to be acceptable on economic grounds, the NPV should be positive. This assumes that all costs and all benefits are considered given a monetary value. A positive NPV means that the option produces net economic benefits, assessed in terms of present values. Where there are mutually exclusive options between any two projects, the option with the highest NPV is preferred. Any project that has a negative NPVs is economically undesirable (James & Predo, 2015).

3.3.2 *Benefit–Cost Ratio (BCR)*

This is the ratio of the present value of benefits to the present value of costs.

The ratio determines the return per every unit of investment made. It will be calculated according to the Eq. 2:

$$BCR = \frac{|PV\ [Benefits]|}{|PV[Cost]|} = \frac{\sum_{t=0}^{N} \frac{|CF_t[Benefits]|}{(1+i_t)^t}}{\sum_{t=0}^{N} \frac{|CF_t[Costs]|}{(1+i_t)^t}}$$

Where:

BCR = Benefit Cost Ratio
PV = Present Value
CF = Cash Flow of a period (classified as benefit and cost, respectively)
i = Discount Rate or Interest Rate
N = Total Number of Periods
t = Period in which the Cash Flows occur

If the *BCR* of a project exceeds one, the present value of benefits is greater than the present value of costs; thus, the project is acceptable in terms of economic efficiency. If the *BCR* is less than 1, the project is not economically viable. This is the case if and only if the NPV is positive. Where there are options and choices to be made, the BCR should not be used to rank mutually exclusive options, however, as it can lead to rankings that are inconsistent with those obtained using NPV as the ranking criterion.

3.3.3 *Internal Rate of Return (IRR)*

The IRR is the rate of discount that equates the present value of benefits with the present value of costs. IRR appears as the 'unknown' i in the Eq. 3:

$$0 = CF_0 + \frac{CF_1}{(1+IRR)} + \frac{CF_2}{(1+IRR)^2} + \frac{CF_3}{(1+IRR)^3} + \ldots + \frac{CF_n}{(1+IRR)^n}$$

Or

$$0 = NPV = \sum_{n=0}^{N} \frac{CF_n}{(1+IRR)^n}$$

Where:
CF_0 = Initial Investment / Outlay
$CF_1, CF_2, CF_3 \ldots CF_n$ = Cash flows
n = Each Period
N = Holding Period
NPV = Net Present Value
IRR = Internal Rate of Return

The *IRR* is typically used to compare the internal financial productivity of a project with the official interest rate or cost of funds, to see whether the project is desirable as a financial investment. The *IRR* should not be used to rank mutually exclusive options, as it can also result in a ranking that is inconsistent with a ranking based on NPV. A distinction is sometimes drawn between an economic IRR and financial IRR. The difference is that for an economic IRR, all values for benefits and costs comprise economic rather than financial values (James & Predo, 2015). The financial IRR will be used in this study.

For this financial analysis the farms were aggregated in categories according with the numbers of farms classified in 3 categories, 1 to 10 number of cages per farm in category A, 1 to 20 cages in category B and the final 21 to 30 cages in category C. This approach was used to run the statistical analysis as well.

3.4 **Statistical analysis**

Further statistical analysis was conducted to determine significance differences among the categories, single factor anova was used to determine if there was a significance difference between C/B, NPV and IRR among the category's farms (A, B, C).

Where category A was described as the farms between 1 and 10 number of cages, category B from 11 to 20 cages and Category C, from 21 to 30 cages.

4 RESULTS

4.1 Total Production calculations

For the calculation of the total production of tilapia farms in Ilopango Lake, the producer's data base from the General Directorate of Fisheries and Aquaculture of El Salvador (CENDEPESCA) was used, which corresponds to the data collected from the technical assistance conducted by personal of the institution, twice a year, and the total production of tilapia farms in Lake Ilopango was calculated. The data base corresponded to the actualization of December 2022.

The production of tilapia in Lake Ilopango is shared by 3 departments, San Salvador, Cuscatlán, and La Paz in the central part of El Salvador.

Three municipalities of San Salvador have tilapia farms, Dolores Apulo, Corinto and Joya Grande. For Cuscatlán department, 3 municipalities were also registered for tilapia farming, San Pedro Perulapán, Cojutepeque and Cuscatlán. In the case of La Paz, only 2 municipalities have tilapia farm activities, San Miguel Tepezontes and San Francisco Chinameca.

As a total, 3 departments of El Salvador are conducting tilapia farm activities in the region of Ilopango Lake, 8 municipalities and 10 cantons are sharing the whole production activities.

In total 110 farms for tilapia farming are operating in the lake, which corresponds to 1,022 cages for the culturing activities. As an average each canton has 9 cages for tilapia farming by each farm, being the lowest average San Martin, Corinto with 7 cages per farm, and the largest San Miguel Tepezontes, El Pegadero, with average of 16 cages per farm.

The total production was calculated considering the cage size, which corresponds to 108 m^3, being the same size for all the cages located in Lake Ilopango, since the regulations introduced by the General Directorate of Fisheries and Aquaculture by the year of 2017 (CENDEPESCA, 2017).

For the survival rate, according with the study conducted by the Ministry of Economics, from the information collected, the producers indicated that the survival rate was from 60% to 75% for 1 cycle of culturing, which corresponds to a total of 4 months, targeting 300 to 350 grams, tilapia size (Ministry of Economics, 2021).

For the estimation of the total production of tilapia in the lake for 1 cycle of culturing, 65 % for survival rate were considered, and the density of fingerlings by cage, which corresponds to 45 fishes (tilapias) by cubic meter. This produces a total of 1,074.06 metric tons of tilapia by cycle (4 months), being a total production of tilapia of 3,223.8 metric tons by year. For the calculation of the total production, the variation of the initial weight and final weight was taken into consideration.

The largest municipality in terms of production was San Pedro Perulapán, San Agustin, with a total production of 417,443.8 Kg. by cycle, which is nearly 40% of the production of lake in one cycle, meanwhile Cojutepeque, Cujuapa was the lowest with an 8,412.0 Kg (Table 1).

Table 1. Total number of farms, cages, production in kilograms and production area in cubic meters by department, municipalities, and canton, for 1 cycle of culture of 4 months for the tilapia farms in Ilopango Lake, El Salvador.

Department	Municipality	Canton	# Of Farms	Number of Cages	Average cage/canton	Production (Kg.)	Production area (m³)
San Salvador	Ilopango	Dolores Apulo	9	74	8	77,810.7	7,992
	San Martín	Corinto	19	126	7	132,488.5	13,608
	Santiago Texacuangos	Joya Grande	12	98	8	103,046.6	10,584
Cuscatlán	San Pedro Perulapán	San Agustín	39	397	10	417,443.8	42,876
		Buena Vista	12	114	10	119,870.5	12,312
	Cojutepeque	Cujuapa	1	8	8	8,412.0	864
	Candelaria	México	8	79	10	83,068.2	8,532
		San Antonio	6	71	12	74,656.2	7,668
La Paz	San Miguel Tepezontes	El Pegadero	2	31	16	32,596.4	3,348
	San Francisco Chinameca	Santa Cruz La Vega	2	24	12	25,235.9	2,592
TOTAL 3	**8**	**10**	**110**	**1022**	**9**	**1,074,628.6**	**110,376**

The production was also estimated considering the cage size in cubic meters, which corresponds to 108 m³ per cage, and the total of cages by farms, given a total production area of 110,376 m³ (Figure 3).

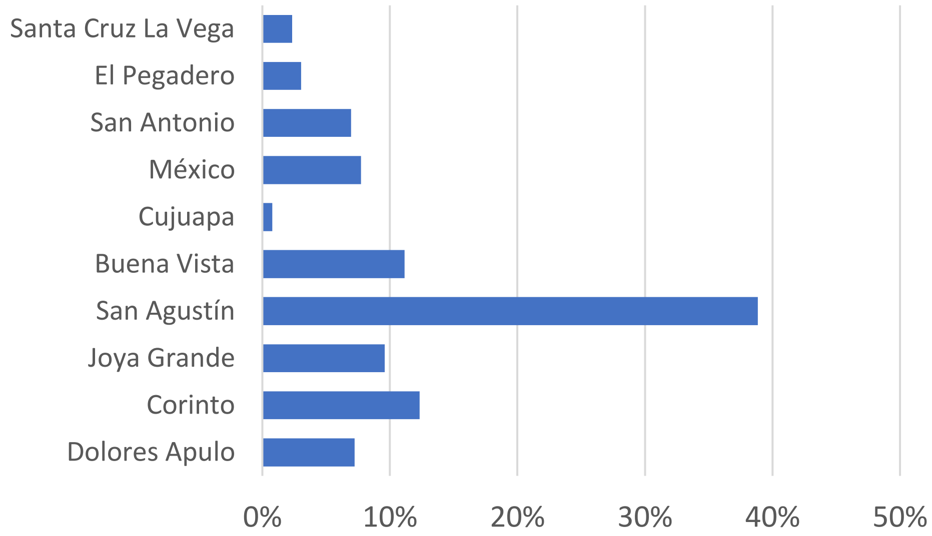

Figure 3. Production of tilapia for one cycle divided by cantons, Ilopango, El Salvador

A single factor anova were applied to compare the area of production for each canton and the total production by canton, given a $p \leq 0.01$, which corresponds to significance different between production and area among cantons.

4.2 Investment, Production cost and Technical-economical elements

4.2.1 Investment

Investment is related to the amount of money spent for building the project and for tilapia cage culture the calculation takes into consideration cage building and guardhouse construction costs. The total investment is suitable to be used for 7 years (Table 2, Table 3), (Rosa, 2019).

4.2.1.1 Building cost per floating cage

Cage cost calculated with local prices in USD dollars in El Salvador, for the construction of one tilapia cage and a total of 8 cages. The price per cage was used to calculate the following outputs (Table 2). Each cage had a dimension of 6.00 m. x 6.00 m x 3.00 m. depth.

Table 2. Materials and costs for building a floating tilapia cage at local prices in USD dollars in Ilopango Lake, El Salvador

Detail	Quantity	Unit Cost ($)	Total ($)	TOTAL 8 cages ($)
Support braces, 1.1/2" diameter galvanized pipe	4	30.00	120.00	960.00
¾" black knotless net bag, for fattening	1	500.00	500.00	4000.00
¾ corrugated iron bar to place 0.40 cm risers to place the aviary	2	7.00	14.00	112.00
Blue colored barrels for flotation, found with frames of the same pipe in the four corners and fastened with rope.	4	25	100	800
Food containment net	24.00 m.	1.25	30.00	240.00
Cement anchors of 0.70 cm x 0.70 cm to fix the cage (8 anchors will be placed for 8 cages.)	1	24.00/anchor	24.00	192.00
1¨ diameter polyethylene Linga for anchoring cages	100 m.	1.75/mts	175.00	1400
¼¨ Linga to tie the bag to the pipe	50 m.	0.12/mts	2.88/cage	23.04
¾ loop for cage divider	4.0 m.	1.62/mts	6.48/cage	51.84
Labor to build	1	420.00/cage	420.00/cage	3360.00
TOTAL			**$ 1,392.36**	**$ 11,138.00**

4.2.1.2 Guardhouse cost

Guard house cost calculated with local prices in USD dollars in El Salvador, only 1 guardhouse is use for each farm.

Table 3. Cost for building a guardhouse for each farm at local prices in USD dollars in Ilopango Lake, El Salvador

Detail	Meter	Cost/meter	TOTAL ($)
Construction of a wooden and sheet shed. (Materials and labor)	30	35	$ 1,050.00

4.2.2 *Production cost*

The Production cost is associated with the amount of money spent to run the farm culturing, in this case, two different production costs were calculated, the production cost per cycle and the variable cost which involves labor cost and consulting technical assistance (Table 4, Table 5), (Rosa, 2019).

4.2.2.1 Production cost per one cycle and one year

Table 4. Production cost of supplies for one cycle and one year of production at local prices in USD dollar for Ilopango Lake, El Salvador.

Supplies	Quantity	Frequency	Unit cost ($)	Cost/4 months cycle	Cost/year (3 Cycles)
Tilapia fingerlings for a 108-meter cage (45 fingerlings per m^3)	5000	One cycle, (4 months)	0.06	300.00	900.00
Bag of fish food (43.5 Kg/bag) (45% protein)	1	One cycle, (4 months)	71.7	71.70	215.10
Bag of fish food (43.5 Kg/bag) (38% protein)	5	One cycle, (4 months)	52.86	264.30	792.90
Bag of fish food (43.5 Kg/bag) (32% protein)	20	One cycle, (4 months)	42.65	853.00	2,559.00
Plastic bags	1 hundred	2	1.25	2.50	7.50
cast net	1	1	60	60.00	60.00
Hand net	2	2	55	55.00	165.00
40-pound scale	1	1	19	19.00	19.00
10-pound crates	12	1	3	36.00	36.00
Other inputs	several	1	75	75.00	225.00
TOTAL				**$ 1,736.50**	**$ 4,979.50**

4.2.2.2 Variable costs per production cycle of 4 months for a module of 8 floating cages

Table 5. Variable cost for one cycle and one year of production at local prices in USD dollars for Ilopango Lake, El Salvador.

Detail	Quantity	Unit Cost	1 Cycle Cost	Cost/Annual (3 cycles)
Direct labor from Aqua culturists	120 d/h	10.00	$ 1,200.0	$ 3,600.0
Eventual indirect labor (technical assistance)	1	300.00/month	$ 1,200.0	$ 3,600.0

4.2.3 *Technical-economic elements and good practices for tilapia farming*

Table 6. Parameters in terms of quantity for a one cage culture in Ilopango Lake, considering economic, and good practices factors.

Parameters	Quantity	Unit
Cage size (6 x 6 x 3 meters)	108	Cubic meters
Fingerlings by cage	45	Organisms
Survival rate	65	Percentage
Tilapia harvest (fingerling x survival rate)	3,159	Organisms
Final weight	0.35	Kilograms
Harvest biomass	1,105.70	Kilograms
Produced biomass (biomass to harvest – biomass of sowing)	1.076.49	Kilograms
Feed conversion factor	1.10	Dimensionless
Food to supply	1,180	Kilograms
Tilapia price	2.75	$/Kg

4.3 **Bioeconomic analysis**

For the bioeconomic analyses, a database collected from CENDEPESCA was used, as well as the results from the study conducted by the Ministry of Economics of El Salvador relating to the promotion of regional coordination in aquaculture value chains for productive job generation in Latin America and Caribbean (Ministry of Economics, 2021).

The data base was composed of the name of farms, representatives, number of fingerlings per farm, area of production, number of cages and location.

With this information, the cash flow per one cycle of production was built for each farm and for the total aquaculture activity in Lake Ilopango.

Figure 4 shows the costs involved in tilapia farming, which are feed (1), fingerlings (2), aquaculture permission fee (3), cage building (4), guard house building (5), utensils (6) and variable costs (7), which is composed of labour and technical assistance.

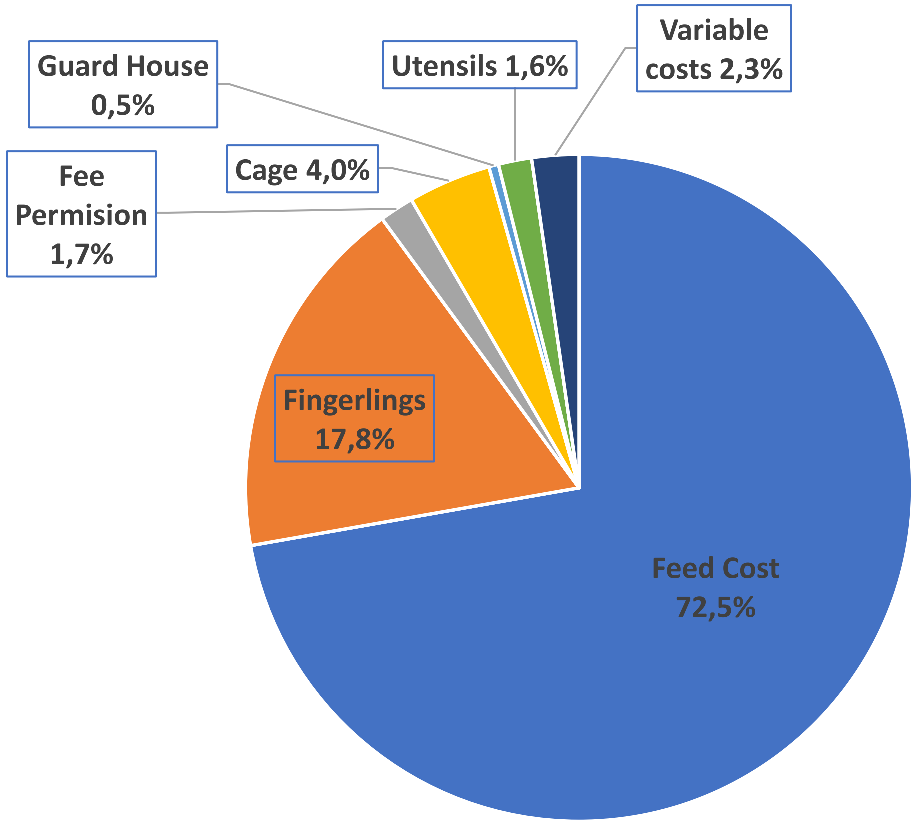

Figure 4 . Production cost in percentages, for one tilapia production in lake Ilopango.

The total production costs for each farm and for the whole production activity were calculated, considering a survival rate of 65 %, the size of tilapia harvest at the end of the cycle which corresponds to 0.35 Kg, the total number of cages per farms, and the density of fingerlings per cubic meter.

This data was used to build the cash flows, used for the calculation of the Net Present Value (NPV), Cost-Benefit analysis (C/B) and the Internal Rate of Return (IRR) for each farm and for the total production in the Lake. The data obtained were used to conduct the final calculations for IRR, C/B and NPV.

4.3.1 Cash flows

For the calculations of the economic analysis, it was necessary to calculate the cash flow for the total production of the tilapia from a total of 112 farms, for the period of the cultured project (Table 7).

The cash flow was built, utilizing the costs involved in the tilapia farming, which were, the feed cost (1), fingerling cost (2), aquaculture permission fee (3), cage building cost (4), guard house building cost (5), utensils costs (6), and variable costs (7), which is composed of labour and technical assistance, these factors represented the total expenses.

The income was calculated utilizing the number of cages, density per cage, survival rate, total weight at the time of starting the culture, and harvest weight, to determine the total weight gain, and selling price of tilapia at local prices.

This information was used to calculate individual cash flows for each farm, which were aggregated in categories for a better interpretation of the results. The sale price for 1 Kg. of tilapia utilized for calculating the income was $ 2.75 per kilogram, according with local prices. (Ministry of Economics, 2021).

Also, the investment was calculated, expenses, and cash flows (CFA) for each of the farm, and then summarized in the 3 categories A, B and C. Category A, 1 to 10 cages, category B, 11 to 20 cages, and category C, 21 to 30 cages. This classification was used for further analysis (Table 8).

Table 7. Data containing income, expenses and cash flow used for the calculation of total IRR, NPV and C/B.

Data	Year / USD $							
	0	1	2	3	4	5	6	7
Income	6,057,525.9	9,086,288.8	9,086,288.8	9,086,288.8	9,086,288.8	9,086,288.8	9,086,288.8	9,086,288.8
Expenses	4,719,940.9	4,719,940.9	4,719,940.9	4,719,940.9	4,719,940.9	4,719,940.9	4,719,940.9	4,719,940.9
CFA	(204,477.0)	3,944,824.0	4,366,347.9	4,366,347.9	4,140,347.9	4,140,347.9	4,366,347.9	4,366,347.9

Table 8. Data containing income, expenses and cash flow used for the calculation of the categories A, B and C in terms of IRR, NPV and C/B.

Data		Year / USD $							
Category		0	1	2	3	4	5	6	7
A	**Income**	36,081.2	54,121.8	54,121.8	54,121.8	54,121.8	54,121.8	54,121.8	54,121.8
1 - 10 cages	**Expenses**	28,479.7	28,479.7	28,479.7	28,479.7	28,479.7	28,479.7	28,479.7	28,479.7
	CFA	(2,034.8)	23,123.3	25,666.8	25,666.8	23,666.8	23,666.8	25,666.8	25,666.8
B	**Income**	95,687.7	143,531.6	143,531.6	143,531.6	143,531.6	143,531.6	143,531.6	143,531.6
11 - 20 cages	**Expenses**	73,715.8	73,715.8	73,715.8	73,715.8	73,715.8	73,715.8	73,715.8	73,715.8
	CFA	(1,302.2)	63,232.5	69,815.8	69,815.8	67,815.8	67,815.8	69,815.8	69,815.8
C	**Income**	150,840.1	226,260.1	226,260.1	226,260.1	226,260.1	226,260.1	226,260.1	226,260.1
21 - 30 cages	**Expenses**	115,458.4	115,458.4	115,458.4	115,458.4	115,458.4	115,458.4	115,458.4	115,458.4
	CFA	(561.4)	100,490.4	110,801.7	110,801.7	108,801.7	108,801.7	110,801.7	110,801.7

4.3.2 Cost Benefit analysis

For this financial analysis the farms were aggregated in categories according with the numbers of farms classified in 3 categories, 1 to 10 number of cages per farm in category A, 1 to 20 cages in category B, and the final 21 to 30 cages in category C.

The discount rate utilized in the financial calculations was 12 %, since according to the Ministry of Economics, is the interest rate that most of the banks offer to the farmers as personal loans, which they can utilize for the production.

4.3.3 Net Present Value (NPV), Internal Rate of Return (IRR) and Cost Benefit (C/B)

For category A, 79 farms were found, for category B, 26 farms, and for the category C, 5 farms were found, C/B, IRR and NPV were calculated (Table 9, Figure 5).

Table 9. Results for the financial analysis of C/B, NPV and IRR of the tilapia farms agregated by categories.

# of Cages	Category	# of Farms	%	C/B	IRR	NPV
A / 0 to 10	A	79	72%	1.8	1146%	$ 104,003.10
B / 11 to 20	B	26	95%	1.9	4866%	$ 286,743.68
C / 21 to 30	C	5	100%	1.9	17911%	$ 456,850.71

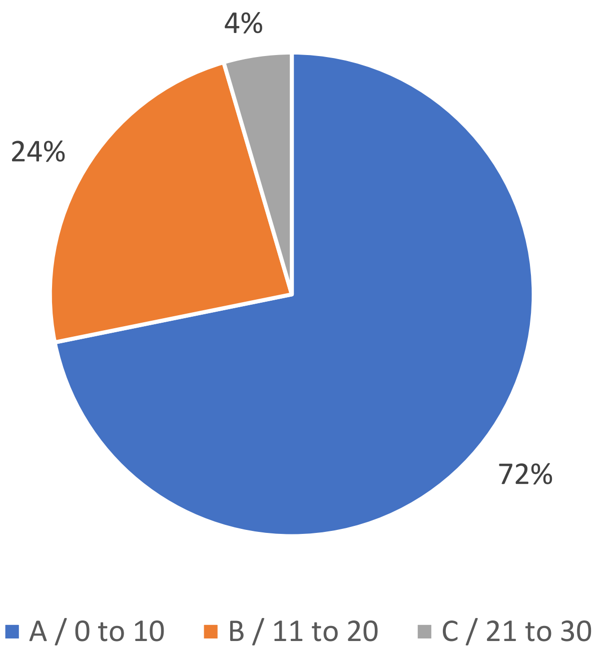

Figure 5. Percentage of farms divided by categories.

The cost benefit for category A was 1.8, which means 1.8 revenue per 1 USD dollar of investment, in the case of the categories B and C was calculated in 1.9.

The IRR for all the categories is above 0, which means, all farms are profitable at certain level.

The NPV values also give positive results, ranking from category A $ 104,003.10 to category, category B $ 286,743.68 and category C $ 456,850.71 (Figure 6).

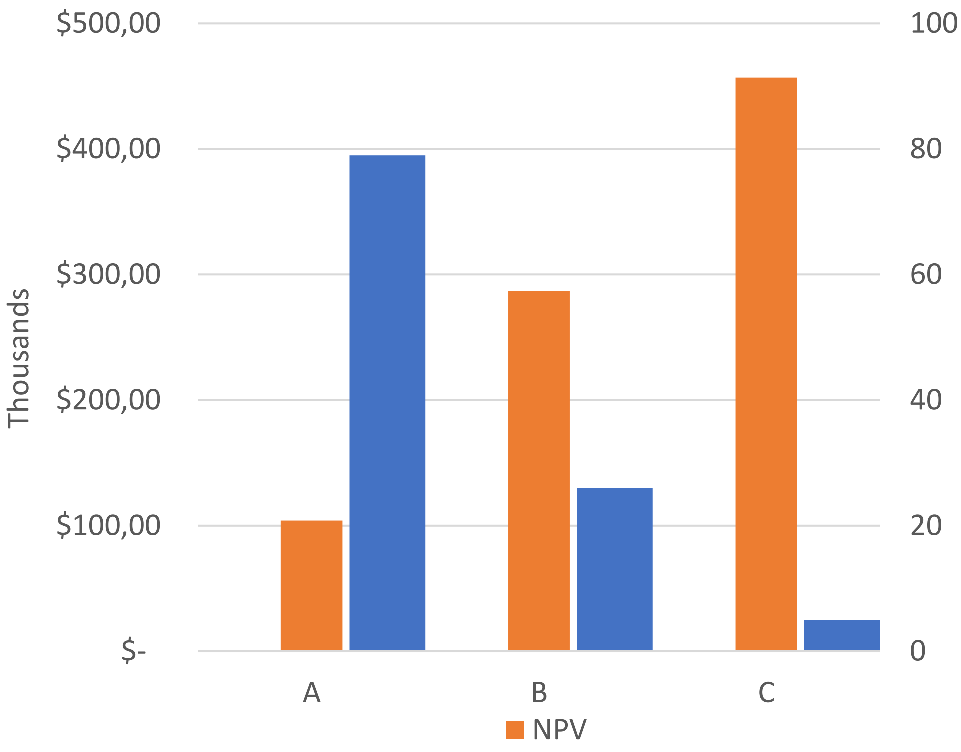

Figure 6. NPV and farms by categories A, B and C.

Single factor anova were used to determine if there was a significant difference between C/B, NPV and IRR among the categories of the farms (A, B, C).

Categories against C/B gives a value of $p \leq 0.18$, categories against IRR a value of $p \leq 0.20$ and categories against NPV a value $p \leq 0.05$.

Table 10. p value corresponding to farm categories (A, B and C against financial analysis (C/B, IRR and NPV)

Categories	**Financial analysis**	**p value**
# of Farms	C/B	0.18
# of Farms	IRR	0.20
# of Farms	NPV	*0.05*

A regression analysis was used to decide the relationship between categories and NPV, given a value of R = 0.95.

5 DISCUSSION

The production of tilapia in Lake Ilopango is shared by 3 departments, San Salvador, Cuscatlán, and La Paz in the central part of El Salvador.

Three municipalities of San Salvador were found who operate tilapia farms, Dolores Apulo, Corinto and Joya Grande. For Cuscatlán department 3 municipalities were also registered for tilapia farming, San Pedro Perulapán, Cojutepeque and Cuscatlán. In the case of La Paz, only two municipalities have farm activities, San Miguel Tepezontes and San Francisco Chinameca.

A total of 10 cantons hosts the aquaculture farms in Ilopango lake. The Cuscatlán department accounts for 65 % of the total production of the lake, following by San Salvador with 29 % and in third position La Paz department with only 5% (Figure 3).

A single factor anova was conducted to compare if there is significance different between the total area of production and the total production by cantons, given a p value ≤ 0.01, that suggests there are differences among these two factors. When analysing the relationship by conducting a linear regression, a strong relationship between production area and total production were found with a $R^2=1$ (Table 1).

The costs involved in tilapia farming are the feed (1), fingerlings (2), aquaculture permission fee (3), cage building (4), guard house building (5), utensils (6) and variable costs (7) which is composed of labour and technical assistance. The highest cost is the feed cost at 72.5 %, and the lowest one the guard house cost at 0.5%. These results suggest that the implementation of tilapia farming relies mainly on the feed price which is the production bottleneck, as found by Wolf (2021) and Meah & Rabeya (2021).

The permission fee cost, only represents 1.7% of the total cost of the production, this suggests that a strong commitment from the aquaculture authority, CENDEPESCA, to facilitate the registration of the farms, which will end up with a collection of income, suitable for pursuing studies, such as the environmental impact of the aquaculture activities in the lake, research investigating better practices in production, genetic improvement in fingerlings for stronger aquaculture activities, and better management practices, suitable for the sustainability of the production (Figure 4).

For the bioeconomic analysis, the farms were aggregated in 3 categories according to the numbers of cages, 1 to 10 number of cages per farm in category A with 72 %, 11 to 20 cages in category B with 24 %, and the final 21 to 30 cages in category C with 4%. Category A being the highest in terms of the number of farms (Table 9; Figure 5).

The cost benefit analysis for category A was 1.8, which means 1.8 revenue per 1 USD dollar of investment, in the case of the categories B and C the calculation was 1.9.

The IRR for all the categories was above 0, which means, all farms are profitable at certain level. Category C being the most profitable, and the least profitable being category A.

The NPV values also give positive results, ranking from category A $ 104,003.10 to category, category B $ 286,743.68 and category C $ 456,850.71. The behaviour of this analysis is similar to the IRR conducted, where category C ranges as the highest, and category A the lowest. (Figure 6).

Further statistical analysis was conducted to determine significant differences among the categories, single factor anova were used to determine if there was a significant difference between C/B, NPV and IRR among the categories of the farms (A, B, C).

Categories A, B and C, against C/B gives a value of $p \leq 0.18$, categories against IRR a value of $p \leq 0.20$ and categories against NPV, a value $p \leq 0.05$ (Table 10).

From this statistical analysis only the NPV represents significant differences among categories A, B and C, which corresponds to the total revenue according to the size of production in terms of number of cages. The NPV value could be useful in analysing further tilapia farms in the future.

A regression analysis was used to determine the relationship between categories A, B and C and NPV, given a value of $R = 0.95$, which corresponds to a strong relation among these two factors. The category A with higher number of farms and a smaller number of cages is less profitable, than the category C, with a smaller number of farms and larger number of cages, findings matching with the literature (OSPESCA, 2022). Therefore, larger farms tend to be more profitable especially due to the reduction of feed cost per mass of fish produced in concordance with the results found elsewhere (Wolf, 2021).

6 CONCLUSIONS

- The tilapia farming production in the Ilopango Lake region is conducted in 3 departments of El Salvador: San Salvador (29%), Cuscatlán (65%), and La Paz (5%). San Agustin, a canton from San Pedro Perulapán and the department of Cuscatlán presented 40% of the total production of tilapia in the whole region.

- The highest production cost for the aquaculture farms is the fish feed cost which represents 72.5% of the total cost of the production, following by the fingerling cost with 17.8 %. These two costs are the most sensible factors to be controlled closely during the culturing period, to make a more sustainable and feasible production activity for further generations. The aquaculture permission fee for the cycle of production only represents 1.7 % of the production costs.

- For the bio economics analysis, C/B, IRR and NPV, were above 0 values in all farms' calculations, suggesting all farms are producing revenue from the tilapia culture activities. From this analysis the NPV should be taken into consideration since this gives a Net Present Value of the culture activity. For this research the more profitable farms where those in category C, followed by categories B and the less profitable category C. This is related to the total investment and the culture area occupied by the farms. When analysing the relationship by conducting a linear regression, a strong relationship between production area and total production were found.

- The comparison between the categories A, B, and C against the C/B and IRR, no significance differences were found, nevertheless, categories against NPV significant difference were found, and a strong relation between these two factors were found as well. Category A with higher number of farms and a smaller number of cages is less profitable, than category C, with a smaller number of farms and larger number of cages, in Lake Ilopango.

7 RECOMMENDATIONS

7.1 For Local Government

- Since the tilapia aquaculture activity in Lake Ilopango is concentrated in 3 departments, La Paz, San Salvador, and Cuscatlán, it is recommended to create a coordination mechanism between the municipalities that share this productive activity, in conjunction with the country's fisheries and aquaculture authority, CENDEPESCA and the environmental authority MARN, to design comprehensive and sustainable long-term management measures for this production activity.

7.2 For the Producers

- An organization of tilapia-producing farms is also recommended, so that they can participate in decision-making, be the architects in their development, allowing for development, innovation, better productive yields, and environmental protection. An organization of the producers could give the power to negotiate feed prices for tilapia with the dealers, and get a better purchase price by volume, being able to lower their production costs, in which feed represents more than 70% of their total production cost.

- Through an organization of the producers and the timely planning of the authorities involved, it is possible to coordinate with the financial institutions and the Ministry of Economy of El Salvador, support for investment in a processing plant, which concentrates the production and allows for its commercialization and marketing at local and international level. Through such an organization, assistance with production plans can be designed based on a specific market and activities can be coordinated with tilapia farms in Lake Ilopango.

7.3 For the Fishery and Aquaculture Authority

- In terms of the fishing and aquaculture authority of El Salvador, CENDEPESCA, it is necessary to constantly monitor the production activities in the lake, from the environmental, social, and production point of view. For this reason, the creation of a registry of aquaculture producers is recommended, promoting the legalization of farms through their registration and cancellation of fees, so that these resources can be invested in training programs in good aquaculture practices, research and development, environmental evaluation assessment of the water conditions of the lake, and, to the extent it is possible, to establish an environmental station in the lake in coordination with MARN, in order to gain information that allows decisions to be made on its management in a timely manner.

- Coordinate with national banks and financial sector, to provide opportunities for tilapia farm owners, by offering better options in terms of loans, interest rate and more flexible payment terms, in order to incentivize production and establish a sustainable, reliable industry.

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