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Economic feasibility of fish cage culture in Lake Victoria, Kenya

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Abstract

Fish cage culture has rapidly grown throughout Lake Victoria's shores, with Nile tilapia (*Oreochromis niloticus*) being the primarily cultured species. However, there is inadequate information on its economic viability. The study investigated the economic feasibility of fish cage farming system in Lake Victoria, Kenya, by evaluating the relationship between cost of inputs and revenue from fish sales and analysing the overall profitability of the fish cage culture in the lake. Systematic sampling was employed to select 200 cage farmers for the study. Structured questionnaire was used for data collection. Data was analysed using descriptive statistics, multiple regression analysis, gross margin analysis, net farm income and profitability ratios. The average quantity of fish produced in the production cycle was 11,971.53 kg from which an average of 9020.77 kg was sold at an average selling price of Kenyan Shillings (KSH) 281.36 (USD 2.60) per kg. The multiple regression results revealed that the cost of feeds (coefficient of −0.603) and fish seed (coefficient of −0.387) had a significant influence on returns from fish cage culture business at $p < 0.01$ and $p < 0.05$, respectively. The costs of feeds and fish seed were significant components of the total production cost, accounting for 60.25% and 33.50%, respectively. Fish cage production was profitable, with an average gross margin of KSH 1146,727.68 (USD 10,545.59) and net farm income of KSH 1020,518.78 (USD 9384.94) in a production cycle, with a benefit cost ratio of 1.43, an expense structure ratio of 0.06, a gross revenue ratio of 0.70 and a return on investment of 0.43. The study recommends formulation of friendly policies, legislations, operating guidelines and an enabling environment for feed and fish seed producers by policy makers to enhance fish feed and seed production and subsequently reduce prices of feed and seed. Through this, economic viability of fish cage culture will be enhanced.

KEYWORDS
aquaculture, input–output relationship, Kenya, net farm income, Nile tilapia, profitability

1 | INTRODUCTION

Aquaculture and capture fisheries are essential sources of fish protein and income for a substantial percentage of the world's population (FAO, 2022). The yield from capture fisheries, however, has been on a downward trend over the past decades due to the dwindling wild fish stocks in natural water bodies (Njiru et al., 2019). With the rapid rise in human population, demand for fish and fish products has gradually increased (FAO, 2016, 2020). Aquaculture has been considered to be the solution in fulfilling the rising demand for fish due to the continuous developments in the sector over time, and comparatively declining levels of fish production from capture fisheries (Araki, 2008; Naylor et al., 2021). Kenya's aquaculture industry has been steadily growing, thanks to government backing through several initiatives such as the Economic Stimulus Programme (ESP) (Musa et al., 2012; Orina et al., 2018). Kenya is currently investing strategically in 'The Blue Economy' to embrace and promote aquaculture as an essential catalyst for economic progress through the creation of jobs and a means of achieving food and nutrition security (Muigua, 2020; Ogello & Munguti, 2016).

The aquaculture sector in Kenya has been dominated by pond-based aquaculture over the years (Munguti, Obiero, et al., 2021). However, pond-based fish farming is typified by operational constraints, including the quick deterioration of water quality, the risk of flooding and the scarcity of land and water, and therefore, more efforts have been put towards cage culture as it is operationally more efficient than pond-based aquaculture (Aura et al., 2018; Orina et al., 2018). Cage farming has a tremendous potential, particularly in water bodies that cannot easily be drained or harvested by seining and are not appropriate for traditional fisheries, including lakes, rivers, dams, large reservoirs and large ponds (Degefu et al., 2011).

There are several benefits associated with farming fish in cages. Fish cage culture enables efficient water body utilization and uses the already existing water, thus offering an alternative which is viable to potential farmers in areas with limited resources who do not have enough land for constructing ponds hence relatively low capital input (Gál et al., 2011; Orina et al., 2018; Soltan, 2016). When cage culture is introduced into a water body, there is an increase in fish carrying capacity and relatively higher production output per unit area (Aswathy, 2019; Musa et al., 2021). There is provision of fresh water and elimination of wastes from fish metabolism, excess fish feeds and other wastes by the water current which flows freely in the water bodies (Vikas et al., 2010). Cages are easy to maintain and produce high-quality fish (Gopakumar, 2009; Jamu & Ayinla, 2003). Moreover, there is the capability of raising mixed-sex Nile tilapia populations in cages without the challenges of undesired breeding and stunted growth that afflict farming in ponds (Degefu et al., 2011).

Accordingly, Kenya tried to adopt fish cage culture for the first time in 2005 in Lake Victoria (Njiru et al., 2019). Setbacks were experienced in the trials but later, cage farming was revived in 2010 due to enhanced efforts in research and participation by the local Beach Management Units (Munguti, Obiero, et al., 2021). Since then, it has sporadically expanded throughout Lake Victoria's shores, primarily involving the monoculture of *Oreochromis niloticus*, and has been acknowledged as a game-changer (Aura et al., 2018; Mary et al., 2021; Opiyo et al., 2018). This is because despite being a relatively new technique, it has contributed significantly to the increasing aquaculture production in the country ever because pond-based production stagnated after the ESP (Musa et al., 2021; Turenhout et al., 2013).

Despite being a promising alternative for many fish farmers, producing fish in cages in Lake Victoria is affected by several challenges, including the high cost of production due to expensive feeds and other inputs, the inadequate supply of quality fish feeds and seed, the theft of fish due to insecurity and lack of market (Mary et al., 2021; Musa et al., 2021). The challenges are experienced from the input node through to the output node, as the input and output components of aquaculture are well established in fish cage culture (Orina et al., 2018). The inputs include seed, feeds, cage construction, labour, among others, whereas the outputs include the fish and the fish products which are sold for income, comprising marketing and distribution (Aswathy, 2019; Islam et al., 2016). The input components have directly created income opportunities for several people in Kenya who are involved in manufacturing, sale and distribution of feeds, cage construction materials, among others. The fish seeds are mostly bought from the local hatcheries to reduce costs of transportation and improve their chances of survival. In the output component, fish traders obtain fish from farmers and sell it through various marketing channels, which are primarily made up of merchants at various local markets. Cage farmers are producers that work full-time and invest a lot of money in their business and because fish are purchased from the farms or at fish outlets in various locations, prices are set by the cage farmers (Orina et al., 2018). However, the farmers lack sufficient market knowledge and information regarding the general economic sustainability of fish cage culture in Lake Victoria, Kenya, which frequently leads to low profits from fish sales at the farm gate (Musa et al., 2021).

Different studies have been done on fish cage culture in Lake Victoria, Kenya. Aura et al. (2018) mapped the location of cages and characterized socio-economic indicators of fish cage culture in the lake, Njiru et al. (2019) reviewed the establishment of cages in the lake and the need for coming up with a decision-support tool for efficient management of the lake, Mary et al. (2021) studied the adoption determinants, challenges and opportunities in fish cage culture in the lake, Musa et al. (2021) conducted a study on the economic viability of different cage sizes used in fish cage culture and Mwainge et al. (2021) conducted a study to determine the health status of cage cultured fish in the lake. However, little has been done on the economic feasibility of fish cage culture in the lake considering the influence of cost of inputs on the revenue generated, and its overall profitability. For example, Musa et al. (2021) investigated cage farmers' investment decisions based on various cage sizes. However, a critical analysis of input–output relationship was not taken into account. Given the preceding, it is necessary to examine input–output relationship and profitability of fish cage farming in the lake. The profitability of cage culture is influenced by several factors, including the type or fish species being cultured, the management of the enterprise, input costs and commodity price (Aura et al., 2018). An understanding of the costs and returns to investment could contribute towards enhancing productivity and increase the supply of cage fish for the world's rapidly expanding population to consume. This study therefore sought to contribute to literature by analysing the overall economic feasibility of culture of fish in cages in Lake Victoria, Kenya. Specifically, it aimed at addressing the gap in information on how revenue from fish sales is affected by costs of inputs in fish cage culture, and its overall profitability. The findings of this study will be valuable to policy makers and relevant stakeholders in the fish cage culture business.

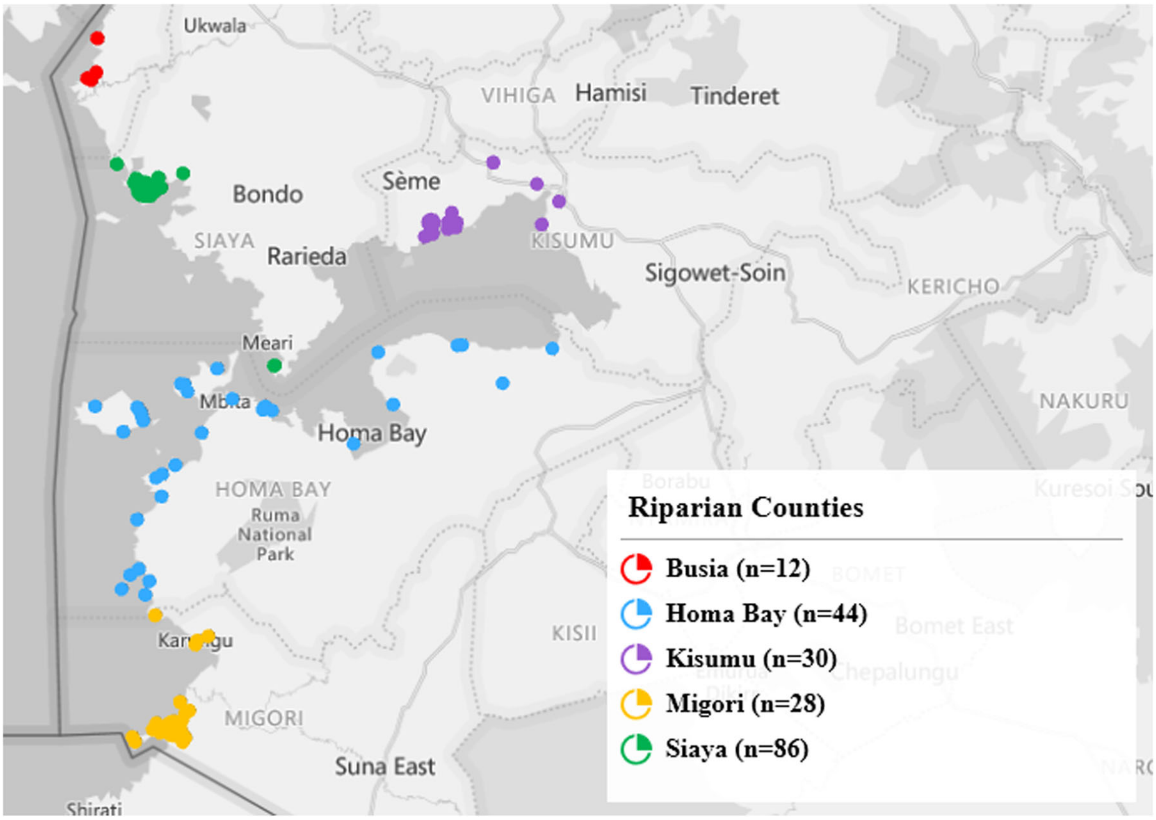

FIGURE 1 Study area showing the riparian counties and study sites in Lake Victoria, Kenya

2 | MATERIALS AND METHODS

2.1 | Study area

A cross-sectional survey was carried out along the beaches in the five riparian counties (Busia, Siaya, Kisumu, Homabay and Migori) of the Kenyan side of Lake Victoria (Figure 1). Migori, Homa Bay, Kisumu, Siaya and Busia counties were purposively selected for the study as they are the riparian counties of Lake Victoria, Kenya, where fish cage culture is practised (Munguti, Obiero, et al., 2021; Opiyo et al., 2018; Orina et al., 2018). Lake Victoria, which is shared by Kenya, Uganda and Tanzania, has a total surface area of 68,800 km (Meremo et al., 2022). It is a eutrophic lake with a high level of primary productivity especially in the littoral zones (Aura et al., 2020; Mwamburi et al., 2020). According to a suitability mapping by Kenya Marine and Fisheries Research Institute, out of 4100 km^2 available lake-scape, the area that is suitable for putting up cages is 362 km^2 which accounts for nearly 9% of the part of the lake on the Kenyan side (Orina et al., 2018).

2.2 | Sampling procedure and data collection

Systematic random sampling was used to select fish cage farmers for the study, using lists of cage farmers provided by the Cage Fish Farmers Association of Kenya in each county. Framers who had active cages during the 2021 production cycle (January to August 2021) were considered. Based on the cage locations along the beaches of Lake Victoria, the cage farmers were chosen at an interval in which all the counties in the study area were considered. A total of 200 farmers were selected for the study.

Information on cage farming for the production cycle was collected using a structured questionnaire through face-to-face interviews with the farmers. Face-to-face interviews have the advantage of allowing for fast follow-up and clarifications, as opposed to other methods like mail and telephone surveys, which have the problem of a high rate of non-response (Hussain et al., 2013). The interviews were conducted only after informed consent from the respondents, which was an indication that they were willing to participate in the study. Information on the demographic characteristics of cage fish farmers, cage sizes, costs of inputs in Kenyan Shillings (KSH), quantity of fish produced in Kilograms (kg) and prices of fish produced (KSH) was collected.

2.3 | Data analysis

Analytical methods employed included descriptive statistics, multiple regression model, gross margin analysis, analysis of net farm income and profitability ratios. Demographic variables were analysed by use of descriptive statistics, in terms of frequencies and percentages.

Input–output economics is a model of production based on a particular type of production function and can be viewed as either a vast collection of information describing our economic system or as an analytical method for explaining and predicting its behaviour (Christ, 1955). Its key interactions are inputs and outputs in production systems (Asche & Oglend, 2016). Input–output analysis is used for consistent forecasting, feasibility tests and sensitivity analysis to determine how the output variables are affected based on changes in other variables which are the input variables (Chong & Lizarondo, 1981; Miernyk, 2020). In aquaculture, production output is determined by, among other factors, the overall management practices and the costs incurred during the production process (Munguti, Odame, et al., 2021; Naylor et al., 2021; Obiero et al., 2019). Multiple regression analysis was done to assess the input–output relationship which is the relationship between the costs of inputs in fish cage farming and the revenue from sale of fish, given that the inputs and output were both calculated monetarily, that is, the inputs were calculated in terms of costs, and the output was calculated in terms of revenue from fish sales. Costs of fish seed, feeds, bird nets, harvesting nets, cage construction, labour and extension services were considered the relevant production costs in the production model, as shown in the following equation:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + e_i \quad (1)$$

where Y_i is the revenue from fish sales (KSH); X_1 is the cost of fish seed stocked (KSH); X_2 is the cost of feeds used (KSH); X_3 is the cost of bird nets used (KSH); X_4 is the cost of harvesting nets (KSH); X_5 is the cost of cage construction (KSH); X_6 is the cost of labour (KSH); X_7 is the cost of extension services (KSH); β_0 is the intercept; β_1 and β_7 are the coefficients of the respective explanatory variables and e_i is the stochastic error term.

2.4 | Test for multicollinearity

A variance inflation factor (VIF) calculation was done to test for multicollinearity to make sure the independent variables in the model were not related to one another. The VIF gauges the severity of multicollinearity in the regression model. According to Gujarati (2003), VIF demonstrates how the presence of multicollinearity causes an estimator's variance to be inflated. VIF is calculated as shown in the following equation:

$$\mathrm{VIF} = \frac{1}{1 - R_i^2} \quad (2)$$

where R_i^2 is the R^2 of the regression with the ith independent variable as a dependent variable. The results of the VIF are presented in Table 1.

The VIF of the explanatory variables ranges from 1.16 to 2.43. The mean VIF is 1.62. The VIF of the independent variables is less than five, indicating no significant correlations between any of the independent variables in the regression model. This rules out the possibility of multicollinearity.

Profitability is the margin between total revenue and total expense. In order to realize profits and improve profitability of fish farming, the variable cost and the total cost must be put into consideration. The individual costs that largely contribute to the variable and total costs need more attention because reducing these costs largely improves the overall profitability of the enterprise (Musa et al., 2021; Olaoye et al., 2013). Gross margin, which is used to asses profitability in situations where the fixed cost forms a negligible percentage of the total production cost as stated by Abah et al. (2013), is the difference between the total revenue and the total variable cost, as shown in the following equation:

TABLE 1 Results of variance inflation factor (VIF) analysis

Variable	VIF	1/VIF
Cost of cage construction	2.43	0.4115
Cost of fish seed	1.88	0.5319
Cost of bird nets	1.68	0.5952
Cost of harvesting nets	1.56	0.6410
Cost of labour	1.42	0.7042
Cost of fish feeds	1.20	0.8333
Cost of extension services	1.16	0.8621
Mean VIF	**1.62**	

$$\mathrm{GM} = \mathrm{TR} - \mathrm{TVC} \quad (3)$$

where GM is the gross margin; TR is the total revenue and TVC is the total variable cost. The total revenue is calculated by multiplying the price of fish by the total quantity of fish sold in the production cycle, as shown in the following equation:

$$\mathrm{TR} = P \times Q \quad (4)$$

where TR is the total revenue from sale of fish; P is the price of fish per kilogram (KSH/kg) and Q is the quantity of fish sold (kg).

The net farm income was used to determine the overall profitability by considering both fixed costs and variable costs. Both enterprise budgets and income statements are important in determining profitability, but income statements are preferable for determining farm profitability and losses (Engle, 2012). Net farm income is a core measure on the income statement which is also known as a profit and loss statement (Britton, 1970). A profit is indicated by a positive net farm income, whereas a loss is indicated by a negative net farm income (Hottel & Gardner, 1983). Net farm income is calculated by subtracting the total cost from the total revenue, as shown in the following equation:

$$\mathrm{NFI} = \mathrm{TR} - \mathrm{TC} \quad (5)$$

where NFI is the net farm income; TR is the total revenue and TC is the total cost. The total cost is the sum of total variable cost and the fixed cost, as denoted by the following equation:

$$\mathrm{TC} = \mathrm{TVC} + \mathrm{FC} \quad (6)$$

where FC is the fixed cost.

Profitability ratios were used to measure the profitability of fish cage farming. John et al. (2017) defined profitability ratios as financial calculations that are used in assessing whether there can be profits made by an enterprise by comparing the costs incurred with the earnings for a specific period. Lesáková (2007) stated that profitability ratios gauge a company's financial health and how effectively it manages its assets, provide insight into a company's capacity to generate an acceptable profit and return on investment. Therefore, a profitability ratio is a metric for determining whether or not a business is generating profits at an adequate level. Because investors with long-term investments are concerned with assessment of profitability, a business with a solid profitability ratio attracts investors (Husain et al., 2020). The profitability ratios employed in the current study were benefit cost ratio (BCR), expense structure ratio, gross revenue ration and return on investment.

The BCR is a profitability indicator used to summarize the value for money of a project or a proposed project. A BCR less than one indicates loss, a BCR of one shows break-even and a BCR that is more than one shows profit (Olaoye et al., 2013; Rymbai et al., 2012). BCR calculated by weighing the total revenue from sale of fish against the total cost of fish production for the production cycle, as shown in the following equation:

$$\mathrm{BCR} = \frac{\mathrm{TR}}{\mathrm{TC}} \tag{7}$$

The expense structure ratio ESR is used to determine the profitability of an investment by assessing the proportion of total cost that is fixed cost. It is calculated by dividing the fixed cost by the total variable cost, as shown in the following equation:

$$\mathrm{ESR} = \frac{\mathrm{FC}}{\mathrm{TVC}} \tag{8}$$

The gross revenue ratio (GRR) is used to evaluate the proportion of the returns that is spent. It is calculated by dividing the total cost by the total revenue, as shown in the following equation:

$$\mathrm{GRR} = \frac{\mathrm{TC}}{\mathrm{TR}} \tag{9}$$

The return on investment is a profitability ratio that is widely used as a tool for decision-making when analysing the profitability of a business (Magni, 2013). It shows the amount gained for every unit amount invested, for example, the amount gained for every KSH invested. It is calculated by dividing the profit by the total cost of investment, as shown in the following equation:

$$\mathrm{ROI} = \frac{P}{\mathrm{TC}} \tag{10}$$

where P is the profit, which is the difference between the total revenue and the total cost, as shown in the following equation:

$$P = \mathrm{TR} - \mathrm{TC} \tag{11}$$

TABLE 2 Volumes and number of cages used in the analysis

Cage volume (m^3)	Number	Mean	Std. deviation
8	36	6.50	10.930
12.5	49	7.80	11.304
12	3	8.00	10.392
16	36	4.83	5.146
18	8	2.75	2.493
32	21	2.90	2.143
50	25	8.84	23.380
60	3	3.67	2.887
72	65	8.65	32.362
128	3	2.33	2.309
200	5	2.20	1.643

The profitability ratios, which were all calculated using the costs and returns for a production cycle, are a summary of the value for money for fish cage culture in an average production cycle.

The analyses were not based on a specific cage size but used overall production costs and returns for varied cage sizes as farmers owned cages of different volumes as shown in Table 2.

The majority of the actively stocked cages were 72 m^3 (n = 65), 12.5 m^3 (n = 49), 8 m^3 (n = 36) and 16 m^3 (n = 36).

2.5 | Assumptions in calculation of average cost and returns

1. The calculations are based on a sample of 200 cage farmers with a varied number of cages of different cage sizes, which was not taken into account in calculations.
2. The farmers have different farm management practices and feeding regimes, which was not considered in the calculations.
3. The data was based on the ability of farmers to recall their production activities details in the production cycle.
4. The calculations are for one production cycle of 8-month period.

3 | RESULTS

3.1 | Demographic characteristics of the cage farmers

Table 3 summarizes the demographic characteristics of the fish cage farmers in the Kenyan part of Lake Victoria. Majority (88.5%) of the fish farmers were males, implying the dominance of men in fish cage culture business in the area. A higher number of the respondents (44%) had attained university/college-level education. The results also revealed that the majority (55%) of the cage fish farmers were undertaking farming only as their primary occupation.

TABLE 3 Demographic characteristics of the cage fish farmers in Lake Victoria, Kenya

Categorical variable	Frequency (*n*)	Percent
Gender		
Male	177	88.5
Female	23	11.5
Level of education		
Primary	57	28.5
Secondary	55	27.5
University/college	88	44.0
Primary occupation		
Farmer	110	55.0
Business	53	26.5
Salary/wage employment	33	16.5
Other	4	2.0

Source: Survey data, 2021.

TABLE 4 Descriptive statistics on production output for 2021 production cycle

Variable	Mean	Std. deviation
Quantity harvested	11,971.53	69,909.900
Quantity sold	9020.77	57,937.102
Selling price per kg	281.36	291.868

Source: Survey data, 2021.

3.2 | Production output

Table 4 shows the production output results for quantities harvested, sold and prices per kg in the 2020/2021 production cycle. The amount of output was measured in kilograms, whereas the prices were in KSH.

3.3 | Input–output relationship

The multiple regression analysis results, which were used to depict the relationship between input costs and revenue from sales of cage cultured fish for the production cycle, are outlined in Table 5. The coefficient of the cost of feeds was negative and significant at $p < 0.01$, and the coefficient of the cost of fish seed was negative and significant at $p < 0.05$. Furthermore, the result indicated an R^2 value of 0.923. The R^2 value revealed that the combined impacts of the predictor variables (costs of inputs) that were included in the model were responsible for 92.3% of the dependent variable (revenue generated).

3.4 | Cost and returns and profitability ratios in fish cage production

The cost and returns and profitability ratios of fish cage farming in Kenya's Lake Victoria are summarized in Table 6. According to the findings, fish producers' average total variable cost per cycle was KSH 2221,582 (USD 20,430.22), which represents 94.62% of the total cost of production. With KSH 1414,636.96 (USD 13,009.35) each production cycle, representing 60.25% of the overall cost, fish feed costs were the highest cost factor in fish cage farming. The outcome also reveals that, on average, cage farmers earned a gross margin of KSH 1146,727.68 (USD 10,545.59) and a net farm income of KSH 1020,517.78 (USD 9384.93) for the production cycle.

The BCR was 1.43, and the expense structure ratio was 0.06, which indicates that fixed cost account for around 6% of the entire cost of fish cage production. The GRR was 0.70, whereas the return on investment was 0.43.

4 | DISCUSSION

This study has assessed the feasibility of fish cage farming in the Kenyan Lake Victoria by analysing the impact of inputs on the income from fish cage farming and the profitability of fish cage farming business in the area. From the results of the current study, the cost of feeds and fish seed had negative and significant impact on the revenue from sale of fish. This implies that increasing either the cost of feeds or the cost of fish seed significantly reduces the revenue from sale of fish. Engle et al. (2020) also reported that the cost of buying feed and fish seed are among the highest costs in all aquaculture production systems, impacting the overall cost of production and revenue from fish farming business. Musa et al. (2021) also reported similar findings revealing that feed and fish seed costs are among the most important determinants of income from tilapia production.

The current study found the highest variable cost to be the cost of feed, taking more than 50% of the total cost. These findings relate to previous findings that reported that the cost of feeds takes more than half of the total cost of production in fish farming (Cheng et al., 2010; Munguti, Odame, et al., 2021; Petersen et al., 2014). The findings imply that the cost of fish feeds needs to be reduced in order to make fish cage culture more profitable to the farmer. The cost of buying fish seed was also found to account for a significant proportion of the total cost, a finding which relates with the findings of other studies that reported that the cost of purchasing fish seed takes up a significant percentage of the costs of aquaculture production in Kenya (Charo-Karisa et al., 2012; Nyonje et al., 2018; Opiyo et al., 2018). Fish cage farming will also be made more profitable by cutting the cost of fish seed which will reduce the cost of production.

The results of this study show a positive gross margin and net farm income. This indicates that fish cage culture in Lake Victoria has a considerable profitability. These findings are consistent with the findings of Aswathy (2019) which reported that fish cage farming is profitable. Kwikiriza (2018), in a study of the prospects of fish cage culture in Uganda, also reported similar findings. Several studies on aquaculture in Kenya have also reported that fish cage culture is a profitable business (Aura et al., 2018; Munguti, Obiero, et al., 2021; Musa et al., 2021; Mwainge et al., 2021; Njiru et al., 2019; Orina et al., 2018).

TABLE 5 Input–output relationship in fish cage production in the study area

Parameter	Standardized coefficient	Std. error	t	Sig.
Cost of fish seed	−0.387**	0. 235	−2.691	0.031
Cost of feeds	−0.603*	0.123	−3.262	0.001
Cost of bird nets	0.103	9.105	0.241	0.284
Cost of harvesting nets	0.068	4.511	0.647	0.412
Cost of cage construction	−0.215	0.163	−1.608	0.106
Cost of labour	−0.182	0.152	−1.485	0.108
Cost of extension services	0.011	17.452	0.103	0.913
Constant	15,925.329	4635.920	0.435	0.264
R^2	0.923			
Adjusted R^2	0.922			

*and ** indicate statistical significance at $p < 0.01$ and $p < 0.05$ respectively.
Source: Survey data, 2021.

TABLE 6 Cost and returns and profitability ratios in fish cage farming in the study area

Items	Amount (KSH)	Amount (USD)	% Of total cost	Value
Variable cost				
Feeds	1414,636.96	13,009.35	60.25	
Fish seed	786,454.78	7232.43	33.50	
Labour	16,319.75	150.08	0.70	
Other	4170.51	38.35	0.18	
Total variable cost	**2221,582**	**20,430.22**	**94.62**	
Fixed cost				
Cage construction	46,121.50	424.14	1.96	
Bird nets	38,833.40	357.12	1.65	
Harvesting nets	41,254.00	379.38	1.76	
Total fixed cost	**126,208.90**	**1160.65**	**5.38**	
Total cost	**2347,790.90**	**21,590.87**		
Total revenue	**3368,309.68**	**30,975.81**		
Gross margin	**1146,727.68**	**10,545.59**		
Net farm income	**1020,518.78**	**9384.94**		
Profitability ratios				
BCR				1.43
ESR				0.06
GRR				0.70
ROI				0.43

Note: 1 USD = KSH 108.74; average exchange rate during the 2021 production cycle.
Abbreviations: BCR, benefit cost ratio; ESR, expense structure ratio; GRR, gross revenue ratio; KSH, Kenyan Shillings; ROI, Return on Investment; USD, US dollar.
Source: Survey data, 2021.

The current study revealed a BCR of more than one, which indicates that fish cage farming in Kenya's Lake Victoria is profitable. The expense structure ratio revealed that the fixed cost accounts for a negligible proportion of the total cost of fish production in cages in the lake. The GRR from the current study indicates that for every one KSH return on the farm, 70 cents are being spent. This implies that 30% of the returns is retained as gross profits, indicating profitability of fish cage culture in Lake Victoria. According to the results of the current study, fish cage culture in the Kenyan Lake Victoria has a return on investment indicating that for every one KSH invested, 43 cents are gained by the farmer, implying that fish cage farming in the area is profitable. The findings of the current study on profitability of fish cage culture are in-line with previous studies from Kenya and other countries that revealed that fish cage culture is economically viable due to its profitability (Chowdhury et al., 2020; Gomes et al., 2006; Moura et al., 2016; Musa et al., 2021).

4.1 | CONCLUSION AND RECOMMENDATION

The economic feasibility of fish cage farming in Lake Victoria, Kenya has been successfully determined by the study. Fish cage culture is a viable business that can help combat hunger, unemployment and poverty. Cost of feeds and fish seed were found to account for a significant proportion of the production cost and had a significant influence the returns from cage farming. Additionally, fish cage production in the Kenyan Lake Victoria was profitable and worthwhile with positive gross margin and net farm income. The profitability ratios indicated a healthy fish cage culture business. From the results of the current study, it is recommended that the policy makers put in place policies, legislations, operating guidelines and an enabling environment for feed and fish seed producers by aligning feed and seed production policies within the manufacturing and agricultural sectors, respectively. Towards this, fish feed and seed production shall be enhanced, leading to reduction in prices of feed and seed, and increase in economic viability of fish cage culture.

AUTHOR CONTRIBUTION

Kevin Obiero: conceptualization, methodology, writing – review and editing, supervision; Jimmy Brian Mboya: investigation, writing – original draft, formal analysis; Kevin Okoth Ouko: investigation, writing – original draft, formal analysis; Dave Okech: conceptualization, investigation.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The authors certify that the data used in this article was collected from the study and can be availed by the corresponding author.

ETHICS STATEMENT

We certify that this is our original scientific research work, and it has not been submitted or published anywhere. The authors are responsible for all the content in the manuscript.

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