ECONOMICS OF CULTURED FISH PRODUCTION IN OSUN STATE, NIGERIA

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ABSTRACT
Cultured fish farming plays an important role in improving food security, generating income, and reducing Nigeria's dependence on fish imports. However, variations in production costs, profitability, and technical efficiency continue to constrain the performance of fish farming enterprises. This study examined the socioeconomic characteristics, costs and returns, technical efficiency, and determinants of technical inefficiency among cultured fish farmers in Osun State, Nigeria. A multistage sampling technique was used to select 120 fish farmers from six Local Government Areas across the three Agricultural Development Programme (ADP) zones. Primary data were collected using structured questionnaires and analysed using descriptive statistics, cost-return analysis, and the stochastic frontier production function. The findings showed that farmers were predominantly within the economically active age groups, with relatively high levels of education and farming experience, although access to formal credit remained limited. Cultured fish production was profitable across all LGAs, with total production costs ranging from ₦1,779.67/kg to ₦2,836.76/kg and net farm income ranging from ₦963.58/kg to ₦1,721.47/kg. Benefit-cost ratios varied from 1.34 to 1.97, confirming the economic viability of the enterprise, while feed constituted the largest variable cost component. The stochastic frontier estimates indicated that pond rent, labour, feed quantity, fingerlings, and depreciation significantly influenced fish output. The mean technical efficiency was 81.7%, implying that farmers could increase output by about 18.3% by minimizing technical inefficiencies using existing resources and technology. The study concludes that cultured fish farming in Osun State is economically viable but recommends improved access to affordable credit, quality production inputs, extension services, and better resource management to enhance productivity and sustainable aquaculture development

Keywords: *Cultured fish farming; Costs and returns; Technical efficiency; Stochastic frontier analysis; Osun State, Nigeria*

INTRODUCTION
Fish production encompasses all activities focused on producing fish, an important component of global food security (United Nations Department of Economic and Social Affairs-UNDEA, 2025). The world population is projected to increase by about 25% from a current 8.23 billion to about 9.9 billion by 2050, while Nigeria, currently the world's 6th most populous country with over 237.5 million people (about 2.89% of the global population), is projected to reach 401.3 million by 2050 (Population Reference Bureau–PRB, 2021, 2025). This growth has intensified pressure on natural resources and competition for food, making fisheries and aquaculture central to reducing protein deficiency and achieving food security (Food and Agriculture Organization–FAO, 2024). The sector employs over 61.8 million people globally and over 1,477,651 people within Nigeria's fisheries industry (FAO, 2024), while also generating foreign earnings (National Bureau of Statistics–NBS, 2024).

Despite Nigeria's considerable aquatic potential, a continental shelf of 43,514 km² (Britannica, 2026) and an 835 km coastline, the country remains heavily import-dependent, spending over $876,081,485 on frozen fish importation against exports of only $106,964 thousand in 2020 (Trend Economy, 2025). National fish production stood at about 1.2 million metric tonnes in 2024 (World Fish, 2024), comprising marine catches (36%), inland waters catches (33%) and aquaculture (31%) (FAO, 2021). Annual per capita fish consumption in Nigeria (estimated at 8.33–13 kg) remains substantially below the global average of 20.7 kg (World Bank, 2025; FAO, 2024; ECOWAS Commission, 2024). Nigeria's annual fish demand of approximately 3.6 million metric tonnes far outstrips domestic production of 1.2 million metric tonnes, leaving a 2.4 million metric tonne deficit, largely met through imports, costing the country an estimated $1.2 billion annually (Food & Beverage West Africa, 2024). This import dependence has considerable implications for the nation's foreign reserves, underscoring the urgency of investment in domestic fish farming.

In Osun State, interest in fish farming has grown markedly over the last decade, with various individuals and parastatals engaged in production across a substantial aquatic ecosystem (Kehinde, 2022). However, fish farmers in the state continue to face challenges in achieving optimal productivity and profitability, compounded by inflation, rising input prices and increasing operational costs. A complete economic assessment of the subsector requires answering two related questions: first, whether cultured fish farming is currently profitable given prevailing cost structures, and second, whether farmers are converting the inputs they use into the maximum output technically obtainable — that is, whether they are technically efficient. A farm can generate positive revenue yet still be unprofitable once full costs are accounted for, and, separately, it can be profitable yet still operate well below its production frontier. Distinguishing between these two issues matters for policy, since interventions that improve cost structures (e.g., cheaper feed, better credit access) address a different problem from interventions that improve management practice (e.g., extension and training).

While several studieshave examined fish farming economics in other parts of Nigeria, there remains limited recent empirical evidence that assesses the economics of cultured fish farming in Osun State. Existing Osun-focused studies (Kehinde, 2022; Idris-Adeniyi *et al.,* 2018; Olasunkanmi, 2012) have tended to be narrow in scope or dated, leaving a gap in current, farm-level evidence needed by farmers, investors and policymakers to make sound decisions on resource allocation and farm expansion. This study fills this gap by providing an integrated farm-level analysis of the costs and returns, and technical efficiency of cultured fish production across six LGAs, thereby generating empirical and location-specific evidence to inform policy, investment decisions, resource allocation, and sustainable aquaculture development and specifically focuses on;(i) describing the socioeconomic characteristics of cultured fish farmers in Osun State, (ii) determining the costs and returns to cultured fish production in the study area, and (iii) estimating the technical efficiency of cultured fish farmers and its determinants.

METHODOLOGY

Study Area

Osun State was carved out of Oyo State on 27 August 1991, with Osogbo as the state capital. It has a land area of approximately 14,875 km² (Government of Osun State, 2024). The state is bounded by Kwara State to the north, Ekiti and Ondo States to the east, Ogun State to the south, and Oyo State to the west (Anamayi et al., 2010; Osun State Government, 2006).

Sampling Procedure and Sample Size

A three-stage sampling procedure was used to obtain a representative sample of fish farmers across Osun State. In the first stage, three Agricultural Development Programme (ADP) zones — Iwo, Osogbo, and Ife/Ijesha — were purposively selected based on the concentration and accessibility of fish farming activity. In the second stage, two Local Government Areas (LGAs) were randomly selected from each zone (Iwo and Ejigbo; Olorunda and Osogbo; Ife-Central and Obokun), giving a total of six LGAs for the study. Within each LGA, two fishing communities were randomly selected from the Osun State ADP register, giving twelve communities in total. In the final stage, cultured fish farmers were selected from each community in proportion to the number of registered fish farmers in that community relative to the LGA total, using the allocation formula

$$\boldsymbol{n_i = \left(\frac{N_i}{N}\right) x\, n} \text{..Eqn (1)}$$

where n_i is the number sampled from community i, N_i is the number of registered farmers in community i, N is the total registered in the LGA, and n is the total allocated to that LGA. This proportional approach yielded an overall sample of 120 fish farmers — 40 from each ADP zone, 20 from each LGA — across the twelve communities.

Method of Data Collection

Primary data were collected through structured interview schedules administered to the 120 sampled fish farmers, covering socioeconomic characteristics (age, gender, household size, education, marital status, farming experience), production cost and revenue items (fingerlings, feed, labour, depreciable assets, sales), and input quantities used in production.

Methods of Data Analysis

Descriptive statistics (frequencies, percentages, means) were used to summarise the socioeconomic characteristics of respondents. The farm budgetary technique was used to estimate the costs and returns to cultured fish production, specified as:

$$NR = TR - (TVC + TFC) \text{ ……………………………………………..………… Equ.(2)}$$

$$TR = P \times Q \text{ ……………………………….…………………..…………… Equ. (3)}$$

where NR is net return, TR is total revenue, P is the unit price of fish, Q is the quantity of fish sold, TVC is total variable cost, and TFC is total fixed cost. Fixed assets (ponds, nets, weighing scales, etc.) were depreciated using the straight-line method:

$D = (P - S) / N$ ……………………………………………………………………… Equ. (4)

where D is annual depreciation, P is purchase value, S is salvage value, and N is the useful life of the asset in years (Olukosi and Erhabor, 1988). Profitability and viability were further assessed using gross margin (TR − TVC), net farm income (TR − TC), benefit-cost ratio (TR ÷ TC), return on investment (NFI ÷ TC × 100), profitability index (TR ÷ TVC), and break-even price and yield.

Technical efficiency was estimated using a Cobb–Douglas stochastic frontier production function, following Battese and Coelli (1995), specified as:

$Y_i = f(X_i; \beta) \exp(V_i - U_i)$ ……………………………………………………… Equ. (5)

where Y_i is the output of the i-th fish farmer, X_i is a vector of inputs, β is a vector of unknown parameters, V_i is an independently and identically distributed random error term, and U_i is a non-negative random variable representing technical inefficiency. In linear logarithmic form:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + V_i - U_i \quad \ldots\ldots\ldots\ldots (6)$$

where Y_i is cultured fish production output (kg); X_1 is rent on pond (m^2); X_2 is labour (man-hours); X_3 is quantity of feed used (kg); X_4 is units of fingerlings stocked (₦); X_5 is depreciated cost of equipment (₦); and ln denotes the natural logarithm. The model was estimated simultaneously with a technical inefficiency model, in which inefficiency (U_i) was specified as a function of farmer age, years of farming experience, gender, education, and marital status. The maximum likelihood estimation yields the variance parameters σ^2 (= $\sigma_u^2 + \sigma_v^2$) and gamma ($\gamma = \sigma_u^2/\sigma^2$), which lies between zero and one and represents the share of total output variation attributable to technical inefficiency rather than random noise (Battese and Tessama, 1993; Battese and Corra, 1977). Mean technical efficiency for each farmer is computed as the conditional expectation of $\exp(-U_i)$ given the composite error.

RESULTS AND DISCUSSION

Socioeconomic Characteristics of Cultured Fish Farmers

Cultured fish farming in Osun State is dominated by middle-aged individuals. Table 2 estimated mean age of cultured fish farmers ranged from 40.0 years in Iwo and Osogbo to 47.0 years in Ejigbo, with mean ages of 43.5, 42.5, and 43.8 years recorded in Ife Central, Obokun, and Olorunda, respectively. This indicates that cultured fish farming across the study area was dominated by economically active middle-aged farmers, suggesting that respondents possess the physical capacity and managerial experience required for efficient aquaculture production. This is consistent with reports that aquaculture is practised mainly by individuals in their productive years (Athirah *et al.,* 2020; Ayeloja*et al.,* 2021; Mebude*et al.,* 2024).

Educational attainment was notably high as 85% of farmers in Ife Central, 95% in Obokun, and 85% in Osogbo had attained tertiary education, while only a few had Qur'anic or no formal education. This dominance of tertiary-educated farmers — also reported by Adewumi and Kolapo (2023) — has important economic implications, enhancing managerial capacity, technology adoption and engagement with formal markets and credit institutions, and runs contrary to earlier perceptions of aquaculture as a low-skill enterprise (Afolabi *et al.,* 2024). Fish farming was also strongly male-dominated, with male respondents accounting for 75–90% of the sample across zones, reflecting the labour-intensive and physically demanding nature of pond management (Gibson *et al.,* 2020; Adetimileyin and Okunlola, 2018). The majority of respondents were married (55–75% across zones), indicating that cultured fish production in the study area is largely a household- and family-driven enterprise (Olaniyi and Ajiboye, 2024).

Pond sizes were generally small to moderate: most farmers operated ponds of 51–100 m² (e.g., 75% in Iwo, 60% in Osogbo), with a notable share in Ife Central and Obokun (up to 40%) operating ponds below 50 m², consistent with reports that fish farmers in Nigeria typically operate moderately sized farms (Sophea *et al.,* 2023; Adhikary *et al.,* 2018). A considerable share of farmers (25–55% depending on zone) had five or more years of farming experience, suggesting an established pool of experienced producers capable of driving subsector growth (Gbigbi and Achoja, 2021).

Table 2 also shows that fish farming served as the major source of income for only a minority of farmers — 65% in Iwo and 55% in Osogbo, but as low as 15% in Ife Central — indicating that aquaculture is frequently a supplementary rather than primary livelihood activity in much of the study area, consistent with reports that aquaculture in South-Western Nigeria often complements crop or livestock farming (Musa and Ibrahim, 2020). Financing of production was predominantly informal: reliance on personal savings ranged from 30% in Iwo and Osogbo to as high as 95% in Ejigbo, while formal financial institutions (commercial and microfinance banks) financed only 5–10% of farmers, and cooperative societies were almost entirely absent as a financing channel. Cooperative membership itself was unevenly distributed, highest in Iwo (80%) and Osogbo (55%) but negligible in Obokun and Olorunda (0%), and access to formal credit ranged from just 15% (Obokun) to 60% (Osogbo). This heavy reliance on personal savings over institutional credit reflects a critical financing gap that likely constrains farmers' ability to invest in higher-quality feed, fingerlings and water-management infrastructure (Ashley-Dejo *et al.,* 2017; Nwakuche *et al.,* 2019; Edun *et al.,* 2018).

Costs of Cultured Fish Production

Table 3 revealed that feed was the largest variable cost component in cultured fish production across the selected LGAs, accounting for 22.30–44.22% of total variable cost (TVC). This confirms that feed remains the dominant cost driver in cultured fish production, driven by rising costs of commercial feed and feed ingredients in Nigeria.

Similar findings have been reported by Omeje et al. (2023) and Imade and Ahmadu (2022), who identified feed as the largest operating expense in aquaculture enterprises and a major determinant of production costs and profitability. Fingerlings represented the second major biological input, accounting for 7.57–9.96% of TVC, while labour, transportation, energy, and land rental also constituted significant production costs, although their magnitudes varied across the LGAs.

The relatively higher transportation and energy costs observed in Olorunda and Osogbo suggest increased expenditure on input procurement, water management, and fish marketing, reflecting variations in production intensity and infrastructure. According to Ragasa et al. (2022), rising input and logistics costs continue to constrain the competitiveness and profitability of aquaculture enterprises in sub-Saharan Africa. The total variable cost ranged from ₦1,208.39/kg in Ejigbo to ₦2,347.58/kg in Osogbo, indicating substantial variation in production costs across locations.

The relatively lower production cost in Ejigbo suggests better resource utilization and cost efficiency, whereas the higher costs recorded in Olorunda and Osogbo reflect greater expenditure on key production inputs. These findings underscore the need to reduce feed and logistics costs through improved feed management, local feed production, efficient input utilization, and strengthened value-chain support to enhance the profitability and sustainability of cultured fish farming in Osun State (Issa et al., 2022; Omeje et al., 2023).

Table 4 revealed the straight-line depreciation of the fixed cost. The estimated fixed cost per kilogram of fish produced varied across the selected LGAs, as shown by Table 5, reflecting differences in investment in fixed production assets relative to output. Obokun recorded the highest fixed cost (₦717.15/kg), followed by Ife Central (₦695.65/kg) and Iwo (₦689.81/kg), indicating relatively higher capital costs per unit of fish produced. Conversely, Osogbo recorded the lowest fixed cost (₦435.10/kg), followed by Ejigbo (₦569.81/kg) and Olorunda (₦593.55/kg), suggesting more efficient utilization of fixed assets or higher output relative to capital investment.

These differences imply that farms with lower fixed cost per kilogram were able to spread depreciation costs over a greater quantity of fish produced, thereby improving cost efficiency. Investment in durable assets such as boreholes, water pumps, generators, and water storage facilities remains essential for efficient aquaculture production, but maximizing their utilization is critical to reducing fixed costs per unit of output. Similar findings have been reported by the Food and Agriculture Organization (FAO, 2024), which noted that improved utilization of production infrastructure enhances operational efficiency and profitability in aquaculture enterprises.

Costs and Returns to Cultured Fish Production

The results in Table 5 indicate that production costs and profitability per kilogram varied across the selected LGAs. Total variable cost ranged from ₦1,208.39/kg in Ejigbo to ₦2,347.58/kg in Osogbo, while total production cost ranged from ₦1,779.67/kg to ₦2,836.76/kg. The lower unit cost in Ejigbo suggests more efficient utilization of production inputs, whereas the relatively higher costs in Obokun and Olorunda reflect greater expenditure on feed, labour, transportation, and other production inputs. Similarly, fixed cost per kilogram varied from ₦435.10/kg in Osogbo to ₦717.15/kg in Obokun, indicating differences in capital utilization and economies of scale. Similar observations were reported by Olaoye et al. (2022) and Afolabi et al. (2023), who found that efficient utilization of production resources significantly reduces unit production costs and improves farm profitability.

Gross margin ranged (Table 6) from ₦1,680.82/kg to ₦2,291.61/kg, while net farm income varied from ₦963.58/kg in Obokun to ₦1,721.47/kg in Ejigbo, confirming that cultured fish farming generated positive returns in all the study areas. The Benefit–Cost Ratio (1.34–1.97) exceeded 1 across all LGAs, indicating a profitable investment, while the Return on Investment (34.0–96.8%) and Profitability Index (1.79–2.90) further confirmed the enterprise's financial viability. In addition, break-even prices remained below prevailing selling prices, indicating that farmers could cover production costs and earn a profit under existing market conditions. These findings agree with those of Adewumi and Akinwande (2022), Olaoye et al. (2022), and FAO (2024), who reported that efficient cost management and favourable output prices are key drivers of profitability and sustainability in aquaculture enterprises.

Technical Efficiency of Cultured Fish Production

The stochastic frontier results in Table 7 revealed that cultured fish farmers operated at relatively high but varying levels of technical efficiency across the six LGAs. Mean technical efficiency ranged from 77.3% in Obokun to 86.2% in Osogbo, indicating that farmers were generally utilizing available resources effectively but had the potential to increase output by 13.8–22.7% without increasing input levels if existing inefficiencies were eliminated. The relatively higher efficiency observed in Osogbo (86.2%) and Olorunda (84.5%) suggests better farm management and resource utilization than in Obokun (77.3%) and Ejigbo (79.8%), where greater opportunities exist to improve productivity through enhanced managerial practices. This finding is consistent with Coelli et al. (2005), Olaoye et al. (2022), and Adewuyi et al. (2023), who reported that variations in farmers' managerial ability and resource-use efficiency explain differences in aquaculture productivity even when farmers operate under similar production conditions.

The estimated gamma (γ) values ranging from 0.904 to 0.934 indicate that over 90% of the variation in fish output was attributable to differences in farmers' technical efficiency rather than random factors beyond their control. This implies that improving managerial capacity, production planning, and efficient resource utilization would contribute more to increasing fish output than simply expanding input use. Similar findings were reported by Afolabi et al. (2023) and Olaoye et al. (2022), who found that managerial efficiency remains a major determinant of aquaculture productivity in Nigeria.

The technical inefficiency model further showed that education and farming experience generally reduced technical inefficiency, while age increased inefficiency in several LGAs. These findings suggest that experienced and better-educated farmers are more likely to adopt improved production practices and make efficient management decisions, whereas older farmers may be less responsive to technological innovations. This finding agrees with Abdul-Rahman et al. (2022) and FAO (2024), which emphasized that farmer education, continuous training, and extension support are essential for improving technical efficiency and promoting sustainable aquaculture development.

Distribution of Technical Efficiency Scores

Table 8 revealed that the estimated mean technical efficiency (TE) of cultured fish farmers in Osun State was 81.7%, indicating that farmers could increase output by approximately 18.3% using the existing level of inputs and production technology if technical inefficiencies were reduced. This finding supports the stochastic frontier theory of production, which suggests that differences in output among producers arise not only from input levels but also from variations in managerial ability and technical efficiency (Aigner et al., 1977; Battese & Coelli, 1995). Similar studies in Nigerian aquaculture have reported efficiency levels within this range, attributing variations to farmers' experience, access to inputs, extension support, and adoption of improved production practices (Olaoye et al., 2022; Abdullahi et al., 2022; Ibrahim et al., 2023). Among the LGAs, Olorunda recorded the highest TE score (86.2%), followed by Osogbo (84.5%) and Iwo (82.4%), suggesting that farmers in these areas operated closer to the best-practice production frontier. In contrast, Obokun recorded the lowest efficiency score (77.3%), indicating greater potential for increasing output through improved input allocation and management practices. Ejigbo (79.8%) and Ife Central (80.1%) also exhibited moderate efficiency levels, suggesting production inefficiencies that can be addressed through improved technical capacity.

The differences in efficiency across the ADP zones further indicate the influence of location-specific factors such as access to quality inputs, extension services, market opportunities, and farmers' managerial skills. The result agrees with the findings of Abdullahi et al. (2022) and Ibrahim et al. (2023), who reported that technical efficiency among aquaculture farmers is largely influenced by farmers' experience, access to production resources, and adoption of improved management practices. The overall findings suggest that increasing fish production in Osun State depends not only on expanding input use but also on improving the efficiency with which existing resources are utilized.

CONCLUSION AND RECOMMENDATIONS

Cultured fish farming in Osun State is undertaken predominantly by middle-aged, married, male, and well-educated farmers who rely heavily on personal savings rather than formal credit and concentrate production on Clarias species sourced mainly from hatcheries and breeders. Although the enterprise generated positive gross revenue in all six LGAs studied, total production costs — driven principally by feed, labour and fixed-asset depreciation — exceeded revenue in every case, yielding negative net farm income, sub-unity benefit-cost ratios, and negative returns on investment throughout the study area; cultured fish farming was therefore not profitable during the period under review. Furthermore, cultured fish farmers in the study area were found to be technically inefficient, with the mean technical efficiency of 37.7%, suggesting that the average farmer could raise output by roughly 62.3% without any additional input use, simply by closing the gap to best-practice production. Farmers' age, farming experience, and education were the predictors of technical efficiency across all LGAs in the study area.
Based on these findings, it is recommended that:

(i) Government and financial institutions provide accessible, affordable credit to reduce farmers' overwhelming dependence on personal savings.

(ii) Farmers be encouraged to form and participate in cooperative societies to strengthen collective input procurement and bargaining power, particularly in zones such as Obokun and Olorunda where cooperative membership is currently negligible;

(iii) Local feed formulation and alternative feed ingredients be promoted to reduce the dominant cost burden of feed, which alone accounted for up to 44.8% of variable cost

(iv) Extension services be strengthened and targeted particularly at older farmers, who exhibited higher inefficiency across all LGAs, to disseminate improved pond management, feeding and stocking practices; and

(v) Policy attention address both cost structure and management practice simultaneously, since the evidence indicates that unprofitability in the study area stems from both an unfavourable cost-price environment and genuine technical inefficiency, neither of which can be fully resolved by addressing the other in isolation.

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APPENDIX

Table 1: Sampling Frame and Sample Size Distribution

ADP Zone	LGA	Community/Village	No. of Registered Fish Farmers	Sampled Respondents
Iwo	Iwo	Iwo Township	45	12
		Akinlalu	28	8
	Ejigbo	Ejigbo Township	52	14
		Erin-Osun	22	6
Subtotal — Iwo Zone			**147**	**40**
Osogbo	Olorunda	Oja-Oba	48	13
		Igbona	25	7
	Osogbo	Oke-baale	55	15
		Powerline	18	5
Subtotal — Osogbo Zone			**146**	**40**
Ife/Ijesha	Ife-Central	Ile-Ife Township	50	13
		Enuwa	20	7
	Obokun	Ijesha-Isu	42	12
		Ibodi	30	8
Subtotal — Ife/Ijesha Zone			**142**	**40**
TOTAL	**6 LGAs**	**12 Communities**	**435**	**120**

Table 2: Selected Socioeconomic Characteristics of Cultured Fish Farmers by LGA

Characteristic	IW (Iwo)	EJ (Ejigbo)	IC (Ife Cent.)	OB (Obokun)	OL (Olorunda)	OS (Osogbo)
Modal age bracket	31–40 (55%)	31–40/51–60	41–50 (70%)	41–50 (55%)	41–50 (55%)	31–40 (55%)
Tertiary education (%)	85%	35%	85%	95%	85%	85%
Male (%)	75%	90%	90%	80%	80%	75%
Married (%)	70%	55%	55%	75%	60%	70%
Modal pond size (m²)	51–100 (75%)	51–100 (45%)	51–100 (45%)	0–50/51–100	51–100 (30%)	51–100 (60%)
≥5 yrs experience (%)	25%	55%	—	50%	40%	25%
Fish farming = major income (%)	65%	35%	15%	35%	35%	55%

Financed by personal savings (%)	30%	95%	80%	70%	60%	30%
Cooperative membership (%)	80%	10%	10%	0%	0%	55%
Access to credit (%)	25%	40%	20%	15%	20%	60%

Source: Field Survey, 2025.

Table 3: Total Variable Cost (TVC) of Cultured Fish Production per Cycle (₦, 6 months) per kg

Variable Cost Item	IW (Iwo)	EJ (Ejigbo)	IC (Ife Central)	OB (Obokun)	OL (Olorunda)	OS (Osogbo)
Total yield (kg/cycle)	79.84	79.85	87.55	87.94	95.48	100.57
Survival rate (%)	78	76	80	79	82	83
Average harvest weight/fish (kg)	1.05	1.08	1.15	1.12	1.25	1.30
Feed	510.21	534.63	679.95	722.36	652.28	523.57
Fingerlings/Juveniles	115.60	120.41	206.17	190.18	196.38	177.74
Medication	23.49	7.11	22.53	19.70	10.10	4.10
Family labour	25.68	35.88	51.00	46.34	49.91	59.66
Hired labour	79.85	120.41	158.19	146.47	191.35	213.24
Lime	17.61	13.27	9.54	11.03	2.20	10.64
Fertilizer	10.96	7.10	3.93	3.81	4.40	9.62
Organic manure	5.17	3.61	4.95	6.75	10.39	18.29
Family consumption	11.99	15.34	51.11	59.42	37.39	55.27
Gifts	5.59	9.52	15.31	24.05	22.65	56.36
Annual union dues	20.54	10.80	37.41	13.30	8.64	43.75
Energy	14.48	14.93	118.73	120.30	153.38	143.84
Miscellaneous	61.06	49.41	89.49	79.26	65.20	69.06
Land rental	48.53	30.99	191.49	215.20	138.90	174.13
Transportation (Hired)	105.21	127.36	153.91	200.93	441.19	310.87
Transportation (Owned)	185.06	98.62	292.58	229.99	222.82	461.37
Water	30.31	22.13	28.80	30.25	25.80	26.00
Total Variable Cost (₦/kg)	1,296.40	1,208.39	2,115.60	2,119.18	2,243.66	2,347.58

Key: LGA – Local Government Area. TVC = Total Variable Cost. Cost/kg = TVC ÷ Estimated Yield. Yield = Avg. Fingerlings Stocked × Survival Rate × Avg. Harvest Weight per Fish. Survival rates and harvest weights based on puchased catfish production benchmarks for Osun State, Nigeria.

Source: Field Survey, 2025

Table 4: Depreciation on fixed cost items(Straight-Line Method)

ADP Zone / LGA	Fixed Cost Item	Total Value (₦)	Salvage Value (₦)	Lifespan (Years)	Annual Depreciation (₦)	Depreciation/ Production Cycle (₦)
IWO ZONE — IW LGA (Iwo)						
	Borehole	₦404,600.00	₦0.00	20	20,230.00	10,115.00
	Water tank	₦302,750.00	₦0.00	15	20,183.33	10,091.67
	Water pump	₦104,500.00	₦10,000.00	10	9,450.00	4,725.00
	Generator	₦485,500.00	₦100,000.00	10	38,550.00	19,275.00
	Harvesting net	₦12,700.00	₦0.00	5	2,540.00	1,270.00
	Measuring scale	₦79,750.00	₦25,000.00	15	3,650.00	1,825.00
	Plastic containers	₦77,750.00	₦0.00	5	15,550.00	7,775.00
Total TFC — Iwo						**55,076.67**
IWO ZONE — EJ LGA (Ejigbo)						
	Borehole	₦379,895.00	₦0.00	15	14,740.00	7,370.00
	Water tank	₦221,100.00	₦0.00	15	8,040.00	4,020.00
	Water pump	₦95,400.00	₦15,000.00	10	10,550.00	5,275.00
	Harvesting net	₦52,750.00	₦0.00	5	4,226.67	2,113.33
	Measuring scale	₦88,400.00	₦25,000.00	15	21,560.00	10,780.00
	Generator	₦265,600.00	₦50,000.00	10	6,520.00	3,260.00
	Plastic containers	₦32,600.00	₦0.00	5	**90,963.00**	**45,481.50**
Total TFC — Ejigbo						**35,319.83**
IFE/ILESHA ZONE — IC LGA (Ife Central)						
	Borehole	₦418,450.00	₦0.00	15	8,346.04	4,173.02
	Water tank	₦350,700.90	₦0.00	15	11,260.06	5,630.03
	Water pump	₦88,460.40	₦5,000.00	10	4,006.67	2,003.33
	Harvesting net	₦56,300.30	₦0.00	5	37,040.00	18,520.00
	Measuring scale	₦75,100.00	₦15,000.00	15	9,860.06	4,930.03
	Generator	₦420,400.00	₦50,000.00	10	**121,789.56**	**60,894.78**
	Plastic containers	₦49,300.30	₦0.00	5	29,886.67	14,943.33
Total TFC — Ife Central						**50,199.74**
IFE/ILESHA ZONE — OB LGA (Obokun)						
	Borehole	₦448,300.00	₦0.00	15	9,245.00	4,622.50
	Water tank	₦243,350.90	₦0.00	15	3,816.73	1,908.37
	Water pump	₦75,700.70	₦10,000.00	10	50,000.00	25,000.00
	Harvesting net	₦46,225.00	₦0.00	5	10,420.00	5,210.00
	Measuring scale	₦82,250.90	₦25,000.00	15	**126,161.86**	**63,080.93**

	Generator	₦550,000.00	₦50,000.00	10	31,630.77	15,815.39
	Plastic containers	₦52,100.00	₦0.00	5	18,363.33	9,181.67
Total TFC — Obokun						**124,818.93**
OSOGBO ZONE — OL LGA (Olorunda)						
	Borehole	₦411,200.00	₦0.00	13	3,716.67	1,858.33
	Water tank	₦275,450.00	₦0.00	15	28,560.00	14,280.00
	Water pump	₦75,200.00	₦15,000.00	10	7,550.00	3,775.00
	Harvesting net	₦87,550.30	₦0.00	5	**113,350.83**	**56,675.42**
	Measuring scale	₦75,750.00	₦20,000.00	15	28,242.00	14,121.00
	Generator *	₦285,600.00	₦0.00	10	15,136.67	7,568.33
	Plastic containers	₦37,750.00	₦0.00	5	4,531.60	2,265.80
Total TFC — Olorunda						**100,543.46**
OSOGBO ZONE — OS LGA (Osogbo)						
	Borehole	₦423,630.00	₦0.00	15	15,152.67	7,576.33
	Water tank	₦227,050.00	₦0.00	15	10,400.00	5,200.00
	Water pump	₦95,316.00	₦50,000.00	10	**87,557.34**	**43,778.66**
	Harvesting net	₦64,252.00	₦0.00	5	20,230.00	10,115.00
	Measuring scale	₦43,660.00	₦25,000.00	15	20,183.33	10,091.67
	Generator	₦237,290.00	₦10,000.00	15	9,450.00	4,725.00
	Plastic containers	₦52,000.00	₦0.00	5	38,550.00	19,275.00
Total TFC — Osogbo						**100,761.66**
Note: Depreciation calculated using straight-line method: Annual Dep. = (Total Value − Salvage Value) ÷ Lifespan. Production Cycle Dep. = Annual Dep. ÷ 2 (6-month cycle).						

Table 5: Estimated fixed cost of cultured fish production per cycle (6 months) per kg in naira.

Zone	LGA	Fish Output (kg/cycle)	Total Fixed Cost (₦/cycle)	Fixed Cost per kg (₦)
IWO ZONE	Iwo	79.84	55,076.67	₦689.81/kg
IWO ZONE	Ejigbo	79.85	45,481.50	₦569.81/kg
IFE/ILESHA ZONE	Ife Central	87.55	60,894.78	₦695.65/kg
IFE/ILESHA ZONE	Obokun	87.94	63,080.94	₦717.15/kg
OSOGBO ZONE	Olorunda	95.48	56,675.42	₦593.55/kg
OSOGBO ZONE	Osogbo	100.57	43,778.66	₦435.10/kg
Zone	**LGA**	**Fish Output (kg/cycle)**	**Total Fixed Cost (₦/cycle)**	**Fixed Cost per kg (₦)**
IWO ZONE	Iwo	79.84	55,076.67	**₦689.81/kg**
Key:LGA – Local Government Area,**IW LGA**– Iwo **EJ LGA** -Ejigbo,**IC LGA** – Ife Central, **OB LGA** – Obokun, **OL LGA** – Olorunda, **OS LGA** – Osogbo Zone				

Source: Field Survey, 2025.

Table 6: Estimated Costs and Returns of Cultured Fish Production per Cycle (₦, 6 months) per kg

Indicator	Iwo	Ejigbo	Ife Central	Obokun	Olorunda	Osogbo
Gross Revenue (₦/kg)	3,500	3,500	3,800	3,800	4,200	4,500
TVC/kg (₦)	1,296.40	1,208.39	2,115.60	2,119.18	2,243.66	2,347.58
TFC/kg (₦)	689.81	569.81	695.65	717.15	593.55	435.10
Total Cost/kg (₦)	1,986.17	1,779.67	2,810.10	2,836.76	2,836.26	2,783.75
Gross Margin/kg (₦)	2,203.60	2,291.61	1,684.40	1,680.82	1,956.34	2,152.42
Net Farm Income/kg (₦)	1,513.83	1,721.47	989.66	963.58	1,362.71	1,717.33
Benefit-Cost Ratio (BCR)	1.76	1.97	1.35	1.34	1.48	1.62
Return on Investment (ROI, %)	76.2	96.8	35.2	34.0	48.0	61.7
Profitability Index (PI)	2.70	2.90	1.80	1.79	1.87	1.92
Break-even Price (₦/kg)	1,986.17	1,779.67	2,810.10	2,836.76	2,836.26	2,783.75
Break-even Yield (kg)	45.31	40.58	64.75	65.65	64.50	62.19

Table 7: Stochastic Frontier Production Function and Technical Inefficiency Estimates of Cultured Fish Farming across in Osun State

Variables / Parameters	**Iwo**	**Ejigbo**	**Ife Central**	**Obokun**	**Olorunda**	**Osogbo**
A. Stochastic Production Frontier						
Constant (β_0)	4.5232*** (0.8421)	0.235*** (0.0932)	4.1182*** (0.8045)	4.0026*** (0.8517)	4.2458*** (0.8354)	4.3864*** (0.7921)
ln(Rent on pond) (₦)	0.220*** (0.0814)	0.110** (0.0468)	0.255*** (0.0724)	0.205*** (0.0783)	0.300*** (0.0732)	0.315*** (0.0695)
ln(Labour) (Man-hour)	0.120** (0.0432)	0.180*** (0.0613)	0.145*** (0.0416)	0.105** (0.0452)	0.170*** (0.0418)	0.175*** (0.0396)
ln(Quantity of feed)(kg)	0.215*** (0.0526)	0.130*** (0.0415)	0.270*** (0.0568)	0.225*** (0.0614)	0.275*** (0.0576)	0.290*** (0.0542)
ln(Fingerlings stocked)(No)	0.135*** (0.0398)	0.120** (0.0524)	0.170*** (0.0381)	0.135*** (0.0406)	0.185*** (0.0387)	0.190*** (0.0364)
ln(Depreciation cost)(₦)	0.110** (0.0476)	0.775 (—)	0.195*** (0.0497)	0.120** (0.0528)	0.155*** (0.0465)	0.165*** (0.0443)
B. Technical Inefficiency Model						
Constant (δ_0)	0.1343NS (0.2753)	0.398** (0.181)	0.162NS (0.151)	0.214NS (0.167)	0.171NS (0.156)	0.148NS (0.142)
Age of respondent (years)	0.440** (0.173)	0.031*** (0.010)	0.026*** (0.009)	0.031*** (0.010)	0.025*** (0.009)	0.022*** (0.008)
Years of farming experience(years)	0.028*** (0.009)	-0.037** (0.016)	-0.042*** (0.015)	-0.036** (0.017)	-0.043*** (0.015)	-0.047*** (0.014)
Gender (Male=1)	-0.041*** (0.015)	0.011NS (0.058)	-0.010NS (0.052)	0.012NS (0.055)	-0.006NS (0.052)	-0.009NS (0.049)
Education (years)	0.008NS (0.053)	-0.029** (0.013)	-0.031*** (0.011)	-0.026** (0.012)	-0.032*** (0.011)	-0.035*** (0.010)
Marital status (Married=1)	-0.034*** (0.012)	-0.003NS (0.031)	0.006NS (0.024)	-0.004NS (0.027)	-0.032*** (0.011)	-0.035*** (0.010)
C. Variance Parameters						
Sigma-squared (σ^2)	0.212*** (0.061)	0.246*** (0.073)	0.186*** (0.054)	0.218*** (0.062)	0.193*** (0.056)	0.205*** (0.059)
Gamma (γ)	0.934*** (0.027)	0.911*** (0.031)	0.918*** (0.030)	0.904*** (0.033)	0.181*** (0.051)	0.172*** (0.048)
Log-likelihood	124.6	120.8	143.7	130.9	201.8	208.6
Mean Technical Efficiency (%)	82.4	79.8	80.1	77.3	84.5	86.2

Note: Values in parentheses are standard errors. *** Significant at 1%; ** significant at 5%; * significant at 10%; NS = Not significant. Mean Technical Efficiency = Mean exp(−Ui).
Source: Field Survey, 2025

Table 8: Mean Technical Efficiency Scores of Cultured Fish Production

LGA	**ADP Zone**	**Mean TE [Exp(−U_i)]**	**Inefficiency Score (1 – TE)**	**Output Gap (% improvable)**	**Rank (1 = Most Efficient**
IW (Iwo)	Iwo	82.4%	17.6%	+17.6%	3rd
EJ (Ejigbo)	Iwo	79.8%	20.2%	+20.2%	5th
IC (Ife Central)	Ife/Ilesha	80.1%	19.9%	+19.9%	4th
OB (Obokun)	Ife/Ilesha	77.3%	22.7%	+22.7%	6th
OL (Olorunda)	Osogbo	86.2%	13.8%	+13.8%	1st
OS (Osogbo)	Osogbo	84.5%	15.5%	+15.5%	2nd
Zone Average					
	Iwo	81.1%	18.9%	+18.9%	
	Ife/Ilesha	78.7%	21.3%	+21.3%	
	Osogbo	85.4%	14.6%	14.6%	
Overall Mean		**81.7%**	**18.3%**	**+18.3%**	

Source: Field Survey Data, 2025