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TECHNICAL EFFICIENCY AMONG THE FISH FARMERS IN OSUN STATE, NIGERIA

Abolupe Oluyemi AYANBOYE[1*], Ahmed Olugbenga BUSARI[1], Zaccheaus Olaniyi OLUWAFEMI[2], Adewale Isaac OLUTUMISE[3]**

[1]Osun State University, *Faculty of Renewable Natural Resources, College of Agriculture, Department of Fisheries and Aquatic Resources Management, **Faculty of Agricultural Production and Management, College of Agriculture, Department of Agricultural Economics and Agribusiness Management, Ejigbo Campus, Osun State, Nigeria, Phones:+2348062075491; +2348052174096, E-mails: oluyemi.ayanboye@uniosun.edu.ng, hamed.busari@uniosun.edu.ng
[2]Oyo State College of Agriculture and Technology, Department of Agricultural Economics, Igboora, Oyo, Nigeria, E-mail: zooluwafemi@oyscatech.edu.ng
[3]Adekunle Ajasin University, Department of Agricultural Economics, Akungba-Akoko, Ondo State, Nigeria, E-mail: adewale.olutumise@aaua.edu.ng

Corresponding author: oluyemi.ayanboye@uniosun.edu.ng

Abstract

This study used the stochastic frontier production function analysis to assess the technical efficiency of fish producers in Osun State, Nigeria. A series of structured questionnaires was used to gather primary data from 90 fish producers in Nigeria's Osun State. According to the computed stochastic frontier function for the 90 respondents, the average efficiency value was 0.801. From this, it can be inferred that 82.22% of the population of fish farmers had above-average fish production performance, while 17.78% of the farmers performed below-average. The coefficients of years of experience, household type, age, and educational attainment were found to be strongly correlated with the degree of inefficiency. This demonstrated that these elements either increased technical efficiency or decreased technical inefficiency. The distribution of findings also revealed that, while not using all the inputs, fish farmers in Osun State are more efficient in their utilization. In order to fulfil the common knowledge gap among fish farmers, it is advised that seminars and worship be held in order to increase the efficiency of the fish farmers in the study area.

Key words*: *aquaculture, Stochastic Frontier, input and output, Osun State, Nigeria

INTRODUCTION

Fish production in Nigeria is currently obtained through two main sources, namely, the capture fishery (capture) and aquaculture fishery (aquaculture). However, empirical evidence has shown that there is a wide disparity between fish supply from all these sources and fish demand. As reported by [60], the Nigerian Minister of Agriculture and Rural Development revealed that, Nigeria's total fish production is estimated at 1.123 million metric tonnes while put the fish demand of the country at 3.6 million metric tonnes of which the country only meet up about 31.19%.
[6] also reported a shortfall of about 1.3 million tons in the fish supply of Nigeria. This deficit in the demand-supply gap may increase fish prices and fish importation bills. For example in 2020 alone, the country spent over $876,081,485.00 million on the importation of frozen fish (excluding fish fillets and other fish meat) and only generated $106,964.00 thousand in export [59]. This is why Nigeria is considered a net importer of fishery products. The hidden truth of the importation is development in the fishery sector in Nigeria will be hindered because a huge amount of money that ought to have been committed to its development is being spent on fish importation.
The situation on fish demand and supply gap is surprising and the rate is alarming when one considers the fisheries resources potential the country is blessed with which could serve as an avenue for economic growth if well harnessed. It was revealed by [36] that Nigeria

has a continental coastline length of 853 km [36] and a continental shelf area of 43,514 km^2 [50]. Its extensive network of inland waters, including rivers, flood plains, lakes, and reservoirs, both natural and man-made, was also disclosed by [51].

In 2020, the fisheries subsector accounted for 1.09% of the nation's GDP, and in the third quarter of 2021, it contributed 0.9% [34]. According to estimates, the inland water mass is around 12.5 million hectares, with the capacity to produce 512,000 metric tons of fish each year. All these are great sources for fish cultivation and the evidence that Nigerians can produce enough fish to meet its demand and export excess, provided the vast aquatic resources are harnessed and utilized with a high level of productivity.

Ironically, despite the aforementioned inadequate fish supply in the country, Nigeria is the largest fish consumer in Africa and among the largest fish consumers in the world [2] with about 3.2 million metric tons of fish consumed annually [57]

Catfish production increased fast with a high rate since 2000 till present at the global level exceeding 6,000,000 Metric Tons. Catfish is largely cultivated in Europe, Asia, Africa and America [58]. Nigeria is currently the largest producer of African catfish in the world [20]. The aquaculture subsector is thought to be a very good substitute for supplying the country's demand for fish production self-sufficiency. This is because, in comparison to capture fisheries, it has a low capital intensity and a good return on investment [29]. Fish culture is the main focus of aquaculture in Nigeria, where the most often cultivated fish species are Heterotis niloticus (slap water), Cyprinus carpio (common carp), Tilapia spp. (tilapia), and Clarias and Heterobranchus spp. (catfish) [43]. Nonetheless, a lot of fish farms concentrate on catfish because their market value can be two to three times that of tilapia [23].

Fishery production is of great importance in Nigeria given its ability to provide a relatively cheap source of animal protein, income, and employment. Fish accounts for nearly 40% of Nigeria’s protein intake, as fish consumption hovers between 11.2 and 13.3 kg/person/per year [4].

In Nigeria, over 1.477.651 people were reported to have been engaged in the fisheries sector of Nigeria in 2014 ([21], [61]). Fish consumption has come to play the role of supplying quality protein, in contrast to protein supply by red meat consumption which scientists have proven to be a source of bad cholesterol, a deadly health issue in the human body which can lead to hypertension. [49] undertook a systematic review and dose-response meta-analysis of prospective studies and reported a positive association between red meat intake and hypertension. Fish functions to protect a human being from a variety of diseases in the world, [55]. The moisture, protein, lipids, vitamins and minerals in fish are important macro and micronutrients, responsible for implying nutritional value to the fish meat [31]. The dietary support of fish is crucial in terms of animal protein, as a portion of 150 g of fish provides about 50-60 percent of the daily protein rations for an adult. As a result, fish can be used as a primary protein source in many underdeveloped nations. Fish made up over 17% of the world's animal protein intake and 6.5% of all protein intake as recently as 2010 [22].

There is widespread hunger and malnutrition in Nigeria, which could be attributed to fish supply gap in Nigeria, because lack of adequate protein intake both in quality and quantity to feed the nation's ever-growing population has been one of the greatest problems confronting millions of Nigerians today. This inadequacy results in the problem of malnutrition.

Most people consider fish and fish products to be acceptable, which contributes to the constantly rising demand for them. Consuming foods high in protein is becoming more and more popular, as noted by [13].

However, the supply side has not been given the appropriate attention to create an equilibrium point with demand. In order to meet the nation's enormous demand for fish, Nigerians must expand aquaculture and fish production using all of the inland water that is accessible.

Interestingly, there is an increasing trend and high level of awareness of farm-raised fish production in Nigeria and farmers are keen on fish farming. Fish farming is expanding rapidly throughout the world and has a high potential for the provision of valuable protein in less developed countries [32].

[47] opined that in most small-scale agricultural production, advanced technology has not enhanced output simply because a lot of such technologies are exhausted without giving a proportionate increase in output. In other words, there is a need to optimise the use of resources and input to enhance profitability and productivity. Optimum yield should be based therefore on full capacity utilization of resources through efficient use of existing technology and policies made bearing in mind this necessity of full capacity [15; 47].

Moreover, it is sufficient to point out that the early model of aquaculture production focused on the biological and technical aspects of aquaculture production with little emphasis on economic performance. For instance, [48] and [8] developed models for different components of aquaculture relating to the design and operation of aquaculture facilities. In Indonesia, [54] found that catfish cultivators had implemented good and correct technical cultivation activities, farming in ponds was financially feasible, and the catfish marketing system was running efficiently in Banjar Regency, South Kalimantan province, In Southwest Nigeria, [7] investigated the profitability of small-scale catfish farming, and in Osun State, Nigeria, [30] examined the economics of catfish farming.

Also, attention has been focused on the optimal harvesting strategies and lots of bio-economic models have been developed to determine the optimal time of harvest based on a number of different cost and price assumption [26] with little or no emphasis on economic efficiency.

Literature review

The majority of empirical studies on efficiency and productivity are grounded in the economic theory of production.

Efficiency is defined as the achievement of a production objective with no waste. The fundamental principle of "no waste" served as the foundation for the several theories of efficiency that economists have developed. But the fundamental concept behind all efficiency indicators is the amount of goods and services per unit of input. Accordingly, if a production unit produces too little from a given bundle of inputs, it is considered technically inefficient.

Efficiency can be measured using two fundamental approaches: the frontier approach and the classical way. The traditional method, known as a partial productivity measure, is predicated on the ratio of output to a specific input. This strategy does have certain drawbacks, though, thus more sophisticated econometric and linear programming techniques were created to analyze production and efficiency. Businesses that operate on the production frontier are said to be efficient, according to the frontier measure of efficiency. Inefficiency is defined as the degree to which a corporation falls below its production frontier. The frontier approach was first discussed in [19].

[19] distinguished three categories of efficiency: economic efficiency (total efficiency), allocative efficiency (price efficiency), and technological efficiency. The ability of a Decision Making Unit (DMU) to generate the most possible output from a specific bundle of inputs or the smallest conceivable quantities of inputs to create a particular level of output is known as technical efficiency (TE). While the latter definition is known as input-oriented TE, the former is known as output-oriented TE. The ability of a technically efficient DMU to use inputs in proportions that minimize production costs given input prices is known as allocative efficiency (AE).

The result of combined TE and AE is economic efficiency (EE) [19]. Accordingly, if a DMU is both technically and allocative efficient, then it is economically efficient. Economists contend that a key factor in determining priorities should be the attainment of (higher) efficiency from limited resources.

The problem of balancing the expanding demand for different services with the resources at hand is becoming more and more difficult for decision-makers. Farrell originally suggested an innovative method of efficiency frontier calculation from actual production measurements in 1957, arguing that the firm's efficiency could be experimentally calculated. The frontier planned form, the estimate method used to obtain it, and the nature and purported characteristics of the gap between the observed production and the ideal production are the three categories into which the frontier estimation techniques can be divided. The frontier form classification makes it possible to differentiate between parametric and nonparametric techniques. A function with explicit parameters (Cobb-Douglass, CES, Translog, etc.) is presented via the parametric approach.

According to [3], the parametric method is the one that shows a function with clear parameters. Numerous econometrical and non-econometrical methods, such as the maximum likelihood method and the least-squares method, allow for the estimation of the production or cost border parameters in the case of a parametric function.

The unique feature of nonparametric frontiers is that they don't force any predetermined form on them [14]. When a functional form is unable to identify the production process, the nonparametric technique is employed. The sole factor that distinguishes the nonparametric techniques is the production's convexity. It allows one to differentiate between that non-convex and the convex nonparametric technique. Farrell utilized the former for the first time in 1957. Farrell's production frontier imposes certain constant outputs at the scale and is linear.

The aim of this article is to use the stochastic frontier production function analysis to evaluate the technical efficiency of fish farmers in Osun State, Nigeria, as well as the factors that influence fish production. This is critical since it would greatly influence the creation and application of policies in the state and the country of Nigeria overall.

MATERIALS AND METHODS

Osun State is where the study was conducted. 9,125 km² make up the total landmass of Osun state. Kwara State borders it to the North, Kogi State borders it to the Northeast, Ondo state borders it to the East, and Ogun State borders it to the South. It is located between latitudes 700 and 800 N.

The rainfall pattern of Osun state is wide and diverse ranging from 125 mm (minimum in the dry season). Thus, there are two rainfall peaks. The average rainfall ranges from 1,125 mm in derived savannah to 1,475 mm in the rain forest belt. The mean annual temperature ranges from 27.2°C in the month of June to 39.0°C in December. The soil types are varied but most contain a high proportion of clay and sand, and are mainly dominated by laterite. Osun state is well drained with some rivers which the indigenes of the area used for domestic purpose and fish cultivation. The region is home to an agrarian community that produces crops, fish, and poultry. Among the states in southwest Nigeria, Osun has the largest percentage of fish producers. With 300 fish farmers, Osun State had the most of the 906 fish farmers in the Southwest, followed by Oyo, which had 234 fish farmers overall [9]. Administratively, Osun state is divided into 30 local government plus 1 area office with an estimated population according to 2006 census of 3423,535. But going by the Osun state Agricultural Development Programme (ADP) method of administration, the state is divided into three zones: Iwo, Oshogbo and Ilesha zones. Ido-Osun and Ofatedo towns are located in Egbedore Local Government while Owode-Ede is in Ede North Local Government of Osun State.

The study areas was chosen from Iwo zone, because it had a higher concentration of fish farmers relative to the other two zones according to the information from Ministry of Agriculture, Fisheries and Aquacultures Department Osun State. Iwo zone comprises of Egbedore and Ede Local Government areas of Osun State. The study was then undertaken in Ido-Osun, Ofatedo and Owode-ede. Ninety catfish fish producers across Iwo zones were randomly selected using a list obtained from Ministry of Agriculture, Fisheries and Aquacultures Department Osun State.

Primary data was used for this study. The data was collected on 2024 catfish production activities using a well-structured questionnaire in a multi-stage sampling technique. Purposive selection was used in the first stage to choose Ido-Osun, Ofatedo (Egbedore Local Government Area), and Owode-Ede (Ede-North Local Government Area) because catfish farming is one of the primary sources of income for the locals. The Second Stage was to obtain the list of catfish farmers in the selected locations from the Fisheries Department of Osun State Ministry of Agriculture, Osogbo and Blossom Vine Catfish Farmers Cooperative Society.

Finally, a total of 90 catfish farmers were randomly selected using proportionality factor adopted by [1].

$$S = \frac{p}{P} x \frac{Q}{1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where:
S =Total number of respondents sampled
p = Number of catfish farmers in each location
P = Total population of catfish farmers
Q = Total number of questionnaires administered.

A total of 40, 20 and 30 respondents were selected from Ido-Osun, Ofatedo, (Egbedore Local Government Area) and Owode-Ede respectively. Ido Osun had a higher concentration of fish farmers relative to other local governments

Data were of primary origin aimed at investigating socio-economic characteristics of the fish farmers as well as efficiency of production. Thus, age of the farmers, household size, educational status, years of experience, number of fish stocked, various cost items necessary for production were among the various variables solicited for using questionnaire.

Catfish farmers' socioeconomic characteristics were described using descriptive statistics. This study examined the technical efficiency (TE) of catfish farmers using the Stochastic Frontier Production Function (SFPF). We employed the SFPF, which was separately proposed by [3] and [33] for the analysis. It has been demonstrated that estimating using the stochastic frontier production function allows one to determine whether variances in technical efficiencies from the frontier output are caused by random external causes or by farm-specific factors [27; 46; 40].

The general implicit form of the model is stated below:

$$\mathrm{LogY} = \beta_0 + \beta_1 \mathrm{logX}_1 + \beta_2 \mathrm{logX}_2 + \beta_3 \mathrm{logX}_3 + \beta_4 \mathrm{logX}_4 + \beta_5 \mathrm{logX}_5 + \beta_6 \mathrm{logX}_6 + (V_1 - U_1)) \ldots\ldots\ldots (2)$$

where:
Log= Natural logarithm
Y = Output of catfish in kilogramme
X_1 =Number of fingerlings in number
X_2 = Quantity of feed in kilograms
X_3 = Labour in hours
X_4 = Lime (kg)
X_5= Fertilizer (kg)
X_6 =Capital input in naira (₦)
β_0. β_1 , β_2. β_3, β_4, β_5, β_6 = Regression Coefficients

Assumed to be identical, normally distributed, and independent of Ui, Vi= are random variables with a constant V variance N (0,sv2) and zero mean.

To account for technical inefficiencies in production, Ui= are non-negative random variables that are frequently assumed to be independent of Vi. In this way, U is the non-negative truncated (at zero) U of half-normal distribution with | N (0,su2)| The inefficiency of production, Ui was modelled in terms of the factors that are thought to affect farmers' production efficiency. These elements are connected to the socioeconomic characteristics of farmers.

The following defines the determinant of technical inefficiency:

$$U = \delta_o + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + e \ldots\ldots\ldots (3)$$

The factor that determines technical where:
U stands for technological inefficiency.
Z_1 = Farmers' age (years)
Z_2 = sex dummy, where female = 0 and male = 1.
Z3 = dummy marital status (married=0, single=0)

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Z_4 = Years of education
Z_5 = Size of household
Z_6 = Experience Years
o = Constant 1 – 6 = Estimated parameters
e is the error term.

It is believed that these factors affect the farmers' technical efficiency. They also calculated the gamma (= o2 / 2) u, which is the ratio of the variance of U (o2) to the Sigma squared (2), which is a summation of variances U and V (o2+ 2). The parameters of the SFPF were estimated using the Maximum Likelihood Estimate Method with the computer FRONTIER version 4.1 [17].

Because it has been scientifically proven to be the most effective for agricultural studies of this kind, the Cobb Douglas form of the frontier model was employed. A mathematical expression for technical efficiency, which is the ratio of the observed output (Y1) to the equivalent frontier output (Y1*) contingent on the farmer's input levels, is as follows in the context of the stochastic frontier equation specified as:

$TE = Y_1/Y_1^*$ .... (4)

$= f(X;B) \exp(V_1 - U_1) / f(X;B) \exp(V_1)$ .... (5)

$= \exp(-U_1)$ ………………………….. ...(6)

where:
Y_1 = observed value of output and
Y_1^* = the frontier output.

The frontier production function is estimated by the Maximum Likelihood Technique. Any farmer who is fully technically efficient will have the value of one. Thus farmers having value lying between zero and one are described as being technically inefficient.

The production function model of the aquaculture production functions was algebraically specified by the Cobb-Douglas function form because of its unique characteristics that are very useful in empirical analyses. These characteristics include: the elasticities of production used in the productivity analysis are equal to the estimated coefficients of the parameters (βi) of the production function and the summation of these elasticities of production gives the types of returns to scale obtained, that is, (Σβi) = RTS.

• When RTS = 1 there is constant return to scale.

• When RTS is between zero and one, that is, 0 < RTS < 1, there is a positive decreasing return to scale. Here, input allocation and output production are optimal and efficient. Any increase in allocation of input will result in increase in the total output but at a decreasing rate. This is known as stage II of production function that the aquaculture farm strives to attain.

• When RTS > 1, there is an increasing return to scale, where output increases at increasing rate with any increase in input. This is the stage I of the production function. The farmer needs to expand production by allocating more of the variable input to get to stage II where production is optimal and efficient.

• When RTS < 0, this is a negative decreasing returns to scale or stage III of the production function where any increased allocation of input for output production results in the decrease in the total output. Here the farmer needs to reduce the allocation of inputs so as to get back to stage II.

RESULTS AND DISCUSSIONS

Socio-economic and production factors

The averages of various production and socio-economic factors of interest are shown in Table 1. Fish farmers in Osun State are middle aged. The mean value for age indicated that the average age of the farmers was 40.8 years. [44] observed that the age bracket of 30-50 years represents an active productive age bracket in agriculture. There is no age restriction in going into catfish farming in the study area. An average fish farmer in the study area has an educational status of about 3 and a household size of 5. Catfish farming operations require a great deal of human effort from stocking, routine management to harvesting. Thus households with increased labour supply are more likely to adopt and participate in labour-intensive new technologies than those with fewer persons per household [35];[11]. The mean stocking capacity (fingerlings) of fish farmers is 56,945.78.

Table 1. The averages of various production and socio-economic factors of interest

Variable	Measure Unit	Mean	Standard deviation	Min	Max
Age	Years	40.8	9.49	18	65
Education	Years	2.79	.50	1	4
Household size	Number	5.18	1.65	2	10
Fingerlings	Number	32,570.12	22,636.12	5,000	90,000
Feed	Kilogram	56,945.78	100,559.1	6,600	800,000
Labour	Man-days	6.74	1.98	2	10
Lime	Kilogram	835	622.22	0	3,000
Fertilizer	Kilogram	371.61	253.04	0	950
Transportation	Naira	2,959.16	1,546.90	700	6,300
Depreciation cost	Naira	2,637.92	1,935.35	770	82,206.74

Source: Authors' computation.
$1 is equivalent to ₦ 1,590.69 as of October 2024 [16].

Determinants of Technical Efficiency

The maximum likelihood estimate of the stochastic frontier production function of fish production in Osun State is shown in Table 2. The results demonstrated that, at the 10% level, the sigma square (δ2) is 0.201 and statistically significant. This shows that the specified distribution assumption of the composite error term is true and fits the data well. Additionally, the estimated gamma (λ) variance ratio, which is significant at the 10% level, is 0.870, indicating that fish farmers in the study area are producing inefficiently. It indicates that variances in fish farming methods were the primary cause of variability in fish yield. Therefore, output can be optimized if the inefficiency effects among the fish producers are minimized. The result shows the relative importance of the variable inputs in fish production.

There are two components to the stochastic production function: the efficiency model and the technical efficiency model The technical efficiency model results show the direct contribution of each fish input employed to the total fish output. While the inefficiency model revealed the indirect influence of some intrinsic attributes of fish farmers on the total fish output

Thus, the result of technical efficiency shows that the estimates of the number of fingerlings stocked, quantity of feed, labour (man-days) and depreciation value of the fixed asset used in the fish production were statistically significant at 1% and 5% respectively. This means that they were directly related to the output that is, output increased as they were increased and vice versa.

The coefficient of fingerling was estimated to be 0.060 and positive. This implies that catfish fingerlings or fish seeds stocked, ceteris paribus, have a positive and significant contribution to the magnitude of fish output derivable on a typical farm. Similar studies by [41] and [18] discovered that the cost of fingerlings was significant in Benue and Cross River states, Nigeria respectively. The significance of fingerlings to table fish production is empirically based on the component of a particular breed or species, type of fish, hatchery management and fish characteristics that determine how the fish would respond to further production input such as fish feeds and other environmental factors within the farm site. Therefore, fish farmers should procure species of fish that are adaptive and responsive to fish feed and other farmers' management.

The quantity of table fish produced by farmers in the study area was strongly influenced by the positive feed coefficient (0.056). A farmer's purchase of fingerlings dictates how much feed he will buy. This is consistent with [42] and [37]. Most often fish feed cost is usually considered very high, [28] reported that feed accounts for at least 60% of the total cost of fish production in Africa, which to a large extent determines the viability and profitability of fish farming enterprise. However, in the study it was noted that the coefficient of feed (0.056) is moderate compared to the estimated coefficient of fingerling (0.060).

Based on the general fish farming practices among the farmers the feed produced and used widely in Africa are categorized into conventional and non-conventional feed stuff [24]. The conventional feeds are formulated and branded fish feeds and oftentimes are costly beyond the economical capacity of most fish farmers. While the non-conventional fish feed is generally organic waste materials such as maggots, insects, hatchery waste, etc. These alternative fish feeds that are used as fish feed supplements aim at reducing the cost of production. But most often, most fish farmers do not weigh and factor these into their production cost and technically the effect of such feed supplement is difficult to capture and measure as fish input.

The majority of farmers who were interviewed in-depth also disclosed that the organic materials used to enhance fish feed are mostly used in their raw state, with little processing or treatment, and that the amount used on a given stock of fish is unpredictable due to inconsistent supplies. Furthermore, a common limitation mentioned by at least 89% of the fish farmers in the study area was the high cost of fish feed.

The coefficient of labour (0.423) is positive and significant. [52] observed that cost of labour had positive effect on production. [53] obtained similar result for the South Tripura district of Tripura State, China. Fish farming operations among small-scale farmers are generally labour-intensive and these small-scale fish farmers constitute 80% of fish aquaculture in Nigeria [12]. According to the analysis's results, labour was also shown to favourably and significantly increase the fish farmers' production of table fish. Fish management typically involves a high level of labor intensity for daily, infrequent, and routine procedures. In the study area, the hourly and strength engagement for scavenging for maggots and other sources of cheap feed materials are magnums to quantify. Therefore, there is a trade-off of labour man-day for the cost of feed that is required to nurture stocked fish seeds to table fish. Aside from this, labour requirements of pond maintenance and other daily fish farm operations are very crucial and are contributory factors for total table fish output.

The depreciation (0.645) value of the fixed fish farming equipment and machines is considered in this analysis because it is believed that these fixed assets do enhance the ease of fish farm operations which normally improves technical efficiency. As a result, the analysis's findings were deemed favourable and noteworthy in relation to the quantity of table fish produced by an average fish farmer in the study area. This is consistent with what [5] found.

The socioeconomic characteristics of fish farmers, which may enhance the efficacy and efficiency of aquaculture management techniques, are the inefficiency factor taken into account in this study. Age, sex, marital status, educational attainment, household size, and years of experience in fish farming are some of the socioeconomic traits of the fish farmers taken into account (Table 2). Years of experience, household size, and educational attainment all had negative coefficients, suggesting that these variables either increased or decreased technical inefficiency.

The outcome of the analysis shows that old age contributes to the inefficiency of aquaculture management. This implies that as the fish farmers are ageing, they might be deficient in the strength required for efficient management of daily fish farm operations. Whereas young fish farmers with able bodies would have the capacity to withstand the daily energy-sapping of fish production. Therefore, for such a typical ageing farmer to still be in fish operations, it would require the employment of able-bodied labour to carry series of tasking fish farm management. The result is in agreement with the studies of [56]; [35]; [25].

The model revealed that the educational attainment of fish farmers enhances fish farm management efficiency. This underscores the multiplier effects of improved knowledge and skills quotient of fish farmers could be tremendous as a determinant of the total fish produced. From this result, it could be deduced that educated and elite fish farmers tend to be more efficient when compared with less educated fish farmers. This supports the a priori prediction that TE should rise as education increases because experience and education are thought to be favorably connected with the adoption of better production methods and technology. This outcome aligns with [39], [38], and [25].

Table 2. The Stochastic Production Frontier Estimates Maximum Likelihood Estimates of the Stochastic Frontier Production Function for Catfish Farmers

Variables	Parameters	Coefficients	St. Error
Constant	β_0	4.576	0.421
Fingerling (number)	β_1	0.060***	0.016
Feed (kg)	β_2	0.056**	0.024
Labour (man-days)	β_3	0.423**	0.201
Lime (kg)	β_4	0.027	0.291
Fertilizer (kg)	β_5	0.123	0.112
Depreciation cost (₦)	β_6	0.645**	0.278
Inefficiency Function			
Constant	δ_0	0.177	0.203
Age	δ_1	0.024***	0.006
Sex	δ_2	-0.009	0.440
Marital status	δ_3	0.003	0.004
Education level	δ_4	-0.032***	0.007
Household size	δ_5	-0.021***	0.005
Experience	δ_6	-0.031***	0.012
Diagnostic Statistics			
Sigma square	δ^2	0.201*	5.973
Gamma	Γ	0.870*	10.053
Log likelihood function	148.855		

Source: Field Survey Data, 2024.
Note: *Significant at 10% level; ** Significant at 5% level; *** Significant at 1%

Additionally, among the respondents in the study area, the size of the fish farmers' households was statistically significant in relation to the efficient production of fish. The variable is said to increase efficiency if the coefficient is negative. This is consistent with what [10] found. According to the inefficiency model's relevance of household size, most fish producers used their own family members to work in fish farms instead of hiring workers. The implication is that households with mature family members would find daily fish farm operations easier and timely and this may not be so for the fish farmers who solely depend on hired labour for major fish farm operations.

Years of farm experience was another significant variable in the inefficiency model. The experience of the farmers on the proper management of fish farms is usually built up over time. The daily routine maintenance of fish farm operations such as feeding, monitoring water quality (water turbidity, aeration), and prevention of predators required prerequisite experience. Proper handling of these ponds and routine maintenance could be difficult for an inexperienced farmer.

Production Elasticities

When all other factors are maintained constant, production elasticities show the percentage change in output in relation to a percentage change in input. The regression coefficient, sometimes referred to as the estimated parameters of each variable in Table 3, represents the elasticity of production of the variables based on the nature of the Cobb-Douglas production function fitted. The number of fingerlings stocked, the total amount of feed, the total amount of labor, and the depreciation cost on fixed costs were all positive decreasing functions to the factors, according to the estimated elasticities of the explanatory variables. This suggests that the variable allocation was in the stage of economic relevance of the production function.

This implies that allocation and utilization of each of the factors (variables) was in stage II of the production functions or positive decreasing return to scale. Then allocation and utilization are efficient.

The Return to Scale (RTS) which is the summation of the elasticity of production inputs involved in fish production is 0.80. Fish production is in stage II (the rational stage) of the production function, as indicated by the fact that it is positive and less than unity.

This means that if all the variables are each increased by a unit, the profit will increase by 0.80. The return to scale (RTS) which is the summation of the elasticities of production of the production function is used to determine the stage of overall production in the production functions. From this study, RTS is < I implies, there is a positive decreasing return to scale. However, this result is not in agreement to those of [38] and [45] who reported the existence of increasing returns to scale but inefficient or irrational stage of production in catfish production in Oyo and River States of Nigeria, respectively

Table 3. Elasticity of production and Return-to-Scale of catfish farmers

Inputs	Elasticity
Fingerling (number)	0.060
Feed (kg)	0.056
Labour (man-days)	0.423
Depreciation cost (₦)	0.645
RTS	0.80

Source: Field Survey Data, 2024.

Productions are quite optimal and efficient among the fish farmers in the study areas according to Table 3. Any increase in the allocation of input results in an increase in total output at a decreasing rate. This is the best stage of production that any producer (aquaculture farmer) strives to attain.

Distribution of Fish Production Efficiency

The level of production efficiency varies with individual fish farmer's intrinsic ability, edaphic and environmental factors, water quality, feed and feeding regime. In order to assess the respondents' performance level in the study area, the distribution of fish production efficiency was examined. Table 4 shows the decile range of the Technical Efficiency frequency distribution.

The average fish production efficiency of typical farmers in the study area is 0.801, and the least or minimum and maximum fish production efficiency values are 0.378 and 0.962.

Table 4. Range of Technical Efficiency

Decile Range of TE	Frequency	Percentage
< 0.40	6	6.67
0.40 – 0.49	10	11.11
0.50 – 0.59	12	13.33
0.60- 0.69	8	8.89
0.70 – 0.79	6	6.67
0.80- 0.89	38	38.89
0.90 and above	10	11.11

Source: Field Survey Data, 2024
Mean Technical Efficiency 80.1%
Minimum Technical Efficiency 37.8 %
Maximum Technical Efficiency 96.2 %

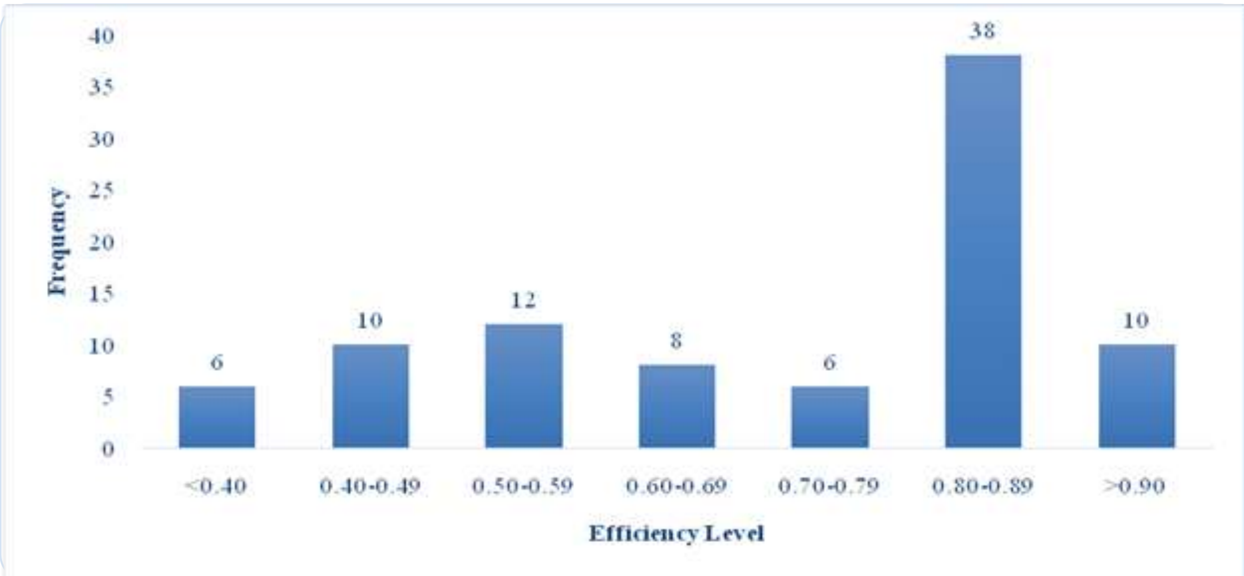

Fig. 1. Frequency Distribution of Technical Efficiency for fish culture in Osun State
Source: Author's Computation.

According to the distribution of fish production efficiency, 11.11 percent had an efficiency between 40 and 49 percent, while 6.7% had an efficiency below 40 percent. Additionally, it was discovered that 13.33% of the respondents had production efficiency between 50 and 59 percent, 8.9% of the fish farmers had 60 to 69 percent, at least 6.67%

of the respondents were operating between 70 and 79 percent, and 50% of the fish farmers had production efficiency above 80 percent.

Summarily, it can be deduced that about 17.78% of the fish farmers were found to perform below average while 82.22% of the fish farmers' population had their fish production performance above average. Detail analysis further indicated that those farmers with less than 50% fish production efficiency were mostly young graduates or beginners who had inadequate experience in fish production.

Therefore, these set of fish farmers should endeavour to either interact with experienced fish farmers or attend fish production seminars or workshops to acquire adequate skills and knowledge to improve fish production efficiency.

The frequency distribution of technical efficiency for fish culture in Osun State is shown in Fig. 1.

CONCLUSIONS

This study aimed to determine the input and output technical efficiencies of fish producers in Osun State. The maximum likelihood estimate of the frontier production showed clearly that the Number of fingerlings, the quantity of feed, labour and depreciation on fixed cost are the most important inputs in fish production. The mean efficiency value of the 90 respondents' estimated stochastic frontier function was 0.801. It may be inferred that 82.22% of the population of fish farmers had above-average fish production performance, while 17.78% of the farmers performed below-average. The factors of age, years of experience, household type, and educational attainment were found to be strongly correlated with the degree of inefficiency. This suggested that either technical inefficiency decreased or technical efficiency increased as a result of these factors. Therefore, seminars and workshops should be held to train and close the knowledge gap among fish farmers in order to boost their efficiency in the study area.

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