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Determinants of technical and allocative efficiencies in catfish (*Clarias gariepinus*) Production in South-East, Nigeria

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Abstract
The study analysed technical and allocative efficiencies and their determinants in Southeast zone of Nigeria with the objectives of examining and identifying the socioeconomic characteristics of the catfish farmers in the area, the technical and allocative efficiency levels of the farmers, the determinants of technical and allocative efficiencies in catfish production, and the effect of pond systems on technical and allocative efficiencies. Multi stage and simple random sampling procedures were adopted in the selection of 384 respondents for the study. The results showed that majority of the farmers were males, educated up to secondary school level, with the mean fish production experience of 9.6 years, and high use of family labour. It was also found that average stocking rate was 2,500 per production phase with average duration of production of 6months. The result on the efficiency distribution showed that the mean technical and allocative efficiency levels of the farmers were 0.73 and 0.87 respectively. The results further pointed out that the socio-economic characteristics included in the study significantly contributed to technical and allocative efficiencies of catfish farmers in the area with experience standing out as the most important. Lastly, it was found that farmers who farmed in earthen ponds allocated their resources more efficiently.

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Introduction

Fish farming is one of the vital sectors that are being explored as it is the best and cheapest source of animal protein for human consumption. The dependence on fisheries by millions of people around the world, coupled with increased consumer demand for aquatic foods and the depletion of global fisheries has created an impetus to expand fish production through aquaculture (Adeogun and Alimi, 2014) [2]. The Nigeria's fishery sector is estimated to employ over 8.6 million people directly and a further 19.6 million indirectly, 70 percent of whom are women. Fisheries contributed 0.88% to the Agriculture GDP and contribution of Agriculture to Nigeria GDP is 22%. Currently, Nigeria produces just over 1 million metric tons of fish, leaving a deficit of over 800,000 metric tons, which is imported annually (FAO, 2022) [14]. Recognizing the importance of fish within the agriculture sector for its potential contribution to alleviating poverty, improving food and nutrition security, reducing youth unemployment and building profitable business ventures.

Nigeria's aquaculture focuses mainly on freshwater fish with catfish species accounting for above 60% of its production. It also accounts for 52% of the total farmed fish production in Sub-Saharan Africa, (World Fish, 2018). The African catfish is an important aquaculture species in various regions in the world with Nigeria contributing more than 67% of the total global production, followed by Uganda, Cuba, Sudan, Hungary, Netherlands, Benin and Brazil (FAO, 2019) [13]. The African catfish has been the most popular farmed species owing to its ability to tolerate adverse environmental conditions such as different salinity levels, low dissolved oxygen and low pH, rapid growth rate allowing for two cycles to be completed in a year, resistance to diseases and efficient food conversion ratios (FCR). It also enjoys preference among freshly prepared live-fish (a.k.a. point-and-kill) consumers as it can be kept alive at restaurants until its ready to be prepared, (Olagunju, 2020) [20]. Fish consumption accounts for over 40% of the protein sources consumed in the country. Fish plays an important role in household food security. Its consumption accounts for over 40% of the protein sources consumed in the country (Worldfish, 2018). The consumption of fish has shown an upward growth trend with an annual consumption of about 3.2 million metric tons, of which 2.1 million metric tons are imported each year (FAO, 2019) [13]. Nigeria is the largest consumer of fish products in Africa as it's an important source of animal protein. It offers the best and cheapest source of good quality protein, macronutrients like vitamin A, iron, zinc, calcium, selenium and essential fatty acids, providing important diet of many poor people in Nigeria, (Adeogun and Alimi, 2014) [2]. In addition, fish has no religious taboo or any cultural limitation affecting its consumption unlike pork and beef.

Demand for food is intensifying as world's population increases. In Nigeria, there is wide gap between food production and population growth, hence the rising wave of food insecurity. While food production increases at the rate of 2.5%, food demand increases at a rate of more than 3.5% due to high rate of population growth of 2.83% (FAO, 2014) [11]. This has led to rising food importation and soaring food prices. This has also led to the widening demand and supply gap for animal protein. The FAO (2018) [12] recommends that the minimum intake of protein by an average person should be 65 g per day; of this, 36 g (i.e. 40%) should come from animal sources. Nigeria is presently unable to meet this requirement as the animal protein consumption is less than 8 g per person per day, which is far below the FAO minimum recommendation FAO (2018) [12]. As a result of the above, widespread hunger and malnutrition are evident.

Statement of the problem

Despite the importance of fish production in Nigeria, fish production is hindered by low productivity, high mortality, water problems, high cost of feed and poor management practices (Amaefula *et al*., 2010). Moreso, Aasa, Usman, Balogun, and Yahaya, (2020) reported that constraints faced by catfish farmers in their business included high cost of production, lack of financial assistance, while Enwelu, Onuorah and Iyere-Freedom (2023) [9] reported that high cost of feed, high cost of fuel and poor electricity were important problems in catfish production. These problems immensely contributed to low level of output per farmer. However, to achieve high productivity in catfish production requires that resources should be used more efficiently with more attention paid on attainment of production goal without waste (Nwaru, *et al* 2010). In an economy where resources are scarce with little opportunities for improved technologies, the role of efficiency in productivity growth cannot be over emphasised. Efficiency indicates the inputs-output relationship of the production function which defines the possible combinations of inputs and the resulting outputs.

Specifically, the objectives of the study are to:

1. Identify the socioeconomic characteristics of the catfish farmers in the area;
2. Determine the technical and allocative efficiency levels of the farmers;
3. Identify the determinants of technical and allocative efficiencies in catfish production;
4. Determine the effect of pond systems on technical and allocative efficiencies.

Materials and Methods

Area of the study

This study was carried out in the South East zone of Nigeria. The zone is one of the six zones of Nigeria representing both a geographical and political zones of the country. The zone is bounded by the River Niger on the west, the riverine Niger Delta on the south, the flat North central region to the north, and Cross River State on the east. The zone is located at Latitudes 4°30^1 and 7°30^1 North of the equator and longitudes 6°45 ^{1} and 8°45^1 East of the Greenwich Meridian with a total land area of ten million, nine hundred and fifty-two thousand, four hundred hectares (10,952,400 ha). The zone contributes greatly to the Nigerian economy due to its endowment with arable land, oil and natural gas reserves along with the growing industrialised economy. Apart from agriculture as the mainstay of economic activities for the majority of the rural communities, the zone is also known for its commerce and trading activities with preponderance of micro, small, and medium scale indigenous industries that are into manufacturing, fabrication and agro-allied produce.

Map of Southeast, Nigeria

Fig 1

Sample size determination

The 'Cochran's' formula for infinite population was utilised in arriving at the sample size as the population of catfish farmers in the zone were unknown.

'Cochran's' formula for infinite or unknown population stated as follows:

$$n = \frac{Z^2 \times p\,(1 - p)}{\epsilon^2} \qquad \text{(equation 1)}$$

$$n = \frac{1.96^2 \times 0.5\,(1 - 0.5)}{0.05^2} = 384$$

Where:
n = sample size
z = z score (based on 5% error margin)
p = population proportion (50%)

ϵ = margin of error (confidence interval, 95%).

Sampling procedure

The Multi-stage sampling procedure was adopted for the study. In the first stage, three (3) states namely: Anambra, Ebonyi and Imo States were randomly selected from the five states in the zone, followed by the random selection of three (3) Local Government Areas from each of the three states through the agricultural zones making it a total of nine (9) LGAs. The third stage involved the random selection of four (4) communities from each of the nine (9) selected LGAs bringing it to thirty-six (36) communities from where three hundred and eighty-four (384) respondents were randomly selected.

Data collection

The study utilised questionnaire designed and structured to consist of opened and closed ended questions. This was made for uniform responses, and to enable the respondents contribute effectively with minimum restrictions and minimised bias. Six trained research assistants aided data collection which was done between October and November, 2023.

Data analysis

The objectives of the study were achieved with the analyses of data as follows: descriptive statistical tools of frequency, mean and percentage for farmers' socio-economic characteristics; technical and allocative efficiency levels of the farmers were achieved using the Stochastic Frontier Analysis (SFA). The technical efficiency (TE) was analysed using the stochastic frontier production function while the allocative efficiency (AE) was analysed using the Cobb-Douglas stochastic frontier cost function.

Model Specification

The models are specified as follows:

$$Yi = \frac{f(Xi\beta)\exp(Vi - Ui)}{f(Xi\beta)\exp(Vi)} = \frac{f(Xi\beta)\exp(-Ui).\operatorname{Exp}(Vi)}{f(Xi\beta)\exp(Vi)} = \exp(-Ui) \quad - \quad \text{(eqn. 2)}$$

$\sigma^2 = \sigma^2 v + \sigma^2 u$ indicates the goodness of fit of the model used; and

γ (gamma) = $\frac{\sigma^2 v}{\Sigma^2 u}$ = (0, 1* (Battese and Corra, 1977).

This measures the deviation of the output from the frontier due to technical inefficiency.

If $\gamma = 0$, it implies that there are no effects of technical inefficiency, and all deviations from the frontier are due to noise (Aigner *et al*., 1977). A value greater than zero implies that there are technical inefficiency effects. Thus, TE has values that range between '0 and 1', with '1' defining efficient catfish farmers and '0' defining inefficient catfish farmers.

Where:

Y_i = Output of the ith farm, X_i = Vector of inputs used by the ith farm,
β = A vector of the parameters estimated, e_i = Composite error term,
V_i = Random error outside farmer's control, U_i = Technical inefficiency effects,
σ^2 = Variance

The Cob- Douglas stochastic frontier production function is specified in its explicit form as:

$$\text{In}Y1 = \beta_0 + \beta_1 \text{In}X_1 + \beta_2\text{In}X_2 + \beta_3\text{In}X_3 + \beta_4\text{In}X_4 + \beta_5\text{In}X_5 + V_i - U_i \quad - \quad - \quad \text{(eqn. 3)}$$

Where:

In =Logarithm to base e, Y = Output of catfish (kg), β_0 = Constant
$\beta_1 - \beta_6$ = Parameters estimated, X_1 = Fingerlings (Number), X_2 = Fish feed (kg)
X_3 = Labour (Man-days), X_4 = Drugs (litres), X_5 = Fuel (litres)
V_i = Random noise (white noise), U_i = Inefficiency effect which are non negative with half normal distribution.

It is assumed that inefficiency effects are independently distributed and Ui arises by truncation (at zero) of the normal distribution with mean Uij and variance δU^2.

Allocative efficiency model adapted from Ike and Udeh, (2011) is as expressed below:

$$AE = \frac{MP \times Py}{pxi} = \frac{MVP}{pxi} = 1 \quad - \quad - \quad \text{(eqn. 4)}$$

Where:

MVP = Marginal value product of individual inputs, MP = Marginal product (coefficient)

pxi = Unit price of the individual inputs, Py = Price of output (Revenue)

Absolute allocative efficiency is confirmed with respect to given input if AE = 1. The input is over-utilized if AE<1 and under-utilized if AE>1.

The determinants of technical and allocative efficiencies, Ui is defined by:

$$U_i = \delta 0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 \quad - \quad - \quad - \quad - \quad - \quad \text{(eqn. 5)}$$

Where:
Ui = Inefficiency effect, $\delta 0$ = Constant, $\delta_1 - \delta 6$ = Parameters to be estimated
Z_1 = Farmer's age (years), Z_2 = Sex, Z_3 = Household size of farmer (number)
Z_4 = Years of formal education of the farmer, Z_5 = Years of farming experience
The Cobb-Douglas stochastic frontier cost function is stated as follows:

$$\ln C_i = \beta_0 + \beta 1\ln X_1 + \beta 2\ln X_2 + \beta 3\ln X_3 + \beta 4\ln X_4 + \beta 5\ln X_5 + V_i + U_i \quad - \quad - \quad \text{(eqn. 6)}$$

Where:
$\ln C_i$ = Value of the catfish output for the ith farmer, X_1 = Cost of fingerlings (₦)
X_2 = Cost of fish feed (₦), X_3 = Cost of labour (₦), X_4 = Cost of Drugs (₦)
X_5 = Cost of Fuel (₦)
β = vector of the coefficients for the associated independent variables in the cost function,
U_i = one sided component, which captures deviation from frontier as a result of inefficiency of the firm,
V_i = effect of random stocks outside the catfish farmer's control, observation and measurement error and other stochastic (noise) error term.
The effects of pond systems/types were achieved using the maximum estimation model explicitly stated as follows:
TE/AE = f(Pt)

$$TE/AE_i = \beta_0 + \beta_i \ln Pt_i \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \text{(eqn. 7)}$$

Where:
TE/AE = Technical efficiency or Allocative efficiency
Pt = pond type adopted by the ith farmer.

Results and Discussion
Socio-economic Characteristics
The estimated socio-economic and enterprise characteristics of the respondents include age, sex, educational level, years of experience in catfish production, household size and stock size. From table 4.1, it is shown that majority (59.7%) of the catfish farmers were between the ages of 31 and 50 years with their mean age of 43.3 years implying that they belonged to the economically active population category who were still vibrant and could adopt new approaches in production which could increase their production performance. This result is in tandem with the findings of Enwelu, Onuorah and Iyere-Freedom (2023) [9] that the mean age of catfish farmers in Anambra State, Southeast Nigeria, was 42.4.

The result also showed that catfish production was dominated by the male folks (59%). This could be because catfish production in the area was rigorous as most of the farms had little investment in technological innovations. It could also be because most females in the study area were saddled with domestic responsibilities. This result also agreed with findings of Enwelu, Onuorah and Iyere-Freedom (2023) [9] who reported male dominance among catfish farmers in Anambra State, Southeast Nigeria.

Table 1.0: Socio-economic Characteristics of the Catfish Farmers (n=384)

Frequency		**%**	**Mean**
Age			
21 to 30	28	14.0	
31 to 40	95	26.2	
41 to 50	200	33.5	43.3
51 to 60	51	21.7	
61 to 70	10	04.6	
Sex			
Males	281	59.0	
Females	103	41.0	
Education			
Primary	78	25.7	
Secondary	197	50.5	12.1
Tertiary	109	23.8	
Experience			
1 – 10	226	51.1	
11 – 20	153	38.5	9.6
> 20	5	10.4	
Household size			
1 – 5	131	45.2	
6 – 10	246	43.9	6.0
11 – 15	7	10.9	
Type of labour			
Family labour	294	76.6	
Hired labour	90	23.4	
Stock size per cycle			

501 – 1,500	96	25.0	
1,501 – 2,500	109.	28.4	2,500.0
2,501 – 3,500	87	22.6	
3,501 – 4,500	65	17.0	
4,501 – above	27	7.0	
Duration of rearing			
3.1 – 6months	208	54.2	
6.1 – 9months	157	40.8	6.0
> 9months	19	5.0	
Type of pond			
Earthen pond	103	26.8	
Concrete pond	197	51.3	
Mobile pond	84	21.9	

Source: Field survey, 2023

The results further showed that majority (50.5%) of the respondents were educated up to secondary school level. This implies that catfish farmers in the area were educated and had the potentials to adopt new technologies and innovations. This is in conformity with Iwu, Adewole, Ishie, and Arowolo (2019) [17] who found that majority of catfish farmers in Niger State, North central Nigeria, had secondary education as the highest level of education. Also, among the respondents, the mean years of production experience was 12.1, while majority (51.1%) of them had years of experience of between 1 and 10 years. This showed that the farmers were vast in the knowledge of poultry farming and could easily and readily adopt new technologies that could better their efficiency levels.

Table 4.1 also revealed that majority (89.1%) of the catfish farmers had household size of between 1 and 10, with the mean number of 6 persons. This finding explained why majority (76.6%) of the farmers utilised family labour. Hence, household size negatively influenced the amount of hired labour in catfish production in the area. This is also similar with Iwu, Adewoe, Ishie, and Arowolo (2019) [17] that majority of catfish farmers in Niger State, North central Nigeria had household size of between 1 and 6 persons. Furthermore, majority (76.6%) of the catfish farmers, as shown in the table, employed the use of family labour. Many of them could have done that to reduce their production cost. This also showed a positive relationship with the household size of the farmers which, as revealed by the study, was reasonably high. In addition, catfish is a distinct breed of livestock in terms of maturity and harvesting age. They are distinct because they can be harvested and consumed at any given age mostly from 3 months and above (from fingerling stage). Majority (54.2%) of the catfish farmers reared and harvested their fish between 3 months and 6months, with the mean rearing period of 6months which is enough for a good number of the fish to attain 1 kilogram body weight. Also, in table 4.1, majority (53.4%) of the farmers stocked between 500 and 5,000 fish in each production cycle with the mean stock size of 2,500.

Lastly, majority of the farmers operated concrete pond. This could be because, with the services of good engineers, concrete pond can be constructed almost on every terrain, only that their construction is more expensive. Earthen pond, on the other hand, is less expensive, but the environment on which it can be constructed, even where they are available, cost a huge fortune to acquire or rent. Lastly, mobile pond is increasingly becoming accepted in the area due to the possibility of moving them from one point to another when the need arises. The mobile ponds included collapsible/tarpaulin pond and plastic tanks. However, it is also not cheap to acquire. This result conforms to the findings of Amachree, Jamabo and Joseph, (2019) [4], that majority of catfish farmers in Rivers State, South-south, Nigeria, used concrete pond. It also agreed with the report of Imade and Egbodon, (2021) [16], that earthen pond was the least used by catfish farmers in Delta State, South-south, Nigeria.

Technical and allocative efficiency of catfish production

Table 2.0: Technical and allocative efficiency distribution of catfish production

	TE		AE	
Efficiency level	**Freq.**	**%**	**Freq.**	**%**
0 – 0.250	4.0	1.0	22.0	5.7
0.251 – 0.450	21.0	5.5	20.0	5.2
0.451 – 0.650	42.0	10.9	18.0	4.7
0.651 – 0.850	258.0	67.2	9.0	2.3
0.851 & above	59.0	15.4	315.0	82.0
Total	384.0	100.0	384.0	100.0
Minimum	0.077		0.052	
Maximum	0.956		1.000	
Mean	0.732		0.837	
Std. Dev.	0.147		0.229	
T-value	97.36***		71.61***	

Source: Field survey, 2023

Technical efficiency distribution

The distribution of catfish farmers' efficiency levels as presented in table 2.0 shows that majority of the farmers (67.2%) operated at technical efficiency levels between 65% and 85% with a minimum of 7.7% and maximum of 95.6% while 17.4% operated below 65% technical efficiency level. This result is an indication that there is a wide difference in the technical efficiency operations of farmers in the area. The table also showed that the mean technical efficiency was 73%; implying that the farmers have room to improving their technical efficiency level by saving 27% of the input. This result is similar to the result of Olagunju (2020) [20] who found that 64% of catfish farmers in FCT, North central Nigeria, were within the upper band of the index having an efficiency score of 70% and above. This result also correlates with the findings of Baruwa and Omodara (2019) [6] who reported that the technical efficiency of catfish farmers in Oyo State, Southwest Nigeria ranged between 0.41 and 0.90 with a mean of 0.74.

Allocative efficiency distribution

The allocative efficiency of catfish farmers in the study area as shown in Table 2.0 showed that 82% of the farmers allocated their cost efficiency above 85%. The result also showed that only about 17.9% of the catfish farmers had allocative efficiency below 85%. The allocative efficiency distribution of the farmers ranged from 5.2% to 100.0% with a mean of 83.7%. This revealed a wide distribution of allocative efficiency among the farmers in the study area. This result implies that resources could be allocated to their best alternative uses and prices could as well be allowed to perform their functions in the use of inputs. This result indicates that for an average farmer to reach the allocative efficiency frontier level, he could experience a cost saving of 16.3% (100 – 83.7). This finding has similarities with the work of Ogenyi (2015) [18] who reported that about 26.67% of catfish farmers had allocative efficiency below 50%, and that the allocative efficiency distribution of the farmers ranged from 29 to 98%.

Determinants of technical and allocative efficiencies

Table 3.0: Determinants of technical efficiency

TE determinants	Estimate	Std. error	Z-value
(Intercept)	1.153	0.334	3.45***
Age	-0.004	0.006	-0.60
Sex	0.003	0.083	0.03
House hold size	-0.012	0.029	-0.40
Education	-0.004	0.014	-0.30
Experience	0.009	0.009	1.05
(Phi) Coefficient	9.193	0.639	14.38***
Log-likelihood	231.100		
Pseudo R-squared	0.500		

Source: field survey 2023

The efficiency model presented in table 3.0 revealed that age had an inverse relationship with technical efficiency. This implies that the older the farmer gets, the lower his technical efficiency becomes. This is an indication that older folks who joined catfish production performed less efficiently than the younger folks. This conforms to the popular assertion that young people tend to withstand stress and put more time in various agricultural operations which often results to increased output. This was, however, not significant. The result is in tandem with the report of Ajiboye *et al*., (2020) [3] who asserted that age decreased technical efficiency in Ekiti State, Southwest Nigeria, though not significantly. Also, the coefficient for sex of the famers also has the expected positive effect on technical efficiency indicating that as more males moved into catfish production, technical efficiency increased. This could be attributed to the fact that it is the male folks who could better handle the rigors of catfish production than the female folks. This result also agrees with that of Ajiboye *et al*., (2020) [3] who reported that sex of the farmer in Ekiti State, Southwest Nigeria, related positively (though not significantly) with technical efficiency, implying that increases in the number of male folks in catfish production increased technical efficiency.

Furthermore, the coefficient for household size was negative. This shows that as the number of persons in a farmer's household increased, technical efficiency decreased. This implies that respondents with larger household sizes tend to be less technically efficient than respondents with fewer household sizes. This result disagrees with the expectation that larger household sizes could result to higher technical efficiency based on thoroughness in operation and substitution of hired labour with family labour. This result shows that most of the household members were yet to garner the requisite skill and experience in catfish production and that could be why their participation negatively affected technical efficiency of their farms. This was also insignificant.

Education plays an important role in agricultural operations since it facilitates the adoption of innovations that will improve output. The coefficient for education was negative; implying that education negatively affected technical efficiency. This is against popular opinion that educational advancement brings about better technical efficiency in farming as a result of easy understanding of farming technologies and adoption of new innovations. This could be attributed to the fact that some of the farmers who acquired more education tend to leave the enterprise for white collar jobs while some others farmed by proxy. However, education was insignificant. This result is, however, in disagreement with the findings of Elsevier (2016) [8] who reported that educational level have a statistically insignificant positive impact on technical efficiency. Years of experience in fish farming was observed to have positive effect on the technical efficiency of fish farmers in the area. This implies that the farmers have acquired more knowledge of fish farming over time enabling them to take better decisions that increased their efficiency level. Also, as a farmer's years of experience increases, the farmer tend to be more familiar with handling the risk in production in terms of technologies, when to stock and harvest, prices of input and output, and predict the market situation precisely. This result is similar to the results reported by Elsevier (2016) [8], that farmers' experience had a positive impact on technical efficiency in Peninsular, Malaysia, and Okoror, Izekor, and Ijirigho (2017) [19], that farming experience had negative and significant effect on technical inefficiency in Edo State, South-south Nigeria, implying a positive effect on technical efficiency. However, this result was not significant.

Table 4.0: Determinants of allocative efficiency

TE determinants	Estimate	Std. error	Z-value
(Intercept)	0.788	0.490	1.67*
Age	0.005	0.009	0.59
Sex	0.187	0.121	1.54
House hold size	0.033	0.043	0.76
Education	-0.018	0.021	-0.84
Experience	0.032	0.013	2.49**
(Phi) Coefficient	3.427	0.247	13.87***
Log-likelihood	274.600		
Pseudo R-squared	0.760		

Source: *field survey 2023*

From table 4.0, it is shown that the coefficient for age of catfish farmers was positive as expected. This implies that catfish farmers' age increased with allocative efficiency. This is not unconnected to the fact that as a farmer grows old in the production of catfish, he garners more knowledge that would help him better allocate his resources. This was, however, not statistically significant. The value of the estimated coefficient for household size is also, as expected, positive with allocative efficiency. This boils down to the fact that household members are more readily available and tend to be more careful in handling farm resources. This was also not statistically significant.

Table 4.0 also revealed that the coefficient for education was inversely related to allocative efficiency of catfish farmers in the study area indicating that the higher the level of education a farmer acquires, the lower the cost efficiency. This result disagrees with apriori expectation that educational level directly affects financial management which positively affects cost efficiency. This could be because the more educated a farmer became, the less attention he paid to his farm, leaving the running of activities to proxies, and the less his efficiency in input cost allocation, though this was also not insignificant. The estimated coefficient for experience in catfish production was direct on allocative efficiency. This shows that improvement in allocative efficiency in fish farming was partly contributed by increase in farming experience. This is in line with the assumption that allocative efficiency of the farmer increases with experience; as the farmer has, over the years, gained information with which he takes better decision when it comes to his production cost allocation. This result was significant at 5% level of probability.

These results seem to have similarities with the result of Baruwa and Omodara (2019) [6] who found that observable socio-economic variables such as fishers' age, gender, fishing experience, and educational status were responsible for the efficiency variations. However, years of fishing experience was significant (P<0.01) and was the only socio-economic variable contributing significantly to inefficiencies in aquaculture systems in Oyo State.

With the (phi) coefficients statistically significant at 1% alpha level in both allocative and technical efficiency (from tables 3.0 and 4.0 respectively), it is an indication that the socio-economic characteristics listed above significantly contributed to technical and allocative efficiencies of catfish production in the area.

Effect of pond types on technical and allocative efficiencies

Table 5.0: Effect of pond types on technical efficiency

Pond type	Estimate	Std. error	Z-value
(Intercept)	1.123	0.104	10.79***
Pond type	-0.079	0.050	-1.58
(Phi) Coefficient	9.207	0.640	14.38***
Log-likelihood	231.400		
Pseudo R-squared	0.007		

Source: field survey 2023

From table 5.0, it is shown that the coefficient for pond types used by the farmers on technical efficiency is negative. This implies that as the farmer shifts from the use of earthen pond to concrete pond and to mobile pond, technical efficiency decreased. This means that producing catfish in earthen pond increased technical efficiency of the farmers. This could be attributed to the natural environment offered to catfish grown in earthen ponds in form of flowing water which energizes the fish by providing more oxygen. This natural environment also provides the fish with natural feeds in the form of preys and aquatic plants which provide better nutritional value thereby increasing the yield and output of catfish production. This positive effect was, however, statistically insignificant.

Table 6.0: Effect of pond types on allocative efficiency

Pond type	Estimate	Std. error	Z-value
(Intercept)	3.8047	0.15835	24.03***
Pond type	-1.12313	0.06843	-16.41***
(Phi) Coefficient	5.5521	0.4152	13.37***
Log-likelihood	342.2000		
Pseudo R-squared	0.3951		

Source: field survey 2023

From table 6.0, it is shown that the coefficient for pond type and allocative efficiency estimate is also negative. This negative effect implies that as the farmer shifts from the use of earthen pond to mobile pond and to concrete pond, allocatve efficiency decreased. This means that farmers who produce their catfish in earthen pond allocated the production costs better, followed by those who used concrete pond and lastly, those with mobile ponds. This could be because farmers with earthen ponds got some of their inputs from nature and/or with little expenditure to augment what nature has given freely. Example is water. Most earthen ponds got their water supply from rivers or streams and some of them discharged or flushed out dirty water from the ponds with the help of topography without having to spend money on fuelling of generators or paying for electricity units. Some others enjoyed flowing water through their ponds which made cost allocation to fuel for pumping of water less important. Also, fish in some earthen ponds fed on zooplanktons and phytoplanktons present in the pond thereby reducing the cost allocated to feeding. This result was significant at 1% alpha level.

This finding is in line with the findings of Oluwatayo and Adedeji, (2019) [21] who found that the most efficient and profitable construction design among earthen, cage culture and plastic tank in Lagos State, Southwest Nigeria, was the earthen pond. This, according to them, was because of its cost-effectiveness in terms of design and management as well as the limited impact on the environment.

The findings of Imade and Egbodon, (2021) [16] also toed the same line when they reported that the mean levels of technical efficiency (TE) of the farmers under the production systems in Delta State, South-south Nigeria, were earthen pond (0.77), concrete pond (0.76) and plastic/tarpaulin pond (0.73) respectively. This was also the case in terms of output as Abasiekong, Ogban, and Idiong, (2021) reported that there were significant differences (P<.01) among the mean output of fish per ponds from the three production systems, with earthen pond having the highest value, followed by concrete pond, and mobile pond in Cross river State, South-south Nigeria.

The (phi) coefficients which are statistically significant at 1% alpha level in both technical and allocative efficiencies (tables 5.0 and 6.0 respectively) implied that pond types/systems significantly affected efficiency of catfish production in the area.

Conclusion

In conclusion, majority of the farmers were educated up to secondary school level, with the mean fish production experience of 9.6 years, and high use of family labour. It was also found that average stocking rate was 2,500 per production phase with average duration of production of

6months. The result on the efficiency distribution showed that the mean technical, allocative and economic efficiency levels of the farmers were 0.73, 0.87 and 0.61 respectively implying that the farmers could save their input and costs by 26% and 16.3% respectively to attain the frontier levels. Furthermore, the results pointed out that the socio-economic characteristics included in the study significantly contributed to technical and allocative efficiencies of catfish farmers in the area with experience standing out as the most important. Lastly, it was found that those who farmed in earthen ponds allocated their resources more efficiently, implying that efficiency is also determined by the farmer's type of pond.

Recommendations

Based on the findings of this study, the following were, therefore, recommended:

a. Farmers are encouraged to work hard, learn from their past mistakes and build on the experience.
b. Farmers are endeared to minimise their resource and cost allocation so as to reach the frontier levels.
c. Farmers who have the means should invest in earthen ponds for better result.

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