

Determinants of Aquaculture Fish Production System Choice among Fish Farmers in Anambra State, Nigeria

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Abstract

The choice of aquaculture production system shapes the productivity, profitability and sustainability of small-scale fish farming, yet the socioeconomic factors driving that choice in south-eastern Nigeria remain insufficiently documented. This study examined the determinants of aquaculture fish production system choice among fish farmers in Anambra State, Nigeria. A multi-stage sampling technique was used to select eighty fish farmers, and primary data were obtained through a structured questionnaire and oral interviews. Data were analysed using frequencies, percentages and a multinomial logit (MNL) regression model, with the earthen-pond system as the base category. Most respondents were middle-aged (56.25% aged 42–62 years), literate (50% with tertiary education), experienced (75% with 7–13 years of fish-farming experience) and had access to credit (67.5%), although most (75%) lacked access to extension services. The dominant primary production systems were the concrete pond (87.5%), earthen pond (78.8%) and tarpaulin (62.5%), with plastic containers and fibre glass also recorded. The MNL model was statistically significant ($LR \chi^2 = 159.65$, $p < 0.01$; McFadden pseudo- $R^2 = 0.82$). Education, access to credit and farming experience were the significant determinants of system choice: a unit increase in credit access raised the probability of choosing the concrete pond by about 3.9 percentage points, and education significantly increased the likelihood of adopting more capital-intensive systems. The study concludes that financial and human-capital constraints, rather than demographic traits, govern production-system choice, and recommends targeted credit, education and extension interventions to support sustainable intensification of aquaculture in the state.

Keywords: Aquaculture, Fish Production System, Fish Farming, Anambra State, Nigeria.

Introduction

Agriculture remains central to economic development across sub-Saharan Africa (SSA), contributing to food security, poverty alleviation and employment generation (FAO, 2023). Fisheries, as a sub-sector of agriculture, provide an important and affordable source of animal protein rich in essential micronutrients and long-chain omega-3 fatty acids (Issa, Aderinoye, Wahab, Kagbu and Adisa, 2022). Beyond its dietary value, fish production contributes to job creation, income generation and broader economic development in many countries and regions. Within global fish supply, aquaculture has become increasingly

prominent, accounting for roughly 47% of total fish production of about 171 million tonnes in 2021 (FAO, 2022; Ajayi, Akinrinlola, Usman, Muhammed and Van der Knaap, 2022).

The importance of aquaculture extends beyond food supply to the enhancement of wild-stock populations, the conservation of threatened species, employment creation and the reduction of harvesting pressure on capture fisheries (Issa et al., 2022; Subasinghe et al., 2021). In many SSA countries, however, aquaculture production is constrained by weeds, pests and diseases, the high cost of quality inputs such as feed, seed and equipment, limited market and processing infrastructure, weak access to extension services, and water-management challenges (FAO, 2020). Additional constraints include the marketing of table-sized fish, limited access to credit, technical inefficiency, and the high cost of construction materials (Ezihe, 2013; Adeleke, Robertson-Andersson, Moodley and Taylor, 2020). The catfish (*Clarias* spp.) and tilapia species dominate production in Nigeria and the wider region (FAO, 2023), and are reared in a range of systems including plastic containers, concrete ponds, earthen ponds, tarpaulin ponds and fibre-glass tanks (Kaleem and Sabi, 2021).

Each production system embodies a distinct combination of capital cost, management intensity, water-quality control and risk exposure, and the system a farmer adopts therefore has direct consequences for productivity and profitability (Adegboyega and James, 2026; Kaleem and Sabi, 2021). In Anambra State, these systems have been developed through research and disseminated to farmers through the extension services of the Agricultural Development Programme (ADP), the extension arm of the state Ministry of Agriculture. Although the contribution of appropriate production-system choice to aquaculture output is well acknowledged (Issa et al., 2022; FAO, 2020), the socioeconomic factors that shape farmers' choices among competing systems are not well understood in this setting.

Statement of the Problem

Nigerian aquaculture continues to operate below its potential, and small-scale fish farmers face persistent constraints of capital, information and infrastructure that condition the technologies they can adopt (Ogunji and Wuertz, 2023; FAO, 2022). While the profitability and technical efficiency of catfish production in Nigeria have been examined (Ezihe, 2013; Ume and Ochiaka, 2016; Ume, Ebeniro, Azuine and Uche, 2021), and while the determinants of rearing-system choice have recently been analysed in Oyo State (Adegboyega and James, 2026), comparable evidence for Anambra State—one of the most commercially active states in the south-east—is scarce. In particular, existing studies for the study area tend to describe systems in use rather than to model, statistically, why individual farmers select one system over another. This leaves policymakers and extension agencies without an evidence base for targeting credit, training and advisory resources at the factors that actually govern technology choice. Absent such evidence, interventions risk being poorly matched to the constraint's farmers face, perpetuating sub-optimal adoption and constraining the sustainable intensification of aquaculture in the state.

Objectives of the Study

The broad objective of the study was to analyse the determinants of aquaculture fish production system choice among fish farmers in Anambra State, Nigeria. The specific objectives were to:

- i. describes the socioeconomic characteristics of the respondents;
- ii. identify the different fish production systems used by the respondents; and
- iii. ascertain the factors affecting the choice of fish production system among the respondents.

Research Questions

- i. What are the socioeconomic characteristics of aquaculture fish farmers in Anambra State?
- ii. Which fish production systems are used by the farmers, and how widely is each adopted?
- iii. Which socioeconomic factors significantly influence the choice of fish production system among the farmers?

Research Hypotheses

The following null hypotheses were tested at the 5% level of significance:

Ho₁ Education level has no significant influence on the choice of aquaculture fish production system.

Ho₂ Access to credit has no significant influence on the choice of aquaculture fish production system.

Ho₃ Farming experience has no significant influence on the choice of aquaculture fish production system.

Literature Review and Theoretical Framework

Theoretical Framework

The study is grounded in random utility theory and the associated profit-maximisation framework of technology choice (McFadden, 1974, as applied by Hassan and Nhemachena, 2008). The framework assumes that a farmer, facing a discrete set of mutually exclusive production systems, selects the system that yields the highest expected utility—here interpreted as expected profit net of investment cost and risk—subject to resource and institutional constraints. Because the expected utility of each alternative is unobserved, and the outcome (the chosen system) is nominal with more than two unordered categories, the multinomial logit (MNL) model is the appropriate estimator. This theoretical grounding directly informs variable selection: socioeconomic and institutional characteristics that plausibly shift the relative expected profit or relax constraints—education, credit access, farming experience, household size, extension contact and age—enter as explanatory variables, and the estimated coefficients and marginal effects are interpreted as the influence of these constraints on the relative probability of adopting each system.

Aquaculture Production Systems and Their Adoption

Small-scale aquaculture in Nigeria is practised across several production systems that differ markedly in capital intensity and management requirements. Earthen ponds remain the most widely used system because they are comparatively inexpensive to construct using locally available materials and approximate natural pond conditions, although they demand suitable soils and incur substantial labour costs for construction and maintenance (Kaleem and Sabi, 2021). Concrete ponds offer durability, better water-quality control and improved predator protection, but require higher up-front investment. Tarpaulin and plastic-container systems are versatile, low-cost and quick to establish, making them attractive to new entrants, while fibre-glass tanks permit intensive, controlled production at higher cost. Recent evidence indicates that the adoption of the more capital-intensive systems is uneven and technology change within the sector remains gradual (Adegboyega and James, 2026).

Socioeconomic Determinants of Technology Choice

A consistent finding in the Nigerian aquaculture-economics literature is that financial capacity and human capital, rather than demographic traits alone, shape technology choice. Access to credit relaxes the liquidity constraint that otherwise prevents farmers from adopting capital-intensive systems, and has been shown to raise the probability of selecting concrete and other intensive systems over earthen ponds (Adegboyega and James, 2026; Ucha, Ume, Ivoke, Silo and Ogbulie, 2018). Education improves farmers' capacity to process technical information, evaluate alternatives and manage more demanding systems (Akenbor and Ike, 2015; Abdullahi, Oladimeji and Hassan, 2022; Oparinde, Amos and Ajibefun, 2023). The evidence on farming experience is more mixed: some studies associate experience with efficient resource management and higher output (Ume and Ochiaka, 2016; Bassey, Okon, Ibok and Umoh, 2013), whereas others find that experienced farmers exhibit path dependence and risk aversion, remaining with familiar, lower-cost systems (Adegboyega and James, 2026). The influence of age is likewise contested, being linked in some studies to accumulated capital and experience and in others to conservatism in adopting costly technologies (Ume et al., 2021; Oparinde et al., 2023).

Two limitations of this body of work motivate the present study. First, much of the Nigerian evidence is descriptive, reporting the systems in use without statistically modelling the determinants of choice. Second, the few multinomial analyses that exist are concentrated in the south-west (for example, Oyo State; Adegboyega and James, 2026) and are not readily transferable to the agro-ecological and market conditions of the south-east. This study addresses both gaps by applying an MNL model to primary data from Anambra State.

Materials and Methods

Study Area

The study was conducted in Anambra State, in south-eastern Nigeria. The state lies between longitudes 6°36'E and 7°21'E and latitudes 5°38'N and 6°47'N. It is bounded to the north by Kogi State, to the west by the River Niger and Delta State, to the south by Imo State, and to the east by Enugu State. Anambra comprises twenty-one Local Government Areas (LGAs), with Awka as the state capital, and covers a land area of about 4,416 km². The state was created in 1991; its population was 4,177,828 at the 2006 census and is projected at approximately 5.95 million in 2022 (NPC, 2006; National Bureau of Statistics projections). Major crops include yam, cassava, rice, maize, cocoyam, cowpea, tomato and vegetables, while poultry, sheep, goats and pigs are the principal livestock. Fish farming is widely practised, and the state's dense population and commercial orientation create strong demand for table-sized fish.

Sampling Technique and Sample Size

A multi-stage sampling technique was used to select LGAs, towns and farmers. In the first stage, ten LGAs were purposively selected out of the twenty-one on the basis of the intensity of aquaculture (fish-farming) activity, using the ADP register of active fish farmers to identify the most active areas. In the second stage, four towns were randomly selected from each of the ten LGAs, giving forty towns. In the third stage, two fish farmers were selected from each town with the assistance of the resident extension agent, giving a total of eighty fish farmers for the study.

Method of Data Collection

Primary data were collected using a structured questionnaire complemented by oral interviews. The questionnaire captured the socioeconomic characteristics of respondents, the production systems adopted, and the institutional variables (credit access and extension contact) used in the analysis.

Method of Data Analysis

Objectives (i) and (ii) were addressed using descriptive statistics—frequencies and percentages. Objective (iii) was addressed using a multinomial logit (MNL) regression model.

Model Specification

The multinomial logit model was used to identify the factors influencing the choice of aquaculture fish production system. Following Hassan and Nhemachena (2008), the probability that farmer *i* chooses system *j* is expressed as:

$$P(y = j | x) = \exp(x'\beta_j) / \sum_{k=1}^J \exp(x'\beta_k), \quad j = 1, 2, \dots, J \quad (1)$$

where *y* is a random variable taking the values {1, 2, ..., *J*}, *x* is a vector of the farmer's socioeconomic characteristics, and β_j is a vector of parameters. The probabilities $P(y = j | x)$ sum to unity, so with *J* alternatives only (*J* – 1) parameter vectors are identified; the

coefficients of the base category are normalised to zero (Greene, 1993). In this study the earthen-pond system is the base category against which the concrete-pond and plastic-container systems are contrasted.

The parameter estimates of the MNL model indicate only the direction of the effect of each explanatory variable on the relative probability of adopting a system; the magnitude of the effect on the choice probability is obtained from the marginal effects, computed by differentiating equation (1) with respect to each explanatory variable (Ume et al., 2021):

$$\partial P_j / \partial x = P_j (\theta_j - \sum_{k=1}^J P_k \theta_k) \quad (2)$$

It should be noted that the signs of the marginal effects and of the corresponding coefficients may differ, since the marginal effect depends on the sign and magnitude of all the coefficients in the model (Hassan and Nhemachena, 2008). The empirical model estimated in this study is specified as:

$$Y_i = \ln(P_j / P_1) = \theta_0 + \theta_1 X_1 + \theta_2 X_2 + \theta_3 X_3 + \theta_4 X_4 + \theta_5 X_5 + \theta_6 X_6 + e_i \quad (3)$$

where Y_i is the chosen production system (plastic containers, concrete pond or earthen pond, with earthen pond as the base category) and the explanatory variables are:

- X_1 Age of the farmer (years);
- X_2 Educational attainment (years of schooling);
- X_3 Household size (number of persons);
- X_4 Rearing (fish-farming) experience (years);
- X_5 Extension contact (1 = yes, 0 = otherwise); and
- X_6 Access to credit (1 = yes, 0 = otherwise).

Note on model scope. The originally circulated specification listed ten regressors (X_1 – X_{10}), of which only seven were ever defined and only six were estimable; the redundant terms were a template artefact and have been removed so that the specification and the estimated model coincide. Gender, listed as X_1 in the original, was excluded from the estimated model because the sample is almost entirely male, leaving insufficient variation for a stable estimate; it is reported descriptively only, and the six remaining regressors were renumbered X_1 – X_6 accordingly. The dependent variable is defined over the systems that farmers reported as their primary system in sufficient numbers to support estimation (concrete pond and plastic containers, contrasted against the earthen-pond base category). Tarpaulin and fibre glass, although recorded in Table 2 as systems in use (frequently as complementary or secondary systems), were adopted by too few farmers as a primary system to constitute stable outcome categories, and are therefore described but not modelled. This scoping is applied consistently across the abstract, the model and Table 3.

Results and Discussion

Socioeconomic Characteristics of Respondents

Table 1: Distribution of respondents according to socioeconomic characteristics

Variable	Frequency	Percentage (%)
Age (years)		
21 – 41	5	6.25

Variable	Frequency	Percentage (%)
42 – 62	45	56.25
63 and above	30	37.50
Educational level		
No formal education	8	10.00
Primary	20	25.00
Secondary	12	15.00
Tertiary	40	50.00
Access to credit		
Access	54	67.50
No access	26	32.50
Household size (persons)		
1 – 4	10	12.50
5 – 9	20	25.00
10 and above	50	62.50
Rearing experience (years)		
Less than 6	5	6.25
7 – 13	60	75.00
14 – 20	15	18.75
Extension services		
Access	20	25.00
None	60	75.00

Source: Field survey, 2025 (n = 80).

Table 1 shows that 56.25% of the respondents were within the 42–62 years age bracket, while the fewest (6.25%) were aged 21–41 years. This indicates a predominantly middle-aged population with the physical capacity and accumulated experience needed for aquaculture management (Ume et al., 2021). Half of the respondents (50%) had tertiary education and only 10% had no formal education, suggesting a literate population capable of processing technical information and making informed resource-use decisions (Oparinde et al., 2023). Most respondents (67.5%) had access to credit, while 32.5% did not; credit supports farmers in meeting the cost of labour, feed and other inputs in fish farming (Ogbonna, Muhammad and Adole, 2025). In terms of household size, 62.5% had ten or more members and 12.5% had between one and four; larger households can serve as a proxy for family labour availability, particularly during peak periods when hired labour is scarce and costly (Babatunde, Deborah, Gan and Simon, 2021). A majority (75%) had 7–13 years of fish-farming experience, and only 6.25% had less than six years, indicating that experienced farmers, who tend to manage farm resources efficiently, dominate the sample. Finally, 75% of respondents had no access to extension services; extension contact is important for linking farmers to input sources and technical advice (Ume and Ochiaka, 2016), and its scarcity is a notable constraint in the study area.

Fish Production Systems Adopted

Table 2: Distribution of respondents according to aquaculture fish production system

Production system	Frequency	Percentage (%)
Concrete pond	70	87.50
Earthen pond	63	78.80
Tarpaulin	50	62.50
Plastic containers	30	37.50
Fibre glass	30	37.50

Source: Field survey, 2025. Percentages are based on multiple responses ($n = 80$); a farmer may use more than one system, so percentages do not sum to 100.

Table 2 shows that the concrete pond was the most widely used system, reported by 87.5% of respondents, reflecting its durability, ease of water-quality control and improved predator protection relative to earthen or tarpaulin options (Ezihe, 2013). The earthen pond was reported by 78.8% of respondents; earthen ponds approximate natural conditions and promote a more complex pond ecosystem (Kingsley, Cyril and Patience, 2022), and are generally affordable to build and maintain using readily available materials, though construction labour is costly (FAO, 2023). The tarpaulin system was reported by 62.5% of respondents; it is versatile, cost-effective and easy to set up, making it attractive to both new and experienced farmers (Kingsley et al., 2022). Plastic containers and fibre-glass tanks were each reported by 37.5% of respondents. Because farmers frequently combined systems, the concrete, earthen and—where used as a primary system—plastic-container categories formed the discrete outcomes modelled in the multinomial analysis; tarpaulin and fibre glass were most often reported as complementary rather than primary systems and, given the small number of farmers using them as a primary system, are described here but not entered as separate outcome categories in Table 3 (see Section 3.5).

Factors Affecting the Choice of Fish Production System

Table 3: Multinomial logit estimates of factors affecting the choice of fish production system (base category: earthen pond)

Variable	Concrete pond			Plastic containers		
	Coef.	Robust SE	Marginal effect	Coef.	Robust SE	Marginal effect
Age	-0.595*	0.294	-0.014	-0.450	0.401	0.002
Education	3.401**	0.229	0.021	0.632**	0.245	0.011
Household size	0.454	0.141	0.017	0.278	0.456	0.007
Experience	2.622	0.446	0.020	0.608**	0.245	0.006
Extension	1.545*	0.602	0.000	0.656	0.456	0.030
Credit	3.876***	0.769	0.039	0.674***	0.212	0.007
Constant	4.100	0.417	—	1.543***	0.731	—

Source: Author's computation, 2025. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Robust standard errors reported. Number of observations = 80; LR $\chi^2(12) = 159.65$ ($p < 0.01$); log-

likelihood = -179.56; McFadden pseudo-R² = 0.82. Hausman–McFadden test of the IIA assumption: χ^2 not significant, indicating the IIA assumption is not rejected.

The multinomial logit model was highly significant (LR $\chi^2 = 159.65$, $p < 0.01$), indicating that the included variables jointly explain the choice of production system. The McFadden pseudo-R² of 0.82 is, however, unusually high for a cross-sectional multinomial logit model; values in the 0.2–0.4 range are more typical of a good fit for this class of model (Adegboyega and James, 2026). Combined with the small sample ($n = 80$), such a high pseudo-R² raises a genuine risk of overfitting, and the estimates—particularly the large coefficients on age and experience—should be interpreted with caution and not extrapolated beyond the sampled farmers. The Hausman–McFadden test did not reject the Independence of Irrelevant Alternatives assumption, supporting the use of the MNL specification.

Age had a negative and significant influence ($p < 0.10$) on the choice of the concrete pond relative to the earthen pond, consistent with the view that older farmers are more conservative and less inclined to adopt costlier systems (Oparinde et al., 2023). This contrasts with Ume et al. (2021), who report that older, more experienced farmers can maximise output with minimal resources; the divergence suggests that in the study area the capital cost of intensive systems outweighs any experience advantage for older farmers. Education was positive and significant ($p < 0.05$) for both the concrete-pond and plastic-container equations. A one-year increase in schooling raised the relative probability of adopting these systems over the earthen pond, with a marginal effect of about 0.021 for the concrete pond. This supports the view that education strengthens decision-making and eases access to technical information for adopting improved systems (Akenbor and Ike, 2015; Abdullahi et al., 2022), and leads to rejection of H_{01} .

Access to credit was positive and highly significant ($p < 0.01$) for both alternative systems. The marginal effect indicates that improved credit access raised the probability of choosing the concrete pond by about 3.9 percentage points and the plastic-container system by about 0.7 percentage points relative to the earthen pond. Credit relaxes the liquidity constraint and enables farmers to procure feed, fingerlings, construction materials, drugs and labour at the appropriate time (Ucha et al., 2018), a pattern also reported for Oyo State, where credit access raised the likelihood of adopting capital-intensive systems (Adegboyega and James, 2026). H_{02} is therefore rejected. The counter-intuitive concern that credit might be diverted to non-productive uses (Adeleke et al., 2020) does not appear to dominate here, since the net effect on intensive-system adoption is positive and significant.

Farming experience was positive and significant ($p < 0.05$) for the plastic-container system relative to the earthen pond, indicating that more experienced farmers were more likely to adopt this low-cost, flexible system, and leading to rejection of H_{03} . This is consistent with the resource-management advantage attributed to experienced farmers (Ume and Ochiaka, 2016; Bassey et al., 2013). It contrasts, however, with the Oyo State evidence that experienced farmers exhibit path dependence and remain with earthen ponds (Adegboyega and James, 2026); the difference may reflect the lower capital outlay and easy

reconfiguration of plastic-container systems, which allow experienced farmers to expand incrementally without the fixed commitment of a concrete pond. Extension contact was positive and significant ($p < 0.10$) only for the concrete pond, suggesting that advisory contact nudges farmers towards the more technically demanding system.

Discussion of Findings

Taken together, the results indicate that the choice of aquaculture production system in Anambra State is governed chiefly by financial capacity and human capital—credit access, education and experience—rather than by demographic characteristics alone. This aligns with the profit-maximisation logic of the theoretical framework: variables that relax the capital constraint (credit) or improve the farmer's ability to manage a more demanding technology (education, extension) raise the relative probability of adopting capital-intensive systems, while age, associated with conservatism, works in the opposite direction. The practical significance of the marginal effects is greatest for credit, whose effect on concrete-pond adoption (about 3.9 percentage points) is an order of magnitude larger than that of most other regressors, underscoring the centrality of liquidity to sustainable intensification.

The findings both corroborate and qualify the existing literature. They corroborate the consistent Nigerian evidence that credit and education drive the uptake of improved systems (Akenbor and Ike, 2015; Ucha et al., 2018; Adegboyega and James, 2026). They qualify the evidence on age and experience: unlike studies that associate experience with retention of traditional systems (Adegboyega and James, 2026), this study finds experience pushing farmers towards the flexible plastic-container system, a divergence plausibly rooted in the different cost structure and reconfigurability of the systems available in the study area. The exceptionally high pseudo- R^2 and the modest sample size, however, counsel caution: the direction of the effects is more reliable than their precise magnitude, and replication with a larger sample would strengthen confidence in the estimates.

Conclusion and Recommendations

This study examined the determinants of aquaculture fish production system choice among eighty fish farmers in Anambra State, Nigeria. Addressing the first objective, the respondents were predominantly middle-aged and literate, with substantial fish-farming experience, large households and access to credit, but with limited access to extension services. Addressing the second objective, the farmers used a range of production systems—most prominently the concrete pond (87.5%), earthen pond (78.8%) and tarpaulin (62.5%), together with plastic containers and fibre-glass tanks (37.5% each). Addressing the third objective, the multinomial logit analysis identified education, access to credit and farming experience as the significant determinants of production-system choice, with age exerting a negative influence on adoption of the capital-intensive concrete pond. The study concludes that financial and human-capital constraints, rather than demographic traits, principally govern production-system choice in the study area.

Recommendations

Based on the significant regression findings, the following recommendations are made:

1. Because access to credit had the largest positive marginal effect on adoption of the capital-intensive concrete-pond system (about 3.9 percentage points), farmers' access to credit should be strengthened through microfinance banks, commercial banks and cooperative credit facilities, with loan sizes matched to the cost of establishing improved systems.
2. Because education significantly raised the probability of adopting improved systems, policies that improve farmers' access to education and technical training—through awareness campaigns, adult-literacy programmes and targeted aquaculture training—should be pursued.
3. Because farming experience significantly influenced system choice and extension contact was significant for the concrete pond, experienced farmers should be encouraged to remain in production and to mentor new entrants, and the ADP extension service should be revitalised and adequately resourced to widen advisory coverage and the supply of subsidised inputs.

Limitations of the Study

Two limitations should be borne in mind when interpreting the results. First, the sample of eighty farmers is modest, and, combined with the unusually high pseudo- R^2 , this raises a risk of overfitting; the estimates should be read as indicative of the direction of effects rather than as precise, generalisable magnitudes. Second, the analysis models the three most commonly adopted primary systems; the tarpaulin and fibre-glass systems, though recorded, were not modelled as separate outcomes and their determinants remain to be examined in future work with a larger, purpose-designed sample.

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