Applied Science, Computing and Energy, 2026, 5(2), 167-187

Integrated Modelling of Sustainable Fisheries and Aquaculture Systems in Nigeria: Effects of Production Efficiency, Environmental Stressors, Digital Technology Adoption, and Socioeconomic Factors

Amos Odunayo Abosede* and Oluwakemi Temitope Oteniya
Received: 17 July 2026/Accepted: 14 October 2026/Published: 24 October 2026

Abstract: *Fisheries and aquaculture are important to Nigeria's food security, employment, income generation, and rural livelihoods. However, their sustainability is constrained by inefficient resource utilization, environmental degradation, climate variability, inadequate digital information systems, limited access to finance, and weaknesses in fish value chains. Although Nigerian studies have examined these challenges individually, there is a need for an integrated framework to explain their combined implications for the sustainability of fisheries and aquaculture. This study develops an integrated conceptual model through a thematic review of Nigerian research on artisanal fisheries, aquaculture production, fish nutrition, environmental management, digital technology adoption, extension services, profitability and livelihood diversification. The reviewed literature includes studies on technical efficiency in Kaduna aquaculture farms, artisanal fishing productivity in inland waters, maximum sustainable yield in Rivers Niger and Benue, fish nutrition and physiological responses, environmental pollution in Lagos and Imo States, and digital communication among fish farmers in Kogi and Lagos States. The synthesis identifies four interrelated dimensions of sustainability: production and resource-use efficiency; environmental and climate resilience; digital technology and extension access; and socioeconomic and institutional performance. An integrated conceptual framework is proposed, linking these dimensions to productivity, profitability, ecosystem integrity, food security and livelihood resilience. The study concludes that sustainable fisheries and aquaculture development requires coordinated improvements in production technology, environmental protection, digital extension, institutional support and value-chain infrastructure. The proposed framework provides a foundation for future empirical research and evidence-based fisheries policy in Nigeria.*

Keywords: *Aquaculture; artisanal fisheries; digital technology; environmental sustainability; fish production efficiency; livelihood diversification; Nigeria.*

Amos Odunayo Abosede*
Department of Crop Science, School of Agriculture, National Open University of Nigeria.
Email: Odunayoamos4@gmail.com
https://orcid.org/0009-0000-0743-3990

Oluwakemi Temitope Oteniya
Department of Animal Science and Fisheries, Faculty of Agricultural Sciences, National Open University of Nigeria, Abuja, Nigeria.
Email: oluwakemioteniya@gmail.com

1.0 Introduction

Fisheries and aquaculture constitute important components of agricultural production, food security, employment and rural economic development. They provide fish and other aquatic products for human consumption while supporting livelihoods through harvesting, farming, processing, transportation, marketing and related services. In developing economies, the sector is particularly important because it contributes to household nutrition, income diversification and local economic activities. Globally, the sustainable development of aquatic food systems has increasingly been recognised as an important strategy for

improving food security while maintaining aquatic ecosystem integrity (Food and Agriculture Organization of the United Nations [FAO], 2024).

In Nigeria, fisheries and aquaculture comprise artisanal inland and coastal fisheries, commercial fish farming, fish processing and marketing. The sector includes a wide range of production systems, from small-scale household ponds to commercial aquaculture enterprises and traditional fishing activities in rivers, lagoons, reservoirs and coastal waters. However, the sustainability of these systems is affected by production constraints, environmental degradation, climate-related risks, limited access to appropriate technologies, inadequate extension services and financial difficulties.

Artisanal fisheries remain important to fishing households, particularly in communities along Rivers Niger and Benue and in the coastal and inland waters of the Niger Delta. The productivity of these fisheries is influenced by fish abundance, fishing effort, access to fishing equipment, water conditions, infrastructure, market opportunities and socioeconomic characteristics of fishing households. Awolumate *et al*. (2018) examined estimates of maximum sustainable yield of artisanal fisheries resources in Rivers Niger and Benue in Kogi State, providing an important fisheries-management perspective on the sustainable utilisation of inland fish resources. Similarly, Awolumate and Fregene (2025) examined efficiency in artisanal fishing in the context of overfishing, pollution and infrastructure development, emphasising the importance of considering environmental and infrastructural conditions alongside fishing performance.

The biological characteristics and composition of fish populations are also important to fisheries sustainability. Awolumate and Inyang (2019) investigated the relative abundance and morphometric characteristics of Heterobranchus bidorsalis and Heterotis niloticus in relation to other fish species in Rivers Niger and Benue. Awolumate (2019) also examined fish species composition and growth performance of Tilapia zillii and Clarias gariepinus in the same river system. Such studies provide a biological basis for understanding species composition, fish growth and the condition of inland fisheries resources.

Aquaculture has become increasingly important as a complementary source of fish production. Its development offers opportunities to improve domestic fish supply, reduce pressure on capture fisheries and create employment. Nevertheless, aquaculture sustainability depends on the efficient use of production resources, particularly feed, fingerlings, labour, water, energy and capital. Awolumate and Inyang (2019) examined technical efficiency differentials in aquaculture resource use among selected fish farms in Kaduna State. Their work provides a basis for examining the relationship between resource allocation, farm management and production efficiency.

Production efficiency is not solely determined by the quantity of inputs used. The nutritional quality of feed, feeding practices, fish species, stocking density, water quality and management procedures also influence production outcomes. Research on alternative feed ingredients and nutrient supplementation has examined the growth performance, haematological responses, carcass quality and nutrient utilisation of cultured fish. For example, Agbo and Awolumate (2026) investigated lysine-supplemented groundnut cake diets and their effects on growth performance and carcass quality of Heterobranchus longifilis fingerlings. Agbo *et al*. (2026) examined the growth, haematological and biochemical responses of African catfish (Clarias gariepinus) fed graded levels of boiled lablab meal. Similarly, Awolumate and Agbo (2025) investigated nutrient retention and feed utilisation efficiency in Clarias gariepinus, focusing on the roles of

lysine and methionine in protein deposition and nitrogen waste reduction.

Environmental conditions represent another important determinant of fisheries and aquaculture sustainability. Aquatic pollution, habitat degradation, excessive fishing pressure, climate variability and mineral exploitation can affect water quality, fish health, species composition and resource availability. Awolumate and Williams (2021) examined household vulnerability and livelihood diversification among fisherfolk in coastal communities of the Niger Delta under changing climatic and environmental conditions. Esheya and Awolumate (2025) investigated the environmental and socioeconomic impacts of mineral exploitation on fisheries in Imo State. These studies demonstrate the importance of linking environmental conditions with the economic and livelihood consequences experienced by fishing communities.

Aquatic pollution may also affect fish health through the accumulation of toxic substances and the development of physiological or histopathological alterations. Ovioma *et al*. (2025) examined the bioaccumulation of polycyclic aromatic hydrocarbons and histopathological alterations in African knife fish (Gymnarchus niloticus) from Epe Lagoon, Lagos State. Bamidele *et al*. (2025) investigated parasitic infections in Gymnarchus niloticus and Heterotis niloticus in Lekki Lagoon. Such studies contribute to understanding the biological and ecological dimensions of aquatic resource sustainability.

Digital technology and information access have also become important in fisheries and aquaculture development. Mobile phones, internet platforms, digital extension systems and electronic market information can improve access to production advice, climate information, input suppliers and buyers. Awolumate (2018) investigated the adaptability and friendliness of information and communication technologies in fish farming in Lagos State. Mundi *et al*. (2024) examined the use of digital platforms and mobile technology in aquaculture communication among fish farmers in Kogi State. Awolumate and Inyang (2019) also examined threats to fish-farming information-use efficiency within a multi-communication infrastructural system in Akwa Ibom State.

The effectiveness of digital technology, however, depends on users' ability to access, understand and apply the information provided. This makes agricultural extension and community-based learning important components of fisheries development. Awolumate and Omosola (2017) examined the impact of extension services on fish farming in Lagos State, while Awolumate and Inyang (2019) investigated the use of mass media for climate-change extension service delivery in Akwa Ibom State. Awolumate *et al*. (2026) further examined community-based adaptive education models for enhancing fisheries sustainability in selected communities of Lagos and Ogun States.

Socioeconomic factors also influence the sustainability of fisheries and aquaculture. Household income, access to finance, education, cooperative membership, gender, enterprise management and livelihood diversification affect the ability of producers to invest in improved technologies and respond to economic and environmental shocks. Awolumate and Fregene (2023) examined socioeconomic variables and household income diversification among fisherfolk along Rivers Niger and Benue in Kogi State. Awolumate and Ashiedu (2026) investigated productivity and profitability responses to cooperative-based institutional support in aquaculture production systems in Lagos State.

The economic sustainability of fisheries extends beyond production to include processing, preservation, marketing and value addition. Awolumate *et al*. (2022) investigated the determinants of profitability and challenges of smoked and dried fish marketers in Lagos State. Awolumate and Muyiwa (2025)

examined the impact of financial constraints on the profitability of small-scale roadside fish processors in Lagos State. Awolumate and Inyang (2020) also investigated constraints to value-addition investments in commercial aquaculture in Osun State.

Fish processing and preservation are particularly important because post-harvest handling influences product quality, safety, marketability and consumer acceptance. Awolumate *et al*. (2022) examined the physical, chemical and microbiological properties of tilapia subjected to charcoal, electric griller and firewood heat sources. Awolumate *et al*. (2023) investigated the effects of selected heat sources on microbial load and water-holding capacity of tilapia. Agbo and Awolumate (2024) examined the effects of oven drying, sun drying and freezing on the nutrient composition of Heterobranchus longifilis.

These studies collectively demonstrate that fisheries and aquaculture sustainability cannot be understood through production indicators alone. It requires an integrated assessment of biological productivity, resource-use efficiency, environmental quality, digital information access, socioeconomic conditions, institutional support and value-chain performance.

Despite the importance of fisheries and aquaculture to Nigeria's economy and food system, the sector continues to experience constraints that limit its productivity, profitability and long-term sustainability. Artisanal fisheries face challenges associated with overfishing, pollution, habitat degradation, inadequate infrastructure and climate variability. Aquaculture enterprises encounter high production costs, feed-related constraints, limited access to finance, inefficient resource utilisation and inadequate technical support.

The available Nigerian literature has examined several of these challenges, but often within separate research areas. For instance, Awolumate and Inyang (2019) examined technical efficiency in aquaculture resource use, while Awolumate *et al*. (2018) investigated maximum sustainable yield in inland fisheries. Environmental concerns have been examined by Awolumate and Williams (2021), Esheya and Awolumate (2025), and Ovioma *et al*. (2025). Digital communication and technology adoption have been addressed by Awolumate (2018) and Mundi *et al*. (2024), while the economic and value-chain dimensions have been investigated by Awolumate *et al*. (2022) and Awolumate and Muyiwa (2025).

Although these studies provide valuable evidence, there is a need for an integrated analytical framework that explains how production efficiency, environmental conditions, digital technology adoption and socioeconomic factors jointly influence the sustainability of fisheries and aquaculture systems.

A further challenge is that interventions are sometimes designed around individual problems without sufficiently considering their interdependence. For example, improving fish feed quality may increase growth performance, but the economic benefit may be limited by high energy costs, inadequate market access or insufficient working capital. Similarly, digital information may improve farm management, but its effectiveness may be constrained by poor communication infrastructure, limited digital literacy and inadequate extension support.

The problem addressed by this study is therefore the limited integration of production, environmental, technological and socioeconomic dimensions in the assessment of sustainable fisheries and aquaculture development in Nigeria.

The aim of this study is to develop an integrated framework for assessing sustainable fisheries and aquaculture systems in Nigeria, with emphasis on production efficiency, environmental stressors, digital technology adoption and socioeconomic factors.

The study is significant to policymakers, fisheries managers, aquaculture investors, extension institutions, researchers and fishing communities. It provides an integrated perspective for understanding the relationship between production efficiency, environmental conditions, digital technology and socioeconomic performance.

For government agencies, the proposed framework provides a basis for designing policies that connect production improvement with aquatic resource conservation, digital extension and rural livelihood development. For fish farmers, it highlights the importance of quality feed, efficient input utilisation, production records, water-quality management and access to appropriate technical information.

For artisanal fishers, the study emphasises sustainable resource utilisation, climate adaptation, fishing efficiency and livelihood diversification. For processors and marketers, it highlights the role of improved preservation technologies, financial access, market information and value-chain infrastructure.

The study also contributes to academic research by identifying measurable indicators and analytical methods that can be applied to future empirical studies of fisheries and aquaculture sustainability in Nigeria.

2.0 Materials and Methods

2.1 Research Design

The study adopted an integrative literature review and conceptual model-development design. This approach was appropriate because the study sought to synthesise evidence from different Nigerian research settings covering fisheries production, aquaculture management, environmental sustainability, digital technology, fish nutrition, socioeconomic development and value-chain performance.

The review considered peer-reviewed journal articles, conference proceedings and relevant institutional publications. The supplied reference list was used as the principal source for identifying Nigerian studies, while selected international literature was used to support the broader conceptual and methodological foundations.

The study did not treat the separate publications as a single empirical dataset. Rather, their findings and research themes were organised into related analytical dimensions to develop a conceptual framework.

2.2 Literature Identification and Classification

The literature was classified into six broad thematic areas:

1. Environmental, climate and biodiversity management.
2. Digital technology, information access and agricultural extension.
3. Fish nutrition, health and production.
4. Fisheries and aquaculture productivity and management.
5. Agribusiness, profitability and entrepreneurship.
6. Fish processing, preservation and value-chain development.

The classification enabled the identification of relationships among the different research areas. For example, studies on fish nutrition were classified under production efficiency, while studies on pollution, bioaccumulation and histopathology were classified under environmental and biological sustainability.

2.3 Analytical Approach

The analysis involved thematic synthesis and conceptual integration. Evidence from the selected studies was organised according to the four main dimensions of the proposed framework:

- Production and resource-use efficiency.
- Environmental and climate resilience.
- Digital technology and extension access.
- Socioeconomic and institutional performance.

The dimensions were subsequently linked to the principal outcomes of sustainable fisheries

and aquaculture, including productivity, profitability, environmental integrity, food security and livelihood resilience.

The approach was designed to preserve the geographical and methodological differences among the reviewed studies. Experimental findings on fish nutrition were not combined with household survey results, and farm-level efficiency estimates were not treated as equivalent to indicators of artisanal fishing productivity.

2.4 Proposed Quantitative Model

The proposed framework can be empirically tested using farm-level, household-level and environmental data. A general model is expressed as:

$$S_i = \beta_0 + \beta_1 PE_i + \beta_2 ER_i + \beta_3 DT_i + \beta_3 SI_i + \epsilon_i \quad (1)$$

Where S_i = sustainability performance of fish farm or fishing household, I, PE_i = production and resource-use efficiency, ER_i = environmental and climate resilience, DT_i = digital technologmy adoption and information access, SI_i = socioeconomic and institutional support, β_0 = constant while other βs are = regression coefficients; and ϵ_i = error term.

For aquaculture, technical efficiency can be estimated using a stochastic frontier production function shown below as equation 2

$$lnY_i = \beta_0 + \sum_{j=1}^{k} \beta_j lnX_{ij} + v_i + u_i \quad (2)$$

where \$Y_i$ represents fish output \$X_{ij}$ represents production inputs, v_i represents random error and u_i represents technical inefficiency.

For artisanal fisheries, productivity may be assessed using catch per unit effort, fishing hours, gear characteristics, species composition and fishing income. Maximum sustainable yield estimates may provide additional information for evaluating the sustainable exploitation of fish stocks.

A composite sustainability index may be presented according to equation 3

$$CSI = \sum_{j=1}^{m} w_i Z_{ij} \quad (3)$$

where CSI is the composite sustainability index, Z_{ij}represents a standardised indicator and w_i represents its assigned weight.

The weights may be derived through principal component analysis or an explicitly justified weighting procedure. This model is proposed for future empirical validation; no new coefficients or sustainability scores are claimed in the present review.

2.5 Proposed Sustainability Indicators

Fisheries and aquaculture sustainability require measurable indicators covering production efficiency, fish nutrition and health, environmental conditions, resource management, technology adoption, institutional support, economic performance, value-chain efficiency, and livelihood resilience.

Production efficiency is assessed using input utilisation, yield, feed conversion ratio, survival rate, and technical efficiency. Fish nutrition and health are evaluated through specific growth rate, nutrient retention, haematological parameters, and carcass quality. Environmental sustainability considers water quality, pollution, habitat conditions, and climate variability, measured through dissolved oxygen, pH, temperature, ammonia, and contaminant levels.

Fisheries resource management focuses on fishing effort, catch, species composition, and fish stocks, using catch per unit effort, species abundance, and maximum sustainable yield. Digital technology and extension support are assessed through ICT adoption, frequency of use, extension contacts, training participation, and cooperative membership.

Economic and value-chain performance are evaluated using gross margin, net income, return on investment, marketing margin, post-harvest losses, product quality, processing efficiency, and market access. Livelihood

resilience is assessed through household income sources, asset ownership, vulnerability, and adaptive capacity.

Table 1: Integrated dimensions and measurable indicators for assessing fisheries and aquaculture sustainability

Dimension	Variables	Proposed indicators
Production efficiency	Feed, fingerlings, labour, energy, water, pond capacity	Yield, feed conversion ratio, survival rate, technical efficiency
Fish nutrition and health	Protein, amino acids, feed formulation, fish physiology	Specific growth rate, nutrient retention, haematological parameters, carcass quality
Environmental sustainability	Water quality, pollution, habitat, climate variability	Dissolved oxygen, pH, temperature, ammonia, contaminant levels, habitat condition
Fisheries resource management	Fishing effort, catch, species composition, fish stocks	Catch per unit effort, species abundance, maximum sustainable yield
Digital technology	Mobile technology, internet, digital platforms, ICT access	Adoption rate, frequency of use, information-use efficiency
Extension and institutional support	Training, extension visits, cooperative membership	Extension contact, training participation, cooperative support
Economic performance	Production costs, sales, income, investment, credit	Gross margin, net income, return on investment, marketing margin
Value-chain performance	Processing, storage, transport, preservation	Post-harvest losses, product quality, processing efficiency, market access
Livelihood resilience	Income diversification, household assets, climate vulnerability	Household income sources, vulnerability index, adaptive capacity

2.6 Conceptual Framework

The conceptual framework presented in Figure 1 illustrates the major factors influencing the sustainability of fisheries and aquaculture systems in Nigeria. It identifies four interrelated dimensions: production and resource efficiency, environmental and climate resilience, digital technology and extension, and socioeconomic and institutional performance. These dimensions collectively influence production outcomes, profitability, environmental quality, and livelihood sustainability.

Production and resource efficiency enhance fish productivity through effective utilisation of feed, labour, water, energy, and other production inputs. Environmental and climate resilience promote sustainable resource use through water quality management, pollution control, and climate adaptation. Digital technology and extension services improve access to information, knowledge transfer, and farm management decisions, while socioeconomic and institutional factors influence access to finance, market opportunities, institutional support, and livelihood improvement.

As illustrated in Figure 1, the interaction of these four dimensions contributes to higher productivity and food security, environmental sustainability, improved profitability, livelihood resilience, and long-term sectoral

sustainability. The framework therefore provides a conceptual basis for examining the combined effects of production, environmental, technological, and socioeconomic factors on sustainable fisheries and aquaculture development in Nigeria.

The framework illustrates how production efficiency contributes to fish productivity and profitability, while environmental resilience supports ecosystem integrity and production stability. Digital technology and extension services facilitate information access and management decisions, whereas socioeconomic and institutional factors influence the capacity of producers to adopt improved practices and sustain their enterprises.

.

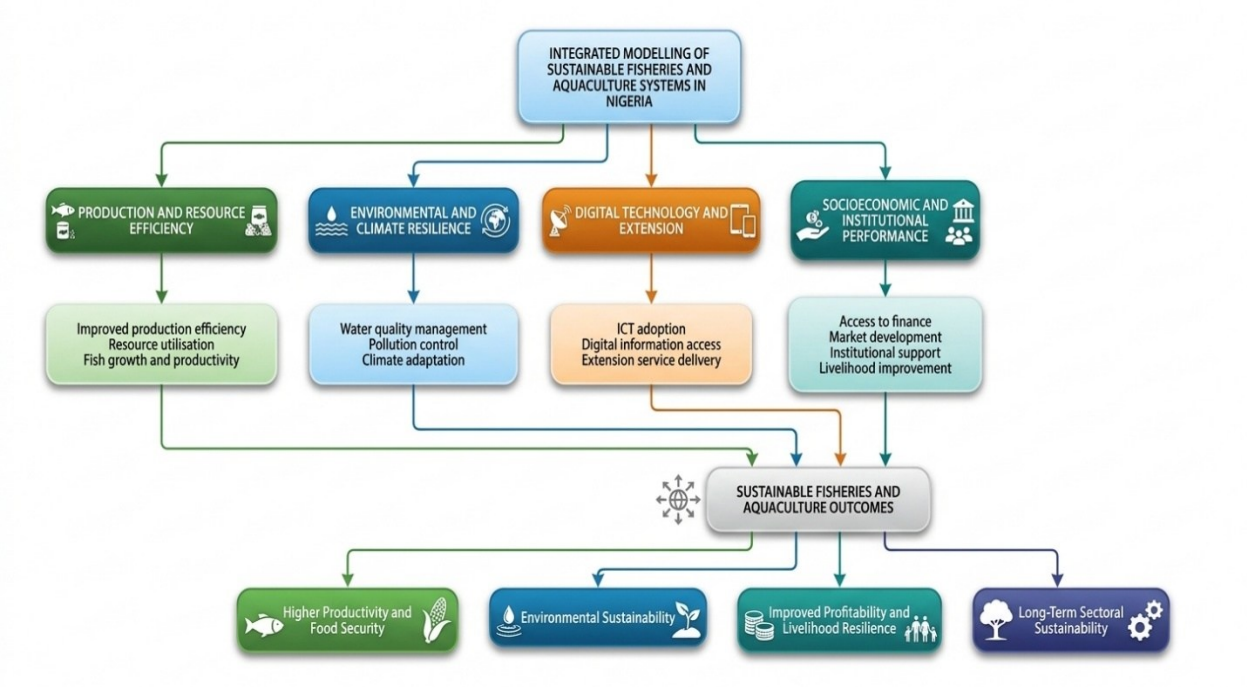


Fig. 1: Integrated conceptual framework for sustainable fisheries and aquaculture systems in Nigeria

3.0 Results and Discussion

3.1 Production Efficiency and Resource Utilisation in Fisheries and Aquaculture

The reviewed literature indicates that production efficiency is a major determinant of the economic and technical performance of fisheries and aquaculture systems. In aquaculture, production efficiency is influenced by feed quality, stocking density, fingerling quality, labour, water management, energy consumption and farm-management practices. In artisanal fisheries, efficiency is influenced by fish abundance, fishing effort, gear, fishing infrastructure, environmental conditions and access to markets.

Awolumate & Inyang (2019) examined technical efficiency differentials in aquaculture resource use among selected fish farms in Kaduna State. This study provides a direct basis for considering technical efficiency as an important component of aquaculture sustainability. Its relevance lies in the recognition that production performance depends not only on the quantity of resources available but also on how effectively those resources are combined and managed.

Similarly, Awolumate *et al*. (2011) examined the operational attributes of urban aquaculture systems in Ibadan Municipal, Oyo State. Operational characteristics are important

because differences in farm organisation, production technology, resource access and management practices can influence productivity and investment performance.

The biological component of production efficiency is also important. Feed composition and nutrient utilisation influence growth, survival, carcass quality and production costs. Agbo and Awolumate (2026) examined lysine-supplemented groundnut cake diets in Heterobranchus longifilis fingerlings, while Agbo *et al*. (2026) investigated the growth, haematological and biochemical responses of Clarias gariepinus fed graded levels of boiled lablab meal. These studies demonstrate the relevance of feed formulation and nutritional supplementation to aquaculture production research.

Further evidence is provided by Awolumate & Agbo (2025), who examined nutrient retention and feed utilisation efficiency in Clarias gariepinus, with emphasis on lysine and methionine supplementation. The relationship between nutrient retention and nitrogen waste is particularly relevant to sustainable aquaculture because feed utilisation affects both production costs and the environmental loading associated with uneaten feed and fish excretion.

Agbo *et al*. (2025) examined the effects of methionine-supplemented groundnut cake on the growth performance and haematology of Clarias gariepinus fingerlings. Awolumate *et al*. (2026) also investigated the histopathological responses of Clarias gariepinus and Heterobranchus longifilis fed methionine-supplemented groundnut cake-based diets. These studies indicate that production assessment should extend beyond weight gain to include fish health and physiological responses.

Alternative feed ingredients are also relevant to reducing dependence on conventional feed materials. Agbo *et al*. (2022) examined the replacement of soybean with Leucaena leucocephala leaf meal in diets for Heterobranchus longifilis juveniles. Kakwi *et al*. (2021) investigated the histology of the liver of Cyprinus carpio fingerlings fed raw and processed Mucuna pruriens diets. These studies provide examples of research on alternative plant-based feed ingredients and their implications for fish nutrition and health.

The sustainability implication is that aquaculture productivity should be evaluated using a combination of technical, nutritional, physiological and economic indicators. Yield alone may not adequately reflect production efficiency if it is achieved through excessive feed use, poor nutrient retention or increased environmental discharge.

For artisanal fisheries, Awolumate *et al*. (2018) examined maximum sustainable yield of fisheries resources in Rivers Niger and Benue, while Awolumate (2022) assessed constraints to artisanal fisheries productivity among fisherfolk in Mbo Local Government Area, Akwa Ibom State. Awolumate & Fregene (2026) further examined spatio-temporal drivers of artisanal fishing productivity in Nigerian inland waters from socioeconomic and technological perspectives. Together, these research areas demonstrate that fishing productivity requires consideration of resource abundance, fishing practices, technology and household circumstances.

The evidence therefore supports the inclusion of production efficiency as a central dimension of the proposed sustainability model.

3.2 Environmental Stressors, Climate Variability and Aquatic Ecosystem Sustainability

Environmental conditions influence the productivity and long-term viability of both capture fisheries and aquaculture. The reviewed literature identifies pollution, mineral exploitation, overfishing, habitat degradation, climate variability and changes in water quality as important environmental concerns.

Awolumate & Williams (2021) examined household vulnerability and livelihood

diversification among fisherfolk in coastal communities in the Niger Delta under changing climatic and environmental conditions. This research is relevant because it links environmental changes with household-level socioeconomic outcomes. Environmental pressures may affect fish availability and fishing income, thereby increasing the need for livelihood adaptation and diversification.

Esheya & Awolumate (2025) investigated the environmental and socioeconomic impacts of mineral exploitation on fisheries in Imo State. Mineral exploitation can affect aquatic ecosystems through sedimentation, pollution and changes in water quality, with possible consequences for fish habitats and fishing activities. The socioeconomic dimension is equally important because environmental deterioration may affect the income and welfare of communities dependent on fisheries.

Awolumate & Fregene (2025) examined artisanal fishing efficiency in the context of overfishing, pollution and infrastructure development in inland waters. Their research provides a basis for considering environmental and infrastructural conditions together when evaluating fishing efficiency. It also indicates that production interventions need to account for the condition of aquatic resources.

Aquatic pollution may also affect fish through the accumulation of harmful substances and physiological alterations. Ovioma *et al*. (2025) investigated polycyclic aromatic hydrocarbon bioaccumulation and histopathological alterations in African knife fish (Gymnarchus niloticus) from Epe Lagoon, Lagos State. This type of evidence is important for assessing the environmental quality of aquatic ecosystems and potential risks to fish health and food quality.

Bamidele *et al*. (2025) examined parasitic infections in Gymnarchus niloticus and Heterotis niloticus in Lekki Lagoon, Lagos State. Fish-health investigations contribute to understanding biological conditions that may influence fish populations, aquaculture management and the quality of fish products.

Water quality is also directly relevant to aquaculture. Kakwi *et al*. (2021) investigated water quality in the culture of Cyprinus carpio fingerlings fed raw and processed Mucuna pruriens diets. This research is relevant to the relationship between feed management and aquatic production environments. In aquaculture systems, poor feed utilisation and inadequate waste management may contribute to water-quality deterioration.

Table 2. Environmental stressors and their implications for fisheries and aquaculture sustainability

Environmental stressor	Related research area	Potential sustainability implications	Proposed management response
Overfishing	Awolumate *et al*. (2018); Awolumate and Fregene (2025)	Declining fish stocks and reduced catch sustainability	Fishing-effort regulation and stock monitoring
Mineral exploitation	Esheya and Awolumate (2025)	Aquatic pollution and socioeconomic disruption	Environmental monitoring and enforcement
Climate variability	Awolumate and Williams (2021)	Household vulnerability and unstable fishing income	Climate adaptation and livelihood diversification

Polycyclic aromatic hydrocarbons	Ovioma *et al*. (2025)	Bioaccumulation and fish tissue alterations	Pollution control and fish-tissue monitoring
Parasitic infections	Bamidele *et al*. (2025)	Fish-health concerns and possible production losses	Fish-health surveillance and appropriate management
Poor water quality	Kakwi *et al*. (2021)	Reduced production performance and fish stress	Water-quality assessment and improved feeding practices
Habitat degradation	Akeredolu *et al*. (2025)	Biodiversity loss and deterioration of aquatic habitats	Habitat conservation and ecological restoration

3.3 Digital Technology Adoption and Fisheries Extension Services

Digital technology is increasingly important in fisheries and aquaculture because it facilitates information access, communication, market participation and production management. The use of mobile phones, internet platforms and other ICT tools can improve access to information on fish farming, feeding practices, disease management, weather conditions, input prices and market opportunities. Awolumate (2018) examined the adaptability and friendliness of ICTs in fish farming in Lagos State. The study is relevant to the assessment of whether available communication technologies are suitable for fish farmers and whether farmers can incorporate them into their production activities.

Mundi *et al*. (2024) investigated digital platforms and mobile technology in aquaculture communication among fish farmers in Kogi State. This research provides a direct basis for including digital communication as a component of the proposed sustainability framework. Digital technology can facilitate communication between farmers, extension agents, input suppliers and buyers, although its effectiveness depends on affordability, accessibility and users' ability to apply the information received.

Awolumate & Inyang (2019) examined threats to fish-farming information-use efficiency within a multi-communication infrastructural system in Akwa Ibom State. This study is particularly important because it distinguishes access to information from the effective use of information. A fish farmer may have access to a mobile phone or other communication channel but may still experience difficulties in obtaining relevant information or translating it into improved production decisions.

Extension services remain important in bridging this gap. Awolumate and Omosola (2017) investigated the impact of extension services on fish farming in Lagos State. Awolumate (2018) also examined mass-media dependency for climate-change information among agricultural and fishery extension service field agents in Akwa Ibom State. In addition, Awolumate & Inyang (2019) investigated the use of mass media for climate-change extension service delivery.

These studies demonstrate that digital communication and conventional extension services should be considered complementary. Digital platforms can expand the reach of extension information, while field-based extension activities can support practical demonstrations and feedback.

The relevance of community-based learning is further reflected in Awolumate *et al*. (2026), who examined community-based adaptive

education models for enhancing fisheries sustainability in selected communities of Lagos and Ogun States. Agbo *et al*. (2026) also examined innovation skills and institutional support in sustainable aquaculture start-up development among open and distance learning students in Nigeria. Although open and distance learning studies are not all direct measures of fish-farm productivity, they provide relevant insights into educational access, digital learning, innovation skills and institutional support. Ofulue *et al*. (2024), for example, developed a research agenda for resilient systems and innovative practices in open and distance learning in Nigeria. These educational dimensions can contribute to the human-capital component of sustainable fisheries development.

Table 3. Digital technology, extension and institutional learning evidence

Research focus	Selected studies	Relevance to sustainability
ICT adaptability in fish farming	Awolumate (2018)	Technology suitability and access
Digital platforms and mobile technology	Mundi *et al*. (2024)	Communication and information access
Information-use efficiency	Awolumate and Inyang (2019)	Effective use of fisheries information
Extension services	Awolumate and Omosola (2017)	Technical advisory support
Climate-change information	Awolumate (2018); Awolumate and Inyang (2019)	Climate awareness and adaptation
Community-based adaptive education	Awolumate *et al*. (2026)	Local learning and fisheries sustainability
Innovation skills and institutional support	Agbo *et al*. (2026)	Aquaculture entrepreneurship and skills
Resilient digital learning systems	Ofulue *et al*. (2024)	Digital education and institutional resilience

The evidence suggests that digital technology adoption should be assessed through indicators such as access to mobile devices, internet availability, frequency of use, types of information accessed, perceived usefulness and application of information in production and marketing decisions.

3.4 Socioeconomic Factors, Profitability and Livelihood Resilience

Socioeconomic conditions influence the ability of fishing households and aquaculture enterprises to maintain production, invest in improved technologies and respond to environmental and economic shocks. Relevant factors include household income, education, age, gender, access to credit, cooperative participation, household labour and livelihood diversification.

Awolumate & Fregene (2023) examined socioeconomic variables and household income diversification among fisherfolk along Rivers Niger and Benue in Kogi State. This study is important because income diversification can influence household resilience when fishing activities are affected by seasonal changes, environmental pressures or market fluctuations.

Awolumate & Williams (2021) also examined household vulnerability and livelihood diversification among fisherfolk in coastal Niger Delta communities. The combined relevance of these studies is that fisheries sustainability should be assessed not only in

terms of fish production but also in terms of the ability of households to maintain livelihoods under changing environmental and economic conditions.

Cooperative institutions may provide an additional mechanism for improving socioeconomic performance. Awolumate & Ashiedu (2026) examined productivity and profitability responses to cooperative-based institutional support in aquaculture production systems in Lagos State. Cooperative arrangements can potentially facilitate access to production inputs, information, credit, training and marketing services. The actual benefits, however, depend on institutional effectiveness and the quality of services provided.

Youth participation and entrepreneurship are also important to the long-term development of the sector. Awolumate & Okoronkwo (2026) investigated determinants of youth participation in urban fish entrepreneurship in Lagos State. This area of research is relevant to employment creation, innovation and the development of new aquaculture and fish-related enterprises.

The financial dimension is particularly important for small-scale fish processors and marketers. Awolumate & Muyiwa (2025) examined the impact of financial constraints on the profitability of small-scale roadside fish processors in Lagos State. This study demonstrates the importance of working capital and financial access in value-chain activities. Financial limitations may restrict the ability of processors to purchase fish in sufficient quantities, acquire processing equipment, improve storage and expand market operations.

Profitability is also influenced by management practices and investment decisions. Awolumate & Inyang (2019) examined the relationship between aquaculture business decisions and profitability among selected firms in Kaduna State. Awolumate & Inyang (2020) investigated business operational profiles and fish-farm investment managerial performance in Akwa Ibom State.

These studies support the inclusion of enterprise management, financial access and institutional support in the proposed framework. They also indicate that aquaculture sustainability should be assessed through both production efficiency and financial performance.

3.5 Fish Processing, Preservation and Value-Chain Performance

The sustainability of fisheries and aquaculture depends not only on fish production but also on the capacity to preserve, process, transport and market fish products. Post-harvest handling is important because poor preservation conditions may reduce product quality, increase losses and affect consumer acceptance.

Awolumate *et al*. (2022) examined the physical, chemical and microbiological properties of tilapia fish processed using charcoal, electric griller and firewood heat sources. Awolumate *et al*. (2022) also examined the profitability and challenges of smoked and dried fish marketers in Lagos State. These studies provide evidence for considering processing technology and market performance as important dimensions of fisheries sustainability.

Awolumate *et al*. (2023) investigated the effects of selected heat sources on microbial load and water-holding capacity of tilapia. Agbo & Awolumate (2024) examined the effects of oven drying, sun drying and freezing on the nutrient composition of Heterobranchus longifilis. Awolumate *et al*. (2026) further examined the efficacy of garlic powder, oil and paste as natural antioxidants for improving the oxidative stability and sensory quality of hot-smoked fish.

These studies indicate that processing and preservation technologies influence fish quality and the potential for value addition. Improved processing can support market development, reduce post-harvest losses and improve the commercial value of fish products. The value-

chain dimension is also supported by Awolumate & Inyang (2020), who examined constraints to value-addition investments in commercial aquaculture in Osun State, and Awolumate & Iniobong (2021), who investigated risk factors associated with value addition in commercial aquaculture. These studies suggest that value addition is influenced by investment constraints and risk factors that extend beyond the technical process of fish production.

Market information is another important component. Awolumate (2026) examined digital market information and smallholder fish supply-chain performance in Lagos State, while Awolumate & Obodo (2026) investigated market information access and the performance of the fish supply chain in Lagos State. These research areas support the integration of digital information systems with market participation and value-chain performance.

3.6 Integrated Relationships among the Sustainability Dimensions

The reviewed literature demonstrates that production efficiency, environmental resilience, digital technology and socioeconomic performance are interconnected.

For example, improved feed formulation may increase growth performance and nutrient utilisation, but the economic benefits depend on feed prices, access to working capital and market prices. Similarly, improved digital information access may strengthen production decisions, but its effectiveness depends on digital literacy, communication infrastructure and extension support.

Environmental conditions also influence economic outcomes. Pollution, overfishing and habitat degradation can affect fish availability and production costs. These environmental effects may subsequently influence household income, livelihood diversification and investment decisions. The interactions are represented in Fig. 2.

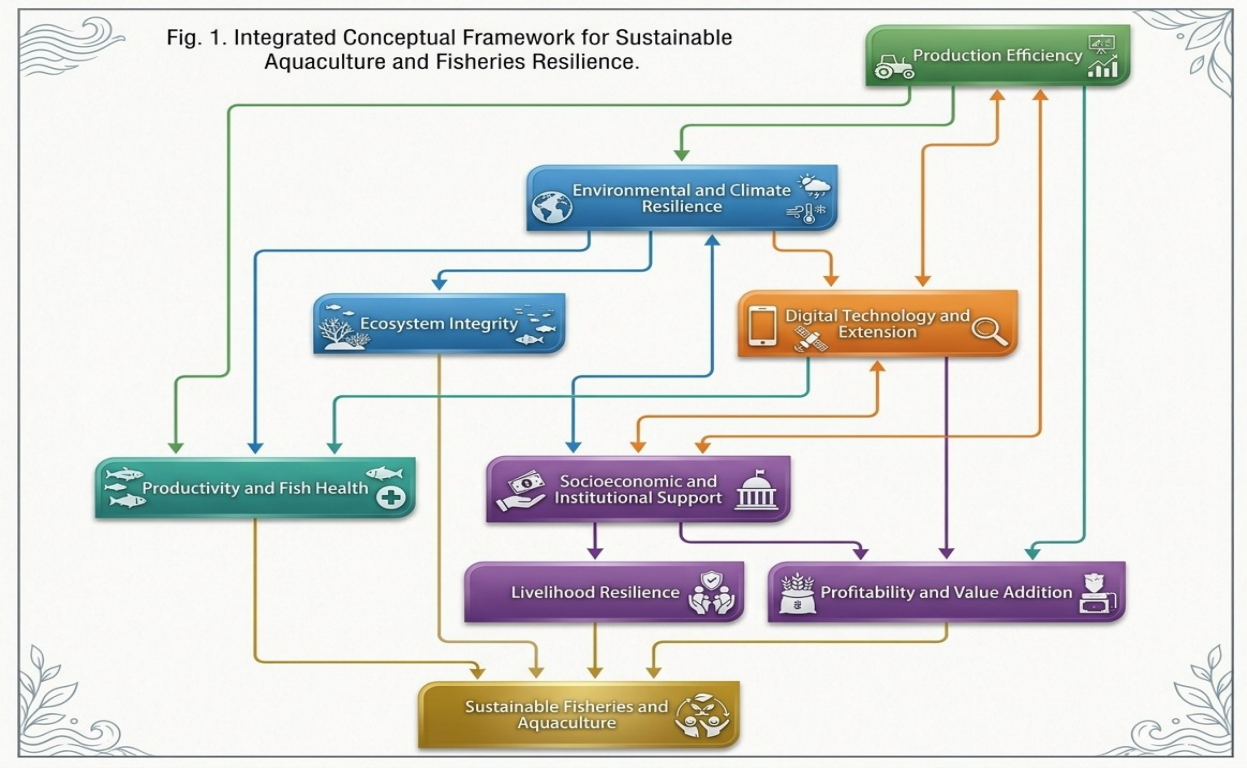


Fig. 1. Integrated Conceptual Framework for Sustainable Aquaculture and Fisheries Resilience.

Fig. 2. Interaction pathways among production, environmental, technological and socioeconomic dimensions

Fig. 2 shows that the dimensions can influence sustainability through both direct and indirect pathways. Production efficiency affects productivity and profitability, while environmental resilience supports ecosystem integrity. Digital technology facilitates information access and management, and socioeconomic support influences the capacity of producers to adopt improved practices.

3.7 Proposed Analytical Techniques for Future Empirical Validation

The framework can be tested through a quantitative study involving fish farmers, artisanal fishers, processors and other value-chain participants. However, the data collection and analytical procedures should reflect the differences among these groups.

For aquaculture farms, stochastic frontier analysis can be used to estimate technical efficiency based on fish output and production inputs. For artisanal fisheries, catch per unit effort, fishing effort, species composition and fishing income may be used to evaluate productivity and resource utilisation.

For fish nutrition experiments, indicators such as feed conversion ratio, specific growth rate, survival rate, nutrient retention and haematological parameters may be used. Environmental assessments may include water-quality parameters, pollutant concentrations, fish-tissue analyses and habitat indicators.

Digital technology adoption can be examined using adoption indices and regression models. Socioeconomic performance can be assessed through gross margin analysis, profitability models, household income diversification indicators and livelihood-resilience measures.

Table 4. Proposed analytical techniques for future empirical validation

Dimension	Proposed method	Expected analytical output
Aquaculture production efficiency	Stochastic frontier analysis	Technical efficiency scores
Artisanal fishing productivity	Catch-per-unit-effort analysis and regression	Fishing productivity and determinants
Fish nutrition and growth	Experimental analysis and analysis of variance	Growth, feed utilisation and health responses
Environmental quality	Descriptive and multivariate analysis	Pollution and water-quality profiles
Digital technology adoption	Adoption index and regression	Determinants and intensity of adoption
Profitability	Gross margin and multiple regression	Financial performance and its determinants
Livelihood resilience	Composite index and regression	Household vulnerability and resilience
Integrated sustainability	Principal component analysis or weighted index	Multidimensional sustainability scores

The techniques should be selected according to the research questions, sample structure and data availability. The framework does not imply that all methods must be applied in one study. In particular, experimental fish-nutrition data should not be combined directly with household survey data without a clearly defined and defensible integration procedure.

3.8 Policy and Practical Implications

The review has several implications for fisheries and aquaculture development in Nigeria.

First, production policies should prioritise efficient resource use, improved feed formulation, quality fingerlings and better farm management. Research on lysine and methionine supplementation, alternative feed ingredients and fish growth performance provides a basis for strengthening feed-related research and extension.

Second, fisheries management should integrate stock assessment, sustainable fishing practices and environmental monitoring. Research on maximum sustainable yield, fishing efficiency, pollution and fish biodiversity demonstrates the importance of managing aquatic resources according to ecological conditions.

Third, digital technology should be integrated into fisheries extension systems. Mobile communication, digital market information and climate information platforms should be supported by practical training, appropriate communication infrastructure and community-based learning.

Fourth, financial and institutional support should be strengthened. Cooperatives, credit arrangements, extension services and value-chain partnerships can improve the capacity of fish farmers and processors to invest in improved technologies and respond to market constraints.

Fifth, fish processing and value addition should receive greater attention. Investment in improved processing equipment, storage, preservation, quality assurance and market infrastructure can strengthen the economic performance of the sector.

Finally, fisheries and aquaculture development should be supported by reliable data systems. Data on fish production, fishing effort, environmental quality, technology adoption, household income, processing and marketing should be coordinated to support evidence-based policy and investment decisions.

4.0 Conclusion

This study developed an integrated conceptual framework for assessing sustainable fisheries and aquaculture systems in Nigeria. The review of Nigerian literature demonstrates that sustainability is influenced by the interaction of production efficiency, environmental and climate resilience, digital technology adoption, and socioeconomic and institutional performance.

The production dimension highlights the importance of technical efficiency, quality feed, appropriate nutritional supplementation, improved farm management and sustainable utilisation of fishery resources. Studies on aquaculture resource use, fish growth performance, nutrient retention and artisanal fishing productivity demonstrate the need to assess both biological and economic aspects of production.

The environmental dimension shows that pollution, overfishing, mineral exploitation, climate variability, habitat degradation and water-quality deterioration can affect fish health, aquatic ecosystems and the livelihoods of fishing communities. Environmental monitoring and sustainable fisheries management are therefore essential for maintaining long-term production capacity.

The digital technology dimension demonstrates the potential of mobile communication, ICT platforms, digital market information and extension services to improve access to technical and commercial information. Nevertheless, the benefits of digitalisation depend on communication infrastructure, digital literacy, institutional support and the ability of producers to apply the information received.

The socioeconomic dimension highlights the importance of access to finance, cooperative participation, enterprise management, value addition, market information and household income diversification. These factors influence the capacity of producers and other value-chain

participants to invest in improved practices and withstand environmental and economic shocks. The study concludes that sustainable fisheries and aquaculture development in Nigeria requires an integrated approach that connects production improvement with environmental protection, digital innovation, institutional support and socioeconomic development. The proposed framework provides a basis for future empirical research and policy formulation. Its quantitative validation will require appropriately designed primary or harmonised secondary datasets.

5.0 References

Agbo, A. N., & Awolumate, S. (2021). Proximate composition of Heterobranchus longifilis from cultured and the wild environment. Proceedings of the 36th Annual Conference of the Fisheries Society of Nigeria, 36(1), 381–385.

Agbo, A. N., & Awolumate, S. (2024). Impact of oven drying, sun drying and freezing on the nutrient composition of Heterobranchus longifilis. Proceedings of the 49th Annual Conference of the Nigerian Society for Animal Production, 1950–1953. https://doi.org/10.51791/njap.vi.7393

Agbo, A. N., & Awolumate, S. (2026). Effects of lysine-supplemented groundnut cake diets on growth performance and carcass quality of Heterobranchus longifilis fingerlings. The NOUN Journal of Agricultural Research and Development, 2(1), 94–101.

Agbo, A. N., Awolumate, S., & Bankole, A. S. (2026). Growth performance, haematological and biochemical responses of African catfish (Clarias gariepinus) fed graded levels of boiled lablab (Lablab purpureus) meal. FUDMA Journal of Animal Production and Environmental Science, 2(2), 138–146.

Agbo, A. N., Awolumate, S., & Oshinbanjo, D. O. (2025). Effects of methionine-supplemented groundnut cake on the growth performance and haematology of Clarias gariepinus fingerlings. Proceedings of the 50th Annual Conference of the Nigerian Society for Animal Production, 1784–1787. https://doi.org/10.51791/njap.vi.8687

Agbo, A. N., Awolumate, S., Okhogbe, A. J., & Olakulehin, F. K. (2026). Innovation skills and institutional support in sustainable aquaculture start-up development among open and distance learning students in Nigeria. Journal of Science and Information Technology, 20(1).

Akeredolu, E., Ashiru, O., Awolumate, S., Adamu, M., & Oladipo, M. S. (2025). Exploration of genetic diversity of earthworms in degraded landscapes in Lagos, Nigeria using random amplified polymorphic DNA (RAPD) markers. Journal of Scientific Research and Development, 24(1), 43–52.

Awolumate, S. (2018). Adaptability friendliness status of information and communication technologies (ICTs) in fish farming in Lagos State, Nigeria. West African Journal of Open and Flexible Learning, 7(1), 143–162.

Awolumate, S. (2018). Assessment of mass media dependency for climate change information sourcing among agricultural and fishery extension service field agents in Akwa Ibom State. Asian Journal of Agricultural Extension, Economics & Sociology, 24(4), 1–9.

Awolumate, S. (2019). Fish species composition and growth performance of Tilapia zillii and Clarias gariepinus in Rivers Niger and Benue, Kogi State, Nigeria. Journal of Wetlands and Waste Management, 3(1), 1–8.

Awolumate, S. (2022). Multidimensional assessment of constraints to artisanal fisheries productivity among fisher folks in some fishing catchments in Mbo Local Government Area, Akwa Ibom State. Production Agriculture and Technology, 8(1), 19–29.

Awolumate, S. (2026). Digital market information and smallholder fish supply-chain performance: An empirical synthesis from Lagos State, Nigeria. Journal of Natural and Artificial Systems, 4(1), 91–104.

Awolumate, S., & Agbo, A. N. (2025). Nutrient retention and feed utilization efficiency in Clarias gariepinus: The role of lysine and methionine in enhancing protein deposition and reducing nitrogen waste. Communication in Physical Sciences, 12(3), 686–695.

Awolumate, S., & Agbo, A. N. (2026). Histopathological examination of tissues from Clarias gariepinus and Heterobranchus longifilis fed methionine-supplemented groundnut cake-based diets. Production Agriculture and Technology, 22(1), 11–20.

Awolumate, S., Agbo, A. N., Alabi, J. A., & Akure, O. C. (2025). Digital learning resilience and financial access among aquaculture learners in climate-affected communities in Southwest Nigeria. West African Journal of Open and Flexible Learning, 14(1A), 195–218.

Awolumate, S., Agbo, A. N., Alabi, J. A., & Akure, O. C. (2026). Enhancing fisheries sustainability through community-based adaptive education models in selected communities of Lagos and Ogun States, Nigeria. West African Journal of Open and Flexible Learning, 14(2), 195–217.

Awolumate, S., Agbo, A. N., Oshinbanjo, D. O., & Majolagbe, A. S. (2026). Comparative efficacy of garlic powder, oil, and paste as natural antioxidants for improving oxidative stability and sensory quality of hot-smoked fish. Journal of Natural and Artificial Systems, 3(1), 1–10.

Awolumate, S., Ashiedu, J. C. (2026). Empirical assessment of productivity and profitability responses to cooperative-based institutional support in aquaculture production systems in Lagos State, Nigeria. Communication in Physical Sciences, 13(1), 17–24. https://doi.org/10.4314/cps.v13i1.2

Awolumate, S., & Fregene, B. T. (2023). Modeling socio-economic variables and household income diversification among fisher folks along Rivers Niger and Benue in Kogi State, Nigeria. Journal of Agricultural Economics and Extension and Science, 8(2), 21–33.

Awolumate, S., & Fregene, B. T. (2025). Efficiency status in artisanal fishing amidst overfishing, pollution, and infrastructure development on inland water fisheries in Nigeria. Applied Science, Computing, and Energy, 2(1), 105–115.

Awolumate, S., & Fregene, B. T. (2026). Spatio-temporal drivers of artisanal fishing productivity in Nigerian inland waters: A socioeconomic and technological perspective for sustainable fisheries policy. The NOUN Journal of Agricultural Research and Development, 2(1), 39–51.

Awolumate, S., & Inyang, E. B. (2019). Correlates of aquaculture business decision and profitability status of selected firms in Kaduna, Nigeria. Journal of Physical and Life Sciences, 3(1), 71–75.

Awolumate, S., & Inyang, E. B. (2019). Incidences and relative rank positioning pattern of mass media usage for climate change extension services delivery in Akwa Ibom State, Nigeria. Journal of Wetlands and Waste Management, 3(2), 52–57.

Awolumate, S., & Inyang, E. B. (2019). Technical efficiency differentials in aquaculture resource use among selected fish farms in Kaduna State, Nigeria. Nigerian Journal of Agriculture, Food and Environment, 15(2), 84–93.

Awolumate, S., & Inyang, E. B. (2019). Threats to fish farming information use efficiency in a multi-communication infrastructural system in Akwa Ibom State, Nigeria. Nigerian Journal of Agriculture, Food and Environment, 15(1), 41–47.

Awolumate, S., & Inyang, E. B. (2020). Evaluation of business operational profile and fish farm investment managerial performance index in Akwa Ibom State, Nigeria. Nigerian Journal of Fisheries and Aquaculture, 8(2), 21–31.

Awolumate, S., & Inyang, E. B. (2020). Constraints to value addition investments in commercial aquaculture in Osun State, Nigeria. Journal of Agricultural Economics and Extension and Science, 6(2), 72–85.

Awolumate, S., & Inyang, A. U. (2019). Relative abundance and morphometric assessment of Heterobranchus bidorsalis and Heterotis niloticus to other species of Rivers in Kogi State, Nigeria. Nigerian Journal of Agriculture, Food and Environment, 15(1), 102–110.

Awolumate, S., & Iniobong, B. I. (2021). Risk factors associated with value addition in commercial aquaculture in Osun State, Nigeria. Journal of Agricultural Economics and Extension and Science, 7(4), 46–65.

Awolumate, S., & Muyiwa, L. H. (2025). Impact of financial constraints on profitability of small-scale roadside fish processors in Lagos State, Nigeria: A multivariate regression approach. Agriculture, Food and Natural Resources Journal, 4(1), 27–34. https://doi.org/10.5281/zenodo.15105560

Awolumate, S., & Obodo, P. O. (2026). Market information access and performance of the fish supply chain in Lagos State, Nigeria. Dutse Journal of Pure and Applied Sciences, 12(2), 10–17.

Awolumate, S., & Omosola, O. T. (2017). Analysis of impact of extension services on fish farming in Lagos State, Nigeria. Journal of Physical and Life Sciences, 1(1), 1–15.

Awolumate, S., & Okoronkwo, C. C. (2026). Determinants of youth participation in urban fish entrepreneurship in Lagos State, Nigeria. Production Agriculture and Technology, 22(1), 1–10.

Awolumate, S., & Williams, O. W. (2021). Households' vulnerability and livelihood diversification in the changing state of climate and environment among fisher folks in coastal communities in Niger Delta Region, Nigeria. Journal of Forestry, Environment, and Sustainable Development, 7(1), 102–110.

Awolumate, S., Okwuokenye, G. F., Agbo, A. N., & Akinbani, D. M. (2022). Determinants of profitability and challenges of smoked and dried fish marketers in Lagos State, Nigeria. Nigerian Journal of Agriculture and Agricultural Technology, 2(2), 1–11. https://doi.org/10.59331/njaat.v2i2.96

Awolumate, S., Oshinbanjo, D. O., Mohammed, M. Y., Anthony, B., & Dashe, M. P. (2022). Physical, chemical, and microbiological properties of tilapia fish as affected by charcoal, electric griller, and firewood heat sources. Nigerian Journal of Agriculture and Agricultural Technology, 2(2).

Awolumate, S., Oshinbanjo, D. O., Mohammed, M. Y., Ositimehin, K. M., Oyedapo, F. A., Kakwi, D. G., Dashe, M. P., & Anthony, B. (2023). Effect of selected heat source on microbial load and water holding capacity of tilapia fish. Proceedings of the 48th Annual Conference of the Nigerian Society for Animal Production, 73–76. https://doi.org/10.51791/njap.vi.4219

Awolumate, S., Agbeja, Y. E., & Fregene, B. T. (2018). Estimates of maximum sustainable yield of artisanal fisheries resources of Rivers Niger and Benue in Kogi State, Nigeria. International Journal of Fisheries and Aquatic Studies, 6(3), 272–275.

Bamidele, A., Awolumate, S., Taiwo, A., Ovioma, G., Akeredolu, E., Otubanjo, Z., *et al*. (2025). Comparative parasitic infections in Gymnarchus niloticus (Cuvier, 1829) and Heterotis niloticus (Cuvier, 1829) in Lekki Lagoon, Lagos State, Nigeria. Egyptian

Academic Journal of Biological Sciences, B. Zoology, 17(1), 315–325.

Esheya, S. E., & Awolumate, S. (2025). Environmental and socioeconomic impacts of mineral exploitation on fisheries in Imo State, Nigeria. African Journal of Agricultural Science and Food Research, 18(1), 214–226. https://doi.org/10.62154/ajasfr.2025.018.010652

Food and Agriculture Organization of the United Nations. (2024). The state of world fisheries and aquaculture 2024: Blue transformation in action. FAO. https://doi.org/10.4060/cd0683en

Kakwi, D. G., Audu, B. S., Awolumate, S., Oyedapo, F. A., Ositimehin, K. M., *et al*. (2021). Water quality in the culture of Cyprinus carpio fingerlings fed raw and corn cob ash-processed Mucuna pruriens diets. Proceedings of the 46th Annual Conference of the Nigerian Society for Animal Production, 1316–1319.

Kakwi, D. G., Awolumate, S., Audu, B. S., Oshinbanjo, D. O., Oyedapo, F. A., Mohammed, M. Y., & Ositimehin, K. M. (2021). Some aspects of histology of liver of Cyprinus carpio fingerlings fed raw and processed Mucuna pruriens diets. Nigerian Journal of Animal Production, 48(3), 50–62.

Mundi, N. E., & Awolumate, S. (2019). Participation of rural women in agricultural production in Kogi State, Nigeria. Journal of Physical and Life Sciences, 3(1).

Mundi, N. E., & Awolumate, S. (2012). Applications of biotechnology in plant and animal production: The role of agricultural extension services. In V. O. Ogunlela, M. O. Olaniyi, A. Ogonsipe, & J. O. Agbu (Eds.), Biotechnology as a tool for peace and national development: Proceedings of the 25th Annual Conference of the Biotechnology Society of Nigeria (pp. 43–48).

Mundi, N. E., & Awolumate, S. (2013). Enhancement of learning for orphaned and vulnerable children through information and communication technologies in open and distance learning. In Proceedings of the Seventh Pan-Commonwealth Forum on Open Learning (pp. 483–487). Commonwealth of Learning.

Mundi, N. E., Awolumate, S., & Ambassador-Brikins, H. O. C. (2024). Digital platforms and mobile technology in aquaculture communication among fish farmers in Kogi State, Nigeria. Nigerian Journal of Fisheries and Aquaculture, 12(2), 1–9.

Ofulue, C., Opateye, J., Awolumate, S., Olakulehin, F. K., Adesina, A., Yabo, A. M., *et al*. (2024). Developing a research agenda for resilient systems and innovative practices in ODeL: Findings from a national study. Journal of Learning for Development, 11(2), 323–348. https://doi.org/10.56059/jl4d.v11i2.1045

Ovioma, G., Awolumate, S., Bamidele, A., Akeredolu, E., Isibor, P., Pentho, K. M., & Fidelis-Okei, D. O. (2025). Bioaccumulation of polycyclic aromatic hydrocarbons and histopathological alterations in African knife fish, Gymnarchus niloticus (Cuvier 1829), from Epe Lagoon, Lagos, Nigeria. Egyptian Academic Journal of Biological Sciences, B. Zoology, 17(1), 289–304.

Declarations

Consent for publication

Not Applicable

Data Availability Statement:

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of Interest

The authors have no competing interests to declare that are relevant to the content of this article.

Ethical Considerations

Not applicable

Funding

The authors declared no external source of funding

Authors' Contributions

Amos Odunayo Abosede contributed to conceptualisation, literature review, data synthesis, development of the integrated sustainability framework, manuscript drafting, and critical revision. Oluwakemi Temitope Oteniya contributed to the literature review, interpretation of fisheries and aquaculture studies, methodological guidance, validation of the conceptual framework, and critical editing. Both authors reviewed and approved the final manuscript for publication.