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Research Article

Development of a Sustainable Fish-Farming Value Chain Model for Food Security, Poverty Reduction, and Employment Generation in Kaduna Metropolis, Nigeria

Bala Dogo [a], Dogo Shalom [b], Yakubu S. Imam [c], Rabiat Idris [d], Alkali Jethro Habila [e]

[a] Department of Geography and Sustainability Studies, Kaduna State University [b] Care and Action Research Non-Governmental Organization, Kaduna, Nigeria. [c] Kaduna State Ministry of Education, Kaduna, Nigeria. [d] Department of Biochemistry, Kaduna State University, Kaduna, Nigeria. [e] Department of Geology, Kaduna State University, Kaduna, Nigeria.

ABSTRACT

This study investigates the current state, challenges and opportunities of fish farming in Kaduna Metropolis, Nigeria, to develop a sustainable fish-farming value chain model. By using a mixed-methods approach, data were collected from 300 stakeholders, including fish farmers, traders, processors and policymakers, through structured questionnaires, interviews, and observations. The findings reveal that a youthful, educated workforce (40% tertiary educated) faces significant barriers: limited credit access (89%), high input costs (80%), and inadequate extension services (70%). Despite these challenges, aquaculture output increased by 237% from 2009 to 2025, with labor productivity increasing by 549%. Regression analysis revealed credit access as the strongest profitability predictor (β=0.45, p=0.001). The study concluded that the sector has demonstrated notable growth driven by technological innovation, with aquaculture output increasing substantially in recent years. This study underscores the critical need for integrated policy support, infrastructure development, capacity building, and environmental management to realize Nigeria's aquaculture potential. The proposed model aims to enhance food security, reduce poverty, and foster employment, contributing to Kaduna's socioeconomic development.

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1 Introduction

Global food systems are under increasing strain from population growth, climate variability, and resource constraints, intensifying the search for sustainable, nutrient-dense sources of protein (Oh & Kim, 2025). Aquaculture has become central to this search. Global fisheries and aquaculture production reached a record 223.2 million tonnes in 2022, with the aquaculture output of aquatic animals overtaking capture fisheries for the first time in history on the strength of approximately five percent annual growth since the turn of the century (FAO, 2024). Although Africa is among the fastest-growing aquaculture regions, with outputs expanding by 455 percent since 2000, production levels on the continent remain far below the global average (FAO, 2024). The FAO situates this growth within a broader "blue transformation" agenda intended to integrate aquatic foods more fully into national strategies for food security, nutrition, and poverty reduction, particularly in low- and middle-income countries (FAO, 2024).

Nigeria's experience reflects this global trajectory, albeit with a persistent and economically costly supply deficit. The country is recognized as the largest aquaculture producer in sub-Saharan Africa, and fish remain among the least expensive and most accessible sources of animal protein for Nigerian households (Ogunji & Wuertz, 2023); however, domestic output continues to fall well short of national demand. As of 2025, domestic fish production, which is approximately 1.4 million metric tonnes, met only 38.9 percent of the estimated 3.6 million metric tonnes required annually, resulting in a deficit of more than 2.2 million metric tonnes bridged through imports that drain scarce foreign exchange (Federal Ministry of Information and National Orientation, 2025). Thus, the federal government has elevated fisheries and aquaculture within its policy agenda, validating a National Fisheries and Aquaculture Policy (2025–2029) and a National Blue Economy Policy explicitly designed to close the supply gap, expand domestic processing capacity, and generate employment along the value chain (CGIAR, 2024). These commitments signal that aquaculture is increasingly treated not as a peripheral rural activity but as a strategic lever for food security and economic diversification.

Kaduna Metropolis offers a particularly instructive setting for examining these dynamics. As northwestern Nigeria's commercial and administrative center, the metropolis has grown rapidly (Abdullahi J. et al., 2025), with its urban agglomeration now exceeding 1.2 million residents and expanding at nearly three percent annually, intensifying demand on the local food system. Kaduna State, home to one of northern Nigeria's earliest government-established aquaculture technology centers, has attracted steady empirical attention: studies of catfish farmers' technical efficiency (Ekunwe & Emokaro, 2009),

Corresponding Author: Dogo, B. profbaladogo@kasu.edu.ng Department of Geography and Sustainability Studies, Kaduna State University, Nigeria.
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the economic analysis and determinants of profitability of catfish farming (Duniya, 2026), and the structure and food safety risks of northwestern Nigeria's fish value chains, much of which are anchored in Kaduna State (Grema et al., 2020). Together, these studies depict a youthful, increasingly literate set of value chain actors constrained by limited credit access, volatile feed costs, weak extension support, inadequate hatchery infrastructure, and fragmented, largely informal marketing, yet they show that genuine productivity gains that a more deliberately structured value chain approach could build upon.

This study is therefore guided by three research questions: (1) What is the current state and socioeconomic profile of fish farming in the Kaduna Metropolis? (2) What are the key challenges and opportunities confronting actors across the fish-farming value chain? (3) What sustainable value chain model can be developed to address these challenges while advancing food security, poverty reduction, and employment objectives?

In pursuit of these questions, this study sets out to develop a sustainable fish-farming value chain model for Kaduna Metropolis that is capable of enhancing food security, reducing poverty, and generating employment. Specifically, it seeks to characterize the socioeconomic and demographic profile of value chain actors, including farmers, traders, processors, and policymakers; to identify and quantify the constraints and opportunities affecting production, processing, and marketing; to determine the factors driving profitability and productivity within the subsector; and, on this empirical basis, to propose an integrated value chain model together with the policy, infrastructural, and capacity-building interventions needed to operationalize it. A rigorous understanding of current practices, constraints, and opportunities along the chain is essential groundwork for any such intervention, since policies designed without reference to the lived realities of farmers, processors, and traders are unlikely to achieve durable uptake. Thus, this study aims to contribute not only to the socioeconomic development of Kaduna Metropolis but also to the broader national effort to close Nigeria's fish supply gap sustainably and inclusively.

1.1 Literature Review

Aquaculture, the cultivation of aquatic plants and animals, has become a significant sector in the global food industry, providing a vital source of protein for human consumption (FAO, 2016). The production of aquaculture products, such as fish, shrimp, and mussels, generates substantial economic benefits and creates employment opportunities for millions of people worldwide (World Bank, 2018). In Nigeria, aquaculture is a growing sector, with the government aiming to increase production to meet the country's increasing demand for fish (Federal Ministry of Agriculture and Rural Development, 2015).

1.1.1 Historical Background of Aquaculture in Nigeria

Aquaculture in Nigeria has a long-standing history that dates back to the 1960s, marking the beginning of organized fish farming activities in the country (Ogunji & Wuertz, 2023). The establishment of the first fish farm during this period signifies Nigeria's initial efforts to harness aquaculture as a means to supplement traditional fishing methods and improve food security (Abdullahi A. et al., 2025). Despite this early start, the sector remained relatively underdeveloped until the 1980s, when concerted efforts were made to promote its growth and sustainability. During this decade, the Nigerian government and various development organizations introduced key institutions and programs aimed at expanding aquaculture activities. Notably, the establishment of the National Fisheries Research Institute (NFRI) provided a scientific foundation for research, innovation, and the dissemination of improved fish farming techniques (Ibikunle et al., 2025). Additionally, the launch of the National Aquaculture Development Project (NADP) played a pivotal role in promoting modern aquaculture practices, increasing fish production, and encouraging private sector participation in the industry (Issa et al., 2022). These initiatives marked a turning point, setting the stage for the sector's ongoing development and integration into Nigeria’s broader food security and economic policies.

1.1.2 Current State of Aquaculture in Nigeria

The aquaculture sector in Nigeria is a vital component of the country’s efforts to enhance food security, generate employment, and foster economic growth. Despite its significant potential, the sector has faced numerous challenges that have hindered its development and sustainability. According to the National Bureau of Statistics (NBS), Nigeria produced approximately 174,000 metric tons of fish in 2019, with a market value of N50.4 billion (NBS, 2020). While this figure highlights the importance of the sector, reports have indicated that domestic fish production is still unable to meet the 3.6 million metric tonne demand, forcing a heavy reliance on imports to bridge this gap.

Several interconnected challenges contribute to the stagnation and decline of aquaculture in Nigeria. Chief among these is inadequate funding, which limits farmers’ ability to expand their operations, modernize their infrastructure, and adopt new technologies (Ogunji & Wuertz, 2023). Many fish farmers lack access to affordable credit and investment opportunities, hampering efforts to increase productivity and improve fish quality (Okon et al., 2025). Additionally, the sector suffers from a lack of

adequate infrastructure. Insufficient pond facilities, poor transportation networks, and limited cold storage facilities hinder efficient production, processing, and distribution. These infrastructural deficits result in higher postharvest losses and restrict market access, especially for smallholder farmers trying to compete in local and international markets.

Another significant challenge is the limited access to extension services and technical support. Extension services are essential for the dissemination of knowledge, best practices, and innovations to farmers (Chukwu et al., 2025). In Nigeria, these services are often inadequate, inaccessible, or poorly coordinated, particularly in rural areas. This results in low adoption of modern aquaculture techniques, poor farm management, and suboptimal productivity levels. Environmental issues also play crucial roles, with water pollution, siltation, and the impacts of climate change threatening fish habitats and breeding cycles (Elenwo & Alankali, 2014). These environmental pressures not only reduce yields but also complicate efforts to scale up aquaculture activities sustainably.

Furthermore, many Nigerian fish farmers still rely on traditional, rudimentary farming methods, which are outdated techniques that limit scalability, efficiency, and overall productivity. The slow adoption of modern, sustainable practices is often due to a lack of awareness, training, and access to appropriate technology (Ogunremi & Olatunji, 2019; Ogunleye & Akinbobola, 2020). Policy and regulatory constraints also pose significant barriers. Weak policy frameworks, poor enforcement of existing regulations, and bureaucratic bottlenecks discourage private sector investment and innovation in the sector. The absence of clear, supportive policies hampers strategic planning and resource allocation, further stifling growth (Ogunji & Wuertz, 2023).

The implications of these challenges are profound and affect Nigeria's food security and economic diversification efforts. To reverse the declining trend and unlock the sector's full potential, comprehensive strategies are needed. Improving access to funding through financial instruments tailored for aquaculture, such as grants, low-interest loans, and public–private partnerships, can stimulate growth. Investing in infrastructure, such as ponds, transportation, and cold chain logistics, will reduce postharvest losses and expand market access. Strengthening extension services through expanded training programs and technical support will promote the adoption of innovative and sustainable practices. Environmental management policies aimed at controlling pollution, conserving water resources, and addressing climate change impacts are also critical for ensuring the sector's long-term sustainability. Finally, establishing clear and supportive policy and regulatory frameworks will encourage private sector participation and investment, creating an enabling environment for growth.

Thus, Nigeria's aquaculture sector has made notable contributions to the economy and food supply, but its future depends on addressing key challenges related to funding, infrastructure, extension services, environmental sustainability, and policy support. Strategic, coordinated efforts among government agencies, private stakeholders, and development partners are essential to transform Nigerian aquaculture into a resilient, productive, and sustainable sector capable of meeting both domestic and export demands. Only through such comprehensive interventions can Nigeria realize the full potential of its aquaculture industry and secure a sustainable pathway for its growth.

1.1.3 *Aquaculture Value Chains in Nigeria*

Aquaculture value chains in Nigeria encompass the entire series of activities involved in bringing aquatic products from initial production to final consumption. These chains include various stages, such as hatchery operations, fish farming, harvesting, processing, packaging, transportation, and marketing (Adam et al., 2025; Duniya, 2026). Each step involves different stakeholders who contribute to adding value to the products, ensuring that they reach consumers in good quality and quantity. According to Mabou (2018), these value chains are critical for transforming raw aquaculture products into market-ready goods, thereby enhancing food security, employment, and income generation.

In Nigeria, the aquaculture value chain is notably long and complex and involves a diverse array of actors. Smallholder farmers, who dominate the sector, often operate at a subsistence level but are increasingly engaging in commercial activities. These farmers are connected to input suppliers, who provide essential resources such as fingerlings, feeds, fertilizers, and farming equipment. Once fish are grown and harvested, processors are involved in activities such as cleaning, grading, smoking, freezing, and packaging to preserve the quality of the products. The processed products are then distributed through various channels, local markets, supermarkets, and export avenues, requiring efficient transportation and logistics systems. Traders, both wholesale and retail, serve as crucial links between producers and consumers, while consumers themselves range from local households to international buyers (Akpabio, 2013).

However, Nigeria's aquaculture value chain faces several challenges that hinder its full potential. Limited access to financing constrains farmers' ability to adopt modern farming techniques or invest in quality inputs.

Poor infrastructure, such as inadequate transportation networks and cold storage facilities, affects product freshness and market reach. Additionally, low levels of technology adoption mean that many farmers rely on traditional methods, which can limit productivity and product quality. Market access remains a significant hurdle because of weak links between producers and markets, coupled with a lack of reliable market information. Regulatory gaps and weak enforcement of standards can also impede growth, especially in export markets (Mabou, 2018; Akpabio, 2013).

Despite these challenges, there are significant opportunities for developing Nigeria's aquaculture value chains. Strengthening linkages among stakeholders can improve efficiency, reduce postharvest losses, and increase profitability. Introducing modern aquaculture and processing technologies can enhance productivity and product quality. Expanding market access—both domestically and internationally—offers avenues for growth, especially through value-added products. Capacity-building initiatives aimed at farmers and processors can improve compliance with standards and increase competitiveness. Additionally, supportive policies, investment in infrastructure, and improved market information systems can further catalyze sector development, making Nigeria a more prominent player in regional and global aquaculture markets (Mabou, 2018; Akpabio, 2013).

1.1.4 Opportunities in the Aquaculture Value Chain

Despite the challenges facing the aquaculture value chain in Nigeria, there are several opportunities for growth and development, including the following:

i. **Increasing demand for fish**: The demand for fish in Nigeria is increasing, driven by the growing middle class and increasing urbanization (World Bank, 2018).
ii. **Government support**: The Nigerian government has committed to increasing support for the aquaculture sector, including the provision of financing and extension services (Federal Ministry of Agriculture and Rural Development, 2015).
iii. **Investment in aquaculture technology**: The adoption of new technologies in aquaculture, such as aquaponics and recirculating aquaculture systems, has the potential to increase productivity and reduce postharvest losses (Mabou, 2018).

In conclusion, the aquaculture value chain in Nigeria is characterized by a long and complex supply chain involving multiple stakeholders. While several challenges have been identified in the value chain, including postharvest losses, a lack of access to finance, and inadequate extension services, several opportunities for growth and development, including increasing demand for fish, government support, and investment in aquaculture technology.

2 Materials and Methods

2.1 Study Area

Kaduna Metropolis, the capital of Kaduna State in northwestern Nigeria, serves as the study area for this research. Located between latitudes 10°25'N and 10°35'N and longitudes 7°20'E and 7°35'E (Figure 1), the metropolis lies within the northern Guinea Savanna ecological zone (Abubakar et al., 2025). It is characterized by a tropical climate with distinct wet and dry seasons, with average annual rainfall ranging from 1,000 to 1,300 mm and temperatures ranging from 25–28°C (Bello et al., 2025; Saleh et al., 2024). The Kaduna River and its tributaries, along with several dams and reservoirs, provide vital water resources that support both rain-fed agriculture and aquaculture activities. The metropolis was selected for this study because of its strategic location, growing urban food demand, existing aquaculture activities, and potential to serve as a model for sustainable value chain development in similar inland urban settings in Nigeria.

The metropolis was selected for this study because of its strategic location, growing urban food demand, existing (although underdeveloped) aquaculture activities, and potential to serve as a model for sustainable value chain development in similar inland urban settings in Nigeria.

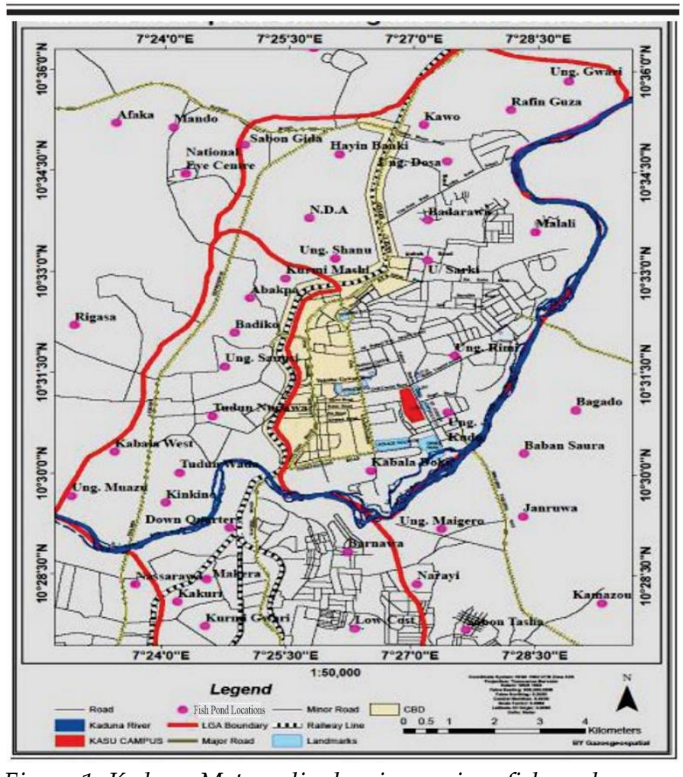


Figure 1: Kaduna Metropolis showing various fishponds

2.2 Research Design

This study employed a descriptive mixed-methods research design to comprehensively explore the current state of fish farming in the Kaduna metropolis, identify challenges, and propose a sustainable value chain model. The mixed-methods approach combines quantitative data, which provide measurable insights into socioeconomic and technical aspects, with qualitative data that capture perceptions, experiences, and contextual nuances (Creswell & Clark, 2017). This design facilitates triangulation, enhancing the validity and richness of the findings.

2.3 Study population

The target population included smallholder fish farmers, fish traders, processors, and policymakers operating within Kaduna Metropolis. Specifically, the population included the following:

- Fish farmers engaged in pond-based aquaculture
- Fish traders involved in wholesale and retail marketing
- Fish processors engaged in value-added activities
- Local government officials and policy implementers overseeing aquaculture initiatives

2.4 Sampling Technique and Sample Size

The sampling frame was constructed on the basis of lists obtained from local agricultural offices, fisheries associations, and market authorities. A multistage sampling technique was employed:

i. Stratification of the Kaduna Metropolis: The city was divided into zones based on the geographic and water resource proximity (e.g., Kaduna North, Kaduna South, and Kaduna Central).
ii. Selection of Zones: Two zones were randomly selected from each stratum to ensure geographic representativeness.
iii. Selection of Respondents: Within each selected zone, a systematic random sampling method was used to choose fish farmers, traders, and processors from the lists, ensuring proportional representation.

Sample sizes were calculated using Cochran's (1977) formula for unknown populations, assuming a 95% confidence level and a 5% margin of error:

$$n_0 = \frac{Z^2 pq}{e^2}$$

where:

- Z = 1.96 (standard normal variate for 95% confidence)
- P = 0.5 (assumed proportion for maximum variability)
- q =1−p = 0.5
- e =0.05 (desired margin of error)

The calculations yielded approximately 384 respondents. Adjusting for finite population correction and a response rate of 78.13%, a total of 300 respondents were targeted for the quantitative survey, including the following:

- 200 Fish farmers
- 50 Fish traders
- 30 Fish processors
- 20 Policymakers and extension officers

2.5 Data collection methods

1. Structured questionnaires:
   Pretested structured questionnaires were administered face-to-face to gather quantitative data on socioeconomic characteristics, farming practices, input costs, income levels, and market dynamics. The questionnaire contained both closed-ended and Likert-scale questions for ease of analysis.
2. Keywords (KIIs):
   Semi-structured interviews were conducted with policymakers, extension officers, and key stakeholders to explore policy frameworks, institutional support, and strategic priorities. KIIs provided in-depth insights into systemic barriers and opportunities.
3. Focus Group Discussions (FGDs):
   FGDs involving groups of farmers, traders, and processors were held to discuss challenges, traditional practices, and perceptions of value chain development. These discussions facilitated a participatory understanding of community-level issues.
4. Observation:
   Field observations were made to assess the infrastructure, pond conditions, water sources, and processing facilities. Photographs and field notes documenting environmental and operational conditions.

2.6 Data Analysis

The data collected for this study were analyzed using both quantitative and qualitative analytical techniques in order to achieve the study objectives. Quantitative data obtained through the structured questionnaire were coded, entered, and analyzed using the Statistical Package for Social Sciences (SPSS) Version 26. Descriptive statistics such as frequencies, percentages, means, and standard deviations were used to summarize respondents' socioeconomic characteristics, fish farming practices, challenges encountered, and access to support services.

To determine the factors influencing fish farm profitability, Multiple Linear Regression Analysis was

employed. The dependent variable was fish farm profitability, measured using income and cost-related indicators. The independent variables included access to credit, technical training, farm size, and water quality. The regression model is specified as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

Where:

- Y= Fish farm profitability
- β_0= Constant term
- X_1= Access to credit
- X_2= Technical training
- X_3= Farm size
- X_4= Water quality
- $\beta_1 - \beta_4$= Regression coefficients
- ε= Error term

The regression analysis was conducted at a 5% level of significance ($p < 0.05$) to determine the extent to which the independent variables influence profitability.

Qualitative data obtained from Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) were analyzed using NVivo 12 software. The data were subjected to thematic analysis, which involved transcription, coding, categorization, and identification of emerging themes. The major themes identified included infrastructural constraints, policy implementation challenges, stakeholder perceptions, and opportunities for value chain development.

To enhance the validity and reliability of the findings, a triangulation approach was adopted by integrating the results from both quantitative and qualitative analyses. This enabled the study to provide a comprehensive understanding of fish farming activities, challenges, opportunities, and profitability determinants in Kaduna Metropolis. The combined findings served as the basis for drawing conclusions and making recommendations for the development of a sustainable fish farming value chain in the study area.

3 Results

3.1 Sociodemographic characteristics of the fish farmers

The socioeconomic characteristics of fish farmers in Kaduna Metropolis were examined. The result is presented in Table 1.

Table 1: Socioeconomic Characteristics of Fish Farmers in Kaduna (n=200)

Variable	Frequency	Percentage (%)
Age		
< 25 years	30	15
25-34 years	80	40
35-44 years	50	25
> 45 years	40	20
Education Level		
No formal education	20	10
Secondary education	100	50
Tertiary education	80	40
Farming Experience (years)		
< 1 year	30	15
1-3 years	100	50
> 3 years	70	35

From Table 1 above, the socioeconomic profile of fish farmers in Kaduna highlights a predominantly young and relatively educated workforce. The largest age group is the 25–34 years category, accounting for 40% of the farmers, indicating that young adults are the main participants in aquaculture activities. The percentage of farmers under 25 years of age is 15%, suggesting moderate youth engagement with opportunities to further involve younger generations. Conversely, older farmers above 45 years constitute 20% of the sample, which could provide valuable experience and facilitate knowledge transfer within the sector. This age distribution reflects a sector that is largely driven by energetic and potentially adaptable individuals, with room for increasing youth participation.

In terms of education, half of the farmers have attained secondary education, and a significant 40% possess tertiary qualifications. This high level of formal education

among farmers suggests that many are equipped with the skills and knowledge necessary to adopt new technologies and innovative practices. Only 10% have no formal education, highlighting that most farmers have at least basic schooling, which can be beneficial for capacity building and sector development. The combination of youth and education levels indicates a workforce with strong potential for growth, learning, and technological uptake.

With respect to farming experience, most farmers (50%) have been involved in aquaculture for 1–3 years, indicating that the sector is still in a relatively early stage of development, with many participants being new entrants. Farmers with less than one year of experience account for 15%, further emphasizing the sector's nascent status. Those with more than three years of experience make up 35%, suggesting that while there are seasoned farmers, the majority are still gaining expertise. Overall, the profile points to an emerging aquaculture sector in Kaduna, characterized by young, educated, and relatively inexperienced farmers, providing a promising foundation for sector growth through targeted training and support.

3.2 Fish-Farming Value Chain Model

In Kaduna Metropolis, the fish value chain can be understood by drawing parallels to the comprehensive value chains and innovation systems observed in other contexts. The Kaduna fish value chain involves several key stages, each contributing to the movement of fish from production to final consumption, and is supported by various institutional and infrastructural actors (Figure 2).

The first stage involves the suppliers of capital equipment, inputs, and services necessary for fish farming. This includes hatchery operators providing fingerlings, feed suppliers, and providers of aquaculture equipment and technology. These actors are crucial for ensuring that fish farmers have access to quality inputs and modern techniques, which can enhance productivity and sustainability.

The second stage encompasses the fish farmers and the aquaculture farms themselves. In Kaduna, smallholder and emerging farmers use ponds and other aquaculture systems to produce fish such as catfish and tilapia. These farms are the primary producers, where fish are cultivated, harvested, and prepared for market. This stage is often characterized by limited infrastructure and technical support, which directly impacts farm productivity and the quality of the fish produced.

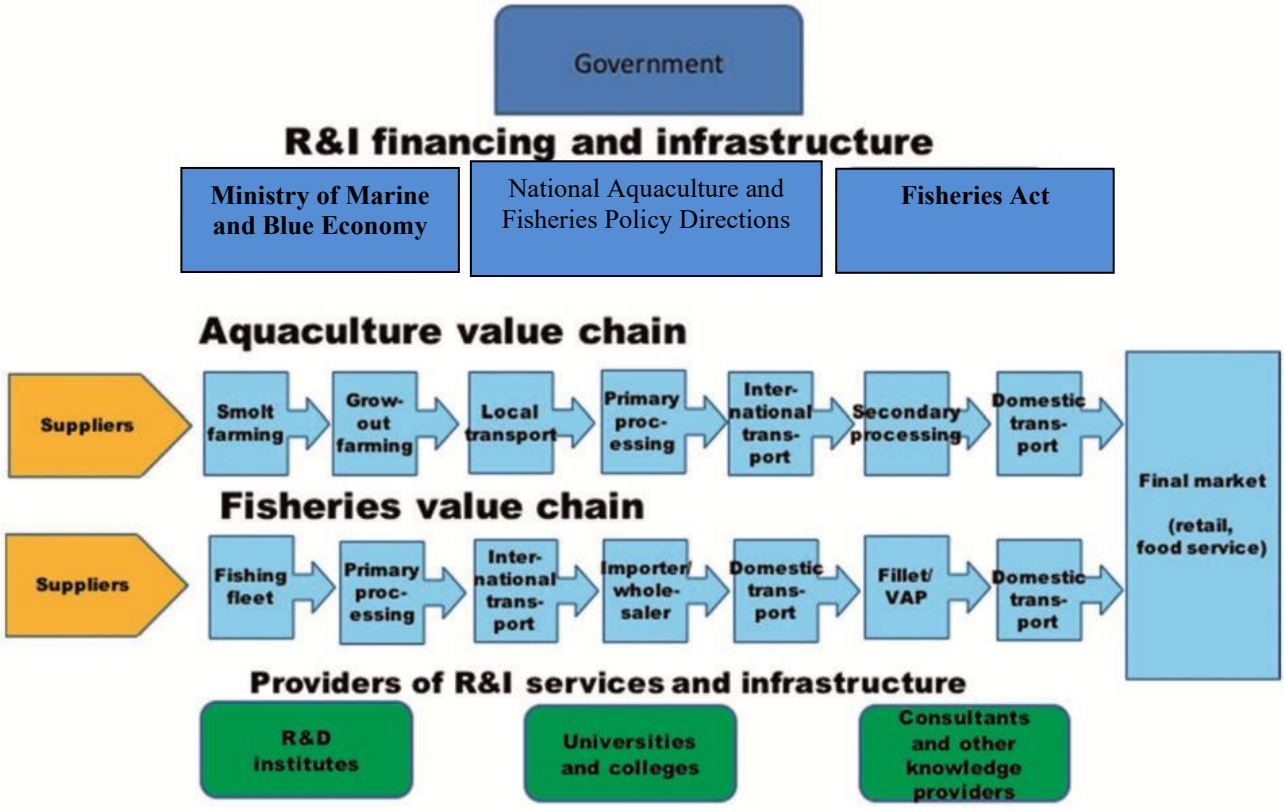


Figure 2: Fish value chain model

The third stage involves downstream activities, including processing, packaging, transportation, and marketing. Fish are processed into various forms, fresh, smoked, or frozen, and then distributed through local markets, supermarkets, and export channels. Traders and processors play a vital role in adding value and ensuring that fish reach consumers in good condition, both locally and potentially for export. However, challenges such as

inadequate cold storage, poor transportation infrastructure, and weak market linkages hinder the efficiency of this stage.

In support of these stages are various institutions and organizations that provide research, technical support, financing, and infrastructure development elements that form the broader fish value chain ecosystem. In Kaduna, strengthening institutional support, such as extension services, financial access, and market information systems, is essential for improving the overall efficiency and competitiveness of the fish value chain.

The Kaduna fish value chain comprises input suppliers, fish farming and harvesting, and processing and distribution, all of which are interconnected through market linkages and supported by institutional frameworks. Enhancing each stage, particularly through innovation, infrastructure development, and policy support, can significantly improve productivity, income, and food security outcomes for the region.

3.3 Production and productivity growth

In the Kaduna Metropolis, the primary production sectors within the fish industry have exhibited distinct trends over recent years. Historically, at the turn of the millennium, both sectors contributed roughly equally to the sector's overall production value. However, their trajectories have since significantly diverged. While aquaculture in Kaduna has experienced substantial growth, fisheries have seen relatively modest increases. This divergence mirrors global trends, where the fish industry has emerged as the dominant growth driver because of technological advancements and increasing investments.

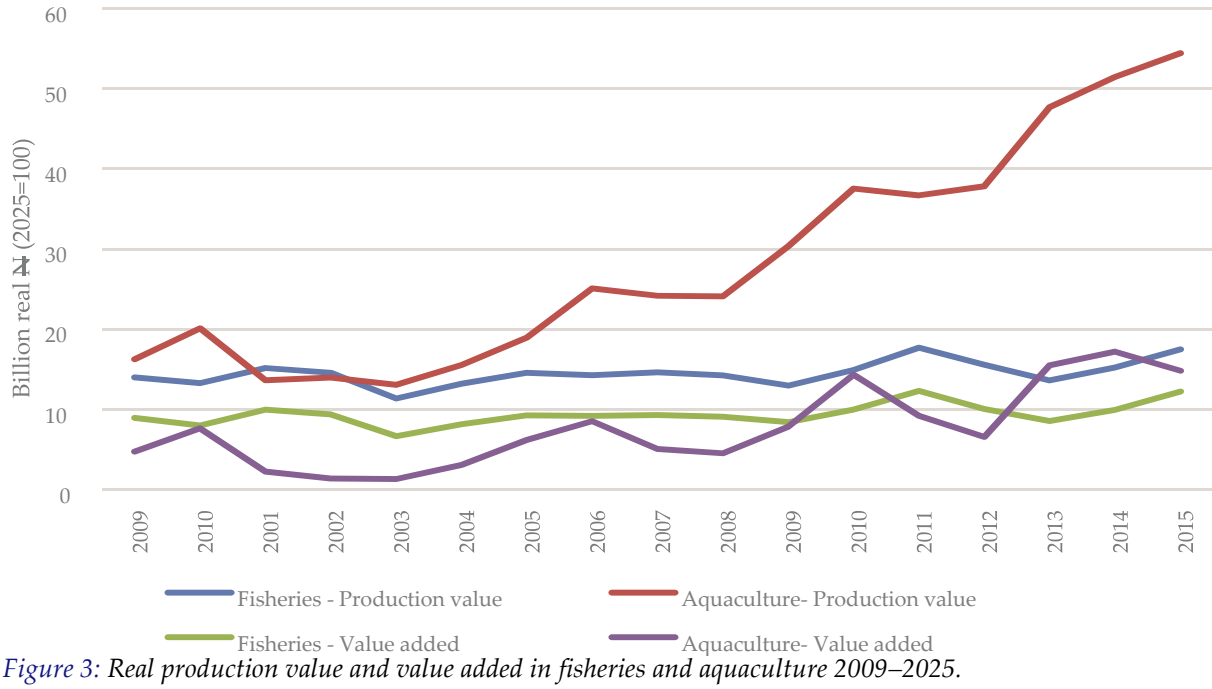


Figure 3: Real production value and value added in fisheries and aquaculture 2009–2025.

At the beginning of the 21st century, the aquaculture and fisheries sectors in Kaduna Metropolis held approximately equal shares in terms of production value. However, over the years, their trajectories have significantly diverged. According to Figure 3, between 2009 and 2025, the real production value in aquaculture increased markedly from 16 billion Naira to 54 billion Naira, driven by increased investment, technological adoption, and expansion of local markets. In contrast, the fisheries sector experienced slower growth, with its production value rising from 14 billion Naira in 2009 to approximately 17.5 billion Naira in 2025. This disparity highlights the more dynamic growth of aquaculture and its potential as a key driver of sustainable food production and economic development within the Kaduna Metropolis.

The value added in the seafood sector reflects similar trends. Aquaculture's real value added increased from approximately 5 billion Naira in 2009 to approximately 15 billion Naira in 2025, despite fluctuations caused by market prices and seasonal variations. On the other hand, the value added of fisheries fluctuated between 8 and 12 billion Naira, with recent years experiencing higher levels partly because of increased demand and rising prices. Seafood processing has also contributed to sector growth, with value added rising from approximately 6 billion to 10 billion Naira. The total value added in these subsectors increased from approximately 20 billion Naira in 2009 to

approximately 35 billion Naira in 2025, indicating a steady expansion of the seafood sector's contribution to Kaduna's economy.

Investments in research, development, and technological innovation have played a crucial role in enhancing productivity across these sectors. Labour productivity, measured by real value added per employee, has shown consistent improvement. Notably, aquaculture has experienced the most significant gains, with a 549% increase in labor productivity from 2013 to 2025. Fisheries also improved considerably, with a 207% increase, while seafood processing experienced modest growth of approximately 15%. These trends suggest that innovation, whether through improved farming techniques, better supply chain management, or new technological inputs, effectively increases efficiency, especially in aquaculture, which has become the most productive subsector in terms of labor gains.



Plate 1: Concrete catfish tanks in the Gamji Park fish-farming village.

The findings revealed that catfish and tilapia are the two dominant fish species cultivated in Kaduna Metropolis, with catfish accounting for the largest share of aquaculture production, while tilapia constitutes the second most important cultured species. Together, these species contribute the overwhelming majority of fish production in the area, making them the backbone of the local aquaculture industry. The dominance of catfish and tilapia highlights the need for targeted technological innovations, improved management practices, and sustainable production systems tailored to these species in order to maintain and increase productivity. Focusing on these key species also creates opportunities for specialization, value addition, market expansion, and diversification within the fish farming value chain.

The prominence of catfish and tilapia farming provides a strong foundation for developing a sustainable fish-farming value chain model in Kaduna Metropolis. Such a model can contribute significantly to improving food security, reducing poverty, and creating employment opportunities. The increasing demand for catfish and tilapia, coupled with improvements in production efficiency, demonstrates the potential of strategic investments in modern aquaculture technologies, farmer training, quality seed supply, feed development, and market infrastructure. These interventions can enhance productivity, profitability, and resilience among fish farmers.

Furthermore, the development of a sustainable value chain requires strengthening linkages among key stakeholders, including fish farmers, input suppliers, extension service providers, processors, marketers, financial institutions, and policymakers. Promoting sustainable farming practices, improving access to credit and technical support, and encouraging value addition through fish processing and packaging can increase income generation and employment opportunities across the value chain. Consequently, a well-structured catfish and tilapia value chain can serve as an effective mechanism for enhancing household livelihoods, ensuring a stable supply of affordable animal protein, and supporting the broader economic development of Kaduna Metropolis.

Table 2: Major Challenges Faced by Fish Farmers

Challenge	Frequency	Percentage (%)
Limited access to credit	178	89
High input costs (feed, fingerlings)	160	80
Water quality and availability	150	75
Inadequate extension services	140	70
Poor market linkages	130	65

From Table 2, the major challenges faced by fish farmers in Kaduna underscore several critical issues that hinder the growth and sustainability of the sector. The most significant challenge is limited access to credit, reported by 89% of the farmers. This finding indicates that financial constraints are a major barrier, as they restrict the ability of farmers to expand their operations, invest in better equipment, or improve their infrastructure. Addressing this issue through improved credit facilities and financial support programs could substantially enhance sector development.

High input costs, particularly for feed and fingerlings, are another major concern, affecting 80% of the farmers. These operational costs directly impact profitability, making it difficult for farmers to sustain or scale their businesses. Water quality and availability pose environmental challenges, with 75% of farmers reporting issues related to environmental conditions that influence production stability. Inadequate extension services, experienced by 70%, point to a need for improved technical support, training, and capacity-building initiatives to enhance farmers' skills and knowledge. Finally, poor market linkages affect 65% of the farmers, highlighting difficulties in accessing markets that could ensure better income and economic viability.

The challenges faced by fish farmers in Kaduna are predominantly financial and infrastructural. Limited access to credit and high input costs are critical barriers that require policy interventions and support services. Improving access to affordable credit, providing technical training, and strengthening market linkages are essential steps to enhance the productivity, profitability, and overall sustainability of fish farming in the region.

Table 3: Access to Policy and Institutional Support

Support Type	Frequency	Percentage (%)
Aware of government policies	120	60
Benefited from policies/initiatives	20	10
Access to credit facilities	50	25
Participation in training/workshops	80	40

From Table 3, the data on access to policy and institutional support among fish farmers in Kaduna reveal a mixed picture. Most farmers, approximately 60%, are aware of government policies related to aquaculture, indicating a decent level of awareness. However, this awareness does not necessarily translate into active engagement or benefit, as only 10% of farmers have benefited from specific policies or initiatives. This suggests gaps in the effective dissemination and implementation of support programs, which limit their impact on the ground.

Access to credit facilities remains limited, with only 25% of farmers reporting having access. This restriction hampers their ability to expand operations, adopt new technologies, or improve their infrastructure. Participation in training and workshops, which is crucial for capacity building, is moderate at 40%. While some farmers are engaging in skill-enhancement activities, there is significant room to increase their involvement to improve productivity and sustainability.

Although awareness of policies is relatively high, the low levels of benefit and participation highlight the need for more effective policy implementation and outreach strategies. Improving access to credit, increasing participation in training, and ensuring that policies actively benefit farmers can play a vital role in strengthening the aquaculture sector in Kaduna. Enhanced support and better communication between policymakers and farmers are essential steps toward sector development.

Table 4: Regression Analysis of Factors Influencing Fish Farm Profitability

Variable	Coefficient (β)	Standard Error	p value
Access to credit	0.45	0.12	0.001
Technical training	0.30	0.10	0.015
Farm size (hectares)	0.25	0.08	0.020
Water quality (score)	0.20	0.09	0.050

The regression analysis reveals that access to credit is the most influential factor driving fish farm profitability in Kaduna. A high coefficient (β = 0.45) and a p-value of 0.001 indicate a strong and statistically significant positive relationship. This suggests that when farmers have better access to affordable credit, they are more likely to invest in improving their farms, purchasing necessary equipment, and expanding their operations, all of which contribute to higher profits. Enhancing credit facilities for farmers could therefore be a highly effective policy measure to increase sector performance.

Similarly, technical training plays a crucial role in increasing profitability (Table 4). The analysis shows a positive coefficient (β = 0.30) with a p value of 0.015, emphasizing that farmers who receive adequate training tend to be more productive and profitable. Capacity building through workshops and training programs equips farmers with modern techniques, disease management skills, and efficient farm practices, leading to improved yields and income levels. Investing in such training initiatives can significantly enhance farm performance across the sector.

Farm size also has a positive and significant effect on profitability, with a coefficient of 0.25 and a p-value of 0.020. Larger farms generally benefit from economies of scale, which can reduce costs and increase output, thereby improving profitability. Additionally, water quality, although it has a less pronounced effect (β = 0.20, p = 0.050), still contributes to farm success. Better water conditions support healthier fish growth and reduce disease incidence, ultimately leading to higher yields and profits.

Therefore, policies aimed at improving access to credit and expanding technical training opportunities are vital for enhancing fish farm profitability in Kaduna. These factors have the most significant and positive effects, and targeted interventions in these areas are likely to stimulate sector growth, increase farmers' incomes, and promote sustainable aquaculture development.

4 Conclusion

The development of a sustainable fish-farming value chain in Kaduna Metropolis presents a vital avenue for achieving food security, reducing poverty, and creating employment opportunities. The findings reveal that while there is considerable potential, several barriers, particularly limited access to credit, high input costs, infrastructural deficits, and inadequate extension services, significantly constrain sector growth. Addressing these challenges through targeted financial support, capacity building, improved market linkages, and infrastructural investments is essential to unlock the sector's full potential. Strengthening policy implementation and fostering stakeholder collaboration will further increase the effectiveness of these interventions, leading to increased productivity, income, and social welfare in Kaduna.

Based on the insights gained from this study, several recommendations are essential for advancing a sustainable fish-farming value chain in Kaduna.

i. The government and development partners should prioritize the provision of affordable credit facilities tailored specifically for smallholder fish farmers to enable expansion and modernization.
ii. Capacity-building programs, including training and workshops, need to be scaled up to equip farmers with modern aquaculture techniques, disease management, and business skills.
iii. Investments in infrastructure, such as cold storage facilities, transportation networks, and processing plants, are critical for reducing postharvest losses and expanding market access.
iv. Policymakers should strengthen regulatory frameworks, ensure effective enforcement, and promote policies that support sector growth and environmental sustainability.
v. Fostering stronger linkages among farmers, traders, processors, and markets through organized cooperatives and information systems will facilitate better market access and price stability. Implementing these strategic recommendations will foster a resilient, inclusive, and sustainable fish-farming value chain that can significantly contribute to Nigeria's broader development objectives.

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