GSC Advanced Research and Reviews
eISSN: 2582-4597 CODEN (USA): GARRC2
Cross Ref DOI: 10.30574/gscarr
Journal homepage: https://gsconlinepress.com/journals/gscarr/

(RESEARCH ARTICLE)

Check for updates

The impact of financial inclusion on the utilization of climate resilience practices among fish farmers in Delta State

Glory Ogochukwu Ndubuokwu and Theophilus Miebi Gbigbi *

Department of Agricultural Economics, Delta State University Abraka, Nigeria.

GSC Advanced Research and Reviews, 2025, 24(03), 122-141

Publication history: Received on 05 August 2025; revised on 11 September 2025; accepted on 13 September 2025

Article DOI: https://doi.org/10.30574/gscarr.2025.24.3.0239

Abstract

This study investigates the role of financial access in driving the adoption of climate-resilient aquaculture practices among fish farmers in Delta State, Nigeria. A multi-stage sampling procedure was employed to select 240 farmers across three agricultural zones, and data were collected using structured questionnaires. Analytical methods included descriptive statistics, logistic regression, and Likert scale evaluations to examine how financial services influence resilience strategies. Findings reveal marked variation in respondents' socioeconomic characteristics: 58.3% were male, 75% fell within the 30–49 age range, and 41.7% possessed tertiary education. While 68.8% accessed formal financial services, a significant proportion (33.3%) relied on informal credit sources. Farmers with greater financial access exhibited higher uptake of resilience-enhancing measures, including disease prevention (89.6%), cultivation of climate-tolerant fish species (87.5%), and use of climate-resilient feed (79.2%). Adoption also extended to adaptive technologies such as improved pond designs and integrated farming systems. Logistic regression results identified access to credit, savings, financial literacy, and cooperative membership as significant predictors of climate-resilient practice adoption. The analysis underscores that financial access not only facilitates investment in adaptive technologies but also strengthens farmers' capacity to manage climate-related risks. The study concludes that expanding affordable and accessible financial services particularly credit and savings facilities can substantially enhance climate resilience in aquaculture. Policy interventions should prioritize integrating financial inclusion strategies into climate adaptation programs to improve productivity, safeguard livelihoods, and ensure sustainable fish farming in the face of escalating climate variability.

Keywords: Climate-Resilient Aquaculture; Inclusive Rural Finance; Sustainable Fisheries; Digital Financial Services

1. Introduction

Aquaculture has emerged as a vital component of global food systems, contributing significantly to food security, nutritional improvement, and rural economic growth. As the global population continues to increase and the demand for animal protein intensifies, aquaculture has become the fastest growing food production sector, now accounting for over half of global fish consumption (FAO, 2022). This rapid expansion has been instrumental in mitigating the depletion of wild fish stocks caused by overfishing and environmental degradation (Boyd et al., 2022). Beyond its role in supplying essential protein, aquaculture serves as a strategic tool for alleviating malnutrition and poverty, particularly in developing nations where access to nutrient-rich foods remains inadequate (Belton et al., 2022). By simultaneously creating income opportunities and improving diets, it is increasingly recognized as a sector with strong potential to address hunger and economic hardship.

In Africa, the aquaculture sector holds considerable promise for transforming rural economies and improving food availability. However, its growth potential is undermined by persistent challenges. Nigeria, as Africa's most populous nation, is experiencing escalating food insecurity driven by climate change, rapid urban expansion, and environmental

* Corresponding author: Theophilus Miebi Gbigbi

degradation. Despite abundant water resources and favorable climatic conditions for aquaculture, production systems remain largely traditional and low input, making them highly susceptible to climate-related shocks. Vulnerabilities such as flooding, erratic rainfall, and salinity fluctuations reduce production efficiency and threaten the livelihoods of farming households dependent on aquaculture for both food and income. These limitations point to a clear need for systemic adaptation strategies to secure the future of the sector.

Climate change represents one of the most pressing threats to aquaculture globally, with pronounced impacts in developing countries where smallholder fish farmers often lack the resources and institutional support to cope. Rising water temperatures affect fish growth rates, feed conversion efficiency, and oxygen utilization (Reid et al., 2021), thereby increasing production risks, operational costs, and mortality rates. Extreme weather events such as floods and droughts disrupt water supply, destroy infrastructure, and interrupt production cycles. These shocks not only undermine profitability but also weaken the resilience of farming households, particularly those operating at subsistence or semi-commercial scales. Without targeted adaptation measures, these climate stressors may accelerate the decline of vulnerable aquaculture systems.

In addition to temperature and weather extremes, aquaculture faces other climate-induced pressures, including water salinization and freshwater scarcity, especially in coastal zones. Sea level rise and saltwater intrusion threaten freshwater sources, while ocean acidification disrupts shellfish production and degrades marine ecosystems (Clements and Chopin, 2021). The cumulative effect of these stressors underscores the urgency of adopting climate-smart aquaculture practices designed to sustain production while enhancing environmental sustainability and economic viability.

Central to the adoption of these practices is the availability and accessibility of financial services. Financial access enables farmers to acquire adaptive technologies, invest in improved infrastructure, and adopt resilient fish breeds. Credit facilities, savings mechanisms, insurance products, and digital payment systems all serve as critical enablers of adaptation (World Bank, 2022). For instance, credit can fund automated feeding systems or water quality monitoring equipment, while savings and mobile banking improve liquidity management, allowing farmers to better absorb income fluctuations (Pham et al., 2022). Likewise, microinsurance products tailored for aquaculture provide a safety net against climate-induced losses, enabling farmers to recover faster and sustain long-term investments (Khan et al., 2023).

Despite the recognized importance of financial services in strengthening climate resilience, the specific relationship between financial accessibility and the adoption of climate-smart aquaculture practices remains underexplored, particularly in ecologically fragile and economically disadvantaged areas. In Nigeria, many smallholder fish farmers face significant barriers to accessing finance, including high transaction costs, limited awareness, and low trust in formal financial institutions. This limits their ability to invest in adaptive solutions, leaving them exposed to increasing climate variability and production risks. Addressing these constraints is essential to unlocking the sector's potential and safeguarding its contributions to food security and livelihoods.

This study seeks to fill this research gap by applying a climate resilience framework to assess how financial accessibility influences the adoption of climate-smart aquaculture practices among fish farming households in Delta State, Nigeria. By examining the socioeconomic characteristics of farmers, the level of financial accessibility, and the extent of adoption of adaptive practices, the study aims to generate evidence that can inform policy and guide interventions by governments, development partners, and financial institutions. The findings will contribute to strategies that enhance food security, stabilize rural incomes, and promote sustainable aquaculture in climate vulnerable regions. Specifically, the objectives are to:

- Describe the socioeconomic characteristics of fish farmers
- Examine the level of financial accessibility among fish farmers
- Assess climate smart aquaculture practices in relation to financial accessibility
- Determine the extent of adoption of climate smart practices among fish farmers
- Analyze the relationship between financial accessibility and the adoption of climate smart approaches among fish farmers.

2. Materials and Method

This study was conducted in Delta State, Nigeria, focusing on selected local government areas (LGAs) within the three agricultural zones where aquaculture is most prevalent. A multi-stage sampling method was employed to ensure a representative sample of aquaculture practitioners across the state. Initially, two LGAs were purposively selected from

each agricultural zone based on the intensity of fish farming and the environmental vulnerability of the areas. Subsequently, four aquaculture settlements were randomly chosen within each LGA. From each settlement, ten fish farmers were randomly selected, resulting in a total sample size of 240 respondents. Primary data were collected using a structured questionnaire designed to capture both quantitative and qualitative information on aquaculture practices, financial inclusion, and climate adaptation strategies. The data were analyzed using descriptive statistics and logistic regression.

2.1. Model Specification

The binary logistic regression model used to examine the determinants of climate resilience among fish farmers is specified as:

$$\text{Logit(Pi)}=In\left(\frac{Pi}{1-Pi}\right)=\beta0+\beta1X1+\beta2X2+\beta3X3+\beta4X4+\beta5X5+\beta6X6+\beta7X7+\beta8X8+\beta9X9+\beta10X10+\beta11X11+\beta12X12+\beta13X13+\beta14X14+\beta15X15+\varepsilon i$$

Where:
Pi= Probability that the i^{th} fish farmer adopts at least one climate-resilient approaches.
$In\left(\frac{Pi}{1-Pi}\right)$=The log odds of adopting climate-resilient approaches.
β0= Intercept term.
β1 to β15= Coefficients of the explanatory variables.
εi= Error term.

- X1 = Credit accessibility (1 = Yes, 0 = No)
- X2 = Loan amount (Sum of loan disbursed in Naira)
- X3 = Ownership of bank account (1 = Yes, 0 = No)
- X4 = Utilization of mobile banking (1 = Yes, 0 = No)
- X5 = Engagement in financial literacy training (1 = Yes, 0 = No)
- X6 = Availability of savings or insurance services (1 = Yes, 0 = No)
- X7 = Ownership of land (1 = Affirmative, 0 = Negative)
- X8 = Pond dimensions (Stocking capacity; quantity of fish introduced)
- X9 = Cooperative membership (1 = Yes, 0 = No)
- X10 = Availability of storage facilities (1 = Yes, 0 = No)
- X11 =Gender, with 1 representing female and 0 representing male.
- X12 = Age (in years)
- X13 =the level of education, quantified by the number of years of formal schooling completed.
- X14 = Income level (monthly or annual income expressed in Naira)
- X15 = Years of experience in aquaculture

3. Results and Discussion

3.1. Socioeconomic characteristics of Aquaculture Practitioners

3.1.1. Gender

The gender reveals that 58.3% of fish farmers are male, while 41.7% are female, highlighting a male-dominated aquaculture sector, which mirrors traditional gender patterns in many agricultural industries. However, the significant 41.7% female participation indicates a positive shift towards greater gender inclusion in aquaculture. This trend could empower women, potentially improving both productivity and sustainability in the sector. Financial inclusion is key to empowering women by providing them with access to resources, enhancing their economic participation, and strengthening community resilience against climate change (Eze and Alugbuo, 2021). Therefore, initiatives to improve financial inclusion for female fish farmers are crucial in bridging the gender gap in aquaculture. The lack of access to resources like loans, particularly for women, underscores the barriers to achieving gender equality in the sector (A et al., 2022). The predominance of men in aquaculture aligns with studies showing that women are often relegated to post-harvest roles, such as marketing, rather than engaging in farming activities (Adam et al., 2025). Therefore, improving women's financial inclusion is essential for boosting sustainability and productivity in aquaculture. This global male dominance is reflected in research showing that women's roles are frequently limited to post-harvest tasks rather than active farming (Omeje et al., 2021).

3.1.2. Age

The age distribution reveals that a significant 75% of fish farmers are between the ages of 30 and 49, with 25% in the 20 to 29 age group. This indicates that the aquaculture sector is predominantly youthful, characterized by energetic and dynamic individuals who are well-positioned to drive change and innovation within the industry. Younger farmers, particularly those in their 20s and 30s, tend to be more adaptable to new technologies and contemporary farming methods. This adaptability makes them more likely to embrace climate-resilient technologies, which are crucial for ensuring the long-term sustainability of aquaculture in the face of climate change. The enthusiasm and willingness of younger farmers to experiment with new techniques can lead to greater adoption of sustainable practices and innovations that improve productivity and resilience. Furthermore, the active involvement of younger individuals in the sector can accelerate the transition toward more technologically advanced and sustainable practices, which are essential for the future of aquaculture (Bello et al., 2022). As these younger farmers continue to grow and develop within the sector, they are likely to play a pivotal role in the evolution of the industry, ensuring its resilience and capacity to adapt to the challenges posed by climate change.

3.1.3. Marital Status

A significant 62.5% of fish farmers are married, followed by 20.8% who are single, and 16.6% who are divorced or widowed. This indicates that family-oriented farming enterprises dominate the sector. Family labour plays a crucial role in enhancing agricultural productivity and resource efficiency, facilitating long-term investments in sustainability. The marital status of farmers influences their decision-making and resource accessibility, which in turn affects their engagement in climate-resilient practices (Onoh et al., 2023). In contrast, Southwest Nigeria aquaculture sectors see a higher proportion of single individuals, influenced by labour migration to urban areas for economic opportunities (Segun, 2024). These findings highlight the need for policies that account for family dynamics in aquaculture development.

3.1.4. Educational level

A large portion of respondents, 41.7%, have completed tertiary education, followed by 33.3% with secondary education. These higher education levels are associated with the adoption of modern agricultural practices and increased productivity (Eze and Alugbuo, 2021). However, 16.7% of farmers have only primary education, and 8.3% have no formal education. Such individuals may face challenges in accessing the skills and technologies necessary to improve fish farming. Higher education enables farmers to adopt innovative techniques, manage their enterprises more efficiently, and respond to market demands, thus enhancing sustainability. Financial literacy education is also essential in improving farmers' ability to interact with financial services and implement climate-resilient practices (Edeminam and Abdullahi, 2022).

3.1.5. Income Level

Most farmers (33.3%) earn between ₦50,000 and ₦100,000 monthly, followed by 25% who earn between ₦100,001 and ₦150,000. Only 12.5% earn over ₦200,000. These figures suggest that while aquaculture provides a steady income, the earnings are relatively modest, limiting farmers' ability to invest in climate resilience (Kazeem and Nurudeen, 2023). Wealthier farmers (12.5%) are better positioned to adopt climate adaptation strategies, but financial constraints for the majority of farmers may hinder their ability to do so. These earnings also reflect the profitability challenges in aquaculture, with factors like high production costs and fluctuating market prices limiting financial success (Gomna and Mamman 2020). Studies show that farmers who implement climate adaptation strategies tend to achieve better financial outcomes, improving household income and food security (Ibrahim et al., 2022).

3.1.6. Fishing Experience

The majority of farmers (41.7%) have been in fish farming for 1–5 years, indicating a relatively young industry in the region. The 33.3% with 6–10 years of experience possess valuable knowledge that could be beneficial for adopting climate-resilient practices (Omeje et al., 2021). More experienced farmers can serve as mentors to less experienced farmers, fostering knowledge transfer and resilience in the sector. Experience plays a critical role in shaping farming practices, particularly as established farmers can leverage their knowledge to adapt to emerging challenges more effectively. Global trends suggest that regions with a higher concentration of experienced farmers tend to have better production outcomes due to the utilization of historical knowledge and practiced techniques ((Issa et al., 2022). Policies should focus on capacity building for both new and seasoned farmers to ensure adaptability to climate challenges.

Table 1 Socioeconomic Characteristics of Fish Farmers

Variable	Category	Frequency	Percentage (%)
Gender	Male	140	58.3
	Female	100	41.7
Age Group (years)	20–29	60	25.0
	30–39	70	29.2
	40–49	60	25
	50–59	30	12.5
	60 and above	20	8.3
Marital Status	Single	50	20.8
	Married	150	62.5
	Divorced	20	8.3
	Widowed	20	8.3
Educational Level	No formal education	20	8.3
	Primary school	40	16.7
	Secondary school	80	33.3
	Tertiary education	100	41.7
Monthly Income from Fish Farming (₦)	Below 50,000	40	16.7
	50,000–100,000	80	33.3
	100,001–150,000	60	25
	150,001–200,000	30	12.5
	Above 200,000	30	12.5
Years in Fish Farming	Less than 1 year	20	8.3
	1–5 years	100	41.7
	6–10 years	80	33.3
	More than 10 years	40	16.7

Source: Field Survey, (2024)

3.2. Level of Financial Inclusion among Fish Farmers

3.2.1. Access to Financial Services

About 68.8% of fish farmers have access to financial services, connecting them to formal or informal institutions for loans, savings, or insurance. This access is essential for managing risks and investing in business growth (Aluge and Gbigbi, 2024). However, 31.2% lack access to such services, which limits their ability to accumulate capital and hinder productivity. The reliance on informal channels, such as money lenders, often leads to higher interest rates and fewer protections, limiting the potential for growth. Expanding financial inclusion through mobile banking and microfinance services could address these gaps and boost economic resilience.

3.2.2. Main Sources of Finance

The majority of fish farmers (33.3%) rely on informal money lenders for financial support, followed by 27.1% using cooperatives and 22.9% accessing microfinance banks. Informal lenders are attractive due to quick and flexible loans but come with risks such as high-interest rates (Adjasi and Torku, 2021). Microfinance institutions and cooperatives offer alternatives but face challenges like limited funding and inefficiencies. Only 4.2% of farmers rely on commercial

banks, reflecting the difficulties in accessing formal credit due to high collateral requirements (Okpukpara and Odurukwe et al., 2021). Policies should focus on enhancing access to formal credit for fish farmers, ensuring that microfinance and cooperative institutions can support small-scale farmers effectively.

3.2.3. Frequency of Interaction with Financial Institutions

About 37.5% of fish farmers report interacting with financial institutions on a monthly basis, while 33.3% engage with them only rarely. This indicates that although financial services are available, a significant portion of the farming community does not utilize these services consistently. The infrequent engagement may be linked to factors such as limited financial literacy or a lack of trust in formal financial systems. Many farmers may not fully understand how to navigate financial products, or they may have had negative experiences with financial institutions in the past, leading to reluctance in using these services regularly. To improve the situation, financial institutions could consider offering products that are specifically designed to meet the seasonal and cyclical needs of farmers, such as microloans or seasonal credit lines. Additionally, providing easier access through digital platforms could enhance convenience, especially in rural areas where physical access to banks may be limited. By integrating digital banking services and focusing on the unique needs of farmers, financial institutions could encourage more frequent interactions, helping to bridge the gap between farmers and formal financial services.

3.2.4. Savings Account Ownership

Approximately 60.4% of fish farmers own a savings account, suggesting that a significant portion of the farming community engages with formal financial institutions. This high level of ownership indicates a growing trust and reliance on formal savings methods. However, 39.6% of farmers still do not have savings accounts, which may be due to various factors, including a lack of trust in financial systems, the high transaction costs associated with maintaining an account, or a preference for informal savings practices, such as saving in cash or through community-based saving groups. The absence of savings accounts among nearly 40% of fish farmers restricts their ability to build financial security and access capital for reinvestment in their farming operations. To address this issue, financial institutions should work to reduce barriers to savings account ownership. This could involve lowering maintenance costs, offering more accessible account types with flexible terms, and increasing awareness of the benefits of saving within formal systems. Tailoring account features to match the income cycles and financial practices of farmers could increase the adoption of savings accounts, providing farmers with greater financial stability and access to capital for growth and development.

3.2.5. Loan Amount Received

Approximately 38.1% of farmers receive loans of under ₦50,000, while 33.3% receive loans between ₦50,000 and ₦100,000, and 28.6% obtain loans greater than ₦100,000. The majority of loans being small suggests that fish farmers tend to address immediate financial needs such as purchasing feed or repairing equipment. These smaller loans are often used to manage day-to-day operations rather than for long-term investments. The relatively low loan amounts highlight the financial constraints that many farmers face, limiting their ability to invest in larger-scale improvements or innovations within their farming operations. The limited access to larger loans points to a need for more flexible financial products that can support long-term growth. Larger loans, which could be used for investments in production capacity, new technologies, or infrastructure improvements, remain less accessible to many fish farmers. To address this gap, financial institutions could design loan products that require lower collateral, offer longer repayment terms, and are tailored to the specific needs of farmers aiming to expand or modernize their operations. Providing better access to larger loans would enable farmers to invest in their businesses and ultimately enhance their productivity and profitability.

3.2.6. Most Used Financial Services

Approximately 50% of fish farmers utilize savings services, followed by 20.8% who access loans, 12.5% who use payment services, and 10.4% who rely on insurance. The predominant use of savings services suggests that farmers prioritize setting aside funds for essential farming needs such as feed, equipment, and emergencies. This focus on saving highlights the importance placed on managing immediate financial needs and ensuring liquidity for day-to-day operations. However, the lower uptake of loans and insurance indicates that many farmers are not fully utilizing other financial services that could help them expand and protect their businesses. The relatively low engagement with loans and insurance suggests a significant gap in the use of available financial tools, which could otherwise support business growth and enhance financial resilience. Increasing access to credit and insurance could help farmers mitigate risks associated with climate change, fluctuating market prices, and other uncertainties. To address this gap, efforts to improve financial literacy and expand access to these services are crucial. By educating farmers on the benefits of loans

and insurance, financial institutions can empower them to make better use of these tools, ultimately improving their ability to cope with financial and climate-related challenges.

3.2.7. Awareness of Financial Programs

The finding that 54.2% of farmers are aware of existing financial programs while 45.8% are not highlights a significant gap in access to essential information. This gap suggests that nearly half of the farmers in the study may be missing out on financial opportunities that could help improve their farming practices. The lack of awareness could be attributed to several factors, including insufficient outreach by financial institutions, low trust in formal institutions, and communication barriers, such as language or geographic isolation. These factors hinder the effective dissemination of information about financial programs, preventing farmers from fully benefiting from the support available to them. The limited awareness of these programs also suggests that farmers are not taking full advantage of financial tools that could assist with risk management, investment in technology, or expansion of their operations. The implications of this finding are significant, as it points to a critical barrier to agricultural development: the lack of access to necessary financial resources. Without proper awareness, farmers are unable to tap into financial products like loans, grants, or insurance, which could improve their economic stability and resilience.

3.2.8. Use of Digital Financial Services

The finding that only 37.5% of fish farmers use digital financial services, such as mobile banking, while 62.5% do not, reveals a significant gap in financial inclusion, particularly in rural areas. This low adoption rate of digital financial services suggests that many farmers are unable to benefit from the conveniences and opportunities that mobile banking offers, such as easier access to credit, savings, and payment systems. The limited usage of these services is likely driven by several factors, including low digital literacy, poor internet connectivity, and the lack of smartphones among a substantial portion of the farming population. These barriers prevent farmers from accessing digital platforms that could simplify their financial management and enhance their overall productivity. The implications of this gap are far-reaching. Without access to digital financial services, farmers miss out on the efficiency, security, and flexibility that these tools offer, limiting their financial inclusion and growth potential. This situation underscores the importance of targeted investments in infrastructure, such as improving internet access and providing affordable smartphones, to enable farmers to take full advantage of mobile banking.

3.2.9. Access to Financial Literacy Training

The study revealed that 35.4% of fish farmers have received financial literacy training, while 64.6% have not. This indicates a significant gap in financial education among farmers, which could limit their ability to make informed financial decisions. Financial literacy is crucial for managing key aspects of farming finance, such as borrowing, saving, and risk management. The low percentage of farmers who have received training suggests that many are underutilizing financial products like loans, savings accounts, and insurance, which could otherwise support the growth and stability of their farming operations. Without the necessary skills to navigate these services, farmers may miss out on opportunities that could help improve their productivity and resilience. The implications of this finding are significant, as the lack of financial literacy could lead to poor financial decision-making, which may hinder farmers' ability to manage debt, optimize savings, or protect their assets with insurance. To address this issue, providing targeted financial literacy training is essential. These programs should be tailored to the specific needs of farmers, focusing on practical skills that will enable them to make better use of financial products and services. By improving financial literacy, farmers can enhance their financial management skills, making more informed decisions and ultimately improving their financial stability. This, in turn, can promote sustainable growth in the agricultural sector, enabling farmers to better manage risks and take advantage of opportunities for expansion and development.

3.2.10. Perception of Financial Inclusion's Impact on Farming

Approximately 66.7% of fish farmers believe that financial inclusion positively impacts their farming operations, highlighting a strong perception that access to financial services can lead to increased productivity, income stability, and long-term growth. This result underscores the recognition among a majority of farmers that financial inclusion plays a crucial role in improving their ability to invest in their farms, manage risks, and enhance the overall quality of their operations. The positive perception suggests that farmers are aware of the potential benefits of having access to financial services, such as loans, savings accounts, and insurance, which can support them in navigating financial challenges and boosting farm productivity. However, despite the optimistic view, 33.3% of farmers do not perceive financial inclusion as beneficial to their farming operations, which points to existing barriers in accessing and effectively utilizing financial services. These challenges could include factors such as high interest rates, inadequate financial products tailored to farmers' needs, or lack of trust in financial institutions. The implication is that while financial inclusion has significant potential, more work is needed to ensure that the benefits reach all farmers. Improving the

design of financial products, expanding infrastructure, and offering targeted financial education are essential to ensure that farmers can fully leverage financial services to improve their livelihoods. By addressing these gaps, financial inclusion can play a pivotal role in boosting the productivity and sustainability of the agricultural sector.

Table 2 Level of Financial Inclusion among Fish Farmers

Financial Inclusion Indicators	Frequency	Percentage (%)
Access to Financial Services		
Yes	165	68.80
No	75	31.20
Main sources of finance		
Commercial Banks	10	4.20
Microfinance Banks	55	22.90
Cooperatives	65	27.10
NGOs	30	12.50
Informal Money Lenders	80	33.30
Frequency of Interaction with Financial Institutions		
Daily	20	8.30
Weekly	50	20.80
Monthly	90	37.50
Rarely	80	33.30
Savings Account Ownership		
Yes	145	60.40
No	95	39.60
Loan Amount Received		
Below ₦50,000	91	37.92
₦50,000–₦100,000	80	33.33
Above ₦100,000	69	28.75
Most Used Financial Services		
Savings	120	50.00
Loans	50	20.80
Insurance	25	10.40
Payments	30	12.50
Others	15	6.30
Awareness of Financial Programs		
Yes	130	54.20
No	110	45.80
Use of Digital Financial Services (e.g., Mobile Banking)		
Yes	90	37.50
No	150	62.50

Access to Financial Literacy Training		
Yes	85	35.40
No	155	64.60
Perception of Financial Inclusion's Impact on Farming		
Yes	160	66.70
No	80	33.30

Source: Field Survey, (2024)

3.3. Climate Resilience Practices by Financial Access

Financial access is a key determinant in the successful adoption of climate resilience strategies by fish farmers. Farmers with access to credit, savings, and insurance are more likely to invest in practices that improve the sustainability and adaptability of their operations (Table 3)

3.3.1. Combine Fish Farming with Crop Farming

The integration of fish farming with crop farming is a highly effective strategy for enhancing resilience to climate change. A significant 72.9% of financially included fish farmers employ this strategy, recognizing the value of diversifying their income streams. By combining these two farming activities, farmers can optimize resource use, such as water and nutrients, and mitigate the risks associated with extreme weather events. This approach allows for better resource management, as fish pond water can be used for crop irrigation, and nutrient cycling between the two farming systems can enhance soil fertility. Financial access plays a vital role in enabling farmers to invest in the necessary infrastructure, training, and technical support needed for successful implementation. However, for farmers without financial access, the ability to integrate fish farming with crop farming is often limited. These farmers face challenges such as land constraints and insufficient capital, which prevent them from adopting integrated farming systems. Without financial resources, farmers may continue to rely on monoculture practices, which increase their vulnerability to climate variability and reduce the sustainability of their farming operations. Financial inclusion can play a critical role in overcoming these barriers by providing access to credit and technical support, enabling farmers to diversify their farming practices and enhance their climate resilience.

3.3.2. Select Climate-Resilient Fish Species

Selecting climate-resilient fish species is a commonly adopted resilience strategy among financially included fish farmers, with 87.5% of farmers opting for species such as tilapia and catfish, which are better equipped to withstand climate change-related stressors, such as temperature fluctuations and poor water quality. These species are particularly well-suited to the changing environmental conditions of aquaculture farms, enhancing productivity, sustainability, and long-term profitability. Financial resources play a critical role in enabling farmers to purchase high-quality, genetically improved fingerlings from reputable sources, thus improving their chances of success and making their farms more resilient to climate-related stresses. In contrast, farmers without financial access often rely on locally available fish breeds, which are typically lower in quality and less adaptable to changing environmental conditions. As Aladetohun et al (2024) indicate, these farmers face a greater risk of poor growth rates, disease outbreaks, and other issues associated with suboptimal fish stock. The lack of financial access limits their ability to purchase better-quality fish breeds and invest in the necessary infrastructure to ensure their success. To support these farmers, policymakers could implement financial assistance programs, such as subsidies for hatcheries or low-interest loans, to increase access to climate-resilient fish species and improve the sustainability of their operations.

3.3.3. Design Ponds with Flood/Drought Resilience Features

Designing ponds with flood and drought resilience features is essential for mitigating the impacts of climate change. Approximately 68.8% of financially included fish farmers invest in modifying their ponds by deepening them, reinforcing embankments, or installing drainage systems to withstand extreme weather events such as floods and droughts. These modifications help ensure that fish farms remain operational even under adverse weather conditions, protecting the farmers' investments and contributing to long-term sustainability. Access to financial resources allows farmers to make these crucial infrastructure investments, which might otherwise be unaffordable for those without financial support. For farmers without financial access, implementing such resilience features can be particularly challenging. Without the necessary capital, they may rely on less effective, temporary solutions, such as using manual water diversion techniques during floods. Although these methods can provide short-term relief, they do not offer the long-term security needed to protect aquaculture operations from future climate-related risks. Financial institutions

can play a critical role by offering targeted loans or grants for infrastructure projects that enhance flood and drought resilience, enabling farmers to build more robust and sustainable farming systems.

3.3.4. Use Climate-Resilient Feed

The use of climate-resilient feed is crucial for maintaining fish health and productivity under environmental stress. 79.2% of financially included farmers invest in high-quality, climate-adapted feed that supports fish growth and reduces the likelihood of disease outbreaks during periods of stress caused by climate-induced changes. These feeds are designed to help fish maintain their health despite challenges such as temperature fluctuations, changes in water quality, and the scarcity of natural food sources. Financial access allows farmers to purchase these specialized feeds, contributing to improved farm productivity and resilience. In contrast, farmers without financial access are often forced to rely on lower-quality, locally available feed, which may not meet the nutritional needs of fish during periods of climate stress. Such feed can lead to poor fish health, reduced growth rates, and lower survival rates, ultimately impacting farm productivity and profitability. Without the means to invest in high-quality feed, these farmers become more vulnerable to climate-related challenges. Financial support, including subsidies for feed purchases or low-interest loans, would help more farmers access climate-resilient feed options, improving their farm sustainability and resilience in the face of climate change.

3.3.5. Use Shade Structures (Nets, Trees) to Moderate Temperature

The use of shade structures such as nets or trees to moderate water temperature is another common resilience practice. 60.4% of financially included fish farmers employ shade structures to help maintain optimal water temperatures and reduce heat stress on fish. This practice is particularly important in regions where extreme heat can negatively affect fish health, growth, and reproduction. By reducing the direct impact of sunlight on ponds, these shade structures help stabilize water temperatures, providing a more favorable environment for fish to thrive. Financial access allows farmers to purchase or install the necessary shade structures, enhancing their ability to adapt to temperature extremes. Farmers without financial access often struggle to afford the installation of shade structures, leaving their farms more susceptible to the harmful effects of temperature fluctuations. Without shade, fish are exposed to high temperatures, which can lead to heat stress, lower survival rates, and reduced productivity. Financial inclusion enables farmers to invest in infrastructure that moderate's temperature and improves the health of their fish. Through targeted financial programs, such as loans or subsidies for shade structure installation, financial institutions can help farmers better manage temperature extremes, contributing to enhanced resilience in the face of climate change.

3.3.6. Implement Soil and Water Conservation

Soil and water conservation practices are essential for maintaining the long-term viability of fish farming operations. Approximately 52.1% of financially included fish farmers implement practices such as building terraces, planting cover crops, or installing water diversion systems to prevent soil erosion and improve water retention. These conservation measures help reduce the impact of erosion, enhance soil fertility, and ensure that water resources are used efficiently, contributing to the sustainability of farming operations. Financial access enables farmers to invest in the infrastructure and resources needed for effective soil and water conservation. Without financial resources, many farmers are unable to implement these vital conservation practices, which can lead to soil degradation, water shortages, and reduced farm productivity. These farmers may lack the capital to invest in necessary tools, equipment, or training to implement effective conservation measures. Financial institutions and governments can play a critical role by providing loans or grants specifically designed for soil and water conservation, ensuring that farmers have the resources needed to maintain healthy, productive farms that are resilient to climate change.

3.3.7. Use Early Warning Systems for Weather Monitoring

Early warning systems are essential for helping farmers make timely decisions regarding their farming practices in response to climate risks. 62.5% of financially included fish farmers use these systems to monitor weather conditions, allowing them to take preventive actions such as adjusting water levels, relocating fish, or preparing for extreme weather events like floods or droughts. These systems provide valuable information on upcoming weather changes, enabling farmers to mitigate potential risks. Financial access allows farmers to invest in the technology and systems needed to monitor weather conditions and respond proactively. Farmers without financial access are less likely to invest in early warning systems due to the high cost of purchasing or implementing the necessary technology. As a result, they may be less prepared for climate-related disruptions, which can lead to significant losses. By improving financial access and offering subsidies or low-cost loans for early warning system installations, financial institutions can help farmers improve their ability to monitor and respond to climate risks, thus enhancing their resilience to extreme weather events.

3.3.8. Build Climate-Resilient Pond Designs

Designing fish ponds with climate-resilient features is essential for protecting aquaculture operations from extreme weather events such as flooding and drought. About 72.9% of financially included fish farmers have implemented resilient pond designs, including features like raised ponds, reinforced walls, and improved water management systems. These design features are crucial in maintaining stable water levels and ensuring that ponds can withstand the stresses of extreme weather. Financial access is vital for enabling farmers to invest in these infrastructure improvements, as the high costs associated with such modifications often exceed the budgets of farmers without financial resources. For farmers lacking financial access, implementing these resilient pond designs can be prohibitively expensive, leading them to rely on low-cost, temporary measures that do not provide long-term protection. This highlights the importance of financial inclusion in enabling farmers to invest in durable infrastructure that safeguards their farms against the adverse effects of climate change. Providing targeted financial products, such as low-interest loans or grants for infrastructure projects, can help bridge this gap and improve the resilience of small-scale fish farmers.

3.3.9. Monitor Water Temperature and Quality Regularly

Monitoring water quality and temperature regularly is a critical practice for maintaining the health of fish and ensuring that farms remain productive during climate stress events. 83.3% of financially included fish farmers regularly monitor water parameters to detect any changes in temperature, pH, or dissolved oxygen levels that could affect fish health. Regular monitoring enables farmers to take corrective actions before problems escalate, thus reducing the risk of disease outbreaks and fish mortality. Financial access allows farmers to invest in the necessary equipment and technology to perform accurate and timely water quality checks, improving the overall sustainability of their operations. Farmers without financial access may struggle to afford the necessary monitoring tools and may not be able to keep up with the changing conditions in their ponds. This lack of access to modern equipment can lead to poor water management, which increases the risk of fish health issues and reduces farm productivity. Expanding access to financial services, such as loans for purchasing monitoring equipment, would allow more farmers to adopt this essential practice and ensure the long-term viability of their aquaculture operations.

3.3.10. Install Flood-Resistant Infrastructure

Installing flood-resistant infrastructure is another key resilience strategy, helping farmers safeguard their operations from the impacts of heavy rainfall and flooding. 52.1% of financially included fish farmers have invested in infrastructure such as raised ponds, concrete dikes, and overflow channels to protect their farms from flooding. These investments are essential for preventing pond erosion, waterlogging, and fish loss during extreme weather events. Financial access enables farmers to afford these infrastructure improvements, which are necessary for ensuring that farms remain operational during periods of climate stress. Research by Ogisi and Enwa (2022) reveals that few fish farmers embraced flood-resistant infrastructure solutions, primarily due to the high cost of construction. Those with financial access are more likely to invest in the establishment of raised pond structures, concrete dikes, and overflow channels designs that significantly enhance resilience against extreme weather events. This disparity illustrates the direct relationship between financial capability and the ability to protect aquaculture operations from climate vulnerabilities. For farmers without financial access, the high costs of installing flood-resistant infrastructure can prevent them from making the necessary improvements. Instead, they may rely on less effective and temporary measures, such as manual water diversion or using natural barriers, which do not provide long-term protection. To improve flood resilience, it is important for financial institutions and policymakers to offer financial products that make these infrastructure investments more accessible to small-scale fish farmers.

3.3.11. Practice Eco-Friendly Feeding Strategies

Eco-friendly feeding strategies play an important role in reducing the environmental impact of fish farming. Approximately 58.3% of financially included fish farmers practice eco-friendly feeding strategies, such as using organic or sustainable feed sources. These strategies help reduce the carbon footprint of fish farming by minimizing the use of synthetic feed ingredients and promoting more sustainable, resource-efficient practices. Financial access enables farmers to purchase high-quality, environmentally friendly feed, which supports both the health of the fish and the overall sustainability of the farm. Farmers without financial access may be forced to rely on cheaper, less sustainable feed options that contribute to environmental degradation. These feeds are often made from fishmeal or other unsustainable ingredients, which can deplete marine resources and contribute to pollution. Financial inclusion programs that provide subsidies or low-interest loans for purchasing eco-friendly feed could encourage more farmers to adopt sustainable feeding practices, reducing their environmental impact and contributing to more resilient aquaculture operations.

3.3.12. Utilize Disease Prevention Measures

Disease prevention is critical for protecting fish farms from climate-induced diseases that can cause significant losses. 89.6% of financially included fish farmers utilize disease prevention measures, such as vaccinations, biosecurity protocols, and regular health monitoring. These measures help reduce the risk of disease outbreaks, particularly those that are exacerbated by climate stressors such as temperature fluctuations and poor water quality. Financial access enables farmers to invest in the necessary technologies and treatments to prevent disease and protect their fish populations. Farmers without financial access may be unable to afford vaccines or biosecurity measures, leaving their farms vulnerable to disease outbreaks. Without the means to invest in these preventative measures, they may experience significant losses, further reducing their resilience to climate change. By improving financial access, policymakers can help small-scale farmers adopt disease prevention strategies, thereby enhancing their ability to manage climate-related risks and improving farm sustainability.

3.3.13. Participate in Cooperative Knowledge Exchange

Cooperative knowledge exchange is a valuable strategy for improving farming practices and building resilience. 70.8% of financially included fish farmers participate in cooperative networks where they share experiences, techniques, and knowledge with other farmers. These networks provide an opportunity for farmers to learn from one another and adopt best practices that enhance their climate resilience. Financial access plays a role in facilitating participation in these networks by enabling farmers to cover membership fees, travel costs, or other expenses associated with involvement. Farmers without financial access may face barriers to joining cooperative networks, limiting their ability to exchange knowledge and adopt new practices. This lack of access to peer learning opportunities can hinder their ability to innovate and improve their farming techniques. Financial inclusion initiatives that support participation in cooperative networks could help level the playing field, providing all farmers with the opportunity to learn from their peers and improve their resilience to climate change.

3.3.14. Receive Training in Climate-Smart Aquaculture

Training in climate-smart aquaculture is crucial for helping farmers adopt sustainable and resilient farming practices. About 81.3% of financially included fish farmers receive training in climate-smart aquaculture, equipping them with the knowledge and skills necessary to implement practices that are adaptable to climate change. Financial access enables farmers to afford the costs associated with these training programs, which can lead to improved farming practices and better management of climate-related risks. Farmers without financial access may not have the resources to participate in training programs, which limits their ability to implement climate-smart practices. This lack of education can result in inefficient farming techniques that increase vulnerability to climate stresses. To address this, policymakers and financial institutions should focus on expanding access to training programs for all farmers, ensuring that financial inclusion helps improve the knowledge base and resilience of small-scale fish farmers.

3.3.15. Invest in Insurance for Climate Risks

Investing in climate insurance is an effective way for fish farmers to protect their operations from climate-induced risks such as floods, diseases, and extreme weather events. Gbigbi and Ndubuokwu (2022) found that farmers with financial access are twice as likely to invest in climate insurance compared to those without financial resources. Insurance helps mitigate financial losses, enabling farmers to recover and maintain their livelihoods during climate shocks. However, insurance uptake remains low, with only 39.6% of fish farmers utilizing such products. The affordability of insurance, along with a lack of awareness and trust in providers, remains a significant barrier for many farmers. Policymakers and financial institutions should consider developing affordable microinsurance options tailored to small-scale fish farmers, helping them protect their investments and recover from climate-related losses.

3.3.16. Store Fish Products During Extreme Weather

The ability to store fish products during extreme weather events is a crucial strategy for minimizing post-harvest losses. Among farmers with financial access, 70.8% utilize modern storage methods such as cold storage facilities and solar-powered refrigeration units, which help maintain product quality and reduce losses during adverse weather conditions. These investments are particularly important for preventing spoilage and improving marketability, leading to enhanced profitability. Farmers without financial access often rely on traditional methods like drying or smoking, which are less effective during extreme climatic conditions. These methods can result in significant losses in fish quality and quantity. To encourage the use of modern storage methods, financial institutions and governments should support post-harvest financing initiatives, helping farmers access the necessary infrastructure to store fish during extreme weather events.

Table 3 Climate Resilience Strategies and Financial inclusion by Fish Farmers

Climate Resilience Strategy	Frequency	Percentage
Combine fish farming with crop farming	175	72.90
Select climate-resilient fish species	210	87.50
Design ponds with flood/drought resilience features	165	68.80
Use climate-resilient feed	190	79.20
Use shade structures (nets, trees) to moderate temperature	145	60.40
Implement soil and water conservation	125	52.10
Use early warning systems for weather monitoring	150	62.50
Build climate-resilient pond designs	175	72.90
Monitor water temperature and quality regularly	200	83.30
Install flood-resistant infrastructure	125	52.10
Practice eco-friendly feeding strategies	140	58.30
Utilize disease prevention measures	215	89.60
Participate in cooperative knowledge exchange	170	70.80
Receive training in climate-smart aquaculture	195	81.30
Develop contingency plans for extreme climate events	170	70.80
Invest in insurance for climate risks	95	39.60
Store fish products during extreme weather	170	70.80

Source: Field Survey, (2024)

3.4. Degree of Climate Resilience Strategies Utilization among Fish Farmers

The findings on the utilization of climate resilience strategies among fish farmers in Delta State, Nigeria, reveal varying degrees of implementation. The analysis, based on a 4-point Likert scale, classifies strategies into "Fully Utilized," "Moderate Utilization," and "Low Utilization." These results align with or challenge existing literature on climate resilience in aquaculture.

3.4.1. Fully Utilized Climate Resilience Strategies

The fully utilized climate resilience strategies, with a mean score of ≥ 3.0, demonstrate significant adoption among fish farmers who are able to implement these strategies effectively. These strategies include utilization of improved pond designs (Mean = 3.1), financial investments in resilience practices (Mean = 3.0), and proportion of climate-resilient fish species (Mean = 3.1). These strategies reflect the strong relationship between financial access and the ability to implement effective climate adaptation measures. Farmers with better access to financial resources are more likely to invest in infrastructure, select resilient fish species, and improve their farming practices to withstand climate challenges. Onyeneke et al. (2019) emphasize that financially stable farmers are more likely to utilize these strategies compared to their less affluent counterparts, signifying a direct relationship between economic stability and resilience against climate variability. Similarly, implementation of disease control measures (Mean = 3.1) and utilization of integrated farming systems (Mean = 3.2) are also fully utilized. These strategies indicate that farmers who are financially secure can invest in biosecurity measures and diversify their operations, which contribute to increased resilience. These fully utilized strategies highlight that when financial resources are available, farmers can implement key practices to enhance farm sustainability and productivity in the face of climate change.

3.4.2. Moderately Utilized Climate Resilience Strategies

Moderately utilized strategies, with a mean score between 2.6 and 3.0, show that these practices are recognized for their value, but there are barriers to full adoption. For example, utilization of water recycling systems (Mean = 2.9) and building and improving climate-resilient infrastructure (Mean = 2.9) have moderate utilization rates. These strategies are essential for improving resource efficiency and ensuring sustainability in aquaculture, but high initial costs and lack

of access to technology hinder their wider implementation. Mungai et al. (2020) point to financial constraints as a common barrier affecting the utilization of water conservation techniques, emphasizing a gap between awareness and practical execution Similarly, eco-friendly feeding practices utilization (Mean = 2.7) and application of training knowledge (Mean = 2.8) are moderately adopted strategies. These practices help reduce environmental impact and improve farm management, but farmers face challenges such as high feed costs and limited access to training programs, which prevent broader adoption. The utilization of ponds designed to handle extreme weather (Mean = 2.9) also falls into this category, indicating that while the strategy is crucial for resilience, the costs of infrastructure upgrades limit its widespread use. The moderate utilization of these strategies underscores the need for financial support and capacity-building initiatives to facilitate broader implementation.

3.4.3. Low Utilization Climate Resilience Strategies

Table 4 Degree of Climate Resilience Strategies Utilization

Climate Resilience Strategy	Not Utilized (n, %)	Partially Utilized (n, %)	Moderately Utilized (n, %)	Fully Utilized (n, %)	Mean Score	Utilization Level
Utilization of improved pond designs	10 (4.2%)	40 (16.7%)	100 (41.7%)	90 (37.5%)	3.1	Fully Utilized
Utilization of water recycling systems	15 (6.3%)	55 (22.9%)	110 (45.8%)	60 (25.0%)	2.9	Utilized
Financial investments in resilience practices	10 (4.2%)	45 (18.8%)	120 (50.0%)	65 (27.1%)	3	Fully Utilized
Proportion of climate-resilient fish species	8 (3.3%)	40 (16.7%)	115 (47.9%)	77 (32.1%)	3.1	Fully Utilized
Membership in climate-smart cooperatives	55 (22.9%)	80 (33.3%)	65 (27.1%)	40 (16.7%)	2.4	Low
Utilization of early warning systems	60 (25.0%)	85 (35.4%)	55 (22.9%)	40 (16.7%)	2.3	Low
Building and Improving Climate-Resilient Infrastructure	12 (5.0%)	50 (20.8%)	120 (50.0%)	58 (24.2%)	2.9	Utilized
Eco-friendly feeding practices utilization	25 (10.4%)	70 (29.2%)	100 (41.7%)	45 (18.8%)	2.7	Utilized
Upgrade of climate-resilient equipment	50 (20.8%)	80 (33.3%)	70 (29.2%)	40 (16.7%)	2.4	Low
Implementation of disease control measures	8 (3.3%)	30 (12.5%)	120 (50.0%)	82 (34.2%)	3.1	Fully Utilized
Application of training knowledge	20 (8.3%)	60 (25.0%)	110 (45.8%)	50 (20.8%)	2.8	Utilized
Ponds designed to handle extreme weather	15 (6.3%)	55 (22.9%)	110 (45.8%)	60 (25.0%)	2.9	Utilized
Utilization of integrated farming systems	5 (2.1%)	30 (12.5%)	120 (50.0%)	85 (35.4%)	3.2	Fully Utilized

Source: Field Survey, (2024) Classification: Fully Utilized (Mean ≥ 3.0)**;** Utilized (Moderate Utilization) (2.6 ≤ Mean < 3.0)**;** Low Utilization (Mean ≤ 2.5)

The low utilization strategies, with a mean score of ≤ 2.5, reflect significant barriers that prevent these strategies from being widely adopted by fish farmers. For instance, membership in climate-smart cooperatives (Mean = 2.4) and utilization of early warning systems (Mean = 2.3) exhibit low utilization. These strategies are vital for building resilience through collaboration and access to early weather information, but lack of trust in cooperatives and limited access to meteorological data prevent farmers from fully utilizing these strategies. As Mustapha et al. (2024) suggest, issues like governance problems and lack of awareness contribute to these low adoption rates. Additionally, upgrade of climate-

resilient equipment (Mean = 2.4) and external support for resilience practices (Mean = 2.3) also show low utilization, reflecting the high costs of acquiring new equipment and the dependency on external aid, which is not always consistent or reliable. These low utilization rates highlight the need for policy interventions that could reduce the barriers to adoption, such as subsidized loans or improved access to cooperative networks. By addressing these challenges, fish farmers could be better equipped to implement resilience strategies that enhance their ability to adapt to climate change.

3.5. Determinants of Financial Inclusion on the Utilization of Climate Resilience Strategies

The logistic regression model in this study explains 30.3% of the variation in climate resilience strategy utilization. With a highly significant likelihood ratio test ($\chi^2 = 78.21$, $p < 0.001$) and an overall prediction accuracy of 80.5%, the model effectively classifies farmers based on their adoption of climate resilience strategies. The log-likelihood value of -102.35 further supports the models fit, highlighting the importance of socio-economic factors in agricultural decision-making for climate adaptation.

3.5.1. Access to Credit and Utilization of Climate Resilience Strategies

Access to credit plays a crucial role in the utilization of climate resilience strategies, with individuals who have access to credit being 2.60 times more likely to adopt these strategies. Credit enables farmers to invest in climate-resilient practices such as drought-resistant crops, water management systems, and insurance against climate-related risks. This highlights the importance of financial liquidity in supporting adaptation efforts, particularly in rural areas where financial resources are limited. However, challenges such as high-interest rates and strict lending requirements can hinder access to credit (Chuba and Hitlar, 2022)). To maximize the impact of credit, supportive financial ecosystems and financial literacy training are necessary to help farmers make the most of available loans and enhance their climate resilience.

3.5.2. Bank Account Ownership and Utilization of Climate Resilience Technologies

Bank account ownership is a strong predictor of climate resilience strategy adoption, with individuals who have a bank account being 2.39 times more likely to use these strategies compared to those without one. Bank accounts enable better financial management, access to loans, and insurance, which are essential for implementing climate adaptation measures. Financial inclusion through bank accounts is particularly important for individuals in rural areas, helping them prepare for and recover from climate-related shocks (Aluge and Gbigbi 2024). However, challenges such as high transaction costs and limited financial literacy can hinder the effective use of banking services, emphasizing the need for targeted financial education and accessible digital banking platforms to improve resource utilization (Arimi et al., 2020).

3.5.3. Use of Mobile Banking and Climate Resilience

The use of mobile banking increases the likelihood of utilizing climate resilience strategies by 2.08 times. Mobile banking platforms offer a vital path to financial inclusion, particularly in rural areas where traditional banking services are limited. These platforms provide access to savings accounts, transfers, microloans, and insurance products all critical for building climate resilience. The growing use of mobile technology in developing economies creates an opportunity to enhance financial inclusion and support climate adaptation. However, challenges in digital literacy and unreliable infrastructure, such as poor connectivity, limit the effectiveness of mobile banking (Okonkwo et al., 2023). To fully harness mobile banking's potential, efforts to improve digital literacy and enhance infrastructure are needed to support farmers in leveraging these tools for climate resilience.

3.5.4. Financial Literacy Training and Utilization of Climate Resilience Strategies

Financial literacy plays a crucial role in enabling farmers to effectively manage resources, make informed decisions about investments, and utilize financial products such as savings, loans, and insurance. Individuals who have received financial literacy training are 1.82 times more likely to adopt climate resilience strategies. This training allows farmers to better navigate financial systems, facilitating long-term investment in climate-smart practices. However, financial literacy alone is not enough. It must be coupled with access to tailored financial products that meet the specific needs of farmers. Integrating financial literacy programs into agricultural extension services is vital for equipping farmers with the tools necessary for making sound financial decisions that support long-term sustainability.

3.5.5. Access to Savings/Insurance and Climate Resilience Utilization

Access to savings and insurance increases the likelihood of utilizing climate resilience strategies by 1.96 times and 1.40 times, respectively. Savings act as a financial buffer during climate-related shocks, while insurance provides protection

against losses caused by climate disasters. These financial tools are essential for helping farmers manage risks and invest in climate adaptation measures. Despite their importance, challenges such as affordability and the complexity of insurance products prevent many farmers from fully utilizing them. Financial institutions must simplify savings products and offer affordable microinsurance options to help farmers better manage risks and enhance their resilience to climate shocks.

3.5.6. Land Ownership and Utilization of Climate Resilience Strategies

Landowners are 1.54 times more likely to utilize climate resilience strategies compared to non-landowners. Land ownership motivates farmers to invest in long-term environmental sustainability through practices such as water conservation and soil management. While land ownership is important, promoting secure land tenure and cooperative land-use models can offer similar incentives for farmers who do not own land. Policies that ensure land tenure security and encourage sustainable land management practices can greatly enhance farmers' capacity to adapt to climate change and improve overall climate resilience.

3.5.7. Pond Size (Stocking Capacity) and Climate Resilience Utilization

Larger pond sizes or higher stocking capacities increase the likelihood of utilizing climate resilience strategies by 1.47 times. Larger operations tend to have more financial resources, allowing for investments in technologies such as climate-resilient fish species and improved irrigation systems. These resources help larger farms adapt to climate-related risks, improving their sustainability. However, small-scale farms also require support systems to enhance their resilience. By providing financial assistance and technical support, small-scale farmers can adopt effective climate resilience strategies, ensuring that the entire aquaculture sector is capable of withstanding climate challenges.

3.5.8. Belonging to a Cooperative and Climate Resilience Utilization

Being a member of a cooperative increases the likelihood of utilizing climate resilience strategies by 1.68 times. Cooperatives offer a platform for collective action, resource-sharing, and mutual support, which are essential for implementing climate adaptation measures. Membership in cooperatives enables farmers to access shared resources, training, and financial assistance, improving their capacity to adopt climate-smart practices. However, the effectiveness of cooperatives depends on their governance and organizational structures. Strengthening management and integrating climate-smart training can enhance their ability to support members' adaptation efforts, ultimately improving resilience within farming communities.

3.5.9. Access to Storage Facilities and Climate Resilience

Access to storage facilities increases the likelihood of utilizing climate resilience strategies by 1.37 times. Storage facilities help preserve fish products and other resources vulnerable to climate impacts, reducing post-harvest losses and allowing better resource management during periods of scarcity. However, limitations such as unreliable energy supply and inadequate infrastructure can hinder the effectiveness of these facilities. Improving storage infrastructure and ensuring reliable energy sources for cold storage systems are essential for enhancing farmers' ability to store fish and reduce financial losses during extreme weather events.

3.5.10. Gender and Climate Resilience Utilization

Women are 1.45 times more likely to utilize climate resilience strategies than men. Women play a central role in resource management, particularly in rural areas where they are responsible for food production, water management, and household welfare. Gender-sensitive approaches to climate adaptation are crucial to ensuring that women have the resources, support, and decision-making power necessary to drive climate resilience. Addressing financial access barriers, such as discriminatory lending practices and limited land rights, is essential to empowering women in agriculture and enabling their contributions to climate adaptation efforts.

3.5.11. Education Level and Climate Resilience Utilization

Higher education levels increase the likelihood of utilizing climate resilience strategies by 1.31 times. Educated individuals have a better understanding of climate change and are more likely to adopt sustainable practices. Education enables farmers to assess climate risks and choose the best adaptation strategies. To enhance resilience, educational programs should blend theoretical knowledge with hands-on training, allowing farmers to implement climate-smart practices that contribute to long-term sustainability. This combination ensures that farmers not only understand the risks but also have the skills to take proactive steps to adapt.

3.5.12. Monthly Income and Climate Resilience Utilization

Higher monthly incomes make individuals 1.60 times more likely to utilize climate resilience strategies. Wealthier individuals have more financial flexibility to invest in climate adaptation measures such as insurance, infrastructure upgrades, and new technologies. This increased financial capacity allows them to take proactive steps to mitigate climate risks. However, the emphasis should not solely be on income generation; awareness of climate risks must also be raised among higher-income households, ensuring that financial advantages are utilized effectively to implement climate adaptation strategies. A broad-based culture of adaptation across all income levels is essential for ensuring resilience in farming communities.

3.5.13. Years in Fish Farming and Climate Resilience Utilization

Each additional year spent in fish farming increases the likelihood of utilizing climate resilience strategies by 1.04 times. Experienced farmers are more likely to recognize the impacts of climate change and adopt resilience practices based on their observations of environmental changes. While experience plays a vital role in implementing climate-resilient strategies, younger farmers tend to be more open to adopting new technologies. Encouraging intergenerational knowledge exchange can help integrate traditional farming practices with modern innovations, fostering resilience across all age demographics in the aquaculture sector. This approach will ensure that both experienced and younger farmers contribute to climate adaptation efforts.

Table 5 Determinants of Financial Inclusion on the Utilization of Climate Resilience Strategies

Variable	**Coefficient (β)**	**Std. Error**	**P-Value**	**Exp(β) (OddsRatio)**	**Significance Level**
Financial Inclusion Factors					
Access to Credit	0.956	0.267	0.000***	2.602	Significant
Bank Account Ownership	0.872	0.295	0.003**	2.392	Significant
Use of Mobile Banking	0.732	0.247	0.003**	2.080	Significant
Financial Literacy Training	0.598	0.185	0.001**	1.818	Significant
Access to Savings	0.671	0.228	0.003**	1.957	Significant
Access to Insurance	0.641	0.132	0.038**	1.404	Significant
Moderating Variables					
Land Ownership	0.429	0.171	0.012**	1.536	Significant
Pond Size (Stocking Capacity)	0.387	0.177	0.029**	1.473	Significant
Belonging to a Cooperative	0.521	0.203	0.010**	1.684	Significant
Access to Storage Facilities	0.314	0.158	0.047**	1.369	Significant
Gender	0.501	0.114	0.003**	1.452	Significant
Age	0.009	0.007	0.102	1.009	Not Significant
Education Level	0.268	0.102	0.008**	1.308	Significant
Monthly Income	0.402	0.112	0.009**	1.602	Significant
Years in Fish Farming	0.142	0.018	0.002**	1.043	Significant
Model Summary					
Log-Likelihood	-102.35				
LR Chi-Square ($\chi 2$)	78.21				
Prob > Chi-Square	0.001				
Pseudo R-Square (McFadden's R^2)	0.303				
Number of Observations	240				

Overall Model Prediction Accuracy	80.50%				

Notes: $p < 0.01$ (Highly Significant **), $p < 0.05$ (Significant *), $p > 0.05$ (Not Significant); Odds ratio > 1 suggests an increased likelihood of utilizing climate resilience strategies; Odds ratio < 1 suggests a decreased likelihood of utilization.

3.6. Implications for Research and Practice

This work offers significant insights into the correlation between financial inclusion and climate resilience, thereby deepening our comprehension of how availability of financial services influences fish farming methods. The results offer vital advice for formulating targeted policies and practices that can enhance fish output via enhanced financial services. By mitigating financial obstacles and advocating resilience techniques, these policies can facilitate sustainable aquaculture advancement. The study's findings are crucial for informing future initiatives designed to improve financial inclusion and climate adaptation within the fishing sector.

4. Conclusion

This study presents persuasive evidence that financial inclusion is crucial for improving climate resilience measures among fish producers in Delta State, Nigeria. The results indicate that fish farmers who have access to financial services, including loans, savings, and insurance, are more inclined to implement climate risk management approaches, such as illness prevention, the selection of climate-resilient fish species, and the utilization of climate-resilient feed. Moreover, access to financial services enables farmers to invest in technologies like improved pond designs and integrated farming systems, thereby enhancing their adaptability to climate concerns. The study identifies multiple obstacles to extensive democratization of finance, including restricted access to official financial services, inadequate financial literacy, and dependence on informal lenders. Notwithstanding these obstacles, the relationship between financial inclusion and the implementation of climate resilience techniques is substantial, indicating that enhanced availability of financial services can significantly augment farmers' capacity to endure climate-related adversities. The key factors influencing the adoption of climate risk management approaches encompass access to credit, ownership of bank accounts, utilization of mobile banking, financial literacy education, availability of savings, access to insurance, land ownership, pond size (stocking capacity), membership in cooperatives, access to storage facilities, gender, educational attainment, monthly income, and experience in fish farming. The variables exert a statistically significant influence on the adoption of climate resilience techniques, underscoring that elements such as availability of financial services, land ownership, cooperative participation, and educational attainment are essential for advancing the implementation of climate-resilient practices. Measures that facilitate access to financial and structural resources are crucial for bolstering the resilience of fish farmers. Enhancing financial services, elevating financial literacy, and promoting cooperative frameworks will substantially bolster the sustainability and resilience of aquaculture amid climate change.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

References

[1] Adekola, S. A., Aluko, O. A., and Adeola, T. M. (2022). Gender differential among fish farmers within Ilorin metropolis, Kwara State, Nigeria. Momona Ethiopian Journal of Science, 14(2), 127-138.

[2] Adam, R. I., Njogu, L. G., Ouko, K. O., Rajaratnam, S., Adeleke, L., Ogunya, L., Akuwa, E.I., Farnworth, C.R., and Fregene, B. (2025). Unveiling gender dynamics and disparities in the aquaculture value chain: Evidence from Ogun and Delta States, Nigeria. Aquaculture International, 33(5), 1-30.

[3] Adjasi, C. K. D., and Torku, K. (2021). Financial engagement of fish farmers in West Africa: Insights from Nigeria. Journal of Agricultural Economics, 72(1), 143-157.

[4] Aladetohun, N., Oche, C., Okeoghene, C., and Barde, I. (2024). Assessment of biosecurity measures in fish farms of Udu local government area, Delta State, Nigeria. Global Journal of Fisheries Science, 6(5), 138-157.

[5] Aluge, P. O., and Gbigbi, T. M. (2024). Gender analysis of financial inclusion on poultry farmers in Delta State, Nigeria. Nigerian Journal of African Studies (NJAS), 6(3).

[6] Arimi, K., Kolayemi, M., Fatufe, O., and Joshua, A. (2020). Cowpea farmers' vulnerability and adaptation to climate change in Iddo local government area of Oyo State, Nigeria. Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi, 30(3), 601-610.

[7] Bello, S., Oyedokun, G., and Adeolu-Akande, M. (2022). Financial inclusion and gender-induced poverty in Nigeria. International Journal of Research in Business and Social Science, 10(8), 266-274.

[8] Belton, B., Little, D. C., Zhang, W., Edwards, P., Skladany, M., and Thilsted, S. H. (2023). Aquaculture's role in nutrition and food security: Contributions, opportunities, and challenges. Reviews in Fisheries Science and Aquaculture, 31(1), 1-22.

[9] Boyd, C. E., McNevin, A. A., and Davis, R. P. (2022). The contribution of fisheries and aquaculture to the global protein supply. Food security, 14(3), 805-827.

[10] Clements, J. C., and Chopin, T. (2021). Ocean acidification and marine aquaculture in North America: Potential impacts and mitigation approaches. Reviews in Aquaculture, 13(4), 1915-1939.

[11] Edeminam, V., and Abdullahi, H. (2022). The effects of financial inclusion on external debt in Africa. Journal of Global Economics and Business, 3(9), 75-94.

[12] Eze, E., and Alugbuo, J. (2021). Financial inclusion and poverty reduction in Nigeria: A survey-based analysis. GSC Advanced Research and Reviews, 7(3), 075-084.

[13] FAO. (2022). The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome, FAO.

[14] Gbigbi, T. M., and Ndubuokwu, T. (2022). Determinants of agricultural insurance patronage among crop farmers in Delta North Agricultural Zone, Delta State, Nigeria. Journal of Agriculture, Faculty of Ege University, 59(2), 235-248.

[15] Gomna, A., and Mamman, Z. (2020). Profitability analysis of fish farming in Niger state, Nigeria. International Journal of Food Science and Agriculture, 4(3), 293-300.

[16] Ibrahim, S., Omonitan, M., Aminu, R., Oyawole, F., Arowolo, A., and Ayinde, I. (2022). Adaptive capacity to climate change and food security among farm households in southwest Nigeria. Ekonomika Poljoprivrede, 69(3), 777-791.

[17] Issa, F., Aderinoye-Abdulwahab, S., and Kagbu, J. (2022). Assessment of aquaculture development programmes in Nigeria. Journal of Agricultural Extension, 26(1), 10-17.

[18] Kazeem, K., and Nurudeen, O. (2023). Economics of cage aquaculture operations in Oyan reservoir, Ogun state, Nigeria. Trends Agric. Sci, 2(3), 232-240.

[19] Khan, Y., Daraz, U., and Bojnec, Š. (2023). Enhancing food security and nutrition through social safety nets: A pathway to sustainable development. Sustainability, 15(19), 14347.

[20] Mungai, E. M., Ndiritu, S. W., and Da Silva, I. (2021). Unlocking climate finance potential for climate adaptation: Case of climate smart agricultural financing in sub-Saharan Africa. In African handbook of climate change adaptation (pp. 2063-2083). Cham: Springer International Publishing.

[21] Mustapha, S. B., Timothy, E., and Shehu, H. (2024). Emerging role of extension services in strengthening the capacity of farmers' resilience to climate change in Nigeria. Journal of Agricultural Extension, 29(1), 95-112.

[22] Ogisi, O. D., and Enwa, S. (2024). Assessing the impact of flood risk and associated factors on profitability of fish farming operations: Evidence from South-South Nigeria. Magna Scientia Advanced Research and Reviews, 11(1), 287-298.

[23] Okonkwo, O., Emayomi, D., and Joseph, A. (2023). Impact of fraud and financial crimes on the growth and development of the Nigerian economy. Direct Research Journal of Social Science and Educational Studies (Drjsses), 11(5), 80-87.

[24] Okpukpara, J. R., and Odurukwe, M. (2021). Assessing the credit risk profiles of smallholder farmers in Nigeria: Prospects for financial inclusion. Annals of Finance, 17(3), 575-596.

[25] Omeje, J., Achike, A., Arene, C., Ifejika, P., and Bankole, S. (2023). Gender analysis of wholesale smoked-fish marketing in Kainji Lake Basin, Nigeria. Agro-Science, 21(4), 28-33.

[26] Onoh, U., Erezi, E., and Clement, B. (2023). Analyzing the role of women in climate resilience building and sustainable farming practices in Nigeria. IJGEM, 9(4), 65-87.

[27] Onyeneke, R., Igberi, C., Aligbe, J., Iruo, F., Amadi, M., Iheanacho, S., … and Uwadoka, C. (2019). Climate change adaptation actions by fish farmers: Evidence from the Niger Delta region of Nigeria. Australian Journal of Agricultural and Resource Economics, 64(2), 347-375.

[28] Pham, L. V., Smith, C., and Pham, H. V. (2022). Climate-smart aquaculture practices in Vietnam: Prevalence, determinants, and impact on fish farm performance. Aquaculture, 546, 737333.

[29] Reid, G. K., Gurney-Smith, H. J., Marcogliese, D. J., Knowler, D., Benfey, T., Garber, A. F., ... and Chopin, T. (2021). Climate change and aquaculture: Considering biological response and resources. Aquaculture Environment Interactions, 11, 569-602.

[30] Segun, A. (2024). Youth migration and its resultant effect on small-scale fish farming in Southwest Nigeria. International Journal on Food Agriculture and Natural Resources, 5(2), 140-144.

[31] World Bank. (2022). Global Financial Inclusion Database. Washington, DC: World Bank.