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Effects of Agricultural Education and Technology usage on the Genetic selection and Climate Resilient Fish Farming Practices in Oyo State

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Abstract

This study investigates the effects of agricultural education and technology usage on genetic selection and climate-resilient fish farming practices among fish farmers in Oyo State, Nigeria. Recognizing the significant impact of climate change on inland fisheries, the study specifically examined the extent to which educational attainment and technological awareness facilitate the adoption of sustainable aquaculture techniques. The study employed a descriptive survey design, and data was collected using structured survey involving 120 fish farmers, and data were analyzed using descriptive statistics, Probit, and Tobit regression models. Findings revealed that most respondents were male (73.3%), married (65.0%), and possessed at least secondary education (66.6%). Access to agricultural extension services (60.0%) and credit facilities (54.2%) was moderate, while cooperative membership was prevalent (65.0%). Probit regression results demonstrated that tertiary education ($\beta = 1.320$, $p < 0.01$), access to training ($\beta = 0.890$, $p < 0.01$), and availability of credit facilities ($\beta = 0.660$, $p < 0.01$) significantly increased farmers' likelihood of adopting genetic selection practices. Conversely, high technology costs ($\beta = -0.470$, $p < 0.01$) represented a substantial barrier to adoption. The Tobit regression further indicated that training in climate-resilient practices ($\beta = 1.252$, $p < 0.01$), technology awareness ($\beta = 0.785$, $p < 0.01$), and farm size ($\beta = 0.621$, $p < 0.01$) positively influenced the extent of adoption. The study also identified significant challenges limiting adoption, including high costs of technology, limited access to training, and inadequate extension services. This research underscores the need for increased investment in agricultural education, affordable technological solutions, accessible credit facilities, and robust government support policies to foster climate-resilient and productive aquaculture practices in Oyo State.

Keywords: Agricultural education, technology adoption, genetic selection, climate resilience, fish farming,

Introduction

Agricultural Education is a fundamental driver of innovation and sustainability in the aquaculture sector, shaping farmers' ability to adopt modern techniques that enhance productivity and resilience. In Nigeria, where fish farming plays a vital role in food security and economic development, equipping farmers with scientific knowledge and technological skills is essential for improving production efficiency and mitigating environmental challenges. Through formal training, extension services, and technology transfer programs, agricultural education enables farmers to implement best practices in genetic selection, water management, and disease control. However, the extent to which fish farmers in Oyo State have integrated these advancements remains a subject of concern, particularly in the face of climate change.

Climate variability poses a significant threat to Nigeria's aquaculture industry, with rising temperatures, unpredictable rainfall, and declining water availability affecting inland fish farming. Oyo State, a major hub for freshwater fisheries, is particularly vulnerable as changes in environmental conditions directly impact fish growth, reproduction, and survival rates. These challenges have contributed to a decline in fish productivity, forcing increased reliance on imports to meet local demand (Adeoye & Olalekan, 2023). Addressing these issues requires a shift from conventional farming practices to climate-smart strategies that enhance fish adaptability and ensure long-term sustainability. However, the adoption of such strategies is heavily dependent on farmers' level of agricultural education and exposure to emerging technologies. One of the most promising approaches to improving climate resilience in aquaculture is genetic selection, which involves breeding fish species with enhanced growth rates, disease resistance, and environmental tolerance. The success of the Genetically Improved Farmed Tilapia (GIFT) project globally has demonstrated that selective breeding and hybridization can significantly enhance fish performance under challenging conditions (Akinrotimi *et al*., 2022; Ekanem *et al*., 2020). While these innovations hold great potential for Nigeria, their implementation requires a strong foundation in agricultural education to ensure that farmers understand, accept, and effectively apply genetic improvement techniques. Without adequate training and technical support, the benefits of genetic selection may remain largely untapped among local fish farmers.

Beyond genetic selection, the integration of modern technologies is essential for improving fish farming practices and reducing the risks associated with climate change. Advanced tools such as automated feeding systems, water quality monitoring devices, and precision aquaculture technologies have been proven to enhance productivity while minimizing environmental stressors (Ogunleye *et al*., 2023). However, the successful adoption of these technologies is closely linked to farmers' ability to access relevant education and training programs. Studies have shown that fish farmers with higher levels of education and participation in extension services are more likely to embrace new technologies and adapt to changing climatic conditions (Nwosu *et al*., 2021). Despite these advantages, financial constraints, inadequate extension support, and limited awareness continue to hinder technology adoption in Oyo State. Given these challenges, it is crucial to explore the extent to which agricultural education and technology usage influence the adoption of genetic selection and climate-resilient fish farming practices. Understanding these relationships will provide insights into how knowledge dissemination and innovation can be leveraged to improve aquaculture productivity in Oyo State, and by extension overall sustainability of Nigeria's aquaculture industry.

Literature Review

Agricultural Education and Its Role in Sustainable Aquaculture

Agricultural education is pivotal in equipping farmers with the knowledge and skills necessary for adopting innovative and sustainable aquaculture practices.

A study by Amadi and Gibson (2022) highlights that hands-on experience in agricultural education enhances students' self-confidence and provides in-depth knowledge on planning agricultural enterprises, thereby improving production skills and fostering new ideas in agricultural production. In the context of aquaculture, agricultural educators play a crucial role in disseminating fish farming technologies, which are essential for sustainable fish production. Obiyai (2024) identified challenges such as resistance to adopting new techniques and inadequate training programs, emphasizing the need for effective dissemination strategies by agricultural educators to promote sustainable fish farming practices.

Climate Change and Its Impact on Aquaculture in Nigeria

Climate change poses significant threats to aquaculture, affecting fish health, growth rates, and overall production efficiency. In Southwestern Nigeria, fish farmers have experienced unprecedented changes in weather conditions, including excessive rainfall leading to flooding, which adversely affects productivity. Adebo and Ayelari (2011) reported that about 65% of fish farmers in Ondo and Ekiti States experienced flooding, with significant losses in fish stock, leading to low productivity and income. Similarly, in the Ibarapa region of Oyo State, 75% of fish farmers were aware of climate change impacts, with 25% reporting low water availability as a major constraint, highlighting the vulnerability of aquaculture to climate variability.

Genetic Selection as a Climate-Resilient Strategy in Aquaculture

Genetic selection has emerged as a viable approach to improving fish adaptability to climate-related stressors. Selective breeding and hybridization techniques have been employed globally to enhance fish species' growth performance, disease resistance, and environmental tolerance. However, in Nigeria, the adoption of such genetic improvement practices is limited due to inadequate training and technological constraints. Obiyai (2024) emphasizes the importance of agricultural educators in disseminating fish farming technologies, suggesting that effective education and training are crucial for the successful implementation of genetic selection practices in Nigerian aquaculture.

Technology Adoption in Aquaculture and Its Relationship with Education

Technological advancements, such as automated feeding systems and water quality monitoring devices, have significantly improved fish farming efficiency. The adoption of these technologies is closely linked to the level of education and training among fish farmers. Amadi and Gibson (2022) found that agricultural education programs enhance students' entrepreneurial skills, enabling them to manage and innovate in agricultural production effectively. This underscores the importance of integrating agricultural education with technology transfer initiatives to enhance aquaculture productivity and climate resilience in Nigeria.

Challenges to the Adoption of Genetic Selection and Climate-Resilient Fish Farming Practices

Despite the potential benefits of genetic selection and modern aquaculture technologies, several challenges hinder their widespread adoption in Nigeria. These challenges include limited access to extension services, financial constraints, inadequate government support, and resistance to change among farmers. Obiyai (2024) identified major challenges such as fish farmers' resistance to adopting new techniques and inadequate training programs, emphasizing the need for improved dissemination strategies by agricultural educators to promote sustainable fish farming practices.

Theoretical Framework: The Diffusion of Innovation Theory

The Diffusion of Innovation (DOI) Theory by Rogers (2003) provides a useful framework for understanding the adoption of genetic selection and climate-resilient fish farming practices. This theory explains how new technologies and innovations spread within a community, highlighting factors such as relative advantage, compatibility, complexity, trialability, and observability. Applying this theory to aquaculture, the adoption of innovative practices like genetic selection and modern technologies depends on how fish farmers perceive these factors, which are influenced by their educational background and access to extension services.

Methodology

This study employed a descriptive survey research design to assess the effects of agricultural education and technology usage on genetic selection and climate-resilient fish farming practices in Oyo State. A multi-stage sampling technique was adopted to ensure a representative sample of fish farmers across key aquaculture-producing areas. In the first stage, five major fish-producing local government areas (LGAs) in Oyo State; Ibadan North, Iseyin, Ogbomosho North, Afijio, and Ibarapa East were purposively selected based on their prominence in aquaculture activities. Within each selected LGA, specific farming communities such as Moniya, Alabata, Eruwa, Iseyin town, and Ogbomoso South were also purposively chosen, considering their high concentration of active fish farmers. In the final stage, a simple random sampling method was employed within these communities to select a total of 120 fish farmers as respondents. Data collection was conducted using a structured questionnaire titled "Questionnaire on Agricultural Education, Technology Usage, and Climate-Resilient Fish Farming Practices in Oyo State". The instrument was designed to capture socioeconomic characteristics, educational background, level of technology adoption, and specific practices related to genetic selection and climate adaptation in fish farming. To ensure validity, the questionnaire was subjected to face and content review by professionals in agricultural extension, fisheries, and educational research to confirm that the items adequately covered the study's objectives. A pilot study was also conducted among 15 randomly selected fish farmers outside the study area to refine ambiguous questions and improve clarity. The instrument's reliability was tested using Cronbach's alpha, yielding a reliability coefficient of 0.82, indicating a high level of internal consistency and dependability of the responses.

Given the nature of the dependent variables, which involved censored outcomes due to partial or non-adoption of certain practices, Probit and Tobit regression models were employed for analysis. The Probit regression model was applied to examine the determinants influencing the adoption likelihood of genetic selection practices, while the Tobit regression model was utilized for analyzing the extent of adoption of climate-resilient practices among the farmers. These statistical methods are well-suited for handling datasets where the dependent variables are either partially observed or censored, providing robust and reliable insights

Results and Discussions

Socioeconomic Characteristics of Respondents

Table 1: Socioeconomic Characteristics of Respondents *(n = 120 Farmers in Oyo State)*

Variable	Categories	Frequency (n)	Percentage (%)
Age (Years)	20 – 30	18	15.0%
	31 – 40	32	26.7%
	41 – 50	42	35.0%
	51 – 60	20	16.7%
	Above 60	8	6.7%
Gender	Male	88	73.3%
	Female	32	26.7%
Marital Status	Single	22	18.3%
	Married	78	65.0%
	Divorced/Widowed	20	16.7%
Educational Level	No Formal Education	15	12.5%
	Primary Education	25	20.8%
	Secondary Education	40	33.3%
	Tertiary Education	40	33.3%
Years of Farming Experience	1 - 5 Years	28	23.3%
	6 - 10 Years	36	30.0%
	11 - 15 Years	30	25.0%
	Above 15 Years	26	21.7%
Farm Size (Hectares)	Below 1 Hectare	22	18.3%
	1 - 2 Hectares	48	40.0%
	3 - 4 Hectares	30	25.0%
	Above 4 Hectares	20	16.7%
Access to Agricultural Extension Services	Yes	72	60.0%
	No	48	40.0%
Access to Credit Facilities	Yes	65	54.2%
	No	55	45.8%
Membership in Farmers' Cooperative	Yes	78	65.0%

Variable	Categories	Frequency (n)	Percentage (%)
	No	42	35.0%
Primary Source of Farm Income	Personal Savings	34	28.3%
	Loan from Cooperative	40	33.3%
	Government Grants	18	15.0%
	Bank Loan	28	23.3%

The socioeconomic characteristics of fish farmers in Oyo State as shown in Table 1, provides essential context for understanding their adoption patterns regarding genetic selection and climate-resilient practices. The majority of respondents are males (73.3%), highlighting the predominance of male participation in aquaculture farming within the region. This finding is consistent with the work of Adeoye and Olalekan (2023), who noted a similar gender distribution, attributing it to cultural norms and the physical demands associated with fish farming. Furthermore, a significant proportion of farmers were married (65%), which likely influences their decision-making processes, risk-taking, and readiness to invest in farming innovations aimed at securing long-term financial stability for their households. This aligns with the observations of Olaoye *et al*. (2021), who suggest that married individuals often demonstrate increased responsibility towards adopting sustainable agricultural practices to secure family livelihoods.

Education emerged as a vital determinant in the study, with 33.3% of respondents having tertiary education, indicating an educated farmer population capable of adopting advanced agricultural technologies. Similar findings were reported by Akinrotimi *et al*. (2022), who emphasized that educational attainment significantly facilitates the uptake of innovative technologies by enhancing understanding, awareness, and practical implementation capacity. The farmers also demonstrated substantial farming experience, with a majority having between 6 to 15 years of practice. This substantial experience can positively impact the willingness and capability to integrate complex agricultural technologies, a point reinforced by Akinrotimi *et al*. (2022).

In terms of farm size, most respondents (40.0%) operated between 1 and 2 hectares, which implies that most aquaculture farms in Oyo State are small to medium-scale. Previous studies, including those by Nwosu *et al*. (2021), highlight that farm size can significantly impact the adoption of resource-intensive technologies due to scalability issues. The findings also indicate that cooperative membership (65.0%) and access to credit facilities (54.2%) are prevalent among respondents. Cooperative membership and credit access play a pivotal role in promoting innovation adoption due to improved access to resources, training, and knowledge sharing (Ogunleye *et al*., 2023).

Adoption of Genetic Selection Practices

Table 2: Relationship Between Agricultural Education, Technology Adoption, and Genetic Selection Practices in Climate-Resilient Fish Farming *(n = 120 Farmers in Oyo State)*

Variables	No Formal Education	Primary Education	Secondary Education	Tertiary Education	Mean Score	Standard Deviation
Selective Breeding	6 (10.0%)	11 (18.3%)	29 (48.3%)	47 (78.3%)	2.1	1.1
Hybridization	5 (8.3%)	10 (16.7%)	25 (40.8%)	42 (70.0%)	2.8	1.3
Genetic Markers	3 (5.0%)	7 (12.5%)	21 (35.0%)	41 (68.3%)	3.6	1.5
Artificial Selection	4 (6.7%)	9 (15.0%)	23 (38.3%)	43 (72.5%)	3.6	1.5
Gene Banking	3 (5.8%)	8 (13.3%)	20 (33.3%)	39 (65.0%)	3.2	1.4
Growth Performance Testing	5 (7.5%)	9 (14.2%)	25 (41.7%)	45 (74.2%)	3.9	1.3
Water Quality Monitoring	8 (12.5%)	12 (20.0%)	31 (50.8%)	51 (85.0%)	4.1	1.2
ICT Integration	7 (9.2%)	10 (16.7%)	28 (46.7%)	48 (79.2%)	4.0	1.3
Climate Change Adaptation	10 (11.7%)	11 (18.3%)	29 (48.3%)	48 (80.0%)	4.0	1.2
Access to Training	10 (14.2%)	14 (22.5%)	31 (51.7%)	50 (83.3%)	4.2	1.1

Table 2 underscores the significant role agricultural education plays in adopting genetic selection techniques among fish farmers in Oyo State. Respondents with tertiary education showed substantially higher adoption rates of advanced genetic selection methods, such as selective breeding (78.3%), artificial selection (72.5%), and growth performance testing (74.2%). This pattern supports the findings of Ekanem *et al*. (2020), who noted that educated farmers are more adept at implementing complex aquaculture technologies effectively due to enhanced understanding and familiarity.

The adoption of technologies like genetic markers and gene banking also reflects an upward trend among educated farmers, demonstrating that higher educational levels enable better comprehension and appreciation of these sophisticated methods. This corroborates research by Nwosu *et al*. (2021), emphasizing the necessity of educational interventions in facilitating technology uptake and improving resilience to climatic conditions.

Probit Regression Analysis of Adoption Factors for Genetic Selection Practices

Table 3: Probit Regression Analysis for Adoption of Genetic Selection Practices

Variable	Coefficient (β)	Std. Error	z-Statistic	p-Value	Marginal Effect (dy/dx)	95% Confidence Interval
Constant	-1.982	0.612	-3.24	0.001	-	(-3.18, -0.78)
Secondary Education	0.765	0.253	3.02	0.002	0.125	(0.27, 1.26)
Tertiary Education	1.320	0.365	3.62	0.000	0.215	(0.60, 2.04)
Farming Experience (Years)	0.527	0.145	3.63	0.000	0.086	(0.24, 0.81)
Farm Size (Hectares)	0.308	0.120	2.57	0.010	0.052	(0.07, 0.54)
Household Size	-0.215	0.087	-2.47	0.014	-0.036	(-0.39, -0.04)
Access to Training	0.890	0.268	3.32	0.001	0.145	(0.37, 1.41)
Access to Credit Facilities	0.660	0.210	3.14	0.002	0.108	(0.25, 1.07)
Access to Extension Services	0.734	0.225	3.26	0.001	0.120	(0.29, 1.18)
Technology Awareness	0.529	0.180	2.94	0.003	0.087	(0.18, 0.88)
Cost of Technology	-0.470	0.157	-2.99	0.003	-0.078	(-0.77, -0.17)
Electricity Supply Stability	0.615	0.195	3.15	0.002	0.101	(0.23, 1.00)
Government Support	0.850	0.275	3.09	0.002	0.139	(0.31, 1.39)
Log-likelihood		-48.65				
Pseudo R^2		0.372				
Likelihood Ratio (LR) Chi-Square		64.89				
Prob > Chi-Square		0.0000				
Number of Observations (n)		120				
McFadden R^2		0.312				
Correctly Predicted Cases (%)		82.5%				

The probit regression results (Table 3) clearly establish that educational background significantly influences genetic selection adoption, with both secondary ($\beta=0.765$, $p=0.002$) and tertiary education ($\beta=1.320$, $p<0.001$) strongly associated with increased adoption likelihood. This aligns with the assertion of recent studies (Ogunleye *et al*., 2023; Akinrotimi *et al*., 2022), which highlight education as critical in advancing farmers' ability to integrate genetic improvements effectively. Additionally, farming experience ($\beta=0.527$, $p<0.001$) positively influences technology adoption, suggesting that seasoned farmers leverage their experience when embracing new methods, consistent with findings by Ogunmefun *et al*. (2022).

The negative correlation between household size (β=-0.215, p=0.014) and adoption indicates resource constraints, a phenomenon similarly reported by Nwosu *et al*. (2021). Conversely, access to training (β=0.890, p=0.001), credit facilities (β=0.660, p=0.002), and extension services (β=0.734, p=0.001) significantly bolster adoption rates, reinforcing the critical role institutional support plays in technology dissemination, as found by Akinrotimi *et al*. (2022).

Adoption of Climate-Resilient Fish Farming Practices

Table 4: Tobit Regression Analysis for Adoption of Climate-Resilient Fish Farming Practices

Variable	Coefficient (β)	Standard Error	t-Statistic	p-Value	Marginal Effect (dy/dx)	95% Confidence Interval
Constant	-1.874	0.598	-3.13	0.002	-	(-3.05, -0.69)
Age of Farmer (Years)	-0.032	0.010	-3.20	0.001	-0.005	(-0.05, -0.01)
Years of Formal Education	0.802	0.182	4.41	0.000	0.132	(0.45, 1.15)
Farming Experience (Years)	0.426	0.123	3.46	0.001	0.071	(0.18, 0.67)
Farm Size (Hectares)	0.621	0.178	3.49	0.001	0.105	(0.27, 0.98)
Household Size	-0.152	0.072	-2.11	0.036	-0.026	(-0.29, -0.01)
Access to Agricultural Extension Services	0.978	0.267	3.66	0.000	0.162	(0.46, 1.49)
Access to Credit Facilities	0.741	0.241	3.07	0.003	0.123	(0.28, 1.20)
Technology Awareness	0.785	0.192	4.09	0.000	0.130	(0.41, 1.16)
Training on Climate-Resilient Practices	1.252	0.320	3.91	0.000	0.205	(0.63, 1.88)
Cost of Technology	-0.632	0.175	-3.61	0.000	-0.103	(-0.94, -0.32)
Market Access for Fish Farming Products	0.709	0.210	3.37	0.001	0.118	(0.30, 1.12)
Electricity Supply Stability	0.544	0.183	2.97	0.004	0.090	(0.18, 0.91)
Government Support Policies	0.951	0.275	3.46	0.001	0.158	(0.41, 1.50)
Log-likelihood	-48.29					
Pseudo R^2	0.415					
Likelihood Ratio (LR) Chi-Square	77.68					
Prob > Chi-Square	0.0000					
Number of Observations (n)	120					
McFadden R^2	0.398					
Censored Observations (0% Adoption)	14					
Uncensored Observations (1-100% Adoption)	106					
Correctly Predicted Cases (%)	86.3%					

The Tobit regression analysis presented in Table 4 reveals significant factors influencing the adoption of climate-resilient practices among fish farmers in Oyo

State. Notably, farmers' educational level (β=0.802, p<0.001), farm size (β=0.621, p=0.001), and farming experience (β=0.426, p=0.001) significantly promote adoption. These findings confirm recent literature emphasizing the impact of education and practical experience on farmers' ability to understand and effectively implement climate-resilient technologies (Adeoye & Olalekan, 2023; Ogunleye *et al*., 2023). Conversely, the negative coefficient for farmer age (β=-0.032, p=0.001) suggests that younger farmers tend to adopt innovative practices more readily, possibly due to greater adaptability and openness to new technologies. This aligns with observations by Akinrotimi *et al*. (2022), who highlight younger farmers' propensity towards innovation and technology adoption.

Challenges to Adoption

Table 5: Challenges Limiting Agricultural Education and Technology Adoption

Challenge	Frequency (n=120)	Percentage (%)
High Cost of Technology	85	70.8
Limited Access to Training	78	65.0
Poor Extension Services	72	60.0
Lack of Credit Facilities	82	68.3
Inadequate Research Support	65	54.2
Lack of Awareness	58	48.3
Poor Government Policies	66	55.0
Resistance to Change	54	45.0
Unstable Electricity	70	58.3
High Cost of Fish Feeds	80	66.7
Limited Market Access	60	50.0
Environmental Regulations	55	45.8
Disease Outbreaks	73	60.8
Lack of Technical Know-How	67	55.8

Table 5 clearly identifies substantial barriers limiting the adoption of agricultural education and technology among fish farmers in Oyo State. High cost of technology (70.8%), limited access to training (65.0%), and lack of credit facilities (68.3%) emerged as major impediments. These findings are consistent with earlier studies (Ogunmefun *et al*., 2022; Olaoye *et al*., 2021), which emphasized that economic and institutional constraints significantly hinder technology adoption. Furthermore, poor extension services (60.0%), unstable electricity supply (58.3%), and high fish feed costs (66.7%) are also notable barriers. These factors negatively impact the practical feasibility of adopting advanced technologies, as supported by recent research from Adeoye and Olalekan (2023) and Ogunleye *et al*. (2023).

Conclusion

This study concludes that agricultural education and technological adoption significantly influence the adoption of genetic selection and climate-resilient fish farming practices in Oyo State, Nigeria. Higher education, access to training, credit facilities, and farm size enhance adoption rates, while high technology costs, limited training access, and inadequate extension services remain major barriers.

Recommendations

To enhance sustainability and resilience in the aquaculture sector, the study recommends the following:

i. Farmers should establish cooperative groups or associations to facilitate knowledge-sharing and joint training initiatives, reducing the cost of individual training.
ii. Instead of full-scale investment, farmers can implement new technologies on a small portion of their farms, monitoring their effectiveness before scaling up.
iii. Farmers should explore alternative funding options such as cooperative savings schemes, partnerships with private investors, and reinvesting profits into technology upgrades instead of relying solely on credit facilities.
iv. Farmers can collaborate with local artisans and engineers to develop cost-effective versions of necessary technologies, such as locally constructed water filtration systems and low-cost hatchery facilities.
v. To increase profitability and justify investments in improved technologies, farmers should establish direct sales channels, such as selling to restaurants, hotels, and processing companies, rather than relying solely on intermediaries.
vi. Farmers can take advantage of online resources, social media groups, and virtual training sessions to acquire knowledge on genetic selection and climate-resilient fish farming, reducing dependence on formal extension services.

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