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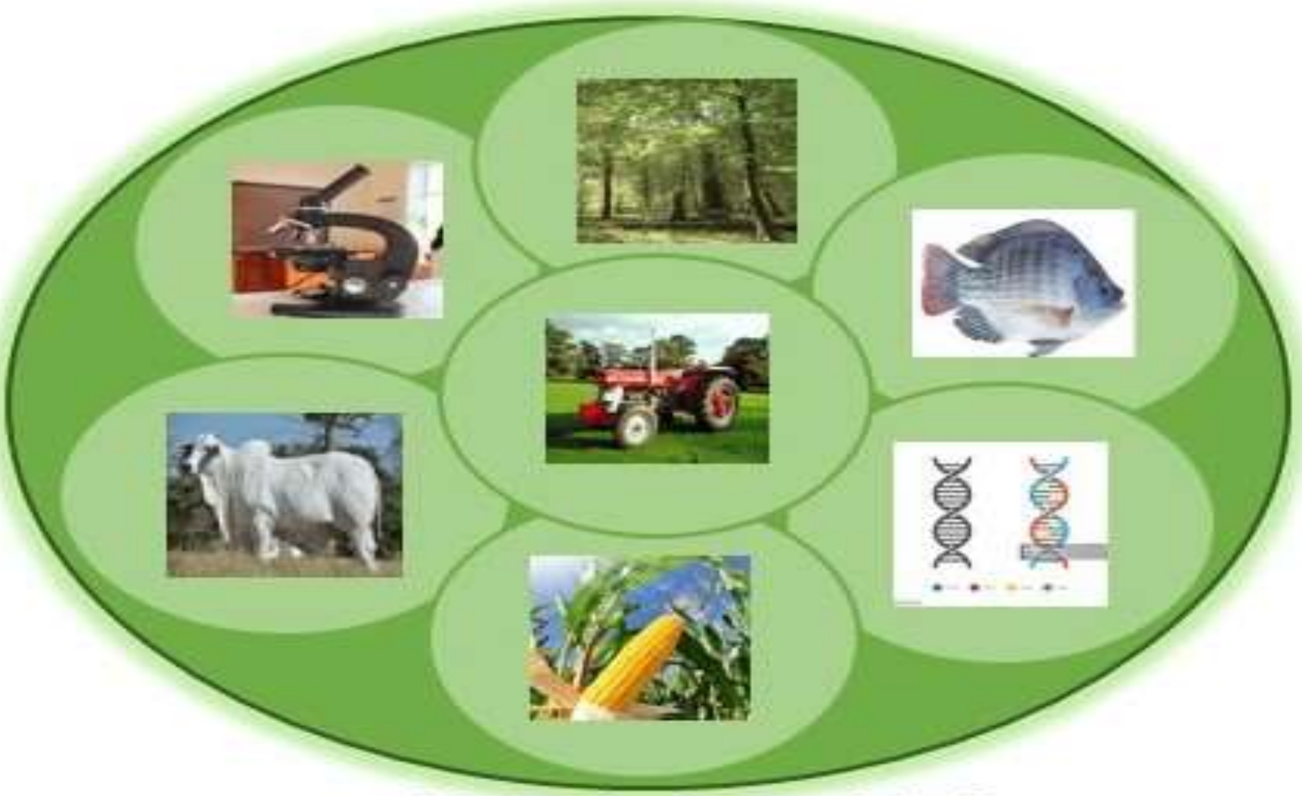

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MICROFINANCE ACCESS ENABLES SCALE BUT NOT PROFITABILITY: AN ECONOMIC AND WATER QUALITY ASSESSMENT OF FISH FARMS IN MINNA, NIGERIA

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ABSTRACT

This study assessed the economic viability and water quality conditions of microfinance-supported fish farms in Minna Metropolis, Niger State, Nigeria. A comparative survey of 30 microfinance beneficiaries and 30 non-beneficiaries evaluated differences in investment scale, profitability, and pond water quality. Results showed that microfinance access significantly increased initial capital investment (median: ₦1,250,000 vs. ₦1,000,000; p = 0.031), enabling beneficiaries to operate at a larger scale, as evidenced by higher feed expenditure. However, this expanded operational scale did not translate into statistically higher net profits (median: ₦1,163,500 vs. ₦1,171,000; p = 0.988) or improved return on investment (mean ROI: 82.5% vs. 84.1%), indicating that capital alone is insufficient to enhance profitability. Water quality parameters including pH (6.87–6.89), dissolved oxygen (6.73–7.26 mg/L), alkalinity (95–96 mg/l), and hardness (88–100 mg/l) remained within acceptable ranges for *Clariidae* fishes in both groups. While water temperatures were only marginally higher among beneficiaries (30.22°C vs. 29.96°C), their significantly elevated biological oxygen demand (BOD: 4.45 vs. 3.95 mg/l) suggests greater organic loading, likely due to intensified feeding practices. The findings suggest that while microfinance effectively alleviates capital constraints, its impact on farm profitability is mediated by non-financial factors such as management capacity, feed efficiency, and market access. Therefore, sustainable aquaculture development in the region requires integrated support that combines credit access with technical training, market linkages, and routine water quality monitoring.

Keywords**:** Microfinance; Economic viability; Water quality; Small-scale aquaculture; Fish farming; Nigeria

Introduction

Aquaculture, the controlled farming of aquatic organisms, plays a vital role in ensuring global food security and as a rapidly expanding industry, it has significant environmental and social impacts that must be carefully considered (Garlock *et al.*, 2022). Aquaculture offers a sustainable alternative to wild-caught seafood, helping to alleviate pressure on declining fish populations (Pradeepkiran, 2019), creates jobs and contributes to local economies (Beveridge, 2010; Elezuo *et al.*, 2024), it provides a reliable source of food for growing populations and allows for controlled conditions that can minimize environmental impacts compared to wild fisheries (Mavraganis *et al.*, 2020). Global aquaculture production has experienced a remarkable increase, rising from a few hundred kilograms in the early 20th century to over 170 million tonnes in 2020 which makes it the fastest-growing food production sector in the world (Verdegem *et al.*, 2023). Fish farming, a core component of aquaculture, involves the controlled raising of fish in enclosed environments for commercial purposes (Føre *et al.*, 2018). While aquaculture is essential in meeting the world's increasing demand for seafood, it faces significant challenges in ensuring its sustainability and minimizing its environmental impact (Bohnes *et al.*, 2022).

With global population growth driving an increasing demand for seafood, aquaculture is crucial for boosting fish production (Issifu *et al.*, 2022). As wild fisheries have reached their maximum sustainable yield, aquaculture represents the primary avenue for expanding seafood supply and ensuring food security (Olaoye *et al.*, 2012; Obiero *et al.*, 2019). Low-income individuals in the communities are encountering increasing obstacles in their efforts to produce and profit from fish (Mondal *et al.*, 2019). Even by the standards of developing countries, artisanal fishers and fish workers are often among the poorest people. They generally operate on a small scale and use traditional fishing practices yet new technologies and environmental requirements favour large-scale capital-intensive operations at the expense of conventional small-scale commercial fishing (Raufu *et al.*, 2009; Falola *et al.*, 2022). One of the reasons for the decline in fisheries' contributions to the economy is the lack of a formal national credit policy and the paucity of credit institutions, which can assist farmers (Pomeroy *et al.*, 2020). Only a few financial institutions provide some credit without collateral for “small” loans (Kehinde and Ogundeji, 2022).

Small-scale fisheries are often considered too risky hence most banks do not include them in their credit loan scheme (Akintola *et al.*, 2017). Credit (capital) is viewed as more than other resources such as labour, land, equipment and raw materials (Okunola, 2017). Loans have been established to affect farmers' investment behaviour and productivity (Adewale *et al.*, 2022). Despite the interest that the government and the commercial sector have shown in fish production in general, fish farming currently has a relatively low growth rate (Kehinde and Bamire, 2023). This may be caused by a lack of access to microcredit among other things. For fish firms to become more commercialized and intensive, credit is a crucial tool (Mitra *et al.*, 2019). The expansion of fish farms has been hampered by insufficient financing access (Kehinde and Bamire, 2023). However, there is presently no adequate basis to suggest that credit or loan use has a positive or negative influence on farm productivity in Nigeria (Samson and Obademi, 2018).

The economic viability of aquaculture is inextricably linked to water quality (Yusoff *et al.*, 2024). Suboptimal water quality significantly impacts fish health and productivity, thereby directly affecting profitability (Zhang *et al.*, 2025). Specifically, unfavourable water parameters induce physiological stress in fish, increasing susceptibility to infectious diseases (Okon *et al.*, 2023). Disease outbreaks result in increased mortality, reduced growth rates, and necessitate costly treatment interventions, all contributing to substantial economic losses

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(Mukaila *et al.*, 2023). Furthermore, suboptimal water quality directly impairs growth, leading to reduced yields and lower market value at harvest (Sinha and Banerjee, 2025). Extreme fluctuations or persistent poor water quality can even cause mass mortality events, resulting in complete or partial stock loss and catastrophic financial consequences (Singh *et al.*, 2024). Therefore, maintaining optimal water quality, through regular monitoring, appropriate treatment strategies and potentially proactive interventions, is crucial for mitigating these risks and ensuring the long-term economic sustainability of aquaculture operations (Baena-Navarro *et al.*, 2025). The operational costs associated with water quality management must be carefully balanced against the potential economic losses stemming from poor water quality to optimize profitability (Safina *et al.*, 2018). Therefore, the study aimed to assess the economic viability and water quality conditions of microfinance supported fish farms in Minna Metropolis, Niger State, Nigeria.

Materials and Methods

Description of the Study Area

Minna (Figure 1), the capital city of Niger State Nigeria, lies within the Southern Guinea Savanna agroecological zone. Characterized by a bimodal rainfall pattern (Ibrahim *et al.*, 2018), Minna experiences wet (April-October) and dry (November-March) seasons. The increasing urban demand for animal protein and limited employment have led to a rise in small and medium-scale aquaculture, specifically catfish farming (Sanusi, 2014). Microfinance institutions providing Credit to fish farmers make Minna suitable for studying financial access, economic performance, and water quality interplay in aquaculture (Titilayo *et al.*, 2020). Minna is located between latitudes 8°15’ – 11°15’N and longitudes 4°00’ – 7°15’E (Idris-Nda *et al.*, 2015).

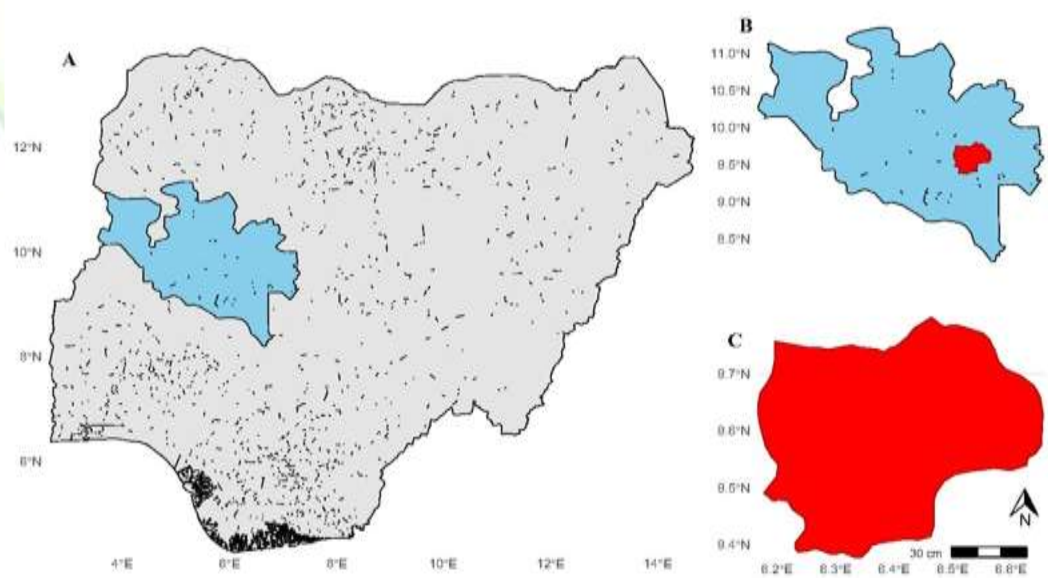

Figure 1: Maps showing the study area. (a) Nigeria, with Niger State highlighted; (b) Niger State with the location of Minna indicated; and (c) a zoomed-in map of the extent of Minna, the focal area for microfinance-supported fish farming assessment

Sampling Technique
A purposive sampling technique was used to select fish farmers who benefited from microfinance bank loans from the study areas to give 30 beneficiaries. Also, 30 non-beneficiary respondents were selected using a simple random sampling technique.

Determination of Water Quality Parameters
Water samples (n=20 per group) were collected bi-weekly for 12 weeks from aquaculture ponds/tanks of selected beneficiaries and non-beneficiaries and transported to the Water Resources, Aquaculture and Fisheries Technology (WAFT) Department laboratory at the Federal University of Technology (FUT) Minna, Niger State. Temperature was measured using mercury thermometers, with readings taken in situ after stabilization. A pH meter (Aquasearcher – AB23pH: Model) was used to determine pH by probe insertion. Electrical conductivity was measured using a conductivity meter (Jenway 4510: Model) via probe insertion. Dissolved oxygen (DO) was measured using a DO meter (Milwaukee – MW600: Model). Biological oxygen demand (BOD) was determined using a Milwaukee MW600 DO meter by measuring initial DO, incubating samples in darkness for five days, and calculating BOD as the difference between initial and final DO [BOD (mg/l) = DO (day 1) – DO (day 5)]. Alkalinity was determined by titrating 50 ml water samples with 0.02 N tetraoxosulphate (VI) acid, using methyl orange as an indicator, and calculated as Alkalinity (mg/l) = (TV × 0.02 × 50,000)/V. Water hardness was determined by titrating 50 ml water samples with 0.01 N EDTA, using Eriochrome Black T as an indicator, with ammonium chloride buffer, and calculated as Hardness (mg/l) = (TV × 0.01 × 100 × 1000)/V, as described in Association of Official Analytical Chemist (AOAC, 2005).

Data Analysis Framework
The data analysis followed a structured, multi-stage approach to examine microfinance's impact on fish farming operations comprehensively. All statistical analyses were conducted using R statistical software (version 4.x.x) with a significance level (α) 0.05 established a priori.

Data preparation and variable recoding
Prior to analysis, the dataset underwent comprehensive cleaning and variable transformation. The key preparatory step involved creating a binary classification variable for microfinance access. This transformation categorized respondents into two mutually exclusive groups: microfinance beneficiaries (BFR = 1) and non-beneficiaries (NBF = 0), enabling comparative analysis between these cohorts.

Descriptive statistics
Initial analysis employed descriptive statistics to characterize the sample and identify patterns. For continuous variables (investment costs, profits, yields), measures of central tendency (mean, median) and dispersion (standard deviation, range) were calculated for the full sample and separately for each group. Frequent distributions and percentages summarised categorical variables (Education, marital status, operational practices).

Comparative statistical analysis
Given the non-normal distribution of financial variables (confirmed through Shapiro-Wilk tests) and the presence of outliers, non-parametric statistical tests were employed for group comparisons: Wilcoxon Rank-Sum Tests (Mann-Whitney U tests) were used to compare the distributions of key continuous

variables between microfinance beneficiaries and non-beneficiaries. This approach tests the null hypothesis that the two groups have identical distributions, making it robust to non-normality and outliers. The test was applied to: Initial investment cost, Net profit, Return on investment (ROI), Survival rate (%), Harvesting yield per cycle, Operational costs (feed, fingerlings, labour), Challenges in finance access and market operations. The effect size for significant results was estimated using the Hodges-Lehmann estimator, which provides the median difference between groups.

Relationship analysis

Bivariate correlation analysis examined the relationship between investment scale and profitability, with separate correlations calculated for each group to identify differential patterns. Multiple linear regression was employed to model net profit as a function of multiple predictors: Given the skewed distribution of financial variables, logarithmic transformations were applied to investment and profit variables to normalize distributions and stabilize variance in secondary models.

Data visualization

Strategic visualization techniques were employed to enhance interpretability: Boxplots visualized the distribution of key variables (investment, profit) by microfinance status, highlighting central tendencies, variability, and outliers. Scatterplots with group stratification illustrated the relationship between investment scale and profitability, with trend lines fitted for each group. All visualizations were created using the ggplot2 package in R, employing colour coding for group differentiation and professional formatting for academic publication.

Diagnostic testing

Regression models underwent diagnostic checking for: Homoscedasticity (via residual plots), Multicollinearity (variance inflation factors), Influence of outliers (Cook's distance), Model assumptions were verified, and robust alternatives were considered when violations were detected.

Software and packages

Analysis utilized the following R packages: dplyr for data manipulation, ggplot2 for visualization, stats for statistical tests, and MASS for robust statistical methods.

Results and Discussions

Initial Investment by Microfinance Status

Microfinance beneficiaries invested significantly more (Figure 2) in their operations than non-beneficiaries, with a median initial investment of ₦1,250,000 compared to ₦1,000,000 ($p = 0.031$; Table 1). The mean investment was also notably higher (₦1,887,875 vs. ₦1,265,000), reflecting greater capital intensity among beneficiaries (Table 2). This confirms that microfinance effectively alleviates a primary constraint to aquaculture expansion access to startup or operational capital. These findings corroborate Ochonogor (2020), who reported that microfinance institutions in Nigeria play a pivotal role in promoting economic growth by enabling entrepreneurial activities among low-income populations. Similarly, Adewale *et al*. (2022) observed that credit access positively influences farmers' investment behaviour and productivity in Nigeria, particularly in capital-intensive sectors like aquaculture.

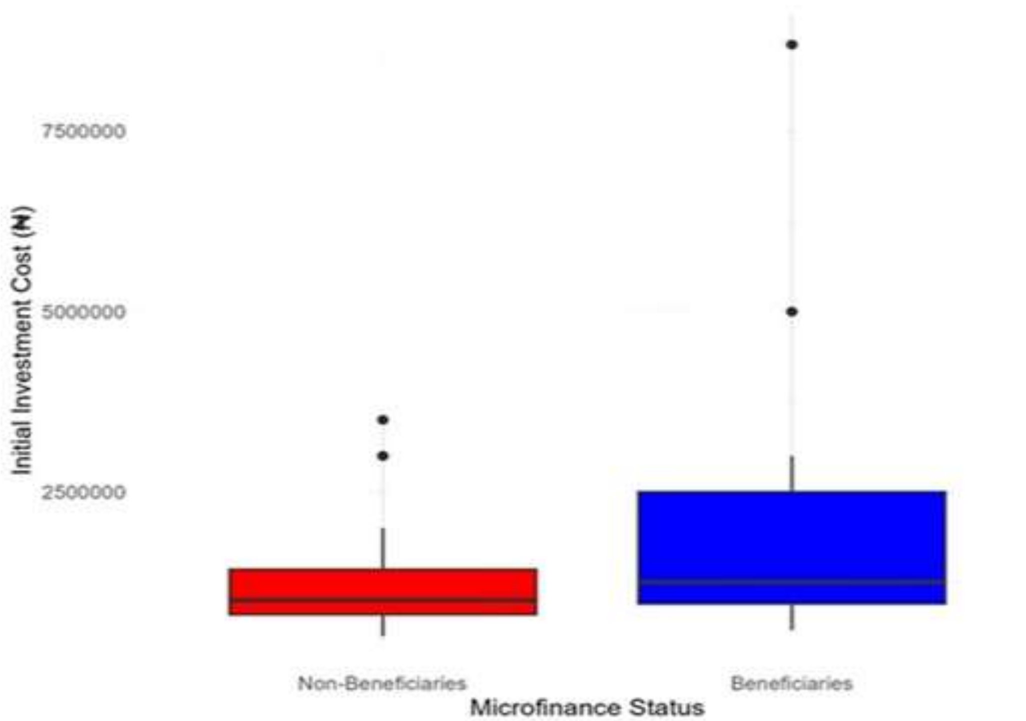

Figure 2: A Box Plot Comparing the Initial Investment Cost (₦) for Microfinance Beneficiaries Versus Non-Beneficiaries. The plot shows that beneficiaries generally have a higher and more varied initial investment cost

Table 1: Wilcoxon Rank-Sum Tests Comparing Microfinance Beneficiaries (BFR) and Non-Beneficiaries (NBF)

Variable	W Statistic	p-value	Effect Size (₦)	Significance
Initial Investment Cost	304	0.031	250,000	Yes
Net Profit	451.5	0.988	-7,500	No
Survival Rate (%)	402	0.455	~0	No
Challenges in Accessing Finance	0	< 0.001	-3.86	Yes

Net Profit and Return on Investment

Despite higher investment and operational expenditure particularly on feed (mean: ₦417,500 vs. ₦329,555), beneficiaries did not achieve statistically higher net profits (Figure 3). Median net profits were nearly identical (₦1,163,500 vs. ₦1,171,000; p = 0.988), and mean returns on investment were comparable (82.5% vs. 84.1%; Table 3). This suggests that increased scale, in the absence of improved technical or managerial efficiency, does not automatically enhance profitability. This observation aligns with Alhassan and Goedegebuure (2015), who emphasized that skills training is a critical complement to microfinance for improving the socio-economic outcomes of beneficiaries. Agbeko *et al*. (2016) further support this, noting that entrepreneurial and business management skills, not just capital are key determinants of microenterprise success. The lack of profitability gains despite higher investment underscores the importance of non-financial support systems in aquaculture development.

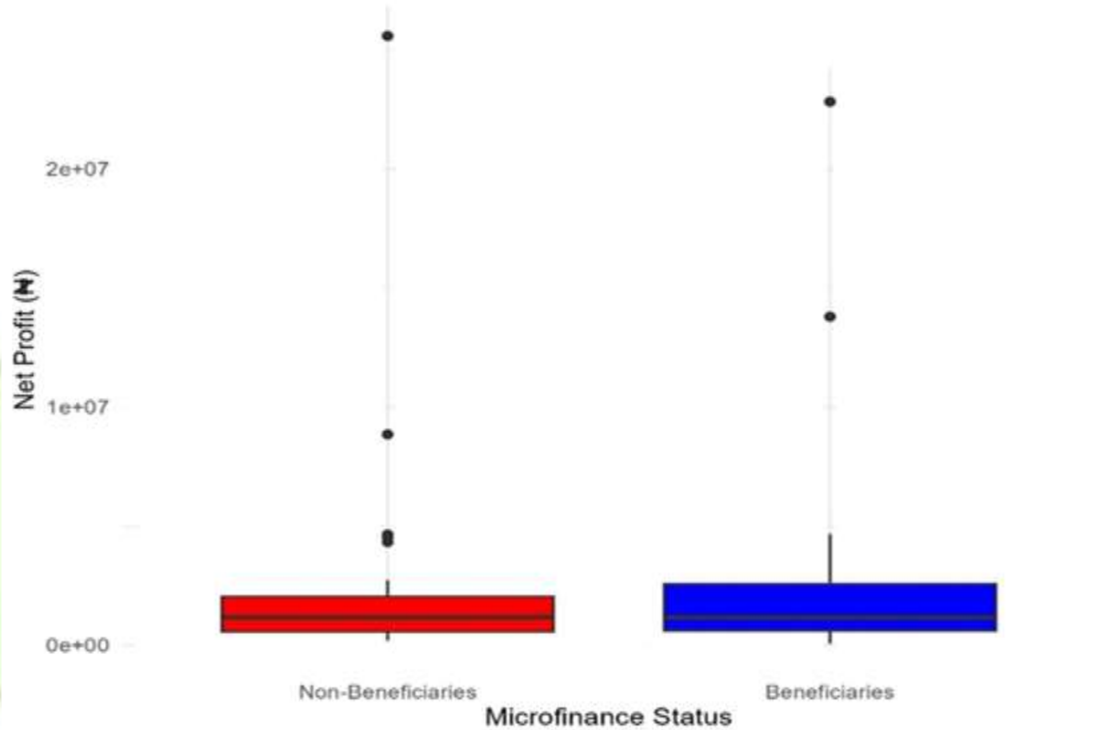

Figure 3: Comparison of Net Profit (₦) Between Microfinance Beneficiaries and Non-Beneficiaries in Fish Farming

Production Metrics and Operational Efficiency

Non-beneficiaries recorded a higher mean yield per production cycle (1,099.5 kg vs. 823.3 kg), though median yields were similar (482.5 kg vs. 500.0 kg), suggesting that a few high-performing non-beneficiary farms skewed the average upward (Figure 4). Survival rates were statistically indistinguishable (mean: 90.7% vs. 88.0%; p = 0.455), indicating comparable husbandry standards across groups. The fact that beneficiaries incurred higher feed costs yet achieved lower mean yields points to potential inefficiencies in feed conversion or stocking density management. Ragasa *et al*. (2022) reported that farmers who receive training in feed formulation achieve better feed utilization and higher income, highlighting the role of knowledge in translating inputs into outputs. Without such training, increased investment may lead to input overuse without proportional gains in productivity.

Table 3: Comparative Summary Statistics of Fish Farmers, Stratified by Microfinance Status

Category	Variable	Non-Beneficiaries (N=30)	Beneficiaries (N=30)	Implied Insight
Demographics	Tertiary Education (%)	60%	80%	Beneficiaries are more highly educated.
	Average Household Size	1.5 (Category 1)	1.8 (Between Cat 1 & 2)	Beneficiaries have slightly larger households.
Financial Performance	Net Profit (₦)	1,000,000 (median) 2,473,150 (mean) 1,171,000 (median)	1,250,000 (median) 2,566,272 (mean) 1,163,500 (median)	Similar profitability despite larger investments
	Return on Investment (%)	84.1 (mean) 87.5 (median)	82.5 (mean) 90.0 (median)	Comparable returns on capital employed
Production Metrics	Yield per Cycle (kg)	1,099.5 (mean) 482.5 (median)	823.3 (mean) 500.0 (median)	Non-beneficiaries have a higher mean yield, but a similar median yield
	Survival Rate (%)	88.0 (mean) 90.0 (median)	90.7 (mean) 90.0 (median)	Similar survival rates across both groups
Input Costs	Cost of Fish Feed (₦)	329,555 (mean) 300,000 (median)	417,500 (mean) 400,000 (median)	Beneficiaries have higher operational costs
Experience	Farming Experience (years category)	1.9 (mean) 2.0 (median)	2.6 (mean) 3.0 (median)	Beneficiaries are slightly more experienced.
Credit and Challenges	Access to Credit (%)	0%	100%	The defining difference between the groups.
	Faced High Interest Rate Challenge (%)	0%	40%	A significant portion of borrowers still cite high interest as a hurdle.

Production Metrics and Operational Efficiency

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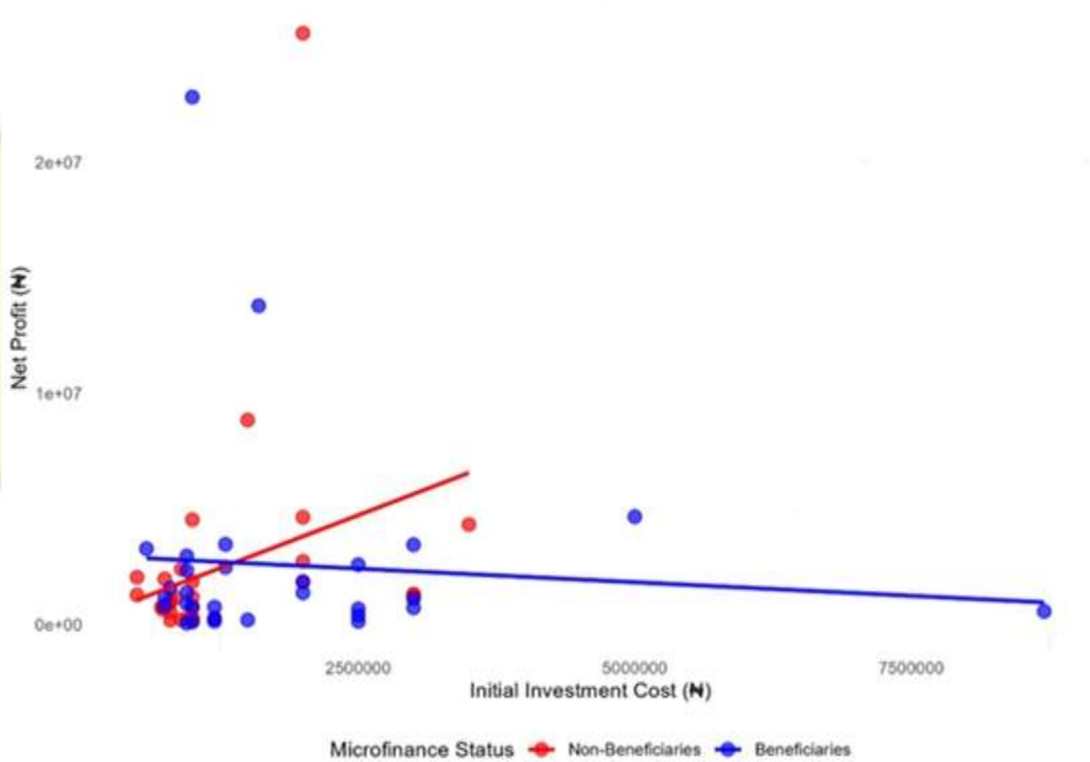

Figure 4: A Scatter Plot Illustrating the Correlation Between Initial Investment Cost and Net Profit (₦) for Two Groups

Water Quality Conditions

Water quality parameters across all farms remained within biologically acceptable ranges for *Clarias* species. Dissolved oxygen (6.73–7.26 mg/l), pH (6.87–6.89), alkalinity (95–96 mg/l), and hardness (88–100 mg/l) were optimal for fish health and growth (Table 4). However, beneficiaries exhibited significantly higher biological oxygen demand (BOD: 4.45 mg/l vs. 3.95 mg/l), likely due to intensified feeding practices without corresponding improvements in waste management or aeration. While still below the regulatory threshold of 5 mg/l (National

Environmental Standards and Regulations Enforcement Agency, NESREA), elevated BOD indicates greater organic loading, which can deplete oxygen during microbial decomposition (Ahmad *et al*., 2024). This finding is consistent with Bulbul and Mishra (2022), who noted that excessive feed input in earthen ponds often leads to oxygen stress, even when DO readings appear adequate during daytime measurements. The slightly elevated temperature in beneficiary ponds (30.22°C vs. 29.96°C) may further exacerbate metabolic stress, especially during nighttime when photosynthetic oxygen production ceases (Rahman and Arifuzzaman, 2021).

The link between water quality and economic performance is well established. Yusoff *et al*. (2024) emphasized that suboptimal water conditions directly impair fish growth and increase disease susceptibility, leading to reduced yields and higher treatment costs. Zhang *et al*. (2025) further noted that chronic exposure to marginal water quality even within "acceptable" ranges can suppress feed intake and growth rates in catfish. Thus, the higher BOD observed among beneficiaries may partially explain their inability to convert larger investments into higher profits, as poor water quality undermines feed efficiency and survival.

Synthesis: Beyond Capital Access

The study reveals a critical insight: microfinance expands operational scale but not necessarily profitability. This divergence between scale and efficiency echoes findings by Bamata and Phiri (2022), who argued that access to finance alone is insufficient for SME success without complementary capacities in management, market access, and technical know-how. In the context of Nigerian aquaculture, where smallholders often lack formal training (Sanusi, 2014), capital infusion without capacity building may lead to inefficient resource use evident in higher feed costs, elevated BOD, and stagnant profits. This supports the call by Pomeroy *et al*. (2020) for integrated financial-inclusion models that bundle credit with extension services to ensure sustainable outcomes in small-scale fisheries and aquaculture.

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Table 4: Mean Water Quality Conditions (±SE) for Beneficiary and Non-Beneficiary of Bank Loan

Parameter	Beneficiaries (Mean ± SE)	Non-Beneficiaries (Mean ± SE)	Aquatic Life Standard (General)	Standard for *Clarias* species	Compliance Status (Beneficiaries)	Compliance Status (Non-Beneficiaries)	Note
pH	6.89 ± 0.03	6.87 ± 0.02	6.5 - 9.0 (NESREA)	6.5 - 9.0 (tolerant)	Compliant	Compliant	Suitable
EC (µS/cm)	535.54 ± 19.70	546.27 ± 22.07	No direct standard, but < 1000 µS/cm for freshwater	Tolerant up to 15,000 µS/cm	Compliant	Compliant	No issue
Alk (mg/l)	96.02 ± 4.87	95.42 ± 4.87	20 - 400 mg/l (as $CaCO_3$) for general fish	Tolerant	Compliant	Compliant	Adequate
WH (mg/l)	87.73 ± 2.57	99.85 ± 6.80	50 - 400 mg/l (as CaCO3) for general fish	Tolerant	Compliant	Compliant	Adequate
Temp (°C)	30.22 ± 0.12	29.96 ± 0.11	≤ 30 °C (NESREA for discharge)	Optimal 25-30°C, tolerant up to 35°C	Marginally High	Compliant	The beneficiaries' mean is slightly above 30°C, but within tolerance
DO (mg/l)	7.26 ± 0.20	6.73 ± 0.15	≥ 5 mg/l (for aquatic life)	> 5 mg/l for growth, but can air breathe	Compliant	Compliant	Adequate
BOD (mg/l)	4.45 ± 0.15	3.95 ± 0.15	≤ 5 mg/l (for clean water)	Prefer low BOD	Compliant (but close)	Compliant	Beneficiaries' value is near the threshold, but still compliant

EC = Electrical conductivity, Alk = Alkalinity, WH = Water hardness, Temp = Temperature, DO = Dissolved oxygen, BOD = Biological oxygen demand, NESREA = National environmental standards and regulations enforcement agency

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Conclusion

This study demonstrates that while microfinance alleviates capital constraints for fish farm expansion, it does not independently increase net profitability. Beneficiary and non-beneficiary farms exhibited statistically similar profits ($p = 0.988$), suggesting that entrepreneurial skill, market access, and managerial efficiency are more critical determinants of economic success than access to credit alone. Water quality analysis revealed acceptable, albeit variable, conditions across all farms. Parameters such as dissolved oxygen and biological oxygen demand fluctuated, likely due to operational practices such as feeding intensity. Beneficiaries recorded significantly higher BOD levels (4.45 mg/l vs. 3.95 mg/l), indicating greater organic loading from intensified feed use, which may undermine feed conversion efficiency and long-term pond productivity. These findings underscore that achieving profitability in small-scale aquaculture hinges not merely on financial investment, but crucially on proficient technical management to maintain optimal environmental conditions and operational efficiency. Therefore, sustainable aquaculture development in Minna and similar contexts requires integrated support models that combine microfinance with training in water quality monitoring, feed management, and market linkages.

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