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Analyzing the financial viability and technical efficiency of aquaculture farming in Delta State, Nigeria: Lessons from cluster operations

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Abstract

This study delved into the comprehensive analysis of aquaculture farming in Delta State, specifically focusing on the financial viability and technical efficiency of cluster operations. As aquaculture plays a crucial in meeting global seafood demands, understanding the dynamics at the regional level become imperative. The study employed a multifaceted approach to assess the financial viability of aquaculture farming, technical efficiency of aquaculture production. By adopting a cluster based perspective, the research aims to unravel the intricacies of collaborative farming operations, identifying synergies that contribute to enhanced financial outcome. Insights garnered from this financial evaluation can provide stakeholders with strategic guidance for sustainable economic practices within the aquaculture sector. The research draws on a diverse set of data source, including financial records, production metrics, focus group discussions and questionnaire distributions. Statistical tools and econometric models are applied to quantify the relationships between various variables, providing a clear understanding of the factors influencing technical efficiency and financial Findings from this study showed that the price of labour, price of fish feeds and price of medicine had a significant effect on efficiency of aqua farming with a coefficient of 0.5468**,-0.7862**, -0.8896** respectively. The result of the technical efficiency , (25.0%) falls within the 0.71 - 0.8 range, indicating a high level of technical efficiency of aqua farmers. This is followed by those in the 0.31 - 0.4 and 0.51 - 0.6 ranges, each with 11.2% of farmers. In contrast. The result of the BCR showed a significant variation in profitability highlights of aqua farming operations in the study area are more financially rewarding, with a net return on investment (ROI) of 0.58. However, the technical efficiencies and productivities of aqua farmers in clusters were significantly high regardless of how biases were corrected, implying that participation in cluster group is positively related to increases in aqua farmers output.

Keywords: Technical efficiency; Financial viability; Aquaculture; Clusters; Fish farming

1. Introduction

Aquaculture and controlled cultivation of aquatic organisms has emerged as a crucial sector in addressing global food security challenges. In the context of Nigeria, and more specifically Delta State, aquaculture has gained significant attention as a potential driver of economic growth and a means to alleviate poverty. This study delves into the financial viability and technical efficiency of aquaculture farming in Delta State, drawing lessons from cluster operations that have become focal points for analysis (Enwa and Achoja 2023).

Delta state, situated in the Niger Delta region of Nigeria, possesses abundant water resources making it an ideal location for aquaculture activities. With a diverse Eco -system comprising rivers, creeks and estuaries, the government of Delta State has actively promoted aquaculture as a strategic initiative to enhance food production, generate employment and stimulate economic development. (FAO, 2022). Cluster operations wherein multiple aquaculture farms are located in close proximity have become a prevailing model in Delta State. This clustering approach is designed to foster collaboration, resource sharing and knowledge exchange among aquaculture practitioners. By analyzing the financial

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viability and technical efficiency within these clusters, valuable insights can be gleaned to inform policy decisions, improve farming practices and spur further development in the sector.

The critical aspect to explore is the financial viability of aquaculture farming in Delta State, evaluate the financial performance of aqua farmers in Delta State; analyze the technical efficiency of aquaculture practices in Delta state and benefits enjoyed as cluster aqua farmers. Factors such as initial investment, operating expenses, market fluctuations and government support programs all contribute to financial landscape of aquaculture. Understanding the economic viability of these ventures for both existing farmers and potential investors, as it informs decision –making processes and long-terms sustainability. Technical efficiency, another pivotal dimension. Refers to how effectively resources are utilized in the aquaculture production process. This encompasses factors like feed conversion ratios, water quality management practices. Examining the technical efficiency of cluster operations can uncover best practices, technological innovations and potential bottlenecks that may impede optimal production. Such insights are invaluable for enhancing productivity, reducing environmental impact, and ensuring the long-term success of aquaculture ventures in Delta State. (Achoja *et al* 2019) learning from cluster operations provides a unique opportunity to identify success stories and challenges faced by aquaculture farmers in Delta State. It allows for the examination of synergies among farms, the impact of collective bargaining power, and the role of shared infrastructure. Additionally, the analysis may reveal common constraints faced by farmers, such as limited access to finance, inadequate training, and market inefficiencies, all of which can be addressed through targeted intervention. As the study looked at the complexities of aquaculture farming in Delta State. It is essential to consider the broader implications for sustainable development. Beyond economic and technical considerations, the social and environmental dimensions of aquaculture also warrant attention. Balancing the need for increased production with environmental stewardship and community well-being is crucial for the long-term success of the aquaculture sector in Delta state.

In conclusion, the financial viability and technical efficiency of aquaculture farming in Delta State are pivotal components of a comprehensive analysis that holds implications for food security, economic development and environmental sustainability. Lessons drawn from cluster operations offers a nuanced understanding of the challenges and opportunities within the sector, guiding policy makers, researchers, and practitioners towards informed strategies that can drive the continued growth of aquaculture in Delta State and Beyond. (Baland et al, 2020).

Study Area

The study was carried out in Delta State Nigeria (figure 1). The area of study was once an integral part of the old Western Region of Nigeria. It became an autonomous entity on August 27th, 1991 after having been part of the old Midwestern state and defunct Bendel State (1976-1991). Delta State started with twelve Local Government Areas. These were split further into nineteen LGA in September 27th, 1991 and to 25 LGAs in 1997. Asaba, located at the northern end of the state, is the capital of Delta State. The study is situated in the tropical region with an average rainfall of about 266.5mm in the coastal area and 190mm in the extreme north. The vegetation varies from mangrove swamp along the coast to the evergreen forest in the middle and the savannah in the north east, which supports the aquaculture and fishing business. (http//www.deltanews.org)

1.1. Map of Delta State, Nigeria

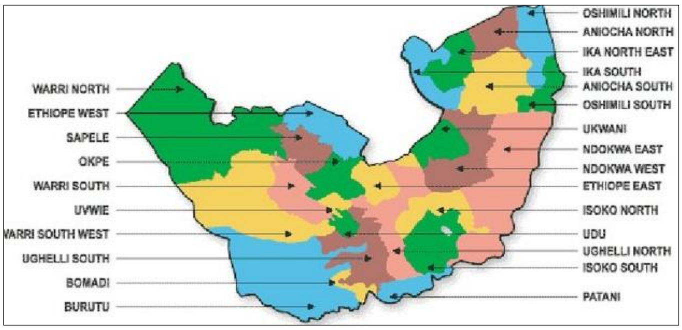

Figure 1 Map of Delta State, Nigeria

1.2. Sampling Technique

A deliberate sampling technique was used in the sample selection process. Because the aqua farmers were in the same region, this technique was deemed appropriate. Eight LGAs with aqua farms were specifically chosen for the investigation. Warri South, Oshimili South, Isoko North and South, Ukwuani, Ethiope East, Ika South, and Uvwie were the LGAs. A purposeful selection of two communities from each of the chosen villages came next. Ultimately, six aqua farmers were chosen from each of the chosen localities, for a total of ninety-six aqua farmers. Using the survey method, primary data were gathered from the sampled aqua farmers by distributing carefully crafted questionnaires. Additional data were collected through key informant interviews. Data gathered were analyzed using descriptive statistics, Benefit cost ratio and Stochastic Frontier Production Function.

Aigner and Chu (1968) established the Production Function (SFP) for technological efficiency as the capacity to generate the greatest amount of output using the available technology from a given set of inputs. Numerous industries have used this paradigm, including aquaculture, finance, agriculture, economics, and transportation (Illiyasu and Mohammed 2016). The magnitude of the aquaculture farms varies greatly. Furthermore, it is simpler to regulate the inputs used in aquaculture farming in underdeveloped nations—such as feeds, fertilizer, fingerlings, labor chemicals, and blood meal—than the output volume. As a result, a model that employs an input-oriented methodology, such as the stochastic frontier model of technical efficiency seems appropriate for this analysis. While basic descriptive statistics were used to determine the advantages aqua farmers experienced in cluster operations, the Cost Benefit Ratio (CBR) was utilized to assess the profitability level of aqua farmers in clusters.

1.3. Model Specification

1.3.1. Stochastic Frontier Production Function

$$yLnII* = \beta o + \beta 1ln\, z1 + \beta 2ln\, z2 + B3lnz3 + \beta 4\, lnz4 + \beta 5\, lnz5 + \beta 6lnz6 + - U1_{ijkl} = \mu + r_i + l_j + p_k + (rl)_{ij} + (rp)_{ik} + (lp)_{jk} + (rlp)_{ijk} + e_{ijkl} \quad \text{(Eq.1).}$$

= natural log

IIi* = gross margin computed for i th farmer (N) defined as gross margin divided by farm specific fish price Py

z1 = farm size

z2 = price of labour (N / man day)

z3 = price of fingerlings (N / kg)

z4 = flood risk (N /kg)

z5 = price of fish feeds (N /litres)

z5 = price of blood meal (N /litres)

βo= constant term

β0-β2............. β7 = Regression coefficients

The Cobb-Douglas Stochastic Frontier Production Function model used is explicitly specified as;

$l_nY = \beta_o + \beta_1 l_n\, x_1 + \beta_2 l_n\, x_2 + B_3 l_n x_3 + \beta_4\, l_n x_4 + \beta_5\, l_n x_5 + \beta_6 l_n x_6 + - U_1$

l_n = Natural Log

Y = output of fish (Kg)

x_1 = farm size (number of pond)

x_2 = labour (man day)

x_3 = quantity of feeds (kg)

x_4 = blood meal(kg)

x_5 = medicines (litres)

β_o= constant term

β_0-β_2............ β_7 = Regression coefficients

V_i = random errors which are assumed to be independent and identically distributed

having N (0, δ^2)

U_1 = Non-negative random variables associated with technical inefficiency

$(\sum\_(\tau = 0)^\wedge \cap CF\tau\ [Benefit]/ \vdash 1 + i\rfloor\tau)/((\sum\_(\tau = 0)^\wedge \cap CF\tau\ [costs])/(1 + i)\tau)$

Where:

CF= cash flow

i= Discount Rate

n=number of Period

t= Period that the cash flow occurs

2. Results and Discussion

Table 1 Efficiency of Aqua Farms in Delta State Nigeria

Variables	Cluster		
	Coefficient	**Standard error**	**t-ratio**
Production function			
Constant	0.5856**	0.2579	2.2706
farm size	-0.4126	0.7259	-0.5684
price of labour	0.5468**	0.2036	2.6856
price of fingerlings	0.2268	0.7789	0.2911
flood risk	0.3698	0.3256	1.1357
price of fish feeds	-0.7862**	0.2754	-2.8547
price of medcines	-0.8896**	0.4268	-2.0843
Inefficiency model			
Constant	-0.2036	0.1796	-1.1336
Improved flood management technique	-0.8965**	0.3622	-2.4751
Level of education	0.4825***	0.1233	3.9132
Farming experience	0.3269	0.4896	0.6676
Household size	0.4758	0.4855	0.9800
Extension contact	0.6985***	0.1203	5.8063
Credit status	-0.8255	0.4165	-1.9819
Operating within a cluster	0.1578	0.1453	1.0860

Gender	1.4673	2.3427	0.6263
Age	0.3569	0.4756	0.7504
Sigma squared	0.7842***	0.1225	6.4016
Gamma	0.7856**	0.3852	2.0394
Log likelihood function	-10.7120		

Where: *** and ** are statistically significant at 1% and 5% level respectively; (Source: Field Survey 2023)

Table 2. Presents the results of an efficiency analysis for fish farms in Delta State, Nigeria. This analysis assesses various variables' impact on the efficiency of fish farming operations.

2.1. Production Function

Numerous variables in the production function have statistically significant effects on productivity. The study reveals that there is a substantial relationship between efficiency and the cost of labor (t-ratio of 2.686) and fish feed (t-ratio of -2.855). This suggests that higher labor costs and lower fish feed prices are linked to higher efficiency.The cost of fish meals is another important factor influencing efficiency (t-ratio: -6.499). Reduced expenses for labor and fish feed have a favorable effect on efficiency. The outcome is consistent with a study by Ibeagwa et al. (2020); Emaziye and Ovhare (2021) which found that the cost of labor and fish meals are the main factors influencing production efficiency improvements. While the study did not consider whether farmers were in a cluster or were alone.

2.2. Inefficiency Model

The inefficiency model investigates the variables that contribute to inefficiency in fish farming. It finds that efficiency is significantly increased by education level (t-ratios of 3.913) and extension contact (t-ratios of 5.806). This implies that increased contact with agricultural extension services and greater educational attainment result in increased efficiency. Enhanced flood control strategies also have a major role in increased effectiveness.

The sigma-squared parameter, however, shows that inefficiency is significantly impacted. The significance of these characteristics implies that there are particular, unmeasured elements influencing the effectiveness of fish farming operations in Delta State. These metrics reveal unobservable factors contributing to inefficiency. This study is consistent with Ishaku and Abdulai's (2020) and Ureigho et al (2005) research on the productivity of shrimp producers in Lagos State, which found that productivity is influenced by the cost of labor and fish feed.

Table 2 Technical efficiency of Aqua farms in Delta State

Technical efficiency level	**(n = 93)**	
	Frequency	Percent
0.21 – 0.3	18	19.4
0.31 – 0.4	8	8.6
0.41 – 0.5	6	6.5
0.51 – 0.6	12	12.9
0.61 – 0.7	10	10.8
0.71 – 0.8	24	25.8
0.81 – 0.9	11	11.8
0.91 – 1	4	4.3
Total	93	100.0
Mean	0.58	
Minimum	0.28	
Maximum	0.91	

Standard deviation	21.627	

(Source: Field Survey 2023)

The technical proficiency levels of Nigeria's Delta State fish producers are displayed in Table 3. Technical efficiency is a metric used to quantify how well resources are used in the manufacturing process; a score of one indicates complete efficiency. The outcome demonstrates that aqua farmers in Delta State have varying degrees of technical efficiency. The majority, or 25.8%, lie between 0.71 and 0.8, which denotes comparatively high technological efficiency levels. Those in the 0.21–0.3 and 0.61–0.7 ranges, with 19.4% and 10.8%, respectively, come next. For clustered aqua farmers, the average technical efficiency is 0.58, meaning that they are using 58% of their potential efficiency on average. These results suggest that there is space for improvement in the way that people use resources among aqua farmers. This outcome is consistent with the research that Adeleke, and Omoboyeje, (2016) conducted. It was discovered that the efficiency of fish enterprises fell within 0.30 to 0.99 falling within the average efficiency rate. Implying that on the average, farmers are able to obtain 85% of their potential efficiency.

Table 3 Profitability level of Aqua farms in Delta State, Nigeria (Financial Viability)

Items	**Cluster**		
Variable cost	Quantity	Price	Amount (₦)
Fingerlings/ juveniles	6,184 fishes	43.06	266,283.04
Feeds	145 bags	12,336.56	1,788,801.20
Water			38,633.77
Fuel			62,023.91
Labour			27,034.53
Medication			70,572.42
Veterinary services			62,090.12
Miscellaneous			144,135.48
Total variable cost			2,459,574.47
Fixed cost			
Rent	1 year		75,200.92
Pond construction	6 ponds	181,685	1,090,109.59
Depreciation			54505.4795
Total fixed cost			1,219,815.99
Total cost			3,679,390.46
Revenue	4,328.8 Kg	1,212.37	5,248,107.26
Gross margin			2,788,532.79
Net revenue			1,568,716.80
Net Return on Investment			0.43

(Source: Field Survey 2023

Table 4. Presents the profitability analysis of fish farms in Delta State, Nigeria. The profitability analysis assesses the costs and revenue associated with fish farming operations.

2.3. Variable Costs

The expenses related to fingerlings and juveniles, food, water, gasoline, labor, medication, veterinary services, and other miscellaneous fees are among the variable costs of fish farming. The overall variable cost borne by aqua farmers is

₦2,459,574.47. Aqua farmers have incurred expenses in multiple areas, such as food and medication. Resource management, farming practices, and farm size are some of the elements that affect these expenses. The high expense of feeds is a reflection of the large sums of money needed for fish feeding.

2.4. Fixed Costs and Profitability

Rent, the building of a pond, and depreciation are examples of fixed costs. ₦1,219,815.99 is the entire fixed cost for aqua farmers. The number of ponds built and the rental prices are two examples of elements that could be responsible for these fixed costs.

Aqua farmers have made ₦2,788,532.79 in gross margins, which indicates their profitability. After deducting variable costs from revenue, the profit is represented by the gross margin. Nonetheless, the farmers in the research region produced a net revenue of ₦1,568,716.80 when net revenue—the profit left over after deducting both variable and fixed costs—was taken into account. This shows that aqua farmers generate more cash than they spend, which may be the result of economies of scale and more effective use of available resources. Despite this, the farmers are still profitable. Aqua farming activities yield higher financial rewards, as seen by the net return on investment (ROI) of 0.43. Citing the results of Acikgoz, (2023), who reported that the profit margin for tilapia farmers in Ogun State was ₦2,330000, while for catfish farmers, it was ₦2,280000.

Table 4 Benefits enjoyed in cluster aqua farms

Benefits enjoyed in cluster fish farms	**Delta (n = 93)**	
	Frequency	Percent
Cooperation	87	93.5
Ready market	75	80.6
Networking	78	83.9
Joint security	81	87.1
Economies of scale	77	82.8
Loan availability	80	86.0
Access to improved flood management technique	51	54.8
Mode	Cooperation	

***Note*: Multiple responses** (Source: Field Survey 2023)

The clustered aqua farmers in Delta State seem to get numerous important advantages. Interestingly, 93.5% of them mention the advantages of working together, demonstrating the farming community's strong sense of camaraderie and support for one another. Furthermore, 80.6% of respondents cite having a ready market, indicating that a sizable percentage of farmers are able to sell their produce with ease. Moreover, 87.1% of respondents state that they have benefited from cooperative security measures, highlighting the significance of security agreements within the cluster. Furthermore, 82.8% of farmers list economies of scale as a benefit, demonstrating their belief that clustering improves efficacy and affordability. Lastly, 86.0% of respondents say they have access to loans, demonstrating strong financial resource availability.

3. Conclusion

In conclusion, the analysis of the financial viability and technical efficiency of aquaculture farming in Delta State, Nigeria with a focus on cluster operations, reveals a nuanced landscape. The findings indicate that while aquaculture presents a promising economic avenue, there are challenges that need careful consideration. Financial viability is evident with positive returns reported in a well managed cluster operations. However, it is crucial to address issues such as access to capital, market fluctuations, and input costs to sustain profitability. Diversification of revenue streams, integration of technology, and targeted government interventions can enhance financial resilience. Technical Efficiency on the other hand, showcases variation among different cluster. Factors like prices of feeds, cost of labour, flood risks, cluster operations significantly impact productivity. Investment in research and development, and adoption of improved flood management techniques are recommended to boost technical efficiency across all aquaculture clusters in Delta State.

Recommendations

While the study made also made some recommendation for policy makers which include;

- Implementation of supportive financial mechanisms, such as low-interest loans and grants, to facilitate capital access to small scale aqua farmers.
- Strengthening extension services and providing technical assistance can enhance farmers capabilities, fostering sustainable and efficient aquaculture practices.
- Fostering collaboration between government agencies, research institute, and private sector stakeholders can stimulate innovation and knowledge transfer. This can lead to the development of resilient aquaculture models tailored to Delta State's unique environmental conditions.

In summary, the financial viability and technical efficiency of aquaculture in Delta State present opportunities for growth, but proactive measures are essential. By addressing financial constraints, improving technical skills, and fostering collaborative initiatives,Delta State can unlock the full potential of its aquaculture sector and contribute significantly to food security and economic development.

Compliance with ethical standards

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Disclosure of conflict of interest

I am writing to affirm that the authors of the manuscript titled "Analyzing the Financial Viability and Technical Efficiency of Aquaculture Farmers in Delta State, Nigeria: Lessons from Cluster Operations:" declare no conflicts of interest associated with the research presented in the manuscript.

Data Availability

Data is available: Sarah Enwa, sarahenwa647@delsu.edu.ng

Authors Contributions Statement

- Sarah Enwa: Conceptualization, Investigation and Formal analysis and Methodology
- Ovuevuraye Dicta Ogisi: Writing review and editing, Supervision
- Achoja Felix Odemero: Visualization, Validation and supervision

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