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BUSINESS CASE

Business Case: Sustainable Tilapia Aquaculture in the North East Region of Ghana

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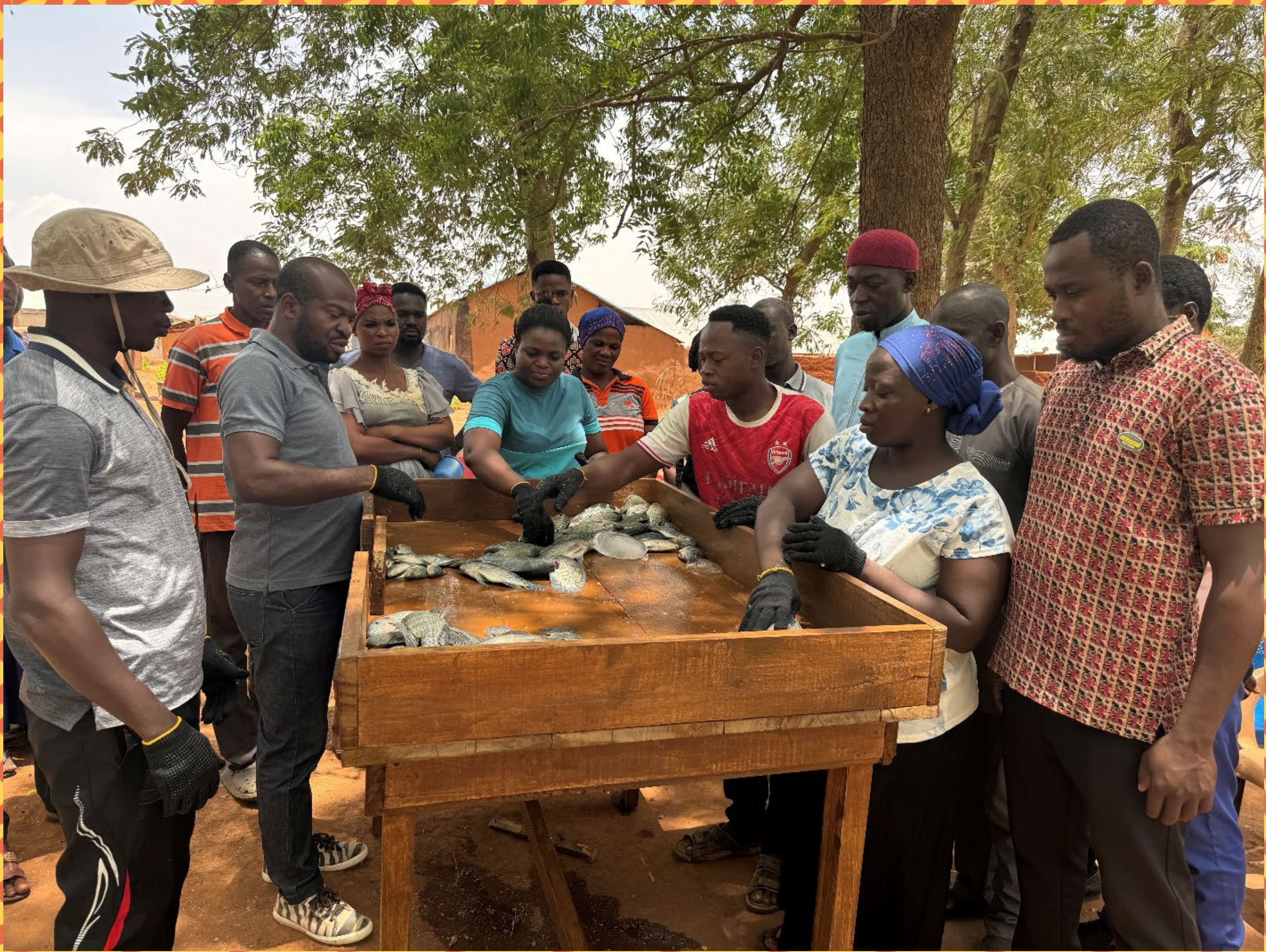

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CGIAR Sustainable Animal and Aquatic Foods Program

The Sustainable Animal and Aquatic Foods Program, launched by CGIAR, focuses on sustainably transforming animal and aquatic food systems to foster inclusive, healthy and nutrient-dense food supply chains. It aims to address the challenges faced by low- and middle-income countries, particularly in the Global South, by providing access to nutritious foods while minimizing environmental impacts and supporting inclusive livelihoods. https://www.cgiar.org/cgiar-research-porfolio-2025-2030/food-frontiers-and-security/

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Front cover photo: Aquaculture group in Nalerigu being trained by CSRI-WRI. (*photo*: Barbara van Rijn)
Back cover photo: Aquaculture cages in Tombu reservoir. (*photo*: Giulia Zane/IWMI)

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Abbreviations

Abbreviation	Full Meaning
1V1D	One Village One Dam Program
ACDEP	Association of Church-Based Development Projects
AFJ	Aquaculture for Food and Jobs
BCR	Benefit-Cost Ratio
BMC	Business Model Canvas
CBA	Cost-Benefit Analysis
CGIAR	Consultative Group on International Agricultural Research
CSIR-WRI	Council for Scientific and Industrial Research – Water Research Institute
FAO	Food and Agriculture Organization of the United Nations
FC	Fisheries Commission
GHS	Ghana Cedi
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Agency for International Cooperation)
GoG	Government of Ghana
IBM / IBMs	Inclusive Business Model(s)
IWMI	International Water Management Institute
MoFAD	Ministry of Fisheries and Aquaculture Development
NPV	Net Present Value
PPP(s)	Public-Private Partnership(s)
RAANAN	RAANAN Fish Feed (commercial feed supplier)
RESULT	Resilient Sustainable Livelihoods Transformation (ACDEP Project)
SAAF	Sustainable Animal and Aquatic Foods (CGIAR Science Program)
SDG	Sustainable Development Goal (singular use)
SDGs	Sustainable Development Goals
USD	United States Dollar

Executive Summary

Background

In Ghana's northern regions, particularly the North East Region, rural communities face persistent challenges in accessing affordable, nutritious protein sources amid declining wild capture fisheries, overfishing, habitat degradation, and seasonal water scarcity (Asiedu et al. 2023; FAO 2023). Small reservoirs, over 2,000 mapped nationwide, with more than 450 suitable for year-round use (Akpoti et al. 2025), represent a largely untapped resource for sustainable aquaculture.

Launched in 2023 under the CGIAR Initiative on Aquatic Foods (continued under the SAAF Program) through International Water Management Institute (IWMI), in partnership with Council for Scientific and Industrial Research – Water Research Institute (CSIR-WRI) and the Fisheries Commission (FC) of Ghana, four youth-led community cage culture pilots were established in Langbinsi and Nalerigu (East Mamprusi District) and Nansoni and Tombu (Chereponi District). Equipped with cages, fingerlings, feed, canoes, and training, these groups (average 13 members, 42% women) aimed to demonstrate viable tilapia production while promoting inclusive livelihoods and multi-use reservoir management.

This study analyses the resulting community-based business model using Business Model Canvas (BMC), SWOT analysis, and cost-benefit analysis (CBA) as of October 2025, following completion, or near completion for some, of the second production cycle.

Overview of Findings

The community-based cage culture model has proven to be technically feasible, socially inclusive, with some improvement and greater efficiency; it has the potential to be financially viable and environmentally sustainable. The model aligns well with Inclusive Business Models, and the SWOT and Cost-Benefit Analyses indicate a promising outlook.:

- **Business Model Canvas**: The model is robust and mature. The groups operate up to four cages, with strong partnerships with IWMI, who provided the initial funding, CSIR-WRI for continuous technical support and monitoring, FC for extension and inputs. Moving toward sustainability and independence from the CGIAR Sustainable Animal and Aquatic Food (SAAF) science program, the groups are expected to continuously partner with the FC, feed suppliers such as RAANAN feeds, community leaders for reservoir access, and commercial buyers such as restaurants and hotels as well as household buyers. Key activities include stocking fingerlings, daily feeding, water-quality monitoring, and value addition through smoking, among others are done by trained members who also transfer knowledge to other members. Value proposition centers on fresh, high-quality local tilapia sold at a premium price of USD 4.35/kg[1], compared to the national farm-gate average of USD 3.81/kg, which has better taste and hygiene compared to other fish and meat alternatives available in the communities. The customer segments include households, restaurants/hotels, and traders; their marketing channels combine direct sales at the side of the reservoir during harvest, social media, and partner linkages. Revenue streams are dominated by fish sales (fresh/smoked) plus ancillary income (fees from using tricycle for transport services, ice sales).[2] Major costs of the business are feed and labor. Currently, feed constitutes about 59% of the variable

[1] $ 1 = GHS 11.50, Bank of Ghana official rate on 16th December, 2025

[2] One of the farmer groups received a tricycle as a prize for a “Best Farmers’ Award in 2024,” this allows them to generate extra income through transport services.

cost, and labor constitutes 27%. Even if the group members who provided labor did not receive any compensation, the opportunity cost of labor is included in our calculation. Initial capital costs (cages, canoes, small equipment) were borne by the partners, and the groups do not pay for the use of the reservoirs.

- **SWOT Alignment**: The strengths of the groups include their trained members, strong teamwork, and the quality equipment that they use. Weaknesses include limited finances to expand operations, transport constraints, high feed/fingerling costs, inconsistent fingerling quality, and no salaries for group members. Opportunities existing for the groups include government support, reservoir capacity for expansion of the number of cages, market expansion to schools/urban centers, and diversified income. External threats to the groups' operations include weather-induced mortality, pollution, market fluctuations, and potential theft of fish in the water.
- **Cost-Benefit Analysis**: The cost–benefit analysis shows that while the first production cycle of the small-reservoir aquaculture pilots faced some inefficiencies, high feed costs, poor weighing, post-harvest losses, and inexperience, the model remains financially viable with strong long-term potential. After the first cycle, two of the four communities generated enough revenue to restock, but once labor and other periodic costs were included, all groups recorded losses; the best group lost USD 1,644 with all costs imputed. However, correcting for undervalued fish prices, weighing errors, and operational inefficiencies significantly improves performance: the best group shifts from a large loss to a small profit (USD 36), the average group approaches break-even, and an ideal-efficiency scenario yields USD 2,433 in profit. Long-term projections further demonstrate viability. Under a conservative selling price of USD 3.04/kg, the project records a positive Net Present Value (NPV) USD of USD 311 and a Benefit to Cost Ratio (BCR) of 1.01, indicating sustainability at break-even levels. At USD 4.35/kg, the more realistic price, the NPV rises sharply to reach USD 19,040 and the BCR improves to 1.44, confirming that with improved management, accurate weighing, reduced losses, and strengthened market access, small-reservoir aquaculture can become a strongly profitable and scalable livelihood model for Northern Ghana.

Conclusion

The study demonstrates that community-based cage aquaculture in the North East Region, piloted under the CGIAR Initiative on Aquatic Foods and SAAF programs, offers a viable, inclusive, and nutrition-sensitive livelihood model. While the first production cycle revealed short-term losses driven by high input costs, operational inefficiencies, and inconsistent market pricing, the Business Model Canvas, SWOT, and cost–benefit analyses coherently show strong long-term potential. Revenues reached up to USD 3,647 for the best-performing group, and ideal-efficiency scenarios point to profitability, youth employment, and improved protein access. The model aligns with Ghana's National Aquaculture Development Plan (2024–2028) and provides a scalable pathway for inclusive and low-emission growth.

Recommendations

Scaling this model requires policy incentives to reduce production costs (e.g., support for local feed and fingerling production), stronger infrastructure to cut post-harvest losses, and enforcement against reservoir pollution. Continued technical training, digital extension, and cooperative-based procurement will improve efficiency and reduce risks. Future research should assess long-term livelihood impacts, test climate-resilient practices, and model scalable operations. Strengthening the Integrated Business Model (IBM) to minimize current challenges and leverage emerging opportunities will enhance sustainability and investment readiness.

Introduction

In rural communities in Ghana and more especially those in the five northern regions, access to affordable and nutritious protein sources such as fish remains a significant challenge (Asiedu et al. 2023). At the same time, Ghana's inland capture fisheries have experienced a steady decline due to pressures such as overfishing, habitat degradation, and reduced natural fish stocks. This decline in the availability of naturally occurring fish further threatens food and nutrition security as the country works toward achieving the Sustainable Development Goals (SDGs) by 2030 (United Nations 2015).

Capture fisheries have become increasingly unreliable, further limiting access to fish. (FAO 2023; World Bank 2023). In the northern part of the country, the scarcity of perennial rivers exacerbates the problem, as many water bodies dry during the long dry season, making year-round fishing nearly impossible (Annor 2023).

To address these challenges, aquaculture presents a viable alternative. However, unlike the southern regions of Ghana, where river-based aquaculture is more feasible, the northern regions lack consistent water sources. Small reservoirs constructed across northern Ghana offer opportunities for aquaculture, pe (Akpoti et al. 2025; Annor 2023; Venot et al. 2011). while some of these reservoirs experience seasonal drying, many retain water throughout the year and hold untapped potential for aquaculture development (Akpoti et al. 2025).

In 2023, IWMI launched four aquaculture pilot projects in the North East Region under the CGIAR Initiative on Aquatic Foods to test community-based cage culture (CGIAR 2025; Zane, et al. 2024a). These pilots, located in Langbinsi and Nalerigu in the East Mamprusi District, and Nansoni and Tombu in the Chereponi District, aimed to enhance the productive use of water resources and improve access to fish protein in rural communities.

This study presents findings from the four pilots, focusing on the business case for sustainable tilapia aquaculture. It analyses the existing community-based cage culture model using tools such as the Business Model Canvas, SWOT analysis and Cost-Benefit analysis, and assesses its viability, scalability, and potential for replication in similar contexts.

The primary objective of this study is to assess the viability and sustainability of the community-based cage culture model implemented in the North East Region Reservoir under the CGIAR Initiative on Aquatic Foods through IWMI.

Specifically, the study aims to:

- **Document the business model** used in the pilot, including its structure, operations, and value proposition.
- **Evaluate the financial feasibility** of the model for smallholder and community-level aquaculture.
- **Identify key constraints and enabling factors** that influence the success and scalability of the model.
- **Apply analytical tools** such as the Lean Business Model Canvas and SWOT analysis to assess the model's strengths, weaknesses, opportunities, and threats.
- **Generate insights** to inform future aquaculture interventions in similar reservoir-based contexts across Northern Ghana.

This report is structured in six sections; The second part focuses on a review of the existing literature in the area of aquaculture in Northern Ghana, the evaluation of Inclusive Business Models and their application in agriculture and aquaculture, as well as situating it in the Northern Ghana Context.

The third section describes the methods employed in the study, the use of field visits, key informant interviews, Business Model Canvas, the SWOT framework, and cost-benefit analysis. The next section, Results and Findings, presents a detailed assessment of the four community-based aquaculture businesses. This includes business descriptions, analysis using the Business Model Canvas, cost–benefit analyses, and a SWOT evaluation.

The discussion section interprets these findings in relation to inclusive business principles and the operational realities of the pilot groups. It also highlights key risks and outlines potential mitigation strategies.

The report concludes with conclusions and recommendations, summarizing the main insights and proposing actionable steps to strengthen the sustainability, profitability, and scalability of small-reservoir tilapia aquaculture in the North East Region of Ghana.

Context and Literature Review

Aquaculture Context in Northern Ghana

Aquaculture development in Northern Ghana represents a critical opportunity for addressing food insecurity, unemployment, and rural poverty, though the sector remains in its infancy relative to more established practices in the southern parts of the country (Zane, et al. 2024a). The northern regions, encompassing Northern, North East, Savannah, Upper East, and Upper West, are characterized by semi-arid conditions, seasonal rainfall, and limited infrastructure, contrasting with the south's perennial water sources like Volta Lake that enable large-scale cage and pond systems (FAO 2025). National aquaculture output reached approximately 89,375 tons in 2021, but the north's contribution is minor, primarily through small-scale, pond, concrete or poly tank-based systems focused on Nile tilapia (Oreochromis niloticus) and African catfish (Clarias gariepinus) (Mapedza et al. 2024). Growth in the sector is driven by escalating fish protein demand, Ghana's per capita consumption is around 26 kg annually, surpassing the global average of 20 kg, amid depleting capture fisheries due to overexploitation and climate effects (Mapedza et al. 2024). Community-based models predominate, often integrated with agriculture, and are supported by donor-funded projects introducing low-cost technologies under the Ministry of Fisheries and Aquaculture Development (MoFAD) strategies for poverty alleviation and livelihood diversification (MoFAD 2012; Zane, et al. 2024b).

Small reservoirs serve as foundational assets for aquaculture in this context, originally constructed for irrigation, domestic supply, and livestock under various initiatives by communities, NGOs, donor agencies, and the government. Recently, the Government of Ghana’s One Village One Dam (1V1D) program created over 300 such structures in the north (Mapedza et al. 2024). This added to the over 2,000 small reservoirs already existing in the areas (Akpoti et al. 2025). These dams, ranging from small dugouts to larger ones like Tono (1,860 ha), provide relatively stable water in areas without perennial rivers, with many sustaining cage culture year-round despite partial dry-season evaporation (Zane et al. 2024b). The CGIAR Initiative on Aquatic Foods, led by IWMI in partnership with the CSIR-WRI and the FC, piloted aquaculture in four North-East reservoirs (Langbinsi, Nalerigu, Nansoni, and Tombu), equipping youth-led groups with cages, fingerlings, and training (Zane et al. 2024a; Zane et al. 2024). By September-October 2024, initial harvests yielded marketable tilapia, generating income for over 50 participants (42% percent women) in the four communities (Zane et al. 2024), which was reinvested into the second cycle of production. Following this, the MoFAD planned to scale it up through their Aquaculture for Food and Jobs (AFJ).

Similar initiatives elsewhere in Ghana highlight the model's broader applicability: the Government of Ghana-German Agency for International Cooperation (GoG-GIZ) Aquapreneurship Project in the Western Region promotes sustainable cage and pond aquaculture for job creation and food security, while the RESULT Aquaculture Project in the Upper East Region, implemented by the Association of Church-Based Development Projects (ACDEP), integrates tilapia farming with resilient livelihoods for smallholder farmers[3].

Despite this great leap, aquaculture in Northern Ghana faces multifaceted challenges requiring adaptive strategies. Water variability in many of the small reservoirs, including seasonal drying, siltation, and high turbidity during the rainy season, reduces reservoir reliability and can cause fish mortality rates up to 50% when the fingerlings are still young as seen in the first cycle of the IWMI-led project in the pilot sites (Mapedza et al. 2024). Technical capacity is limited, with smallholder farmers, often subsistence-oriented, lacking training in feed management, disease control, and best practices, compounded by sparse extension services (Buchanan 2016; Mapedza et al. 2024). Access to inputs remains a bottleneck: quality fingerlings and feeds are scarce in the part of the country, with costs inflated by transportation, and equipment like cages requires high upfront investments (Zane et al. 2024). Market constraints include poor roads, underdeveloped cold chains leading to post-harvest losses, and reliance on local sales (Amenyogbe et al. 2018). Institutional challenges include weak stakeholder coordination, bureaucratic registration under Fisheries Act 625, and inconsistent policy enforcement (Mapedza et al. 2024), especially after changes in political governments. Broader factors include land tenure insecurities, climate vulnerabilities like droughts, and socio-cultural barriers prioritizing other reservoir uses (Buchanan 2016).

At the same time, there are opportunities to transform these challenges into sustainable growth (Mapedza et al. 2024). Local interest in aquaculture is growing as a dry-season livelihood, especially among youth facing unemployment (Mapedza et al. 2024) and in most cases travelling to the southern part of the country during the dry season for menial jobs. Existing infrastructure, including over 2,000 reservoirs mapped via satellite, provides a scalable base, with more then 450 being categorized as highly suitable sites for all-year-round aquaculture (Akpoti et al. 2025; Zane et al. 2024b). Programs like the CGIAR SAAF and its research activities, such as a June 2025 co-design workshop in Tamale (37 participants), propose inclusive models such as integrated farming, polyculture, cooperatives, contract farming, and public-private partnerships to better advise investors and stakeholders, emphasizing capacity building and networking (Appiah et al. 2025). Nutritional and livelihood impacts are also evident: aquaculture can improve dietary diversity in areas with low fish intake (10 kg/person/year in the north compared to the national average of 26) and yield profits up to 27% in smallholder systems (Mapedza et al. 2024; Zane et al. 2024a).

Inclusive Business Models in Aquaculture

Inclusive business models (IBMs) are defined as profitable, scalable business strategies that deliberately integrate low-income and marginalized populations, such as smallholder farmers, women, and youth, into value chains as producers, suppliers, distributors, or consumers, thereby creating shared value while addressing poverty and inequality (Kaminski et al. 2020; Kruijssen et al. 2020) These models emphasize mutual benefits, equitable terms, and long-term sustainability without perpetual donor support.

In the Ghana and across Africa, IBMs are critical for tilapia aquaculture amid rising demand (per capita 26 kg/year) and declining capture fisheries. Ghana's TiSeed project (2018–2021) and the CGIAR Initiative on Aquatic Foods

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[3]https://acdep.org/new/index.php/programmes-projects/agriculture/resilient-sustainable-livelihoods-transformation-project-result

pilots in Langbinsi, Nalerigu, Nansoni, and Tombu demonstrate practical archetypes that are profitable, inclusive, and adaptable to northern reservoir constraints.

To situate aquaculture IBMs within the broader agri-food systems literature, Table 1 presents a typology of inclusive business models commonly applied in agricultural and aquaculture contexts, summarizing their operational features, empirical performance, and inclusivity outcomes based on Kaminski et al. (2020). The table illustrates how mechanisms such as outgrower schemes, aggregation hubs, localized input supply, and service provision can simultaneously deliver competitive returns while integrating smallholders, women, and youth into value chains.

Table 1. IBMs in agriculture and aquaculture contexts

Category	Description	Profitability/Inclusivity
Outgrower Schemes	Firms supply inputs/technical aid; farmers produce for fixed purchase.	25% ROI; includes 80% smallholders. (Kaminski et al. 2020)
Collection/Aggregation Points	Reduce transport losses via local hubs.	Cuts losses 20%; women sorters.
Input Supply Models	Localized seed/feed production.	Margins 20%; youth entrepreneurs. (Kruijssen et al. 2020)
Service Providers	Agents for logistics/advisory.	Fees 10% premium; gender training.

Source: Kaminski et al. 2020

Building on these general archetypes, Table 2 narrows the analysis to aquaculture-specific IBMs implemented in Ghana and comparable African settings, drawing on empirical cost–revenue data from Kruijssen et al. (2020). The table demonstrates that models such as nurseries, feed mills, hatcheries, and mobile seed agents generate positive margins (20–30%) while deliberately reducing entry barriers through proximity to farms, low capital requirements, and cooperative or youth-led organizational arrangements, making them particularly suitable for inclusive reservoir-based tilapia production systems.

Table 2. IBMs in Ghanaian and African aquacultural context

Model	Costs (GH¢/unit)	Revenue Price	Margin	Inclusivity Features
Nursery	0.44/fingerling	0.69-0.78	20%	Near-farm; women/youth labor. (Kruijssen et al. 2020)
Feed Mill	2.24/kg	3.0-3.1	25%	Local ingredients; training.
Seed Agent	0.10 premium	Fees 300-1000/client	Variable	Mobile; low capital.
Hatchery	0.13/fingerling	0.21-0.24	30%	Broodstock management; cooperatives.

Source: Kruijssen et al. 2020

The ongoing CGIAR SAAF program in Northern Ghana (2023–2025) has operationalized these archetypes through youth-led community cage groups with an average 42% female participation. By October 2025, all four pilots have completed two profitable cycles, reinvesting revenues autonomously and validating IBM principles at scale across reservoir-based systems. Co-design workshops (Tamale, June 2025) further refined the models toward polyculture, cooperatives, contract farming, and public-private partnerships, aligning with MoFAD's Aquaculture for Food and Jobs initiative and the National Aquaculture Development Plan (2024–2028).

Methodology

The study employed a combination of qualitative and quantitative techniques to document and evaluate the business models of the aquaculture groups in the Northeast Region of Ghana. The key methodological components are described below.

Field Visits

Field visits were carried out across all four project sites. Visits to Langbinsi and Nalerigu were conducted on 25th October 2025, followed by visits to Tombu and Nansoni from 26th to 29th October 2025. These visits enabled direct observation of the groups' operations, production activities, harvesting processes, and interactions with buyers, particularly at Nansoni, which undertook harvesting on the morning of 29th October 2025.

The visits provided firsthand insights into operational practices, challenges, group dynamics, and market interactions. They also created the opportunity to conduct Key Informant Interviews with group leaders.

Key Informant Interviews

Semi-structured interviews were developed using the **Business Model Canvas** and **SWOT Analysis Matrix** as guiding frameworks. These interviews were conducted with leaders of the aquaculture groups to obtain detailed information on:

- Management and organizational practices
- Production and marketing processes
- Partnerships and support systems
- Costs, revenue patterns, and operational challenges
- Strengths, Weaknesses, Opportunities and Threats
- Any elements relevant to the Business Model Canvas components

Business Model Canvas

The Business Model Canvas, developed by Alexander Osterwalder and Yves Pigneur (Osterwalder and Pigneur 2010; Sparviero 2019), was applied to map how the aquaculture groups create, deliver, and capture value. The use of the framework also takes into consideration the concept of Inclusive Business Models (IBMs). The framework supported the systematic identification of:

- Key partners
- Core activities
- Key resources
- Customer segments
- Value propositions

- Revenue streams
- Cost structures

This approach offered a coherent structure for analyzing the economic and operational viability of the groups.

SWOT Analysis

A structured SWOT analysis, originally introduced by Albert Humphrey in the 1960s at the Stanford Research Institute, was used to assess:

- **Internal Strengths and Weaknesses** influencing group performance
- **External Opportunities and Threats** affecting sustainability and growth

The SWOT analysis complemented the Business Model Canvas by highlighting strategic positioning and areas for improvement.

Results and Findings

Business Description

The businesses included in this study are the four pilots started under the CGIAR Initiative on Aquatic Foods (continued under the SAAF Program) in the North East Region of Ghana, particularly Nansoni and Tombu in the Chereponi District and Langbinsi and Nalerigu in the East Mamprusi District (Zane et al. 2024a).

Initial inputs, including two 5m × 5m × 3m cages per group, a canoe, and life jackets as capital investments, 4,000 tilapia fingerlings per cage and feed for one production cycle as first-cycle supplies, and technical training on fish culture, business management, and group dynamics were provided to the groups, which also received additional support from the government under the Aquaculture for Food and Jobs initiative through the FC, including extra cages, some already stocked with fingerlings, while others awaited fingerlings and other inputs.

The businesses are managed by group members constituted from each community with a good representation of youth (aged 18–35) and adults, ensuring inclusivity through selection criteria that emphasize gender balance, local residency, and commitment to the venture. Table 3 gives a summary of the group and business characteristics. These community-based models focus on cage culture of Nile tilapia in small reservoirs, with groups encouraged to register formally as businesses to facilitate scalability and access to further financing.

Table 3. Summary of group and business characteristics

Characteristic	Average	Notes
Group Size	13	Mix of youth (18–35) and adults
Female Composition	42% women	Deliberate gender inclusion criteria
Number of Cages	3	2 initial (IWMI) + additional ones from AFJ
Production Cycle Status (2025)	Second cycle harvesting	Variation based on stocking timelines and support delivery

Source: Data compiled by CSIR-WRI partner

By October 2025, some groups had started, or were close to starting, their second harvest cycle, demonstrating potential for income generation, nutritional improvement, and livelihood diversification without conflicting with other reservoir uses such as irrigation or livestock watering. The cages stocked by the FC were operational among some groups, even though not all groups had been fully stocked or received their feed and/or fingerlings from the FC yet.

Business Model Canvas

The Business Model Canvas shown in Table 4 provides a structured overview of how the aquaculture groups create, deliver, and capture value. It highlights the key partners, activities, resources, customer segments, value propositions, channels, revenue streams, cost structure, and social and environmental impacts that underpin the sustainability and growth of their cage-based tilapia production. This framework allows for a clear understanding of the operational and strategic elements of the business while identifying opportunities and challenges for expansion.

Key partners

The key partners in the current business model implemented include:

- **International Water Management Institute (IWMI)**: The CGIAR through IWMI provided the initial fundings for the businesses to start. This included providing the groups with cages, feed, canoes, life jacket and freezers. IWMI continues to offer ongoing in-kind support to the groups. IWMI, as a research for development organization is also actively engaged in conducting research around investment models and understanding consumer's preferences to better advice the groups on which areas to focus on.

- **CSIR-WRI**: The project was started with a partnership with CSIR-WRI, who provides technical training on cage management, feeding, water quality checks (pH, salinity, turbidity, temperature), and value addition (e.g., smoking). They conduct monthly visits for water sampling, fish health assessments, and buyer linkages; coordinates fingerling and feed supplies (e.g., from RAANAN feeds). They also give the groups continuous support through regular communication on WhatsApp.

- **MoFAD – FC**: The FC serves as a regulatory body over aquaculture activities in the areas. They provide extension services to the groups, provided a fish smoker to enable the farmers to add value to the fish and also to preserve fish against spoiling due to power outage or low market. In the implementation of the governments' AFJ, the FC provided additional cages and fingerlings to the group. They also link the group to support that comes from the government. For instance, during the 2024 farmers day celebration, the Nansoni group won the Regional Best Fish Farmers awards with the support of the FC, in which the group was given a tricycle, also known as Motorking to support their business operations.

- **Bridgeway Development Consult:** During the first cycle, the project provided additional training on entrepreneurship, financial literacy, and group governance, delivered by Bridgeway Development Consult. The organization also supported the group with the activities necessary to register as a cooperative: opening bank accounts, drafting a constitution, etc.

- **Community Leaders and Opinion Leaders**: The leaders in the various communities, including the chiefs, assembly members, and unit committee members play a key role in the aquaculture ongoing in the communities. Considering that the dams are owned by the community, the leaders grant access to the groups to use the reservoirs for aquaculture. They also helped in forming the groups to start the project as well. Beyond this, they provide various assistance to the groups from time to time. For instance, the assembly man of Nansoni connects the group to buyers and has been at the beginning of the project participating in various activities of the group including harvesting. In Langbinsi, the Assembly man is the leader of the aquaculture group.

- **Input Dealers**: a critical part of an aquaculture setup is inputs, and with the groups, the RAANAN Fish Feed is the main supplier of feed to the groups. Fingerlings are brought to groups from the south, which is facilitated by CSIR-WRI and FC.

- **Market**: The market for the fish produced by the groups currently includes hotels, restaurants, government workers, within and around the communities. There is also a growing demand from the indigenes of the communities in which the project is being implemented. For instance, in Nelerigu, the group leader reported that, when they harvest during a time when Nalerigu College of Nursing and Midwifery is in session, majority of their buyers are students from the colleges, even though individual households also come to buy fish from them.

These partners, together play a role towards the sustainability of the groups. Unlike in philanthropic projects, the major partners, i.e.. IWMI, CSIR-WRI, FC do not just donate cages to the groups to keep but continually provide guidance to the group ensuring that if in the long run, they withdraw their services, the groups do not suffer from it. Also, with ensuring inclusivity, the local folks are involved not only in the part of producing but also serve as a market for the produced fish, although not yet in very large quantities.

Key activities

The key activities in the current business model implemented include a range of operational, managerial, and supplementary tasks essential for maintaining the tilapia cage culture system, ensuring product quality, and driving revenue generation. These activities are mainly led by the groups with regular support from partners. The key activities include.

- **Stocking Fish:** The groups begin each production cycle by stocking Nile tilapia fingerlings in the cages, typically around 4,000 per cage based on initial pilot baselines. This activity involves careful placement of fingerlings into the cages to minimize stress and mortality. This is often coordinated with partners like CSIR-WRI or the FC. In future cycles, the groups hope to reduce dependency on the hatcheries in the south by exploring local hatchery options, as poor fingerling quality or long distance in transporting fingerlings has led to high mortality rates (e.g., dropping from 4,000 to around 2,000 in some recounts after stocking).

- **Feeding Fish (3 times daily):** The group feed the fish on daily basis; they do that three times a day, at 8am, 12pm and 4pm, to promote healthy growth without waste, using pellets supplied by RAANAN Fish Feed. This activity is done rotationally by group members as decided by the group using the canoe available to the group. During feeding, they also monitor fish behaviors such as feed floating to indicate too much feed given earlier or otherwise, as well as picking dead fish floating at the time of the visit if any and recording the numbers in their logbooks.

- **Checking Water Quality**: Through the training by CSIR-WRI, the groups regularly monitor the reservoir water parameters, such as pH, salinity, turbidity, and temperature. This activity is critical to detect issues that could cause fish mortality (up to 50% in unsuitable conditions). Monthly visits from CSIR-WRI include sampling to validate group efforts, ensuring the shared reservoir remains viable for multiple uses without conflicts.

- **Marketing**: Groups promote their products through various means, especially when they are about to start harvesting. They do this through social media announcements (e.g., posting photos on Facebook and WhatsApp groups), community announcements through community information center and directly calling previous customers to inform them.

- **Meetings**: The groups hold regular meetings led by defined roles (e.g., chairman, secretary, treasurer, organizer) to facilitate idea-sharing, financial planning, conflict resolution and discussions issues that the business face. These sessions are also held to sustain teamwork as well as planning all other activities of the group such as who is to feed the fish when and who is to attend a particular training or meeting outside the community.
- **Supplementary Activities**: To diversify income and support core operations, groups engage in ancillary tasks like using awarded tricycles (e.g., Nansoni's Motorking from 2024 Farmers' Day) for transporting goods and charging fees or selling ice from freezers during peak times like Ramadan. From time to time, the groups also nominate members to attend trainings and meetings organized by key partners such as IWMI and the FC.
- **Value Addition**: To extend shelf life and appeal to diverse consumers, groups process harvested tilapia through smoking, using smokers provided by the FC. This activity, adopted in the second cycle hopes to reduce post-harvest losses (estimated at 30% without cold chains) and targets buyers preferring preserved products. It also enables women in the groups to add value and earn supplementary income by smoking and reselling, fostering gender inclusivity. ·

Key resources

The following resources are available to the groups, which are used for their activities.

- **Physical**: Unlike other aquaculture setups in Northern Ghana that rely on constructed concrete or poly tanks requiring regular water changes, the groups utilize community-owned reservoirs that retain water year-round, eliminating the need for artificial water sourcing or frequent replacements. Each group has at least two cages (5m x 5m x 3m) for tilapia production, along with a canoe, life jackets, and a freezer for storage and ice production. Additional equipment includes probes for water quality testing (pH, salinity, turbidity, temperature). Other value-adding assets include a smoker oven to preserve fish during low market periods or power outages, and a tricycle for transporting goods and generating extra income.
- **Human**: The groups benefit from skilled members trained by key partners, IWMI, CSIR-WRI, Bridgeway Development Consult, and the FC, on essential practices like cage management, feeding, water quality monitoring, value addition (e.g., smoking), and business skills. In Nansoni, for instance, 8 out of 12 members are directly trained and capable of handling production tasks, with the group leader specializing in water checks and planning to disseminate knowledge to others for resilience during absences. Additionally, groups have ongoing access to partner staff expertise, such as CSIR-WRI's monthly visits for sampling and technical advice, fostering capacity building and reducing dependency over time.
- **Capital/Financial:** Registered as cooperatives, each group maintains a dedicated bank account to deposit revenues from fish sales and supplementary activities (e.g., tricycle fees or ice sales). These funds are available to support reinvestment in future cycles, such as purchasing feeds, fingerlings, or maintenance supplies, and potential expansions like additional cages or hatcheries. For example, after recovering costs from the first cycle, groups like Nansoni use these savings to sustain operations with little external cash injections, aiming for self-financed growth within 4-5 years while planning for member stipends as profits increase.

These resources collectively enhance the model's viability by minimizing upfront barriers such as cost and capacity, and promoting inclusivity, particularly for youth and women through training and shared assets.

Value proposition

A key part of a sustainable business model is providing unique value to customers, and with the aquaculture groups, their unique value propositions include:

- **Providing quality fish**: With regular training on best practices from key partners, the group produces fish that are of high quality for their customers, for which reason some of the customers queue to buy fish from them during harvest. Unlike other fish vendors in the area, who sell imported fish that spend a lot of time in long storage at sea and at the ports before reaching the final consumers, the groups provide a better option, selling fresh fish right from the water to the final consumers with good hygienic practices.

- **Providing healthy nutritional alternatives**: The groups provide healthy nutritional alternatives to the communities by making tilapia fish, which is not common in the area, available for the common people to afford as an alternative to other protein options known to them, such as meat, while also serving as a source of essential micro-nutrients like vitamin B12, vitamin D, selenium, and phosphorus that are vital for healthy diets yet rarely available locally. .

- **Variety and accessibility**: Starting in the second cycle with the provision of smokers, the groups provide fresh or smoked options to customers to meet their varied demands. They also sell the fish by weight (e.g., USD 4.35/kg), making it more accessible and affordable for people of various budgets (e.g., USD 0.87 for small portions; half kg at USD 2.17). Moreover, local production reduces transport needs for the customers. For instance, one of the restaurants that buys fish from the Nansoni and Tombu groups in Chereponi district mentioned that they initially had to travel to Bolgatanga in the Upper East Region, which is 212 kilometers away from them, to buy tilapia, which came with its own challenges such as transport costs and ensuring the fish remained in good condition during the long-distance transport without proper cold infrastructure.

- **Sustainability**: With the support of CSIR-WRI, the group regularly monitors the water quality and other parameters to ensure that the production of fish in the reservoirs does not pollute it or make it unusable for other users. Also, the feed given to the fish was carefully selected, keeping in mind its environmental impact.

- **Unique appeal**: The groups often grow the fish until they are about 350 g before selling. A high demand for their fish is created due to taste and size; one of them stated "when they taste the fish for once, then they have to come for more because of the taste and how big they are."

Customer relationships

The aquaculture groups relate to their customers in the following ways.

- **Direct Engagement**: They keep personal contacts of their customers, which allows the groups to call them ahead of harvesting dates to create an immediate market. They also reach out to other potential clients through posts on social media platforms such as Whastapp. This creates room for building trust and loyalty as well as getting real-time feedback from customers. For the customers who stay within the same community, they reach out to them through the community information scenters or the 'gong beaters', who go round the community to announce upcoming harvest dates.

- **Support from Partners**: The support of key partners is also crucial in dealing with their customers, for example, CSIR-WRI often links the groups to external buyers.

Customer segments

The aquaculture groups serve a diverse range of customer segments, primarily within and around their local communities in the North East Region of Ghana. These segments are targeted based on demand for fresh, nutritious tilapia, with a focus on affordability, taste, and convenience. The main customer segments include:

- **Households**: Local community members form the core base, particularly farmers who buy during post crop harvest when they have disposable income from crop sales, however they lack enough money to buy fish during the peak of the rainy seasons and a few months before planting. These customers appreciate the nutritious value and affordability, often purchasing small portions (e.g., USD 0.87 for 0.2-0.4 kg) for family meals. In areas like Langbinsi, indigenous households increasingly patronize the fish as a protein alternative, though not yet in large volumes.

- **Institutions/Government Workers**: This segment includes employees from the education ministry (e.g., teachers), students at Nalerigu College of Nursing and Midwifery), health institutions and other white-collar workers posted to work around the communities, who are primary buyers also due to their preference for healthy, high-quality protein. They often buy in more quantities than the indigenous households due to their higher disposal income, for instance, during school sessions in Nalerigu, students become major buyers for the Nalerigu Aquaculture Group, boosting sales for the aquaculture group.

- **Restaurants/Hotels**: Restaurants and hotels are the main commercial buyers for the fish groups, valuing the fresh supply for their menus. All of the groups indicated various hotels and restaurants in their community and in closer towns who patronize their fish in large quantities during harvest. These entities benefit from reduced transport needs, as local sourcing eliminates long trips (e.g., to Bolgatanga, 212 km away) and associated costs or spoilage risks under hot conditions without proper cold chains. For instance, during a harvest that took place during a field visit at Nansoni, a restaurant owner was present to buy 60 kg of fish, which prompted the group to go for a second catch, as their initial catch could not meet their demand and other customers who came earlier.

- **Traders/Retailers**: Women within the communities and nearby communities act as informal traders by purchasing fresh tilapia, adding value through smoking, and reselling at a markup. This creates opportunities for supplementary income and extends market reach, particularly for preserved products preferred by distant or bulk buyers.

- **Bulk/External Buyers**: These include buyers from outside the immediate area, linked via partners like CSIR-WRI (e.g., external patrons directed to the groups twice in the first cycle). The group also express interest in reaching out to other potential customers outside of their district and regions, for example, the Nansoni group leader mentioned that with their tricycle, they will explore the option of carrying the fish to bigger markets like Tamale, where they can sell the fish at higher prices.

Channels

The aquaculture groups utilize a mix of direct, digital, and partner-supported channels to reach customers, ensuring efficient distribution while minimizing costs. These channels emphasize accessibility and freshness, with plans to expand for broader market penetration. Key channels include:

- **Direct Sales**: Fish are sold at the reservoir site or local markets, where groups package and display fresh or smoked tilapia hygienically. This hands-on approach allows immediate transactions and builds trust, especially during harvests when customers queue. Community announcements via "gong beaters" or information centers notify locals of upcoming sales.

- **Digital**: Social media platforms like Facebook and WhatsApp groups are used for outreach, posting photos of fish to attract inquiries and orders. While no dedicated group page exists yet, members share in existing networks, enabling real-time communication and expanding reach beyond the community without high costs.
- **Intermediaries**: Women in the groups serve as intermediaries by buying fish, smoking it for value addition, and reselling, which extends shelf life and appeals to diverse preferences. The awarded tricycle (e.g., Nansoni's Motorking) facilitates transport to multiple markets or communities, generating ancillary fees while delivering products.
- **Partner-Driven**: CSIR-WRI plays a key role by connecting groups to external buyers, such as bulk patrons from outside districts. Potential future contracts with hotels and restaurants could formalize this, while linkages to government programs (e.g., school feeding) are explored for stable demand.
- **Markets and Storage Extensions**: Groups target multiple local markets but face transportation limits in covering them simultaneously; the fridge aids by enabling storage and ice sales, preserving fish quality to extend reach during low-demand periods or power outages.
- **Future Expansions**: Plans include scaling to hotels, restaurants, and inter-district sales with delivery options for large orders, leveraging the tricycle for logistics to overcome current constraints and tap into high-demand areas.

Cost structure

The cost structure of the aquaculture groups is dominated by variable inputs essential for production, with minimal fixed costs due to the initial investment by partners and the availability of the reservoirs. The groups focus on cost management through reinvestment and innovation to achieve profitability. Their major cost elements include:

- **Variable Costs**: The largest expenses of the groups are on feed sourced from distant suppliers like RAANAN Fish Feed, incurring high transport and purchase fees (e.g., per bag). Fingerlings are the next largest cost incurred by the groups, which if often faced with quality issues leading to high mortality, for instance the Langbinsi group faced about 50% losses in the second cycle, after the fish were transported for long distance before reaching to them. The groups are exploring local feed production and hatcheries to reduce these costs.
- **Fixed Costs**: As mentioned earlier, the major fixed cost of the aquaculture such as the cages, nets, canoe and life jackets were provided by the partners. Regular maintenance of nets and cages is ongoing, with poor net quality causing escapes or holes detected during re-counts. The farmers do not pay any fees to use the reservoirs as they were given free access to them by the community leaders. Some of the groups also suffer with leaking canoes and need to either replace or repair them for effective functioning. For instance, during the field visit to the Tombu group, the paddle of the group was damaged after returning with stakeholders from the cages to the shore of the reservoir and needed to be replaced.
- **Labor**: Currently, all the group members are working on voluntary bases with no salaries, as profits are reinvested; this keeps costs down but may evolve to monthly stipends when cages expand and profits grow. However, in an ideal situation the group is expected to either share profits or set an amount agreed by them to pay members based on work input. The 12-member groups rotate tasks like feeding and monitoring.

- **Other Costs**: Training for group members has so far being provided free by partners (IWMI, CSIR-WRI, FC). Potential future loans from banks could introduce interest costs, but groups have not accessed them yet.

Revenue streams

The revenue for the aquaculture groups comes primarily from tilapia sales, supplemented by ancillary activities such as selling ice during Ramadan and Nansoni's group use of tricycle. All earnings for the groups are deposited into group bank accounts for reinvestment. Their key revenue streams include:

- **Primary**: Sales of fresh or smoked tilapia at USD 4.35/kg, regardless of size (small, medium, large) are the main sources of revenue for the groups.
- **Ancillary**: The tricycle in Nansoni is used to generate income through the fees charged from transporting goods and people to Chereponi market on market days, adding to group funds. The groups also sell ice from the fridge, during the harmattan period but more especially during the month of Ramadan, with potential for stocking drinks to create ongoing retail income.
- **Other Potential Streams of Income**: The groups currently do not generate any income from selling fingerlings, training others, or selling fish waste to be recycled for other purposes, for instance, they discard the intestines during the degutting process after harvesting. However, incorporating hatcheries in the future could enable fingerling distribution. Providing training for other individuals interested in going into aquaculture can also generate a form of income for groups. Moreover, proper training on postharvest management can generate extra income for the group, depending on how they recycle the fish waste after harvesting.

Social and environmental costs

The social and environmental costs of the groups' aquaculture activities include:

- **Community Relations and Conflicts**: The groups face minor disruptions from other domestic users of the reservoirs, such as children entering the reservoir with donkey carts or tricycles, causing defecation, urination, or oil/petrol spills, which if not well managed may affect the health of the fish. Currently the groups resort to advice and warnings to perpetuators, which are sometimes ignored.
- **Market and Community Access**: Because the majority of the community members depend on farming as their main source of income, seasonal availability of income to farmers affects the demand for fish, which can force price reductions and reduce revenues. The groups, especially those with no tricycle, face the challenge of having to transport their fish to bigger markets, in instances the local market is not enough for them. The roads in the area, especially those of Tombu and Nansoni are not very motorable.
- **Water Quality and Pollution**: Extreme weather (e.g., excessive heat or cold) can elevate fish mortality rates, for instance, during the first cycle, some groups stocked their fish during the rainy reason, when the water turbidity was high and it led to very high mortality rates. Unmanaged feed residues by the groups from over feeding can also degrade water quality over time.
- **Resource Use and Sustainability**: The groups reliance on distant, external suppliers for fingerlings and feeds due to lack of suppliers in their immediate environments increases costs and quality risks.
- **Long-Term Effects on Irrigation Agriculture**: Accumulation of aquaculture wastes (nitrogen, phosphorus, organic matter) may cause eutrophication, algal blooms, and oxygen depletion in the reservoir, degrading

irrigation water quality and potentially lowering crop yields or necessitating extra treatment, as observed in similar reservoir studies. The ongoing monitoring and studying of water quality by CSIR-WRI aim to minimize this challenge.

Social and environmental benefits

The activities of the aquaculture groups have led to some social and environmental benefits to the communities and group members, these include:

- **Availability of alternative protein source to community**: By producing fresh and nutritious tilapia locally, the groups provide an affordable protein alternative to traditional options like meat, which is less common or more expensive in the area; this enhances food security and household nutrition, with customers appreciating the taste and health benefits, often returning for more after trying it once.
- **Ensuring multiple uses of water**: The operations promote harmonious shared use of the reservoir for aquaculture alongside irrigation, livestock watering, and domestic purposes, with no major conflicts reported; through regular monitoring and campaigns against contamination (e.g., advising against vehicle or animal entry), the groups help maintain water quality suitable for all users, fostering community cooperation.
- **Maintaining of reservoir**: The groups contribute to reservoir upkeep, such as during the last rainy season when the Nansoni group used their awarded tricycle to fetch gravel and sand to repair erosions and fix a leak on the dam wall, preventing water loss and ensuring long-term usability for the community.
- **Long-Term Effects on Irrigation Agriculture**: Controlled nutrient inputs from fish wastes (e.g., nitrogen and phosphorus) can act as natural fertilizers in irrigation water, potentially boosting soil fertility and crop yields if monitored effectively; strategic cage placement in deep, well-flushed areas minimizes negative impacts, supporting multi-use reservoirs where aquaculture complements agriculture without compromising water quality for farming.

Table 4. Business Model Canvas

<table>
<tr>
<td rowspan="2">Key Partners
IWMI (funding, cages, feed, canoe, freezer, guidance), CSIR-WRI (training, water checks, inputs, buyer links)
MoFAD/FC (extension, cages, fingerlings, smoker, awards)
Community Leaders (access, support, markets)
Input Dealers (feeds, fingerlings)
Market (hotels, restaurants, households).</td>
<td>Key Activities
Stocking
Feeding
Water quality monitoring
Marketing
Meetings
Value addition
Supplementary activities</td>
<td rowspan="2">Value Propositions
Fresh and smoked tilapia
Affordable alternative protein source
Sustainable production practice
Quality and healthy fish</td>
<td>Customer Relationships
Direct engagement
Social media
Community announcements
Partner-supported buyer linkages</td>
<td rowspan="2">Customer Segments
Households (local residents)
Institutions/Gov’t workers (teachers, students, health workers)
Restaurants/Hotels
Traders/Retailers (mostly women)
Bulk/External buyers via partner networks.</td>
</tr>
<tr>
<td>Key Resources
Physical (cages, nets, canoe, freezer, smoker, tricycle)
Human (trained members)
Financial (cooperative funds)</td>
<td>Channels
Direct sales at reservoir/markets
Social media (Facebook, WhatsApp)
Intermediaries (smoked fish traders)
Partner-driven bulk sales, future school feeding.</td>
</tr>
<tr>
<td colspan="3">Cost Structure
Variable: feed, fingerlings, transport.
Fixed: cages, nets, canoe, life jackets (partner-provided), maintenance.
Labour: voluntary.
Other: training free</td>
<td colspan="2">Revenue Streams
Primary: fresh/smoked tilapia sales (USD 4.35/kg).
Ancillary: tricycle fees, ice sales, value-added products.
Potential: fingerling sales, training services, fish waste recycling.</td>
</tr>
<tr>
<td colspan="3">Social and environmental costs
Conflicts with other reservoir users
Market fluctuations
Pollution (feed, oil, runoff)
Dependency on distant suppliers
Extreme weather affecting mortality.</td>
<td colspan="2">Social and environmental benefits
Affordable nutritious protein
Sustainable multi-use reservoirs
Maintenance and repair of reservoirs
Natural fertilizer from controlled fish waste, skill development
Job creation for youth and women.</td>
</tr>
</table>

Source: Author’s Field Interviews

SWOT Analysis

The SWOT analysis examines the internal capacities and external environment within which the aquaculture groups operate. The analysis highlights the strengths that position the groups for growth, the weaknesses that hinder progress, as well as the opportunities and threats that shape the sustainability of their operations (see Figure 1).

Strengths

The internal strengths of the aquaculture groups reflect the existing capacity and commitment of members to sustain their activities. These strengths include:

- **Availability of Proper Equipment:** The groups have at their disposal the essential equipment needed for smooth aquaculture operations, including cages, nets, a probe, canoe, baskets, fridge, oven, and in the case of the Nansoni group, a tricycle for transportation.
- **Capacity of Group Members:** Several members have been trained in feeding, harvesting, water-quality monitoring, and basic management practices, enhancing their technical competence. The transfer of knowledge among members and continuous training by key partners further enhances their abilities.
- **Teamwork and Voluntary Spirit:** The strong teamwork, unity, and voluntary participation of members contribute significantly to the day-to-day running of the aquaculture activities and ensure collective responsibility. Currently all groups members are working without pay and are committed to the work regardless of no monetary benefits to them yet.
- **Quality Production:** The groups have the ability to produce hygienic, high-quality fish with the added potential for smoking and value addition, increasing their market appeal.

Weaknesses

The internal weaknesses of the groups represent the challenges that limit their operational efficiency and growth. These weaknesses include:

- **Limited Finances for Expansion:** Despite the income earned from the first cycle of production and the ongoing second cycle, the groups do not have sufficient financial resources yet to scale up operations, purchase adequate feed, or replace worn-out canoes and nets on their own.
- **Transportation Constraints:** Apart from the Nansoni group, the other three groups do not have dedicated means to transport their fish to larger market for sales and also to transport inputs when the need arises.
- **Limited Marketing Strategies:** Currently, the groups rely mainly on local or existing buyers, WhatsApp status and community information centers, resulting in limited market visibility and reduced access to higher-value buyers, especially bigger hotels and restaurants in nearby cities.
- **Quality of Fingerlings:** The long distance between the production sites and the source of fingerlings affect the quality of fingerlings and leads to high mortality rates which affects the success rates of production cycles.
- **High Cost of Feed:** Feed is a major cost of the production activities of the groups and hence reliance on external feed sources, which often comes with transportation costs, reduce profitability and put pressure on the groups' already limited resources.

No Salary for Members: Even though the group members have worked in two production cycles without any financial compensation, the absence of salaries or regular incentives affects motivation and may hinder long-term participation and commitment.

Opportunities

External opportunities exist within the wider environment that the groups can leverage to strengthen and expand their aquaculture activities. These opportunities include:

- **Support and Collaboration with Key Partners:** The ongoing engagement with key partners such as IWMI, CSIR-WRI, government agencies such as the FC under MoFAD, and development partners provides avenues for training, financial assistance, and technical support.
- **Government Interest in Aquaculture:** In recent times, the government of Ghana has shown a particular interest in expanding the countries aquaculture capacities through projects such as Aquaculture of Food and Jobs, Youth in Aquaculture and special provision in its 2026 Budget for the sector creates an enabling environment for expansion and improved access to inputs and other support needed to grow the production capacity of the groups.
- **Community Support:** The strong community interest and cooperation, especially with the Assembly members and chiefs enhance security and promote collective responsibility towards the use of the reservoirs.
- **Reservoir Capacity for Expansion:** The reservoirs in which the groups are operating have the physical space to accommodate more cages, providing room for scaling production. For instance, the Nansoni group mentioned that their dam could handle about 50 cages and the Langbinsi group mention 40, and that by expanding the number of cages, they will earn more profit which can be used for reinvestment and payment of group members for their services.
- **Market Expansion: There exist o**pportunities to supply school feeding programs especially as the Government of Ghana now mandates all schools to use locally produced food. They can also expand their reach to urban buyers, and bulk purchasers such as cold store operators in the cities, thereby increasing income potential.
- **Diversified Income Streams:** The groups can generate additional income through training other groups or individuals interested in starting their own aquaculture production, postharvest management through recycling or adding value to waste generated, value addition from smoking and processing fish, and the rental of equipment such as the tricycle and fridge.
- **Awards and Recognition:** Platforms such as Farmers' Day celebration offer opportunities for awards that enhance visibility and motivation of the group's activities.

Threats

The external threats present risks that can hinder the progress and sustainability of the groups' operations. These threats include:

- **Quality of Fingerlings:** Poor-quality fingerlings and stressed fingerlings from long distance between hatcheries and production sites lead to high mortality and production losses.
- **Extreme Weather Conditions:** Fluctuating water levels, heat stress, and unpredictable weather patterns affect fish survival and growth. For instance, stocking fingerlings when water turbidity is high can lead to very high mortality rates.

- **Pollution and Conflicts over Water Use:** Pollution of water from motor kings, donkeys, and other community activities poses health risks to the fish and may cause conflicts over reservoir use.
- **Market Fluctuations:** Seasonal demand and inconsistent purchasing power among community members affect sales and income stability. Community members usually have higher disposable income during harvest seasons and very little income during planting and the peak of the cropping season, which can force fluctuation in prices of the fish to meet customers purchasing power.
- **Theft:** Theft of fish and equipment remains a significant risk that can affect the security of production.

Figure 1. SWOT matrix of Business Model

Strengths (Internal)	Weaknesses (Internal)
• Strong teamwork and unity among members. • Skilled members (8/12 trained in feeding, harvesting, and water-quality management). • Availability of key equipment: probe, canoe, oven, fridge, tricycle. • Ability to produce hygienic, high-quality fish with value addition (smoking).	• Limited finances for expansion. • Transportation constraints (only one tricycle). • Limited marketing channels, mainly local markets and WhatsApp. • Low or inconsistent quality of fingerlings and nets. • High cost of feed. • No salaries for members, risking reduced motivation.
Opportunities (External)	**Threats (External)**
• Support from NGOs, government agencies, and financial institutions. • Renewed government interest in aquaculture. • Strong community support. • Large reservoir capacity (potential for 50+ cages). • Income diversification, training services, postharvest management, equipment rental. • Market expansion (school feeding programmes, urban buyers). • Award opportunities such as Farmers' Day recognition.	• Theft of fish or equipment. • High fingerling mortality from poor-quality hatcheries. • Extreme weather conditions affecting water levels and survival. • Pollution/conflicting reservoir activities (motor kings, donkeys, runoff). • High cost of feed. • Market and income fluctuations in the community. • Capital shortages affecting continuity.

Source: Authors' field interviews

Cost-Benefit Analysis

Revenues and variable costs from fish sales in the first cycle were compared to finding out if enough revenues could be generated to cover variable costs and generate some profits, which when put together can cover the investment cost in the long run. As at the time of writing this report, the second cycle of harvest was not yet complete, and hence data on their full cost and benefits were not available to be included. Below are the analysis of the costs and benefits in the first cycle of production, which was characterized by a lot of inefficiencies as well as analysis on the potential income if efficiency is improved upon. The analysis presents the cost and benefits associated with the performance of the average of the four groups, the best performing group and that of the worst performing group.

Short-term cost-benefit analysis

Table 5 reports the short-term cost-benefit analysis, taking into accounts revenues and variables costs experienced in the first cycle of production. The table shows that feed cost constituted approximately 49% on average, 58% for the best group, 46% for the worst group, but an ideal situation would have incurred being 59% of the total variable costs. These results are consistent with previous studies which found out that the cost of fish feed in aquaculture was the highest variable cost, accounting for more than 50% of total costs (Obiero et al. 2022).

The pilot project successfully demonstrated the feasibility of aquaculture in small dams in the short-term. Two out of the four communities achieved satisfactory harvests during the first cycle, obtaining about USD 100 gross profit (before imputing labor costs), which was enough to cover cost of fish and fingerlings to start a new cycle. Labor costs were excluded from the first stage of analysis because group members worked voluntarily without any form of pay.

However, to assess the true economic profitability of the enterprise, the opportunity cost of labour was imputed in a second-stage analysis. Labour cost was estimated using the prevailing local casual labour wage rate of USD 0.43 per hour. Routine farm activities during the growing phase required three persons working for 1.5 hours per session across morning, afternoon, and evening sessions, amounting to six labour hours per day. This resulted in an average daily labour cost of USD 5.87. Labour was assumed to be supplied continuously over seven days per week for four weeks per month over a six-month production cycle, yielding a total of 168 labour days. Additional labour costs associated with harvesting, marketing, and feeding during the harvest period were calculated based on the number of workers involved, the applicable daily wage rates, and the frequency of each activity, as in Appendix A. These imputed labour costs were then incorporated into the variable cost structure to derive a more realistic estimate of net profitability.

When labor and other periodic costs were considered, no profit across the four groups; even the best group would incur a loss of about USD 1,644. Yet, this is based on the first season which as indicated earlier had a lot of challenges or inefficiencies. In the absence of those inefficiencies, a profit of USD 728 would have been generated, as shown in the last column of Table 5.

With the lessons learned from the first cycle and the continuous learning opportunities for the groups, they should be able to increase efficiency and obtain substantially larger outputs in the long run. For example, by reducing post-harvest losses, which for the best group accounted for 7% of the total quantity harvested, total losses incurred could be reduced by approximately 21%.

Table 5. Cost-benefit analysis in the short-term

	Worst group	Average	Best Group	Potential
Fingerlings (#)	8000	8000	8000	8000
Quantity harvested (kg)	237	735.8	1289.2	1960
Total Revenue (USD)	**656.78**	**2,078.15**	**3,647.39**	**5,965.22**
			Variable costs	
Feed (USD)	1446.26	2129.22	3053.22	3101.43
Fingerlings (USD)	347.83	347.83	347.83	347.83
Harvest expenses (USD)	9.04	34.43	79.13	34.43

Electricity bills (USD)	12.35	38.35	67.22	38.35
profit/loss (*before labor and other cost*) (*USD)*	**-1158.70**	**-471.67**	**100**	**2443.18**
Cost of transporting feed (20kg/bag) (USD)	93.91	322.61	264.35	234.96
Labor (USD)	1160.87	1422.07	1393.04	1393.04
Periodic Maintenance (USD)	86.96	86.96	86.96	86.96
Total Variable costs (USD)	**3157.22**	**4381.46**	**5291.74**	**5236.99**
Balance (profit/loss) (USD)	**-2500.43**	**-2303.30**	**-1644.35**	**728.23**
Feed bags used (#)	72	106	152	154.4
Post-harvest losses (kg)	7	34.68	93	0
Value of post-harvest losses (USD)	21.30	105.55	283.04	0
Balance (profit/loss) (USD) (in the absence of post-harvest loses)	**-2479.13**	**-2197.75**	**-1361.30**	**728.23**

Source: Data compiled by CSIR-WRI partner

Effect of pricing and operational inefficiencies on profitability

A key inefficiency identified during the analysis was the **undervalued selling price per kilogram of fish**. The unit price of **USD 2.78/kg** used in the first cost–benefit computations was derived from total sales divided by reported quantities sold. However, field observation during the second harvest revealed **improper weighting** resulting in an underestimation of total sales weight. Specifically, approximately **14.1 kg** of fish were not captured in sales calculations due to scale inaccuracies or rounding. This suggests that similar weighing errors may have occurred in the first cycle as well.

In reality, farmers sold their fish at **USD 3.48/kg**, yet the misreporting resulted in an effective unit price of **USD 2.78/kg**, a distortion that significantly reduced apparent revenue. When figures are recalculated using the **competitive market price of USD 3.91/kg, with reference for the weekly prices posted by the Chamber Aquaculture Ghana**, the financial performance changes substantially (see Table 6).

Under the corrected pricing scenario and assuming improved operational efficiency:

- The **best group** would move from an initial loss of **USD 1,361** (original table) to a **positive margin of USD 36,** in the absence of post-harvest losses, even after accounting for full labor and periodic costs.
- The **potential (ideal-efficiency) scenario** yields a significant profit of **USD 2,433**, demonstrating that small-reservoir aquaculture becomes strongly profitable under efficient management.

This evidence reinforces the argument that **inefficiencies, rather than the production model itself, were responsible for the poor cost–benefit outcomes in the first cycle**. Improved weighing accuracy, reduced post-harvest losses, and selling at proper market prices would have shifted the financial results meaningfully in favor of profitability.

Table 5. Adjusted Cost-benefit analysis in the short-term

	Worst group - Adj	Average -Adj	Best Group - Adj	Potential -Adj
Fingerlings (#)	8000	8000	8000	8000
Quantity harvested (kg)	237	735.8	1289.2	1960
Total revenues (USD)	**927.39**	**2879.22**	**5044.70**	**7669.57**
Variable costs				
Feed (USD)	1446.26	2129.22	3053.22	3101.43
Fingerlings (USD)	347.83	347.83	347.83	347.83
Harvest expenses (USD)	9.04	34.43	79.13	34.43
Electricity bills (USD)	12.35	38.35	67.22	38.35
profit/loss (*before labor and other cost) (USD)*	**-888.09**	**329.39**	**1497.30**	**4147.53**
Cost of transporting feed (20kg/bag) (USD)	93.91	322.61	264.35	234.96
Labor (USD)	1160.87	1422.07	1393.04	1393.04
Periodic Maintenance (USD)	86.96	86.96	86.96	86.96
***Total Variable costs** (USD)*	**3157.22**	**4381.46**	**5291.74**	**5236.99**
Balance (profit/loss) (USD)	**-2229.83**	**-1502.24**	**-247.04**	**2432.57**
Feed used (#)	72	106	152	154.4
Post-harvest losses (kg)	7	34.68	93	-
Value of post-harvest losses (USD)	21.30	105.55	283.04	-
Balance (profit/loss) (USD) (in the absence of post-harvest loses)	**-2208.52**	**-1396.69**	**36.00**	**2432.57**

Source: Data compiled by CSIR-WRI partner

Long-term cost-benefit analysis

While the short-term assessment of the aquaculture groups' model shows limited profitability due to high start-up risks and operational inefficiencies, the long-term outlook is considerably more favorable. Most inefficiencies observed during the first production cycle, such as poor feeding practices, inadequate monitoring, improper weighing, and limited knowledge of feed conversion, were largely due to the groups' inexperience. As the groups acquire more technical skills and adopt improved practices, operational efficiency is expected to increase, resulting in higher survival rates, improved growth performance, and access to wider markets. These gains collectively enhance long-term profitability.

The following section presents an analysis of the potential long-term costs and benefits of the model based on projected revenues, fixed and variable cost structures, and discounted cash flow analyses.

Revenue estimates

Revenue projections were based on a **reference survival rate of 70%** and an **average harvest weight of 350 g per mature tilapia**, consistent with established findings by Ofori et al. (2010) and Mensah et al. (2018). We assume one harvest per year (even thought, with increased efficiency, an average of 3 harvests in two years should be attainable).

Two revenue scenarios were developed:

- **Scenario 1:** Uses **USD 3.04/kg** as the selling price, based on the average realized sales during the first cycle.
- **Scenario 2:** Uses **USD 4.35/kg**, derived from:
    - the average market price of tilapia in the last week of November 2025 (**GHS 43.439/kg or USD 3.78**),
    - an upward adjustment to reflect transportation costs to Northern Ghana and prevailing market prices in the region,
    - observed selling prices during the second production cycle.

Fixed costs

Fixed costs represent the investment required to operate two cages (5 meters(m) × 5 m × 3 m) over a **10-year lifespan**. Items include cages, canoe, safety equipment, water quality monitoring tools, post-harvest handling equipment, and processing equipment such as an Ahoto oven and freezer. Full fixed-cost details are presented in Table 7.

All fixed assets were depreciated using the **straight-line depreciation method**:

$$\text{Depreciation} = \frac{\text{Cost of Asset} - \text{Salvage Value}}{\text{Useful Life}}$$

Table 6. Detailed fixed costs

Fixed cost	Unit cost (USD)	Quantity supplied per group	Total cost (USD)	Life expectancy
Cage	391.30	2	782.61	10
Canoe	173.91	1	173.91	2
Life jacket	21.74	4	86.96	10
Scale	22.61	1	22.61	4
Water quality probe	702.87	1	702.87	5
Scoop net	21.74	1	65.22	5
Bowls	4.22	5	21.09	2
Basket	1.91	5	9.57	2
Crates	5.65	5	28.26	10
Knifes	1.26	5	6.30	2

Gloves	0.65	5 pairs	3.26	3
Fish sorting tables	75.65	1	75.65	10
Apron	0.43	10	4.35	2
Freezer	304.35	1	304.35	5
Ahoto oven	826.09	1	826.09	10
Total fixed cost			**3113.10**	

Source: Data compiled by CSIR-WRI partner

Variable costs

Feed: An average of **154 bags** (20 kg each) of feed were required per production cycle at an average cost of **USD 20.09 per bag**. Transportation costs ranged between USD 1.30 – 1.73 per bag; therefore, an average of **USD 1.52** was adopted.

Fingerlings*:* Each group stocked **8,000 fingerlings** (4,000 per cage) at a unit price of **USD 0.043**.

Labor: Labor requirements reflect the average district labor rates:

- **USD 2.61** for 6 hours (USD 0.43/hour),
- **USD 4.34** for 9 hours (USD 0.48/hour).

Labor hours were estimated as follows:

- Daily cage management: *9 persons*, each working 1.5 hours per morning, afternoon, and evening session.
- Harvesting: *12 persons*, each working 9 hours/day for 4 days.
- Continued feeding and monitoring: *9 persons* for 3 days.
- Marketing: *2 persons* transporting fish.

These figures represent the realistic labor effort for a full production cycle.

Profitability indicators

Net Present Value

A discounted cash flow approach was employed to compare the present value of benefits and costs over the **10-year lifespan** of the cage system (see Table 8).

Scenario 1: NPV Using USD 3.04/kg Selling Price

- Discount rate: **20%** (Bank of Ghana reference rate, Dec 2024)
- Income tax rate: **25%**

Table 7. NPV Summaries (Scenario 1)

Year	Cash inflows (USD)	Cash outflows (USD)	NPV (USD)
0		3068.52	-3068.52
1	4697.02	4273.04	423.98
2	4438.13	4015.84	422.29
3	4193.51	3797.00	396.51
4	3962.37	3611.90	350.47
5	3743.97	3393.40	350.58
6	3537.61	3207.58	330.03
7	3342.63	3050.48	292.14
8	3158.39	2865.41	292.98
9	2984.30	2708.07	276.23
10	2819.81	2575.08	244.74
Total	**36877.74**	**36566.32**	**311.43**

Source: Data compiled by CSIR-WRI partner

A positive NPV indicates that the project generates returns above its cost of capital under this pricing scenario. The model is therefore financially viable under the conservative assumed price of USD 3.04kg.

However, the narrow NPV margin suggests sensitivity to market fluctuations, reinforcing the need for sensitivity analysis.

Scenario 2: NPV Using USD 4.35/kg Selling Price

- Discount rate: **11.57%** (Bank of Ghana rate, 28 November 2025)
- Income tax rate: **25%**

Table 9 summarizes the discounted cash flow outcomes for Scenario 2

Table 9. NPV Summaries (Scenario 2)

Year	Cash Inflow (USD)	Cash Outflows (USD)	NPV(Inflow-Outflow) (USD)
0	3068.52		-3068.52
1	5436.85	7638.02	2201.17
2	5409.28	7638.02	2228.74
3	5411.42	7638.02	2226.60
4	5443.30	7638.02	2194.72
5	5415.06	7638.02	2222.96
6	5416.60	7638.02	2221.42

7	5447.94	7638.02	2190.08
8	5419.23	7638.02	2218.79
9	5420.34	7638.02	2217.68
10	5451.29	7638.02	2186.73
Total	57339.83	76380.20	19040.38

Source: Data compiled by CSIR-WRI partner

Benefit-Cost Ratio (BCR)

Scenario 1: NPV Using USD 3.04/kg Selling Price

For this scenario, the total revenue (TR) is **USD 36,878**, while the total cost (TC), made up of total fixed cost (TFC) and total variable cost (TVC), is calculated as:

TC = 3,068.52 + 33,479.79 = USD 36,566.32.

The net revenue (NR) is therefore:

NR = 36877.74 – 36,566.32= USD 311.43.

Similarly, the gross margin (GM) is obtained as:

GM = 36,877.74 – 33,479.79 = USD 3,379.95.

The Benefit–Cost Ratio for first scenario is given as:

BCR = $\frac{36,877.74}{36,566.32}$ = 1.01.

Under this scenario where the fish is sold at **USD 3.04 per kg**, the Benefit–Cost Ratio (BCR) is **1.01**. A positive BCR value of 1.01 means that for every USD invested in the aquaculture project, an amount of **USD 1.01** will be generated. This implies that the project is economically sustainable and generates benefits slightly above the break-even point. However, improvement in efficiency and management practices is required to increase the level of profitability in scenario 2.

Scenario 2: NPV Using USD 4.35/kg Selling Price

For this scenario, total revenue (TR) rises to **USD 52,732**, while the total cost (TC) remains **USD 36,566**, since fixed and variable costs do not change with output price.

The net revenue (NR) becomes:

NR = 52,732– 36,566 = **USD 16,166**.

The gross margin (GM) also improves substantially:

GM = 52,732– 33,498 = **USD 19,234**.

The Benefit–Cost Ratio for the second scenario is therefore:

BCR = 52,732.17/ 36,566.31 = **1.44**.

In this scenario, where the fish is sold at a higher market price of **USD 4.35 per kg**, the project demonstrates a much stronger financial performance. The BCR under this scenario increases to **1.44**, indicating that for every USD invested, the project generates **USD 1.44** in return. This reflects a significantly more profitable venture with greater potential for reinvestment and expansion, especially if market access and value chain linkages are strengthened.

Discussion

The findings from this study on the community-based cage culture model for tilapia aquaculture in the North East Region of Ghana reveal a promising yet nascent pathway for addressing food insecurity, rural livelihoods, and sustainable resource use in water-scarce environments. Drawing on the Business Model Canvas (BMC), SWOT analysis, and cost-benefit assessment, the inclusive business model demonstrates viability in leveraging small reservoirs for year-round production, aligning closely with inclusive business principles while highlighting areas for refinement to enhance scalability and resilience.

Alignment with Inclusive Business Principles

The piloted model embodies key tenets of IBMs as outlined in the literature (Kaminski et al. 2020; Kruijssen et al. 2020), particularly in integrating low-income, marginalized groups, such as youth and women, into the aquaculture value chain. By forming community-led cooperatives with gender-balanced participation (e.g., over 33% women in all groups), the initiative fosters shared ownership and decision-making, moving beyond donor dependency toward self-sustaining operations. The provision of initial assets (cages, fingerlings, training) by partners like IWMI-CGIAR, CSIR-WRI, and MoFAD mirrors IBM archetypes such as input supply and service provider models, enabling smallholders to access quality resources at reduced costs.

In the Ghanaian context, this model contextualizes IBMs to challenges in the northern part of the country, such as seasonal water variability and input scarcity, by utilizing existing reservoirs (over 2,000 mapped, with 450+ suitable for aquaculture; Akpoti et al. 2025). It promotes multi-use water systems, where aquaculture complements irrigation and livestock without conflicts, enhancing environmental sustainability. Social benefits, including improved dietary diversity (from 10 kg/person/year fish intake) and reduced youth migration for menial jobs, align with SDGs 2 (Zero Hunger) and 8 (Decent Work) (United, Nations 2015). Compared to southern Ghana's Volta Lake systems, this reservoir-based approach is a decentralized, low-emission alternative, requiring less energy-intensive infrastructure and operations, and, with stronger market linkages, has the potential to increase community incomes by 20–30%, similar to gains observed in other African Inclusive Business Models (Kruijssen et al. 2020).

The cost-benefit analysis underscores short-term challenges, with inefficiencies like high mortality (up to 50%) leading to losses (e.g., USD 1,644 for the best group including labor), but potential profits (USD 728 in ideal conditions) indicate long-term feasibility. Moreover, by enforcing better management, such as accurate weighing, reducing post-harvest losses, and selling at competitive market prices (USD 3.91-4.35/kg), the groups could shift from losses to positive margins, as shown in the adjusted scenario analyses. Feed costs (48.5–59.2% of variable costs) dominate, consistent with regional studies (Obiero et al. 2022), yet local feed innovation could reduce this by 20–30%, further improving profitability. Long-term financial projections reinforce this potential: under a conservative selling price of USD 3.04/kg, the project yields a positive NPV of USD 311.43 and a BCR of 1.01, while a higher market price of USD 4.35/kg increases the NPV to USD 19,040 and BCR to 1.44, demonstrating that small-reservoir aquaculture can become highly profitable under efficient management.

Overall, the model’s alignment with Inclusive Business Models (IBMs) makes it scalable, and by addressing the operational inefficiencies within the groups, it has the potential to function as a standalone, viable investment project.

Risk and Mitigation Strategies

Despite strengths the groups have such as strong teamwork and partner support, risks identified in the SWOT analysis threaten sustainability. Internal weaknesses, such as limited finances and high feed/fingerling costs, amplify external threats like weather variability and possible pollution of reservoirs from other users. For example, turbidity-induced mortality during rainy seasons and distant supplier dependency increases vulnerability, potentially eroding profits by 20-50%.

Mitigation strategies should prioritize resilience-building:

- Create local inputs supplies such as hatcheries, feed mills, or feed distributors, reducing transport risks and costs, which inflates production cost (inspired by TiSeed project; Kruijssen et al. 2020);
- Enhance water governance via community agreements to curb pollution of reservoirs; this can be supported with findings from the monitoring made by CSIR-WRI;
- Strengthen marketing with digital platforms and contracts: for instance, contracts with the government’s various school feeding programs and hotels can create an assured market for the aquaculture groups to stabilize revenue against seasonal fluctuations. All year-round aquaculture is possible for dams which have low turbidity during the raining season to allow for fingerlings stocking without risking high mortality rates.
- Introduce incentives such as stipends post-expansion to sustain group member motivation. Groups could also implement profit-sharing, as the business belongs to them; however, this should consider reserving funds for expansion and ensuring fair compensation based on each member’s contribution to production activities.
- Leverage government policies (e.g., USD 8.70 million allocation in the 2026 budget for aquaculture development) for expansion and funding. Long-term, integrating polyculture, such as co-culturing Nile tilapia with African catfish in the same cage system or adjacent setups, where catfish can scavenge uneaten feed and improve water quality by reducing organic matter accumulation, could mitigate environmental costs like eutrophication, turning fish waste into natural fertilizers for agriculture (de Graaf and Janssen 1996; Banini et al. 2024). This approach has been demonstrated in experimental cage systems in Ghana, enhancing overall productivity and resilience in reservoir-based aquaculture.
- Enhance group efficiencies through capacity-building and training programs, focusing on proper feeding, record-keeping, harvesting techniques, and post-harvest handling, particularly smoking using improved ovens like the Ahoto design to reduce post-harvest losses by extending shelf life and minimizing spoilage, to increase survival rates, lower waste (up to 30% reductions observed), and improve profitability (Salifu et al. 2024; Sakyi et al. 2019).
- Consider insurance schemes to cover risks such as extreme weather events, fish mortality, or input supply disruptions, providing financial protection and stability for the groups.

In summary, while the model navigates Northern Ghana's constraints effectively, addressing risks through adaptive IBMs will be crucial for replication across similar West African contexts.

Conclusion and Recommendations

This study contributes to the understanding of sustainable aquaculture in resource-limited settings by documenting and analyzing the community-based cage culture model piloted under the CGIAR Initiative on Aquatic Foods and continued under the CGIAR SAAF project in Ghana's North East Region. Through the Business Model Canvas, it maps a viable structure that integrates key partners, resources, and activities to deliver fresh tilapia as an affordable protein source, generating revenues (e.g., up to USD 3,647 in the first cycle for the best group) while fostering social benefits like youth employment and nutritional access. The SWOT analysis highlights internal strengths (e.g., trained members, equipment) against weaknesses (e.g., input costs), and external opportunities, e.g., government support) versus threats (e.g., pollution). The cost-benefit analysis reveals short-term losses due to inefficiencies but potential profitability (USD 728 ideally), affirming the model's economic promise. Overall, it demonstrates how reservoir-based aquaculture can align with IBMs to promote inclusive, low-emission growth, contributing empirical insights to Ghana's National Aquaculture Development Plan (2024-2028) and broader African strategies.

Recommendations

- **Policy and Investment Guidance**

To support scalability, policymakers should prioritize incentives like subsidies for local feed production and fingerlings across various regions in National Aquaculture projects or initiatives as intentional steps to reduce production cost. Investments should also target infrastructure (e.g., roads, cold chains) to reduce post-harvest losses (up to 7% observed), with blended finance models (e.g., grants + loans) for cooperatives. Encourage registration as formal enterprises to access credit and enforce regulations against reservoir pollution to safeguard multi-use systems.

- **Technical and Institutional Support**

Enhance technical capacity through ongoing training on polyculture, waste recycling, and digital tools, delivered by CSIR-WRI and FC. Institutionalize partnerships via cooperatives for bulk input procurement. Develop e-extension services for real-time advice on water quality and markets and establish monitoring protocols to mitigate environmental risks like eutrophication.

Future Research and Implementation Pathways

Future research should focus on longitudinal impacts, such as nutritional outcomes, long-term profitability and gender dynamics. Exploring polyculture and climate-resilient tilapia strains can help reduce mortality, while economic modeling of scaled operations, considering reservoir capacity, water quality, and suitability, will better inform investment and policy decisions. Implementation pathways include piloting local hatcheries, digital marketing tools, and Public-Private Partnerships (PPPs) for finance, with monitoring frameworks to track SDG alignment.

An improved IBM could also be developed that deals with the challenges faced in the current model, reducing the threats as well as increasing the strengths and tapping into the opportunities that exist.

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Appendix A. Labour Costs

Table A.1. Growing (Routine Labor)

Wage rate: Gh₵5.00 per hour

Working time: 6 hours per day (3 sessions × 1.5 hrs × 3 persons)

Session	Persons	Hours per person	Rate (Gh₵/hr)	Cost per session (Gh₵)
Morning	3	1.5	5.00	1.96
Afternoon	3	1.5	5.00	1.96
Evening	3	1.5	5.00	1.96
Total per day				**5.87**

Number of working days:

7 days per week

4 weeks per month

6 months

Total days per year:

7 × 4 × 6 = **168 days**

Annual Growing Labor Cost:

5.87 × 168 = USD 986.96

Table A.2. Harvest and Marketing Labor

Activity	Persons	Rate (Gh₵)	Duration / Frequency	Total Cost (Gh₵)
Harvesting	12	50	4 days	208.70
Marketing (3× per 4 weeks)	2	50	12 times	104.35
Feeding (28–4 days in harvest)	3	5	3 sessions	93.91
Total Harvest and Marketing				**406.96**

Table A.3. Grand Total Labor Cost

Category	Amount (Gh₵)
Growing labor	986.96
Harvest and marketing labor	406.96
Total Labor Cost	**1,393.92**

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