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Accelerating pond aquaculture development and resilience beyond COVID: Ensuring food and jobs in Ghana

Catherine Ragasa [a,*], Seth Koranteng Agyakwah [b], Ruby Asmah [b], Emmanuel Tetteh-Doku Mensah [b], Sena Amewu [c], Mathew Oyih [d]

[a] International Food Policy Research Institute, Washington, D.C., United States of America
[b] CSIR-Water Research Institute Accra, Ghana
[c] International Food Policy Research Institute Accra, Ghana
[d] Fisheries Commission Accra, Ghana

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ABSTRACT

Over the past decade, the aquaculture sector in Ghana has experienced tremendous growth—driven mainly by large-scale cage aquaculture. Pond aquaculture, traditionally extensive and with limited external inputs, has been transforming over the same period. Farm profitability was wide-ranging, between −12.00 and 46.00 Ghanaian cedi (GHC) per square meter (m^2), with an average of GHC 8.82/m^2 for farmers active in 2019. Despite wide variability in production and profits, the majority of farmers experienced positive profits—on average, GHC 3.24 per kilogram of tilapia produced, or a 27% profit margin. Farmers who adopted good aquaculture practices and intensified their production have high productivity and positive profits. Nonetheless, the cost to produce 1 kg of tilapia in Ghana (roughly US$1.51 on average) was much higher than in other major tilapia-producing countries (averaging roughly US$0.78 to 1.29). COVID crisis further affected fish farmers: 54% experienced difficulties in accessing inputs, 56% experienced difficulties selling their fish, and farmgate fish prices went down in April–August, although slowly bounced back by end of 2020. Improving the competitiveness and resilience of Ghanaian tilapia sector will require improved seed, increased adoption of good management practices, lower-cost quality feed, and enabling policies and regulations.

1. Introduction

Over the past decade, Ghana's aquaculture has experienced tremendous growth in production, contributing to improved incomes and livelihoods (Ragasa et al., 2018). Research found that recent growth in tilapia farming in Ghana is largely due to four factors: (1) an improved local Akosombo strain developed and released in 2005; (2) government policy support initiatives; (3) improved management practices and technologies at hatcheries and grow-out production systems; and (4) availability of high-quality feeds locally (Ragasa et al., 2018). This growth has inspired the government to expand its flagship program, Planting for Food and Jobs (PFJ), to include Aquaculture for Food and Jobs (AFJ) to accelerate aquaculture development. AFJ aims to increase fish production by 91,000 metric tonnes (mt) over three years (2018 to 2020), develop aquaculture value chains, and create 86,177 jobs (directly and indirectly), especially for unemployed youth and women (based on the original project document, MoFAD, 2018). The components of AFJ are (1) encouraging the private sector through economic incentives to increase investment in commercial fish farming; (2) promoting small-scale fish farming; (3) supporting institutions, such as schools, prisons, or the military, that have the potential to produce fish; (4) supporting existing and new entrant fish farmers with inputs, with a focus on youth; (5) strengthening extension services, as well as fish health and environmental management; and (6) developing fish markets and providing marketing assistance to fish farmers. Implementation of AFJ's original plans has been slow; and as of 2020, it has focused on supporting youth associations and institutions with inputs, facilities, and training to start or expand their production.[1]

* Corresponding author.
E-mail address: c.ragasa@cgiar.org (C. Ragasa).

[1] Personal communication, Mr. Mathew Oyih, head of aquaculture department, Fisheries Commission. https://www.graphic.com.gh/news/general-news/456-persons-benefit-from-aquaculture-for-food-and-jobs-initiative.html; https://goldstreetbusiness.com/2019/business/govt-secures-funds-to-implement-aquaculture-for-food-and-jobs/

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In 2018, the sector produced 76,600 mt of farmed fish, mostly tilapia, valued at US$200 million. Since 2018, Ghana has become the largest producer of tilapia in Sub-Saharan Africa (SSA), second only to Egypt on the African continent. Among African countries, Ghana's aquaculture grew the fastest, at an annual rate of 28% from 2006 to 2019 (Fig. 1). Because this growth was driven mainly by large-scale cage farming around Lake Volta, much of the investment and research have focused on cage farming, although most micro- and small-scale farmers are involved in pond farming. Pond aquaculture, however, can have stronger backward and forward linkages and a larger multiplier effect on local economic growth and poverty reduction than commercial cage farming does (Kassam and Dorward, 2017). Pond aquaculture has traditionally been extensive and with limited use of external inputs, but this paper shows that it has been transforming with an increasing amount of semi-intensive and intensive pond farming over the past decade. There is little systematic evidence on the performance and dynamics of pond aquaculture in Ghana, and more broadly in SSA (Ragasa et al., 2021), and how they can be strengthened to be drivers for food security, job creation, and resilient agri-food systems. This paper aims to contribute to this literature.

The past two years also show the vulnerability of Ghana's aquaculture sector. In late 2018, infectious spleen and kidney necrosis virus (ISKNV) spread through tilapia farms in Lake Volta, causing high mortality of fish in cage systems (Ramirez-Paredes et al., 2019) and a drop in aquaculture production to 52,000 mt in 2019 (raw data from MoFAD, 2000-2020). The outbreak was likely triggered by poor management practices, seasonal water quality issues, and illegal imports of foreign tilapia strains. Then, in March 2020, just as the sector had started to bounce back, the COVID-19 pandemic and its related lockdowns and restrictions began affecting the aquaculture value chain. Whereas ISKNV affected mainly cage aquaculture, the COVID-19 crisis has affected both pond and cage systems. Production in 2020 is estimated to be only 64,000 mt (raw data from MoFAD, 2000-2020).

Ghana's aquaculture value chain is particularly vulnerable to the COVID-19 crisis and related response measures for several reasons. With respect to consumption demand, the value chain relies heavily on hotels and restaurants as well as on informal chop bars or tilapia joints, all of which closed during the partial lockdown and then reopened with substantially reduced operations. Because tilapia is relatively expensive in Ghana—two to three times as expensive as imported chicken (Andam et al., 2019; Ragasa et al., 2018)—it is among the first purchases given up when incomes fall. Studies on the immediate impact of COVID-19 in Ethiopia, India, and Myanmar have shown decreased consumption of more expensive foods, even if those foods, such as meat, fish, dairy, and vegetables, are more nutritious (Harris et al., 2020; Lambrecht et al., 2020; Hirvonen et al., 2020; Headey and Ruel, 2020). On the production side, fish mortality and productivity are largely influenced by feed availability and feeding timing, which makes any disruption in feed access potentially detrimental to fish farming operations. Fingerlings and fish are highly perishable, so any disruption in transportation services and in Ghana's limited cold chain and processing facilities makes aquaculture susceptible to fingerling and fish mortality, food wastage, and opportunistic behavior that disrupt the flow of inputs, services, and fish.

This paper is written against the backdrop of these two crises. On the one hand, strengthening pond aquaculture will help diversify production and reduce overreliance on cage farming on Lake Volta. Moreover, cage farming technologies (including for seed and feed) and experience with policies and regulations can be transferred and adapted to pond aquaculture, consequently generating positive spillovers and faster growth of the whole aquaculture sector. On the other hand, the COVID-19 crisis has affected both systems, and they could learn from each other about how to cope and build resilience.

This paper focuses on pond aquaculture in Ghana and makes three contributions to the literature and to program implementation. First, it provides timely, useful, and practical recommendations to guide the strategies, investments, and implementation of Ghana's newly launched AFJ program. Second, it uses up-to-date and rich datasets, including a 2019 census of active pond farmers and hatchery operators in major pond aquaculture regions in Ghana, follow-up phone surveys conducted in June 2020 to assess the impact of COVID-19 on value chain actors, and in-depth group discussions of farmers and value chain actors conducted in July and August 2020. Third, it provides a comprehensive, systematic, and rigorous assessment of the sector and a synthesis of lessons learned, using a value chain approach and subsector analysis, and building on several years of work by the authors in the sector. The paper is structured as follows. Section 2 provides the study's data sources and methods. Section 3 characterizes fish farmers and farming households. Section 4 presents the characteristics and performance of farms. Section 5 describes the challenges of pond aquaculture and strategies for developing it. Section 6 provides some concluding remarks, recommendations, and broader implications for SSA.

2. Data sources and methods

This paper uses various sources of data, including a structured household survey, group interviews, key informant interviews, expert opinion, and desk review. First, a household survey was developed jointly by the International Food Policy Research Institute (IFPRI) and the Council for Scientific and Industrial Research–Water Research Institute (CSIR-WRI), implemented by the FMMS survey firm from May to June 2019, and validated by a team of CSIR-WRI and Fisheries Commission (FC) zonal officers in October–November 2019. The survey covered all active small-scale cage and pond tilapia farmers and a sample of inactive farmers in the focus regions—Ashanti, Brong Ahafo (Bono, Bono East, Ahafo),[2] Eastern, and Volta. The total sample is 603 farmers, of which 472 are pond farmers (Table 1). The paper reports only on those pond farmers.

The household survey instrument covered modules on pond sizes and characteristics, performance indicators, costs and constraints in production, and socioeconomic indicators. The face-to-face interviews lasted for 2–3 h, using tablet-based and computer-assisted personal interviewing. The interviewee was either the manager or owner (if different) of the fish farm/firm, or the person who made most decisions on fingerlings and inputs and who would likely attend production trainings. Other staff or family members answered some of the modules and questions. Most interviews with the managers/owners were conducted at their fish farms (GPS coordinates were recorded).

The interviews included an added module on challenges and opportunities for women owners and managers. This additional module for women respondents took about 5 min. We also interviewed the opposite-gender partner or spouse of the primary decision-maker in the sample households to get some sense of gender-based constraints or opportunities. The main respondent of the household survey (owner or manager) was usually a man; the second respondent was usually his wife. A total of 603 households were interviewed, of which 279 had second respondents (usually the wife of the owner or manager). Because most interviews with the managers or owners were conducted at their farms, the second respondents often could not be contacted or located.

Second, in August and September 2019, the IFPRI, CSIR-WRI, and FC teams conducted a semistructured survey of 18 commercial hatchery operators and additional 29 grow-out farmers with hatchery operation. Third, the IFPRI team conducted phone surveys in June and July 2020 with 369 pond and cage farmers and 425 consumers to understand how the COVID-19 crisis had affected them. Last, 10 cluster/group discussions of 225 farmers, extension officers, youth extension trainees,

[2] This paper uses the old Brong Ahafo region, which is now divided into three regions but is still being widely used in official data. We included a sample of inactive farmers to get insights on the challenges they faced. Moreover, many of these inactive farmers surveyed indicated interest in farming again.

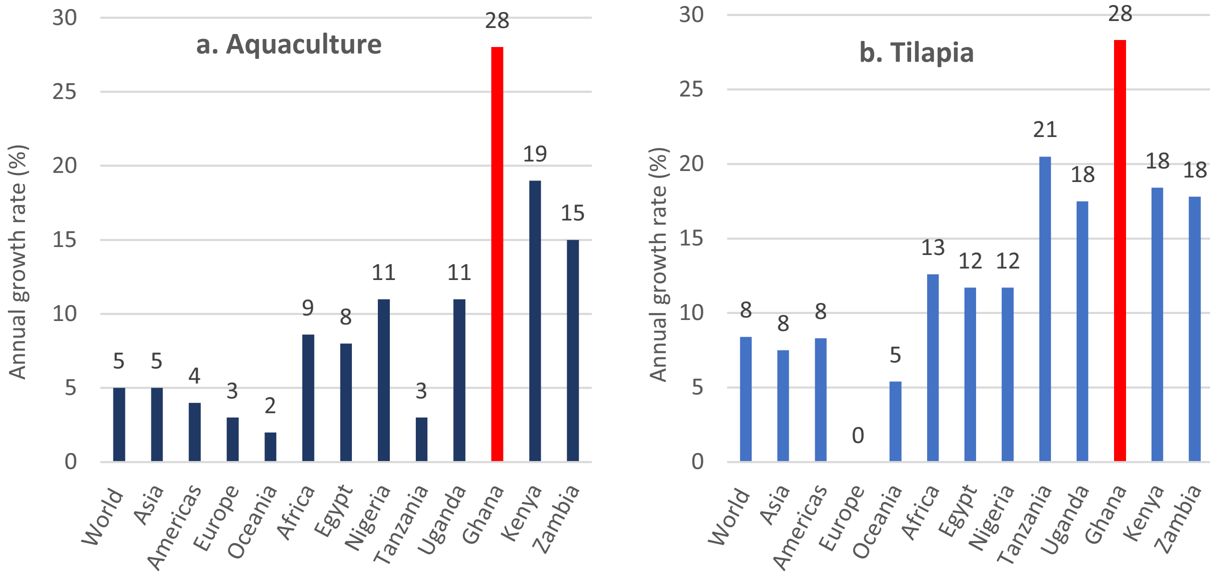

Fig. 1. Annual growth rate in aquaculture and tilapia production, globally and in top producing countries in Africa (2005–19).
Source: FAO FishStatJ database, accessed June 5, 2021 at http://www.fao.org/fishery/statistics/software/fishstatj/en.

Table 1
Number of pond farmers surveyed, by region.

Region	Active [/a]	Inactive [/b]
Ashanti	112	40
Brong Ahafo	191	45
Eastern	62	9
Volta	11	2
Total	**376**	**96**

Source: IFPRI/WRI survey (2019). Note: [/a] Includes all active small-scale tilapia farmers. [/b] Includes a random sample of inactive tilapia farmers (did not farm in the last two years, but indicated interest in farming tilapia again).

hatchery operators, and aquaculture experts were conducted in July and August 2020 in 19 districts in these focus regions. About one to three nearby districts (with about 20–30 fish farmers each) were clustered and provided with technical training organized by the FC, WRI, and IFPRI. Each cluster received a two-day training workshop; the first day involved lectures and discussions with experts and the second day field visits and another set of discussions and lecture. The recorded discussions provide important insights into the challenges and opportunities of pond aquaculture.

All these data sources provide rich and systematic data and information and have been analyzed using a value chain approach to systematically examine the constraints and opportunities of developing pond aquaculture in Ghana. A value chain is the full range of activities required to bring final products or services from conception to delivery to consumers (El-Sayed et al., 2015; Hellin and Meijer, 2006; Kaplinsky and Morris, 2001). Value chains can be analyzed in terms of product flows, information flows, and management and control in the different stages of the chain (Taylor, 2005). Value chain analysis enables researchers and practitioners to identify the main actors in the sector, analyze levels of productivity and profitability, identify the strengths and weaknesses of the sector, and evaluate policy options for improving sector performance.

For the measurements, we used common and comparable indicators, such as stocking density, prices, ratio of prices, costs per kilogram (kg) of tilapia produced, and feed conversion ratios (roughly defined as kg of feed used per kg of fish produced). Stocking density is the number of fingerlings stocked in the pond per square meter (m^2). Profits or gross margins were calculated as total value of harvest less the total costs of production per pond per cycle. One cycle usually is 6 to 7 months. Total harvest per pond per cycle was self-reported by the farmer, triangulated with data on the stocking density, survival rate, and average weight of fish harvested. Operational costs include feed, fingerlings, fertilizer, lime, electricity/fuel, drugs, disinfectants, transportation, and hired labor. These indicators are compared to available studies and figures from top tilapia-producing countries, including Bangladesh, China, and Egypt, and summarized in Ragasa et al. (2018). Figures discussed are pre-COVID-19 levels, complemented with discussions on how the COVID-19 crisis has affected the value chain actors.

For the analysis, we used (1) descriptive and comparative analysis to characterize the production system and profitability of the ponds compared to other countries and (2) regression analysis to identify factors that are statistically associated with higher productivity and profitability of fish farms. We modeled the relationship between productivity and profitability and management practices as follows:

$$Y_{1,i} = \beta' X_i + \epsilon_i$$

where Y_1 is the measure for productivity and profitability for farmer i, β are the coefficients; $\boldsymbol{X}$ is the vector of management practices, and ϵ is the error term. Moreover, to understand which farmers are likely to adopt these practices and achieve higher productivity or profitability, we modeled the relationship of productivity, profitability, and management practices with the socioeconomic and geographical factors as follows:

$$Y_{2,i} = \gamma' Z_i + \delta_i$$

where Y_2 is the measure for productivity, profitability, and management practices for farmer i; γ are the coefficients, Z is the vector of socioeconomic and geographical variables; and δ is the error term. The definition and descriptive statistics of variables are in Annex Table A1.

3. Characteristics of farmers and farming households

Household survey respondents were mainly owners (79%), who also doubled as managers in most cases. Of the owners, 13% had either no formal schooling or only primary schooling, and 33% had at least a college degree (Annex Table A2). Of managers, 17% had either no formal schooling or only primary schooling, whereas 23% had at least a college degree.

Fish farming contributed less than half of household income (Annex

Fig. A1). Most farmers, especially in Brong Ahafo and Ashanti, were also engaged in crop farming (particularly maize) or other non-farm businesses (mainly trading) as their main livelihood (Annex Fig. A2). The majority (84%) of the farms were within just 2 km (or a 15-min walk) of the respondent's house.

Most farmers (77%) started fish farming on their own or as a partnership, whereas 9% purchased their fish farm from other farmers and 7% inherited from parents or relatives. The most commonly cited reasons for starting fish farming were having received training and technical assistance and having seen successful fish farmers in their community (Annex Fig. A3). Most farmers learned about fish farming for the first time from other farmers. Other sources of fish farming information were FC extension agents, reported by 36% of respondents (Annex Fig. A4).

Fish farms are usually family farms with household members working together. Sixty-three percent of tilapia farmers used family labor, and 60% hired laborers when family labor was not available or was insufficient (Table 2). On average, a tilapia farmer used a total of 55 person-days of hired labor and 35 person-days of family labor from pond preparation to harvesting and marketing for the farm's largest pond.

Youth (ages 15–35) had a high level of engagement in fish farming. Fourteen percent of owners and 24% of managers were youth (Annex Table A3). Youth also contributed 68% of the total person-days in family and hired labor on farms (Table 2). Sixty-four percent of younger owners and 61% of younger managers were married.

Fish farming is still a male-dominated sector, although some women are very active as owners and managers, and as laborers, especially in post-harvest processes. A total of 45 fish farm owners or managers were women (9%). Most women managers/owners were married or cohabiting with a husband or partner (62%); three had husbands who had been away for more than six months, so they and their children had been taking care of the fish farms. Thirty-eight percent of women owners/managers were single, divorced, or widowed. The 45 women owners/managers were asked about the advantages and disadvantages as well as the opportunities and challenges of being a woman owner or fish farmer. Commonly reported advantages are that fish farming brings income, employment, and food for the family and that it creates employment for other people in the community. One female respondent said, *"I processed my tilapia harvest into* koobi[3] *and it provides income for my family."* Many of the women respondents also mentioned the empowering effect of their fish farming. One woman said, *"It brings respect and knowledge to women."* Another woman said, *"Women become more brave, confident, and empowered."* And another said, *"Women become more financially independent."* When the female spouses of male owners/managers were asked if they wanted to be more engaged in fish farming, the majority said they did. They noted that helping their husbands would help reduce costs and would allow them to take over from the spouse if he decides not to continue.

Table 2
Person-days of family and hired labor in largest pond, per cycle.

Variable	% of farmers with family/hired labor	Mean	SD	Min	Max
Hired labor					
Total hired labor	60	55	174	0	1680
Young male	50	35	139	0	1680
Older male	20	17	90	0	1298
Young female	7	2	22	0	278
Older female	4	0	3	0	60
Family labor					
Total family labor	63	35	94	0	1083
Young male	43	19	58	0	580
Older male	26	10	44	0	645
Young female	11	4	49	0	903
Older female	11	2	11	0	181

Source: IFPRI/WRI household survey (2019). SD = standard deviation.

4. Characteristics and performance of farms

The surveys and interviews reveal varied experience of pond farmers and heterogeneity of fishponds, and we describe here some patterns. On average, almost all pond farmers in the focus regions were micro- and small-scale.[4] Pond farmers usually owned five ponds and used two in 2018. Thirty-six percent of respondents used only one pond in 2018, and 64% used more than one pond. One farmer used as many as 17 ponds in 2018. The most common pond dimensions were 10–60 m in length and 10–60 m in width. The most common depth was 1–2 m. The average area across ponds was 982 m^2. Ponds in Ashanti were larger on average at 1819 m^2. Ponds in Brong Ahafo and Eastern were the smallest with areas averaging 559–569 m^2. The main specie cultured is tilapia, although catfish production is increasing. Mixed tilapia-catfish culture was common among pond farms (30% of pond farmers), and three ponds have a mix of tilapia, catfish, and heterotis fish species. Most of the ponds (92%) were earthen ponds, 6% concrete or tank, and 2% hapas or cages installed in large earthen ponds.

4.1. Farm productivity, inputs, and costs

The survey asked about production, inputs, practices, costs, sales, and profits of the biggest tilapia pond[5] of the farmers surveyed in 2019, with results described below. The figures discussed below are pre-COVID-19 levels, complemented by discussions on how the COVID-19 crisis is affecting value chain actors.

Recommended stocking density in tilapia ponds is 3–8 fingerlings per m^2 (FAO (Food and Agriculture Organization of the United Nations), 2010; Pant et al., 2019). Data show that 71% of farmers followed this recommendation, but 22% understocked and 7% overstocked. Surprisingly, the reported survival rate from stocking to harvest was 90% on average. Data show that 3% of farms had lower than a 50% survival rate and 25% of farms had a survival rate of less than 80%.

If the recommended stocking density (number of fingerlings stocked per m^2) of 3–8 fingerlings per m^2 is followed, the survival rate is assumed to be 90%; if the average tilapia size at harvest is assumed to be 300 g, then productivity is expected to be between 0.81 and 2.16 kg per m^2. Data show that 84% of farms achieved productivity close to this level (particularly 0.5–2.4 kg per m^2), whereas 15% of farms achieved very low yields (<0.5 kg per m^2) based on the farmers' reported total harvests (Table 3). Productivity is lower on average in Ashanti than in other regions (Table 3). Annex Table A3 shows the range of productivity measures across various ponds (largest pond by farmer) that were stocked in 2019.

Fish farmers also reported wide variability in input usage, costs, and profits. The main inputs in fish farming are feeds, fingerlings, hired labor, and other materials (Annex Table A4), and the average total cost of GHC 8.76 per kg (US$1.51) of tilapia harvested includes the following

[3] Fresh tilapia that is salted and then dried to prolong its shelf life.

[4] Micro- and small-scale farmers are defined as those producing less than 50 mt per year, which is consistent with Environmental Protection Agency (EPA), FC, and WRI definitions (Karikari et al., 2016). All pond farmers are considered micro- and small-scale.

[5] Thirty-six percent of farmers had one tilapia pond, and this is the farm analyzed and described in this section. For the remaining farmers with more than one tilapia pond, their biggest tilapia pond was selected and described in this section. Follow-up questions indicate that the majority of farmers usually apply similar practices and inputs across their multiple ponds, so data for the biggest pond can be generalized to all other ponds used by the farmers.

Table 3
Proportion of farmers, by productivity (tilapia harvested per m^2) (%), 2019.

Harvest (kg per m^2)	Ashanti	Brong Ahafo	Eastern	Volta	Total
<0.5	15	8	5	0	10
0.5–1.4	79	64	26	20	64
1.5–2.4	5	19	26	20	15
2.5 or more	0	9	43	60	11

Source: IFPRI/WRI survey (2019).

breakdown of costs: feed costs amounting to GHC 6.93 per m^2 or GHC 6.60 per kg of tilapia harvested (69% of total costs on average); seed costs of GHC 1.62 per kg of tilapia harvested (17% of total costs); hired labor, which accounted for 9% of the costs; and lime, fertilizer, drugs, vaccines, disinfectants, fuel, electricity, and other costs, which accounted for 5% of the total costs.

The cost to produce 1 kg of tilapia in Ghana (roughly US$1.51 on average) was much higher than in major tilapia-producing countries (Bangladesh, China, and Egypt), where it was roughly US$0.78–1.29 on average (Ragasa et al., 2018). Ghana's higher cost per kg of tilapia indicates lower productivity than in other countries and reflects the high price of feed—about twice as high in Ghana as in the other countries (Ragasa et al., 2018; see also Macfadyen et al., 2012). Interviews with Ghana's main feed producer indicate that the high cost of some ingredients, such as maize and soybeans, leads to a higher overall cost for fish feed. One feed importer indicated that 80% of the cost of imported feed goes to tariffs, taxes, and transportation. Clearly, feed costs must be reduced for Ghanaian farmers to competitively produce tilapia.

Finally, a noticeably high proportion of the price paid by final consumers goes to trade and transportation. Other studies have pointed to higher handling and transportation costs in Ghana compared to other countries (World Bank, 2013). This can be an area that can be improved in order to lower tilapia prices for consumers, making it more affordable.

With COVID-19, 54% of pond farmers experienced difficulties in getting feeds and other inputs, and 59% reported increased input prices. The average increase in feed prices was roughly GHC 2.00 per kg from 2019 average prices of GHC 19.00 per kg for starter feed and GHC 4.25 per kg for grow-out feed. Between January and June 2020, the average fingerling price rose GHC 0.27 per piece from a 2019 average price of between GHC 0.15 and GHC 0.80, depending on fingerling size, location, and hatchery. Fifty-four percent of pond farmers and 11% of cage farmers experienced difficulty in accessing labor for fish farming. Several respondents said, "*Workers did not come to work due to fear of contracting COVID-19.*" One farmer said, "*It was more difficult to maintain and hire workers because of loss of income from fish farming and other livelihoods.*" Most sample farmers did not experience any changes in wages, although 16% reported increases in fish farm wages. Cost of production will likely be higher with COVID-19.

4.2. Market demand and farm profits

In terms of consumer demand and market, as a lower-middle-income country with a growing middle-income population, Ghana is experiencing an expanding market for high-value products, including tilapia. Fish consumption stands at about 28 kg per person annually in Ghana, one of the highest consumption levels both in Sub-Saharan Africa (SSA) and globally (FAO (Food and Agriculture Organization of the United Nations), 2018; Chan et al., 2021). Fish accounts for 60% of Ghana's national dietary intake of animal protein (Rurangwa et al., 2015; FAO (Food and Agriculture Organization of the United Nations), 2018; Chan et al., 2021), about four times higher than the global average (Hishamunda et al., 2009). The current gap between fish demand and supply, which is filled by imports, is about 60% of total fish production. Expansion in fish demand (due to rapid population growth, urbanization, increasing incomes, and changing consumer preferences) is expected to continue, and therefore, the supply-demand gap is expected to widen in 2050 since only marginal increases in fish production can be expected from improved capture fisheries management and if aquaculture could not expand tremendously (Chan et al., 2019).

In Ghana, there is a strong demand and established market for tilapia. Tilapia is expensive—two to three times more expensive than imported chicken (Ragasa et al., 2018)—and is the most popular fish species in hotels, restaurants, tilapia joints, and chop bars in Ghana's urban areas.

The tilapia value chain in Ghana is relatively short and simple, reflected in the integration of production and sales. Although salted, dried, and smoked tilapia have been traditional sources of protein in the country for decades, in recent years, consumer preference for fresh tilapia has increased significantly (Andam et al., 2019). Consumers' preference for fresh tilapia provides locally farmed tilapia with a natural comparative advantage over frozen imports, mainly from China.[6]

Tilapia is sold in various sizes: Size 4, more than 800 g; Size 3, 600–800 g; Size 2, 450–600 g; Size 1, 300–450 g; Regular, 200–300 g; and Economy and Rejects, 100–200 g. Generally, basic value addition—degutting, scaling and, cleaning—is carried out by retailers who are predominantly women. The fish is held by retailers and presented for sale in alternating layers of fish and ice. Farmers report that smaller fish up to Regular size sell faster but bring in lower profits compared to fish of Size 1 and larger, for which competition is stiff and customers are usually hotels and restaurants. Larger farms such as Tropo Farms dominate the market for larger tilapia. Smaller-scale farms cannot compete in the large-sized tilapia market because they cannot provide consistent supplies of large fish.

Tilapia prices per kg typically vary by the size of the fish, where it is sold, and how it is processed. The average farm gate price in Ghana at the time of the 2019 study was GHC 11.00–13.00 per kg (US$1.90–2.24 per kg) for Regular and Size 1 tilapia, the most common sizes. This price is much higher than the US$1.23–1.88 per kg at farm gate in major tilapia-producing countries, such as Bangladesh, China, and Egypt.[7] Prices at cold stores and roadside outlets in Volta and Accra range from GHC 15.00 to GHC 25.00 for Regular and Size 1 tilapia; these retail prices are what final consuming households pay for tilapia. Prices can vary widely in supermarkets, going as high as GHC 40.00 per kg. Unlike in Greater Accra, markets in Brong Ahafo and Ashanti are served mainly by pond farmers who do not sort harvested tilapia into the various sizes. Pond-farmed tilapia is sold per kg—in two main sizes, large or small—with farm gate prices ranging from GHC 15.00 to GHC 18.00 per kg. Farmers sometimes process unsold tilapia into *koobi* as a loss-mitigating measure when they lack cold chain facilities to store fish. Although it involves additional effort, such processing reduces the market price by about 50% because most people prefer fresh tilapia to *koobi*.

Farmers reported selling often to aggregators who come to the farm and pick up the harvested tilapia. Others reported selling directly to sales or market outlets. On average, a farmer made a profit of GHC 3.24 per kg of tilapia produced in 2019, or a 27% profit margin; however, the profitability of fish farms of active farmers in 2019 was wide-ranging, from a loss of GHC 12.00 to a gain of GHC 46.00 per m^2, with an average of GHC 8.82 per m^2 (Table 4). This disparity is due to the varied levels of input use, stocking, and production among farmers and the wide variety of practices and performance in fish farms.

Regression analyses show a strong association between productivity

[6] Visits to market outlets revealed that imported tilapia is packaged and sold by Fujian Jiazhong Biotechnology Development Company Ltd. (http://www.gifoods.ne/En/ProductList.asp; http://www.gifoods.net/En/About.asp), which also exports to the European Union, Mexico, the United States, Dominica, and Africa (for example, Angola). The tilapia is sold in 10-kg packages containing eight very large pieces of tilapia with individual weights ranging from 1.2 to 2.3 kg.

[7] http://www.fao.org/giews/data-tools/en/.

Table 4
Average profits from tilapia farms.

Indicators	Mean	SD	Min	Max
Total revenue (GHC per pond)	15,439.08	21,638.12	408.00	129,080.00
Profit (GHC per pond)	3917.87	6198.66	−9600.44	25,121.97
Profit margin per kg of tilapia produced (%)	27.22	43.33	−79.64	89.91
Profits (GHC per m^2)	8.83	12.16	−12.52	46.06

Source: IFPRI/WRI household survey (2019). SD = standard deviation.

and profitability indicators and management practices (e.g., stocking density, rwater management practices, and sanitation and biosecurity measures) (Annex Table A5a). Farm managers' education level, age, group membership, and access to extension services are strongly associated with higher farm performance and greater adoption of good management practices (Annex Table A5b). Education seems to matter in record-keeping: farmers with higher education level are more likely to keep more records. Younger managers are more likely to adopt more record-keeping and biosecurity practices. Those fish farmers that are in poorest groups and those with less share of income from fish farming tend to keep less records. Farmers with visits or interactions with FC zonal officers tend to keep more records. Farmers who are members of organizations or associations tend to adopt more good management practices, including water management, record keeping and biosecurity practices. Those practicing mixed tilapia-catfish systems are more like to stock more fingerlings per m2 and have higher productivity and profits.

5. Challenges and strategies for pond aquaculture development

This section presents a deep dive into the challenges of pond aquaculture and discusses possible strategies to address these challenges, to accelerate pond aquaculture development, and to inform AFJ program implementation. The four top challenges reported in the interviews were high feed costs or lack of affordable local feeds, access to high-quality seeds, lack of technical know-how, and lack of capital or financial resources. These are also reflected in the reasons given by a sample of inactive farmers for discontinuing fish farming: lack of funds, expensive feeds, fingerling and fish mortality, low demand for fish (when farmers produce smaller sizes of fish), and natural disaster (such as flood or drought) (Annex Fig. A5). We structure these challenges and offer potential solutions by subsector—seed, feed, extension and credit, water quality and environmental sustainability, and marketing—and discuss the role and implications for different actors in the aquaculture value chains, from input supply and production to marketing. The role of policies and regulations is also discussed in each of these subsectors.

5.1. Fingerlings

Tilapia farming starts with and depends upon the availability of quality fingerlings. Most farmers in Ghana purchase fingerlings from hatcheries, both public and private. All the large-scale commercial farms produce fingerlings for their own farms, and some medium-scale and small-scale farmers have also integrated fingerling production. The FC estimates that there are 47 private and 3 public hatcheries: CSIR-WRI's Aquaculture Research and Development Centre (ARDEC), the Pilot Aquaculture Center (PAC), and Ashaiman Aquaculture Development Center (ADC) in current operation. Kassam (2014) asserts that the growth in aquaculture production in Ghana has been largely due to the availability of quality fingerlings. Improved strains over wild stocks, conditioning, and management of hatcheries in recent years have led to higher productivity and profitability of tilapia farming.

For nearly two decades, the main breed for farmed tilapia in Ghana has been the local Akosombo strain, first developed in the early 2000s and now in its 11th generation (Attipoe et al., 2013). Many value chain actors interviewed indicated that the state-approved local Akosombo strain is reaching its limits in terms of performance and stress resistance and that, therefore, they experiment with mixing the available strains from hatcheries or farms. Interviewees from hatcheries also raised concerns about the deteriorating quality of the Akosombo strain, the use of illegal strains, and the lack of monitoring of these illegal strains as well as the poor quality brood stock and lack of good brood stock management practices. Productivity improvements with the current improved Akosombo strain are still possible if issues in the system of producing fingerlings and the extension services are addressed (Ansah et al., 2014).

The main alternative to the Akosombo strain is the newer generation of Genetically Improved Farmed Tilapia (GIFT) strain from Asia or Genetically Improved Abbassa Nile tilapia (GIANT) strain from Egypt. The GIANT strain fueled the aquaculture revolution that saw Egypt become Africa's leading tilapia producer and third globally (Ibrahim et al., 2019). The GIFT fast-growing strain was developed in 1988 from wild strains in Africa, including strains from Egypt, Ghana, and Kenya, and continuously developed in various countries under the coordination of WorldFish, a member of the CGIAR consortium of international agricultural research centers. The GIFT strain is currently in use in several countries in Asia and Latin America (Ponzoni et al., 2007). Under the Tilapia Volta Project (TIVO) coordinated by the Food and Agriculture Organization (FAO) in Ghana between 2009 and 2013, GIFT were imported to Ghana under a special state protocol for a comparative study with local strains at ARDEC. Many farmers interviewed believe that switching to the GIFT strain would cut the time to maturity by between 4 and 5 months. Farmers also view the GIFT strain as being less susceptible to disease, such as ISKNV.

Earlier impact studies on GIFT show an 18–58% higher bodyweight at harvest compared to unimproved strains (Dey et al., 2000). Newer generations of GIFT show additional improvements in productivity. Globally, GIFT is the best documented strain of improved tilapia, with genetic gains in harvest weight ranging from 10 to 15% per generation over 10 generations of selection (Khaw, 2015).[8] The introduction of GIFT in Africa, however, has been slow and greeted with some resistance. GIFT is considered by government and research institutes in many SSA countries as an exotic crossbred species that could pose a risk to the genetic resources of wild tilapia on the continent (Gupta et al., 2004; Brummett and Ponzoni, 2009; Ansah et al., 2014). In Ghana, despite considerable interest in GIFT expressed by most industry actors interviewed, no risk assessment has been done to assess whether the commercial introduction of the fish strain in Ghana would be prudent.

Although Akosombo is the only breed officially permitted by local regulatory bodies, recent assessment shows that almost all hatcheries have been using mixed strains derived from combinations of pure Akosombo strains, wild stocks, Chinese strains, or GIFT or its derivatives (CSIR-Water Research Institute, 2019). Fingerlings available to tilapia farmers are, therefore, mostly mixed. CSIR-Water Research Institute (2019) confirms the report of Frimpong and Anane-Tabeah (2018) that both Chinese and GIFT or its derivatives are exotic/alien strains that have been introduced into Ghana's aquaculture system. Current regulatory provisions permit the use of local strains, restrict the use of certified/approved imported strains for research purposes, and completely ban importation of alien strains for commercial food production (Fisheries Act 2002; Fisheries Regulations 2010 (Li1968); Environmental Regulations – Permits (Sec. 8.0, 9.6(i), 9.18(iv)).

According to our survey, most fish farmers in Ashanti and Brong Ahafo sourced their fingerlings from a public hatchery, PAC. Others sourced from private hatcheries, directly from ARDEC in Akosombo, or from friends and neighbors. Most farmers in Eastern and Volta sourced

[8] Progift Nile tilapia show a genetic gain of 11% per generation (Thodesen et al., 2013); GenomMar Supreme tilapia grows 35% faster after 17 generations of selection (GenoMar Breeding Services, 2016); and the GET-EXCEL strain grows faster by 38% compared to unimproved tilapia stocks (Tayamen, 2004).

their fingerlings from ARDEC or private hatcheries. Some farmers in the four regions produced their own fingerlings in their own hatchery facilities or just left the tilapia in the ponds to breed for the next season. A few other farmers in the four regions sourced fingerlings from the wild. Most farmers rated their source of fingerling as either good or very good (Fig. 2). Seventeen percent of farmers who sourced their fingerlings from Ashaiman ADC rated the fingerlings as somewhat good, whereas 5% of farmers buying from ARDEC and another 5% sourcing from private hatcheries rated their fingerlings somewhat good. These ratings show a need to improve fingerling production and marketing to fish farmers.

The farmer interviews reveal many challenges in seed availability, seed quality, transportation issues, packaging issues, and mortality during transport. These challenges are more pronounced in Brong Ahafo and more remote areas in other regions. Seed availability reflects some degree of seasonality; many farmers stock at the same time in order to harvest for sales during the end-of-year festive season, when a peak in demand occurs. Some farmers also indicated having challenges with timely availability of fingerlings. For pond farmers in the Eastern region, the challenge is mainly related to traveling long distances to source fingerlings, rather than to availability. Farmers appear not to trust the quality of seed produced by some of the hatcheries in their vicinity. Also, some farmers indicate they lack information on fingerling sources.

Farmers in all regions also mention the issue of fingerling quality, including the lack of uniformity—or differences in growth rates of the fingerlings—and incomplete sex reversal. The latter results in differences in growth performance (between male and female fish) and means that fish stocked will continue to multiply in the ponds, leading to inbreeding issues. Farmers explain that large differences exist in quality and prices at different hatcheries. Some farmers buy from multiple sources to spread the risk. Most farmers consider the relationship with the hatchery important, especially because many hatcheries, especially those in Eastern and Volta regions, also provide technical advice.

Transforming the seed sector is critical for improving the productivity and profitability of aquaculture. It is fundamental under the AFJ program to invest in aquaculture research and development, including strengthening breeding capacity, facilitating the risk and economic assessment of alternative strains, enhancing the capacity to monitor seed quality, and enforcing seed policies and regulations. Active medium and large private companies and farmers working primarily in the vibrant cage aquaculture around Lake Volta could be a vehicle for the much-needed greater attention and transformation of the seed system.

5.2. Feed

As noted earlier, feed is the key determinant of the cost-effectiveness and competitiveness of the industry. Feed represents nearly 70% of the cost of production of farmed tilapia. The local feed sector is dominated by one producer, Raanan Fish Feed West Africa, which also imports to neighboring countries.[9] Imported feeds, such as Multifeed, Pira, Coppens, and AllerAqua, cost about 30% more than Raanan (Rurangwa et al., 2015; Ragasa et al., 2018), with prices dependent on the exchange rate.

Most farmers used Raanan feeds. Farmers with means preferred using imported feed at early stages of fish production and then continuing with cheaper locally produced feed from Raanan. Farmers who could not afford optimal use of Raanan feeds fed their tilapia self-produced feed, mainly milled maize and other available crops. The FC has conducted training for farmers on local feed formulation, but the lack of a standard formulation leaves farmers to experiment with diverse ingredients, resulting in poor performance. Especially in Ashanti and Brong Ahafo, about 10 feed producers mix local ingredients for their own use and to sell to other farmers; however, their operations are small and unstable, depending on demand by farmers.

On average, a farmer used 1428 kg of feeds per pond or 1.49 kg of feeds per m^2. The average feed conversion ratio (FCR), defined as the ratio of quantity of feed used to the weight of harvested fish, was 1.32 (Annex Table A6). Across the sample farms, the reported quantity of feeds used, and therefore the FCR, was wide-ranging and mainly different from expected levels. For example, most farmers reported either lower or higher values than the expected FCR (Annex Table A6). A majority of farmers in Brong Ahafo reported an FCR of less than 1.0, which means that farmers did not use enough commercial feeds and likely used mostly self-produced feeds. Many farmers in Ashanti reported an FCR higher than 3.0, indicating that farmers used commercial feeds but were not compensated with more and larger tilapia harvested. This result is likely linked to seed quality (in-breeding) and poor management practices (such as water quality) reported by many farmers, especially in Ashanti.

Because it improved the availability and reliability of supply, the establishment of a local feed mill (Raanan) has had a positive impact on the growth of Ghana's aquaculture sector (Kassam, 2014). Raanan started operations in 2011 and has grown quickly, increasing its annual production to more than 30,000 mt by 2015. Despite a production capacity of 3500 mt per month, Ranaan currently produces 2600 mt because of lower demand for fish feed after the 2016 and 2018 disease outbreaks on Lake Volta and because of farmers leaving fish farming thanks to high production costs.

The high cost of raw materials is the main challenge facing fish feed producers. The tedious and costly process of acquiring certification for fish feed production or for importing raw materials is another. High import tariffs and taxes and other fees, estimated at between 20 and 30% of feed costs, as well as the depreciation of the Ghanaian currency, have made imported ingredients more expensive and fish feed more expensive for tilapia farmers. For instance, although the price of soybeans has remained stable on the international market, exchange rate depreciation in Ghana has made soybean more expensive locally (Amewu et al., 2020).

Just as the aquaculture sector began a gradual recovery, slowly bouncing back from the two fish disease crises, the COVID-19 pandemic hit. In June 2020, Raanan indicated that local sales of feed had dropped by about 50% because of the partial lockdown and social distancing restrictions, and that the addition of border closures reduced exports of Raanan feed to neighboring countries by about 20%. Ranaan sources 30% of its main raw materials—maize, soybeans, and fish meal—from outside Ghana and is affected by lower demand for feeds from hatcheries and grow-out farmers in Ghana and abroad.

As the backbone of the aquaculture industry, the feed sector must be supported—especially during this challenging time. Tax incentives and lower tariffs can help. Micro- and small-scale feed producers will also need support through loan and stimulus packages and training on feed production as well as on biosecurity measures and marketing. The availability of safe but cheaper feeds can substantially lower production costs, encourage the use of more feeds, and improve productivity and profitability. The FC has already started offering some training on local feed production so that micro- and small-scale farmers can produce their own safe feeds using available raw materials. This effort can be further expanded.

5.3. Extension and access to credit

Through the provision of effective and efficient response to farmers' challenges, aquaculture extension delivery is strongly linked to aquaculture development and increased productivity and food security. Aquaculture extension delivery in Ghana has gone through various phases with modifications, but the approach remains the same: the government provides free extension services to farmers. Initially, aquaculture extension was part of the general agricultural extension

[9] Other local producers include Beacon Hill and some Chinese farms that have integrated feed production with aquaculture production, but they make up a very small proportion of the fish feed market in Ghana.

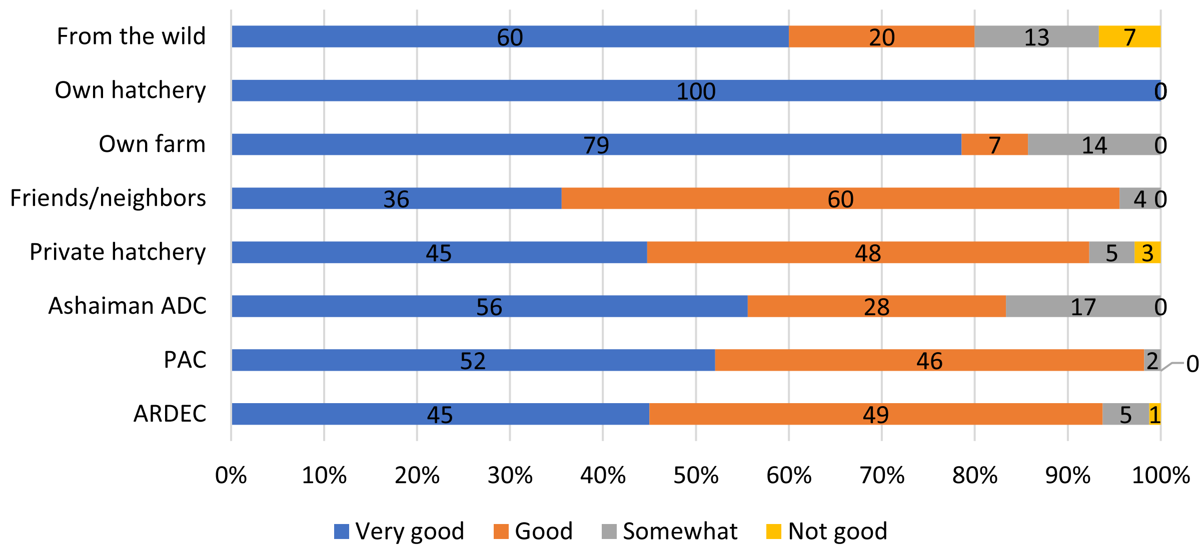

Fig. 2. Proportion of farmers, by perception of quality of fingerling source (%).
(Source: IFPRI/WRI survey (2019). ARDEC (Aquaculture Research and Development Center), PAC (Pilot Aquaculture Center), and Ashaiman ADC (Aquaculture Development Center) are three public hatcheries.)

system managed by the Ministry of Food and Agriculture (MoFA); however, poor coordination and logistics and lack of trained personnel led to the creation of a unified agricultural extension system in 1992. The new system used the training-and-visit approach to extension delivery, and a Department of Agricultural Extension Services was created to enable equitable access by all farmers to extension services. The major challenge to the training-and-visit approach was the weak research extension link, found to be non-responsive to the needs of farmers. In order to make extension services pragmatic and serve the needs of farmers, MoFA together with CSIR established research extension farmer linkage committees to serve as a link between research and extension, and to provide demand-driven services to farmers. When the government adopted a decentralization policy in 1997, extension services provision and management were transferred to the agricultural units at the district level with a focus on increasing farmers' productivity and incomes.

In 2006, extension provision in aquaculture saw a marked improvement when the Ministry of Fisheries was carved out of MoFA; consequently, manuals for extension agents and farmers were created, FAO training materials were adopted, staff trainings were conducted, and adaptive trials with farmers conducted. Realizing the importance of aquaculture to national development and the broad contrast between aquaculture and marine fisheries, the government then created the Ministry of Fisheries and Aquaculture Development (MoFAD) in 2013 to replace the Ministry of Fisheries. This led to further improvement in extension delivery with zonal officers now in charge of extension services delivery across all districts, where they work directly with farmers or farmer groups. Zonal officers have been trained in extension methods and group dynamics as well as hands-on training in aquaculture through collaborations between MoFAD and national research institutions (e.g., WRI-ARDEC and University of Ghana) and other international organizations such as FAO. Although logistical challenges still exist, the government has made efforts to provide zonal officers with vehicles, motorbikes, test kits, and other materials to aid their work.

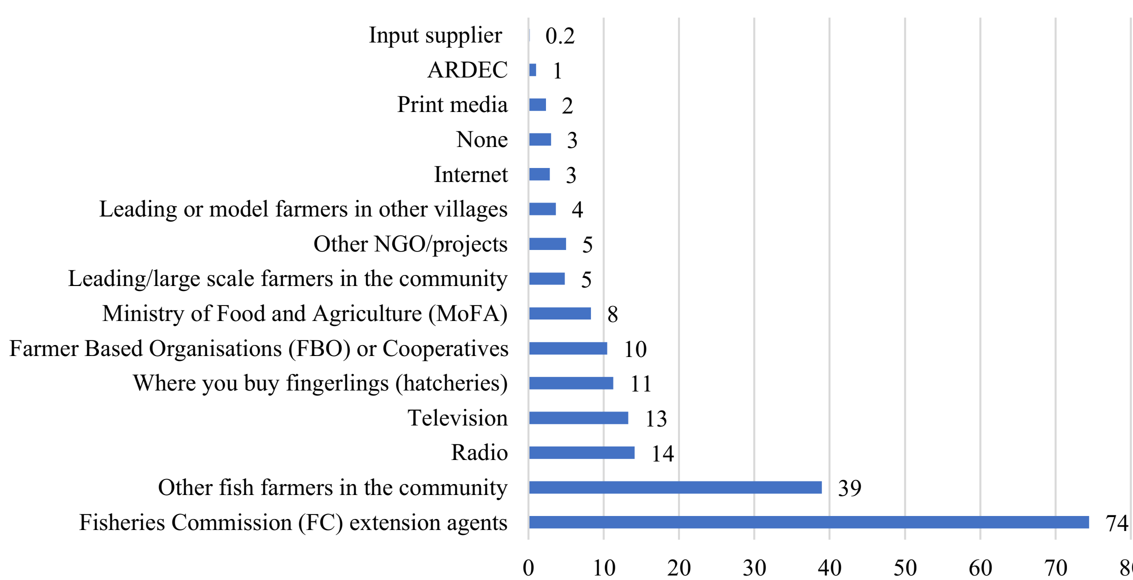

Fig. 3. Proportion of farmers, by source of fish farming information (%).
(Source: IFPRI/WRI survey (2019). NGO = nongovernmental organization.)

As seen in the survey, 74% of fish farmers received information on fish farming from FC extension agents (Fig. 3). These agents have been critical for disseminating aquaculture information and providing technical support to farmers. The second most common source of information on fish farming was other fish farmers in the community, reported by 39% of farmers, which indicates the strong social learning and peer effect within communities.

With regard to access to capital and credit, one has to be careful of introducing distortionary measures and artificial financial support that will not be sustainable in the long-term. It appears that lack of access to credit and capital is an issue for some farmers but not for most. According to the baseline survey, more than half of farmers reported that they could access credit or a loan if needed, but only 10% had actually applied for a loan. More than half of those who did not apply for a loan said they did not need credit (Fig. 4). Twenty-eight percent said they did not have access to credit. Sixteen percent said the interest rate was too high, 10% said they did not have adequate collateral, 9% said the loan application processes were cumbersome, and 2% said there were no lenders available (Fig. 5). These figures indicate that about 28–37% of farmers needed credit but did not apply. The COVID-19 crisis has meant that most farmers have experienced lower incomes from fish farming and all other livelihoods, with implications for decreased funds available for fish farming. Challenges posed by COVID-19 may require more financial assistance for farmers—at least in the short term during recovery. Nonetheless, the profitability of fish farming is the major and more urgent issue and must be addressed to promote real demand for credit and to enable repayments.

5.4. *Water quality and environmental sustainability*

Water quantity and quality are key components of all aquaculture ventures. For a tropical country like Ghana, water availability generally ensures year-round production. According to the survey, water for pond fish production in Ghana is sourced from streams, groundwater, boreholes, springs, and rainfall. In interviews and group discussions, most farmers reported selecting sites for their pond aquaculture production merely at the sight of a perceived reliable water source without taking into consideration other factors such as water quality, soil type, or availability of production inputs. For most farmers these sources are perennial, but some water sources do dry up in the dry season, resulting in cessation of farming activities during these periods.

A major challenge associated with small-scale pond fish farming is the discharge of untreated production effluent into receiving water bodies. Based on our survey, only 9% of pond farmers reported treating water before discharging to water bodies (Fig. 5). Only 7% maintained water quality records and 3% maintained wastewater management records. Half of farmers check water quality at least weekly by observing the color and smell of the water; and only 7% uses instruments or gadgets to check for water quality. Other causes of water quality deterioration in ponds are overfeeding, use of poor-quality feed, overstocking, overfertilization, absence of water quality monitoring schedules, and generally poor water quality management practices (Agyakwah et al., 2020). These causes are all attributable to a poor understanding of fish farming practices (Agyakwah et al., 2020).

To support the AFJ and ensure environmental sustainability, the government will have to institute measures such as scheduled water quality monitoring programs for fish farmers and provision of regular training sessions on good farming practices. Many farmers have resources to purchase and invest in water quality equipment as long as they have the incentive and understand the usefulness of doing so. One farmer said, "*I purchased my own instruments to monitor pH and ammonia levels in my farm and this has helped me a lot.*"

5.5. *Marketing*

Based on the interviews and group discussions, challenges in marketing small-sized tilapia from Ashanti and Brong Ahafo regions arise because many farmers still do not regard fish farming as a serious business, do not follow good aquaculture practice to maximize productivity, and do not have marketing strategies to maximize market access and incomes. Other difficulties reported in the interviews and group discussions in Ashanti and Brong Ahafo include the lack of a dedicated market facility for tilapia, inability to produce bigger tilapia that command higher prices, and production of mostly small-size tilapia that cannot compete with cheaper imported chicken for poorer households.

Before COVID-19, fresh tilapia was in high demand—especially by the hospitality industry, chop bars in urban areas, and generally well-off households. With the pandemic, demand has decreased, with almost everyone experiencing income losses and weaker purchasing power. Of those harvesting fish when COVID-19 hit (April–June 2020), 56% of pond farmers and 78% of cage farmers experienced difficulties selling their fish (Fig. 6). Higher proportions of pond farmers in Ashanti and Brong Ahafo regions than in Eastern and Volta experienced difficulty selling. The reasons reported for these difficulties were lower demand or no buyers, lower tilapia prices, and higher transportation costs (Fig. 6). One farmer said, "*Buyers are afraid of their movements to and from the production centers.*" Farmers about to harvest fish to sell were told by aggregators to wait. "*Most farmers were expecting to sell fish during the Easter celebration, which didn't happen due to the lockdown. Most of them were forced to sell the fish at lower prices after the lockdown*," said a fish feed producer. Farmers have some flexibility to keep tilapia in their cages or ponds for a bit longer, but doing so means additional costs of continued feeding and higher risk of exposure to diseases and natural calamities. Large farms with cold storage may harvest and store, but small-scale farmers—most fish farmers in the country—do not have such facilities.

As a result, distressed selling—farmers with tilapia to sell just trying to sell off their fish even at much reduced prices—led to an initial decrease in prices during lockdown; one farmer reported that the average price for Size 1 tilapia went from GHC 14.50 per kg before COVID-19 to GHC 12.00 during the crisis. This finding is consistent with the price monitoring effort by the Chamber of Aquaculture Ghana. Average farm gate prices reported by large fish farmers in Volta and Eastern show a sharp decline in June–July, but they slowly bounced back in September (Fig. 7). The farm gate price in September was still about GHC 1.00 lower than before COVID-19. Food prices in general have gone up, and fish registered the highest price increase since the start of the COVID-19 crisis (GSS (Ghana Statistical Service), 2020).

5.6. *Policies and regulations*

Aquaculture in Ghana is governed by various national policies and regulations to ensure environmental sustainability, food safety, and industry resilience. The Food and Drugs Authority (FDA) and Ghana Standards Authority (GSA) are responsible for regulating and monitoring the quality of feeds. The FC is currently pilot-testing a certification system for hatcheries. For fish traders, FDA is responsible for strategies and regulations to ensure food safety.

Import restrictions on tilapia have been in place for several decades, but they have not been actively enforced; there are regular reports of illegal imported tilapia flooding the market (Ragasa et al., 2018). In 2012, the government launched the Ghana National Aquaculture Development Plan (GNADP), which sought to increase annual aquaculture production from the 2010 baseline level of 10,200 mt to 100,000 mt by the end of 2016, increasing both the market share and the value of Ghanaian farmed fish (MoFA (Ministry of Food and Agriculture), and FC (Fisheries Commssion), 2012). The plan outlined an extensive list of constraints in the aquaculture sector, which it aimed to address, including issues with fish feed, financing for local production, institutional and regulatory arrangements, and research. Several activities have been implemented under the GNADP, including training sessions

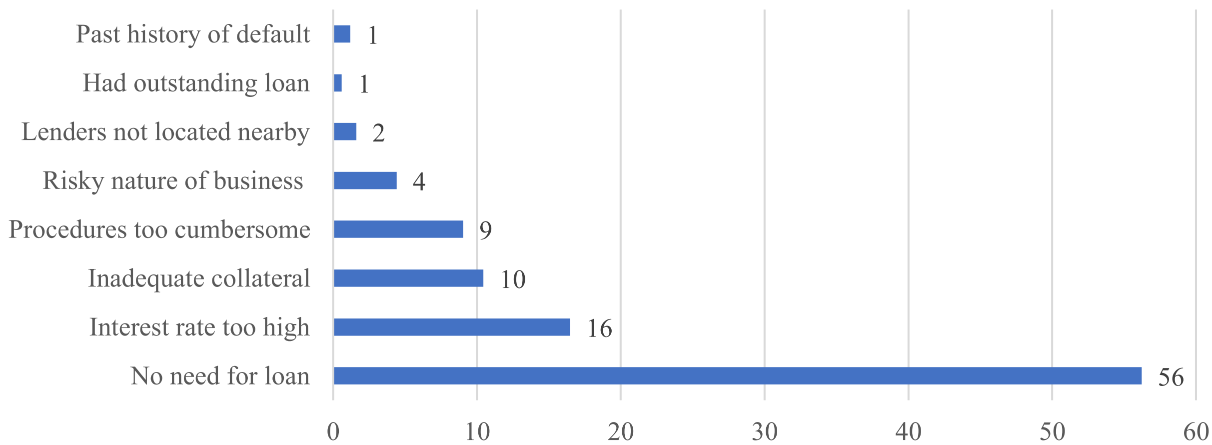

Fig. 4. Proportion of farmers not applying for a loan, by reason (%).
Source: IFPRI/WRI survey (2019).

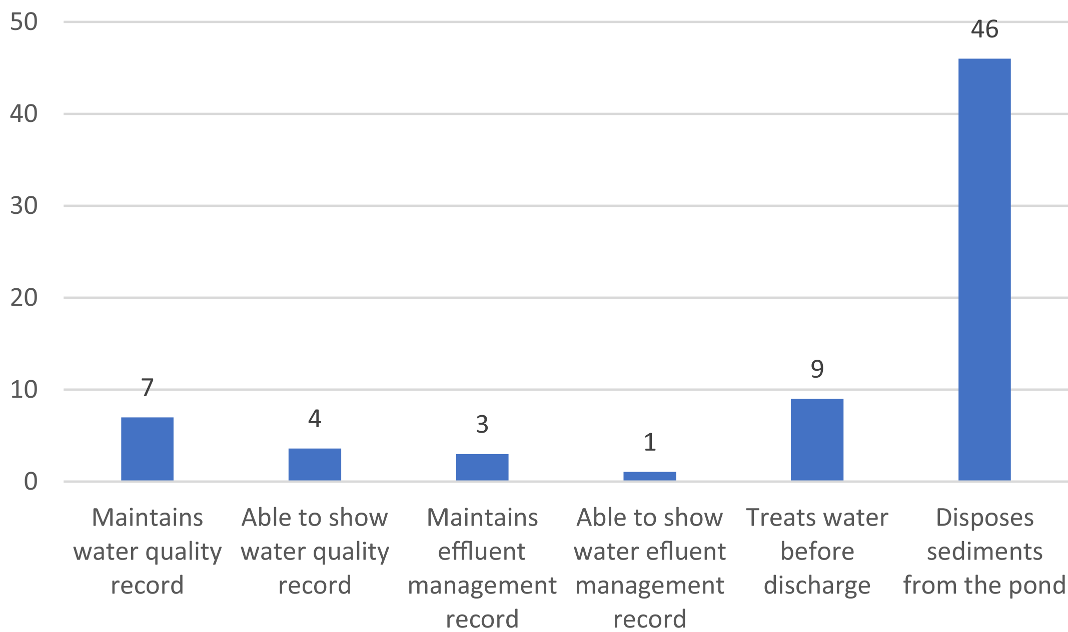

Fig. 5. Proportion of farmers by water management practices (%).
Source: IFPRI/WRI survey (2019).

for improved fingerling production, zoning of Lake Volta to facilitate site selection for new farmers, setting up a fish disease laboratory, and renovation of ARDEC. The GNADP production targets, however, were not achieved by 2016. Interviews and the authors' experience and observations indicate the targets were ambitious and part of the problem in implementing the plan was the lack of sustained investment, effective policy, and institutional and regulatory reforms. Similarly, the current AFJ program supports institutions and youth associations in starting or expanding their fish farming operations, but its budget allocation and implementation were delayed and the necessary policy and regulatory reforms and enforcement are lacking. In response to aquaculture sector actors who await a new national strategy to accelerate growth in the sector, a national aquaculture technical working committee made up of experts from different organizations was formed in early 2018 to help address some of the challenges in the sector.

Certain policies and regulations can restrict, rather than enable, investments in the sector. Industry players highlight the regulatory hurdles that they have faced in getting productive tilapia strains, such as GIFT, approved. Other countries have also used fiscal incentives to encourage private sector growth. China has adopted a zero-tax policy for fish exportation. In Indonesia, entrepreneurs are eligible for tax holidays. Vietnam provides incentives for aquaculture through land tax exemptions to commercial farmers (Hishamunda et al., 2009). Such tax measures have encouraged investment in aquaculture, mainly by local entrepreneurs. In several of the countries studied, the capital for most activities in the sector comes from local entrepreneurs despite some small foreign investment in aquaculture (Hishamunda et al., 2009). In Ghana, however, most medium and large tilapia farms are foreign-owned.

The regulatory cost of doing business in Ghana has been a major complaint of these foreign investors. For example, the Ghana Investment Promotion Council (GIPC) requires a US$500,000 minimum investment, a level considered high and restrictive for smaller foreign investors interested in aquaculture. Foreign aquaculture farmers interviewed mentioned that countries like Ethiopia, Nigeria, and Zambia do not have such restrictions and are generally less bureaucratic than Ghana. Ghana

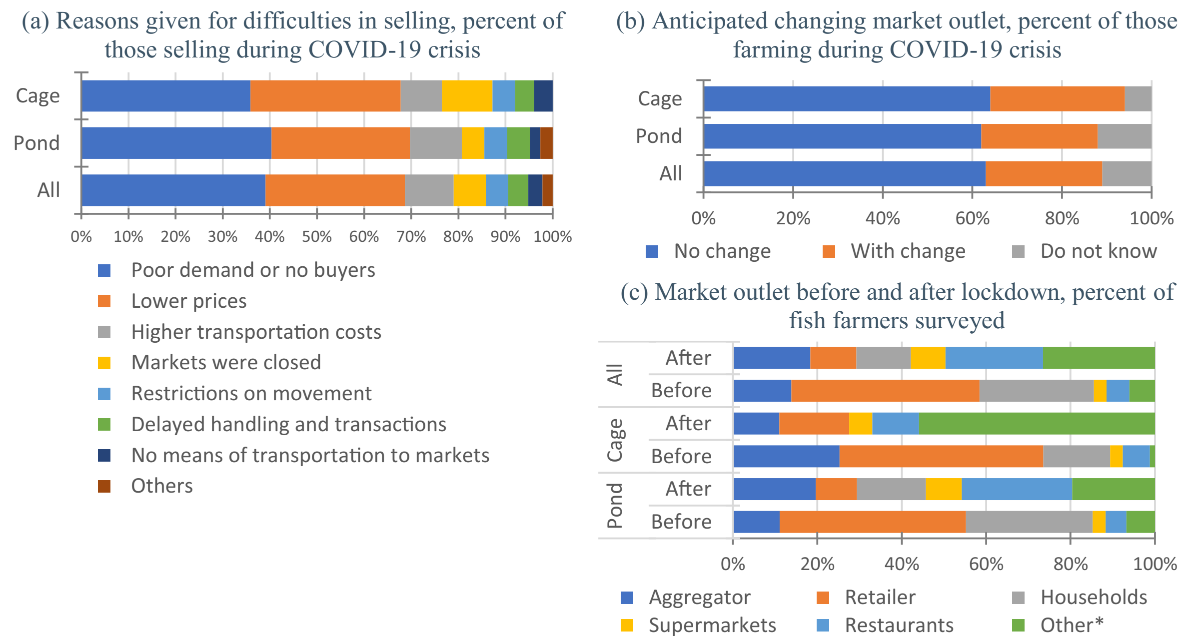

Fig. 6. Effects of COVID-19 crisis on fish marketing and sales among fish farmers surveyed.
Source: IFPRI/FMMS phone survey of fish farmers (June 2020).
Note: * "Other" responses include farmers planning to focus on institutional buyers such as schools, invest in cold chain facilities, or find international buyers.

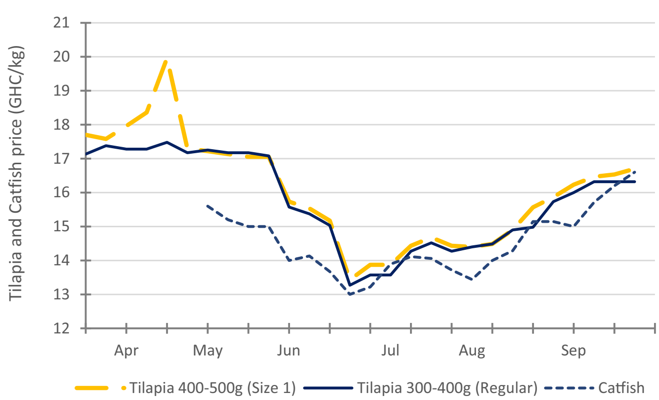

Fig. 7. Average farmgate price of tilapia (Size 1 and Regular) and catfish, April–September 2020.
Source: http://www.chamberofaquaculture.com/portfolio.html

ranks 118 of 190 countries in terms of the ease of doing business index of the World Bank, with a score of 60.0 out of 100 (World Bank, 2019). This score is slightly above the SSA average (51.8); better overall than Bangladesh (45.0), Ethiopia (48.0), and Nigeria (56.9); similar to Egypt (60.0) and Uganda (60.0); and worse than Zambia (66.9), Indonesia (69.6), Vietnam (69.8), Kenya (73.2), and China (77.9). On the basis of this index, Ghana can be viewed as generally less attractive to both foreign and local investors compared to many of the top aquaculture-producing countries in SSA and elsewhere (Brummett et al., 2008).

Tariffs are considered quite high in Ghana: import duties for imported feeds are 5%, but other taxes and fees mean that between 20 and 30% of feed cost is reported to be the difference in the price of fish feed between its arrival in port and after it leaves the port. One feed importer also mentioned that about 80% of imported feed costs goes to tariffs, taxes, and transportation. These high cost components point to the need to review regulations and consider fiscal incentives that would facilitate the development of aquaculture in Ghana, such as the tax holidays or exemption on import duties offered in countries such as Indonesia, Myanmar, and Vietnam (Ragasa et al., 2018).

6. Summary and concluding remarks

This paper provides a comprehensive and systematic assessment of pond aquaculture in Ghana, which has traditionally been extensive and had limited external inputs, but which has been transforming into semi- and intensive systems over the past decade. The paper complements the research heavily focused on cage culture, which has driven the fast growth in Ghana's aquaculture sector in the last decade. It uses a unique and rich dataset from a 2019 census of 472 pond tilapia farmers and 37 hatchery operators in major aquaculture-producing regions in Ghana. This census is complemented by a phone survey conducted in June 2020 to assess the impact of the COVID-19 crisis, 10 group discussions among farmers and other actors in July and August 2020, and 25 interviews with hatchery operators, breeders, government officials, feed producers, and consumers. We also compared Ghana's figures with those of other countries. The main findings are as follows.

- Ghana's aquaculture sector has experienced rapid growth mainly due to the improved local Akosombo strain developed and released in 2006 and the local availability of high-quality feeds. The assessments conducted in 2019 identified as many as 45 public and private commercial hatcheries or fingerling producers. Nonetheless, many remote areas continued to lack access to quality fingerlings. Moreover, WorldFish's recent evaluation of the Akosombo strain showed deteriorating performance and a need to revive the strain. In the short term, supporting more hatcheries or establishing nurseries in remote areas could help increase farmers' access to quality fingerlings from the existing Akosombo strain. In the long term, investments in reviving the Akosombo strain or introducing improved foreign strains (GIFT or GIANT), bred for fast growth, stress resistance and feed efficiency, coupled with stricter enforcement of fish seed regulations and building national capacity to manage these strains, come as top priorities to sustain growth in the sector.

- The majority of tilapia farmers who were actively farming in 2019 experienced positive profits, despite wide variability in experiences and production. On average, a farmer received a profit of GHC 3.24 per kg of tilapia produced (a 27% profit margin). Farmers who adopted good management practices and used mixed tilapia-catfish system are more productive and more profitable than those who did not adopt. The survey results show that most farmers had poor management practices, including poor record keeping, water management practices, and biosecurity measures. There is tremendous potential to improve productivity and profitability among small-scale farmers by improving their management practices. Despite the smaller contribution of fish farming than crop farming for most fish farmers, fish farming offers a great opportunity for income and livelihood diversification among small-scale farmers.
- In terms of social inclusion, the data show that youth had a high level of engagement in fish farming but that women did not. Youth represented 14 and 24% of owners and managers, respectively, and contributed 68% of total family and hired labor on farms. Women also engaged in fish farming, but mostly in harvesting and post-harvest, and their participation was much lower than men's. Nine percent of farm managers and owners were women, and an additional 9% of farms engaged women in some decision-making. Moreover, women contributed 16% of family labor and 5% of hired labor on farms. Factors contributing to low engagement of women in fish farming were time burden—juggling fish farming and domestic chores—and gender bias around women's role in domestic chores and men's role in economic activities. At most, 25% of the respondents—mainly men—believed that fish farming is a man's job. Gender awareness campaigns could help to break this gender bias and challenge gender norms. Opportunities to involve more women will arise as the productivity and profitability of these farms improve. Greater profitability will likely provide greater incentive to shift family labor and greater capacity to hire more labor, which is especially important for women to better balance domestic and productive work.

COVID-19 exposes the vulnerability of aquaculture, causing disruptions in its supply and demand sides. More than half of farmers experienced difficulties in accessing inputs and higher input prices, resulting in lowered production and operations of producers and other value chain actors for seveal months. The hospitality industry, food service sector, and household consumers also reduced tilapia demand and purchases, leading to reduction in sales and lower tilapia prices, although prices are slowly bouncing towards the end of 2020. Decreased incomes from fish farming and other livelihoods have resulted in a sharp decline in available funds for farming operations and for expanding productive capacity. Especially in this time of crisis, the government's COVID-19 response should include strategies to sustain the growth achieved in the aquaculture value chains and build their resilience. Our recommendations for COVID-19 response and the AFJ program are as follows.

- The weaker demand (lower purchasing power) of consumers of fresh tilapia and other high-value products points to the need to **aggressively explore and expand markets and to provide market intelligence, cold chain infrastructure, and greater industry coordination.** Many neighboring countries—including Cameroon, Côte d'Ivoire, and Niger—rely on fish imports, including tilapia, mainly from China (Ragasa et al., 2018).[10] With trade restrictions and greater concerns regarding food safety and the spread of COVID-19, countries are turning to local or regional production.[11] Now is an opportune time to strengthen regional trade, which can offer a win-win strategy for producers and consumers in West Africa and the continent. Ghana is in a good position to act as a producer of fresh and frozen tilapia and catfish and fish feed for the region.

- **Support of local fish farming** can be achieved through temporary subsidies or loan programs for farmers and input suppliers. The sector, unlike cocoa or maize, has not benefitted much from public policies like subsidies and other public investments (Ragasa and Byerlee, 2013; Ragasa et al., 2013). Reduced incomes from various livelihood sources, due to COVID-19, have reduced private funds available for investing in fish farming. Programs supporting the sector may need to reduce project expectations and provide short-term financial support to help fish farmers cope with their production and marketing challenges. Small input packages, such as free fingerlings or a bag of starter feeds, may help farmers greatly in times of uncertainty. This support will also ensure that small-scale hatcheries and feed producers—critical actors in the value chain—have constant orders of fingerlings and feeds and will stay in business.

- In the long term, transforming aquaculture in Ghana will require quality feeds at lower costs, improvements in the tilapia strain used, targeted extension services to improve farm management practices, fiscal incentives to attract investments into the sector, closer attention to water and feed quality, and enforcement of biosecurity and food safety regulations.

Despite some differences, many of the experiences in Ghana mirror that of other SSA countries and lessons from Ghana are relevant for them. Many SSA countries have water bodies and agricultural lands suitable for aquaculture. Tremendous expansion of cage aquaculture has occurred across SSA inland waters in the last decade—from 9 cage aquaculture installations in 2006 to 263 installations with more than 20,000 cages in 2019 (Blow and Leonard, 2007; Musinguzi et al. 2019). Commercial cage farming in lakes and other water bodies will remain the main driver of aquaculture growth and major investment and promotion area in Ghana and other SSA countries. Nonetheless, there is vast potential to develop pond farming, the main system practiced by thousands of small-scale farmers across Ghana and other SSA countries. Concrete pond or tank systems are very productive, and many earthen ponds have been productive. Recirculation aquaculture systems (closed-loop production systems that continuously filter and recycle water, enabling large-scale fish farming with little environmental impact) are more commonly used in Asia and increasingly being used in hatcheries in SSA; more demonstrations are underway to promote these systems to grow-out farmers in the subcontinent.[12]

Countries in SSA also share similar increasing trends in the fish supply and demand gap and in import dependence. Africa's fish imports in 2015–19 were 1.5 times higher than its aquaculture production (FAO (Food and Agriculture Organization of the United Nations), 2005-2019). Rapid population growth, urbanization, and increasing incomes are expected to lead to higher demand for fish and higher-value foods, triggering higher fish imports. If aquaculture does not rapidly expand, the supply-demand gap will widen, and per capita fish consumption will drop if imports cannot fill the gap (Chan et al., 2019; FAO (Food and Agriculture Organization of the United Nations), 2020). Under a business-as-usual scenario modeling, African aquaculture production will likely be 2.8 million mt in 2050; however, it needs to grow by an additional 5.0 million mt by 2030 and 10.6 million mt by 2050 to reduce dependence on imports—two and four times higher than current rates, respectively (Chan et al., 2019). Invigorating local production and accelerated aquaculture growth could generate about 8 million jobs along the value chains in the subcontinent (Chan et al., 2021).

[10] See also FishStatJ database for updates at http://www.fao.org/fishery/statistics/software/fishstatj/en.

[11] https://www.reuters.com/article/us-health-coronavirus-kenya-fish/coronavirus-provides-unexpected-boost-for-kenyan-fishermen-idUSKBN21A1H8.

[12] https://foodtechafrica.com/ras/

This study and recent literature show that strategies to accelerate both cage and pond aquaculture growth in the subcontinent can include increasing access to genetically improved strains, lower-cost quality feeds, and highly productive and climate-smart technologies; enhancing extension services and human capacity development; and improving fish disease surveillance and fish health management practices. Stable and enabling policies, regulations, and public investments will significantly help further attract private sector investment, safeguard the environment, and ensure inclusive and sustainable growth of the sector.

Author statement

Catherine Ragasa led the Conceptualization, Funding Acquisition, Questionnaire Design, Data Analysis, Writing.

Seth Koranteng Agyakwah contributed on Questionnaire Design, Hatchery Assessment, Group Discussions, Data and Analysis on Strains and Seeds, Writing.

Ruby Asmah contributed on Questionnaire Design, Group Discussions, Data and Analysis on Water Quality, Writing.

Emmanuel Tetteh-Doku Mensah contributed on Questionnaire Design, Hatchery Assessment, Group Discussions, Data and Analysis on Strains and Seeds, Writing.

Sena Amewu contributed on Questionnaire Design, Training and Managing of Survey Enumerators, Hatchery Assessment, Group Discussions, Interviews, Data Management, Writing.

Mathew Oyih contributed on Questionnaire Design, Hatchery Assessment, Interviews, Group Discussions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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