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Inclusive Business Models for Access to Quality Fish Seed and Technical Assistance

Insights from Ghana

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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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Abstract

Over the past decade, Ghana's tilapia farming has experienced tremendous growth in production; however, much of the growth has been driven by large-scale cage farmers around Lake Volta. It remains unclear how this growth is and can be made more inclusive of poor and young women and men. This study was conducted to analyze different inclusive business models along the fish seed value chain that can potentially be implemented in Ghana. Based on literature review, field interviews, analysis of survey data, and stakeholder workshops, this study develops four business model prototypes for seed multiplication and distribution to increase farmers' access to and use of quality tilapia seed: (1) **Nursery** , which buy fish fry from a reliable hatchery, transport them to locations near other farmers, and grow it to a larger size; (2) **Local feed mill**, with pelleting machine and technical knowledge to advise on feed formulation; (3) **Agents**, technical experts who supply fingerlings, handle transport and marketing, and provide technical advice; and (4) **Local hatchery**, which obtains brood stock from a reliable source, produces local fingerlings to sell to nearby farmers, and provides technical support. Initial ex ante financial and profitability analyses were undertaken and will be refined according to the actual context in the particular district where the sensitization and pilot-testing will take place. These business models have the potential not only to increase farmers' access to and use of quality tilapia seed but also to provide livelihood and income generation along the fish seed value chain.

Keywords: inclusive business models, value chain, seed systems, nurseries

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Acronyms

ARDEC	Aquaculture Research and Development Centre
BMC	Business Model Canvas
CSIR	Council for Scientific and Industrial Research
CSR	corporate social responsibility
FC	Fisheries Commission
FGD	focus group discussion
FISH	Fish Agri-Food Systems
GIFT	Genetically Improved Farmed Tilapia
IFPRI	International Food Policy Research Institute
KIT	Royal Tropical Institute
LSP	local service provider
PAC	Pilot Aquaculture Development Centre
PIM	Policies, Institutions and Markets
QDS	quality declared seed
SDG	Sustainable Development Goals
TiSeed	Accelerating aquaculture development in Ghana through sustainable Nile Tilapia seed production and dissemination
WRI	Water Research Institute

1. Introduction

Over the past decade, Ghana's tilapia farming has experienced tremendous growth in production; however, much of the growth has been driven by large-scale cage farmers around Lake Volta (Ragasa et al. 2018). It remains unclear how this growth is and can be made more inclusive of poor and young women and men. The three-year program Accelerating Aquaculture Development in Ghana through Sustainable Nile Tilapia Seed Production and Dissemination (TiSeed) was launched in February 2019; it addresses issues in the tilapia seed and extension system in order to improve productivity and profitability of tilapia cage and pond farming in Ghana and ensure that this development includes the poor and young women and men. The project has a particular focus on women and youth small-scale fish farmers and focuses on six regions: Eastern, Volta, Ashanti, Bono, Bono East, and Ahafo. Because the latter three regions only recently divided, the project proposal and the remainder of this report refers to those regions by their former joint name, Brong Ahafo.

This multifaceted project conducts research, effectiveness analysis, and process and impact evaluation on specific interventions in the area of brood stock development and management, seed distribution, seed quality monitoring, certification system, and extension services. The program runs from 2019 to 2022 and is being implemented by a consortium of international and local research institutes, led by the International Food Policy Research institute (IFPRI) supported by the Water Research Institute (WRI) of the Council for Scientific and Industrial Research (CSIR) in Ghana, KIT Royal Tropical Institute in the Netherlands, and WorldFish in Malaysia. Other partners are the Fisheries Commission (FC, a government institution) and two private hatcheries (S-HOINT Ltd. and Crystal Lake Ltd.). The program is a research grant from the government of the Netherlands (through NWO-WOTRO, the Dutch Research Council) and the CGIAR Research Programs on Policies, Institutions and Markets (PIM) and Fish Agri-Food Systems (FISH). It is among the nine research proposals selected and awarded through the Netherlands-CGIAR research program on seed systems development.

This project aims to generate and share knowledge on (1) how to best develop the public and private hatchery sector and the systems to disseminate sustainable high-quality Nile Tilapia seed to small-scale cage and pond tilapia farmers, and (2) how to improve adoption of quality seeds and good aquaculture practices among small-scale farmers in order to improve their productivity and profitability. An essential part of these processes is developing business models along the value chain that are inclusive of small-scale farmers and entrepreneurs, particularly women and youth.

The report includes a review of the gray and peer-reviewed literature on seed systems and fieldwork carried out in September 2019, with the aim of identifying and selecting potential inclusive business models to improve access to quality seed and technical assistance for small-scale fish farmers. It starts to address the sub-question:

- Which seed multiplication and distribution business models can be promoted to increase farmers' access to and use of quality tilapia seed? (objective 2)

In addition, it contributes to answering the sub-questions:

- Which cost-effective extension models can be promoted to increase farmers' knowledge and adoption of good seed management and aquaculture practices? (objective 2)

- How can public and private hatcheries be developed to become economically viable, and gender- and youth-inclusive, and produce high-quality fingerlings that meet the demand of men and women farmers? (objective 1)

The literature review looks at improved models of seed multiplication and distribution in agriculture and aquaculture globally, as solutions for the issue of lack of quality fish seed. On the basis of this literature review, we formulated 10 potential business models. The analysis of field findings and ideation resulted in the development of four business model prototypes: nursery, local feed mill, seed agents, and local hatchery for tilapia and catfish. For each of these four business models, the report presents the business model canvas, an initial financial model, and farmer perceptions of the models collected during fieldwork. Initial financial models will be updated and refined according to the specific context in the areas where these models will be piloted.

The remainder of this report is structured as follows. Section 2 presents the methodology for the development of this report. Section 3 reports the results of the literature review and Section 4 reports results of the fieldwork. Section 5 then provides the four business models that resulted as possible options from the review and fieldwork. Section 6 highlights the main conclusions from the validation workshops, and the final Section offers some next steps.

2. Methodology

2.1 Approach

The research in this report is based on elements of the human-centered design approach, which originates from design thinking, specifically participatory and user-centered design from technological and product industries. Design thinking is an approach to creating solutions that takes into account the culture and needs of the customers (Brown and Wyatt 2010). Traditionally, designers focused on the functionality of products only, but in recent years they have broadened their approach to include deep consumer insights, rapid prototyping, and multiple feedback cycles. Although businesses were the first to embrace this approach, non-profits are beginning to adopt it to address complex development issues (Brown and Wyatt, 2010). Chick (2012) argues that design can be critical in addressing sustainable development agendas, because it can have significant economic, environmental, social, and cultural ripple effects. In addition, design thinking is a fundamental shift from conventional organizational planning for social enterprises because *"it has the potential to shift attention away from the client as the 'problem' towards an approach that would allow a voice for clients to express their unmet needs and concerns as a group, and for them to be heard and become actively involved in the process of individual, communal and societal change and innovation"* (Douglas et al. 2014, 12).

Douglas et al. (2014) mention that, within the broad area of design thinking, a range of different approaches exists, such as co-design, design activism, eco-design, collaborative design, inclusive design, and user-centered design. They share the idea of democratizing the design process and the shift from design for commercial outcomes to design for public or social outcomes.

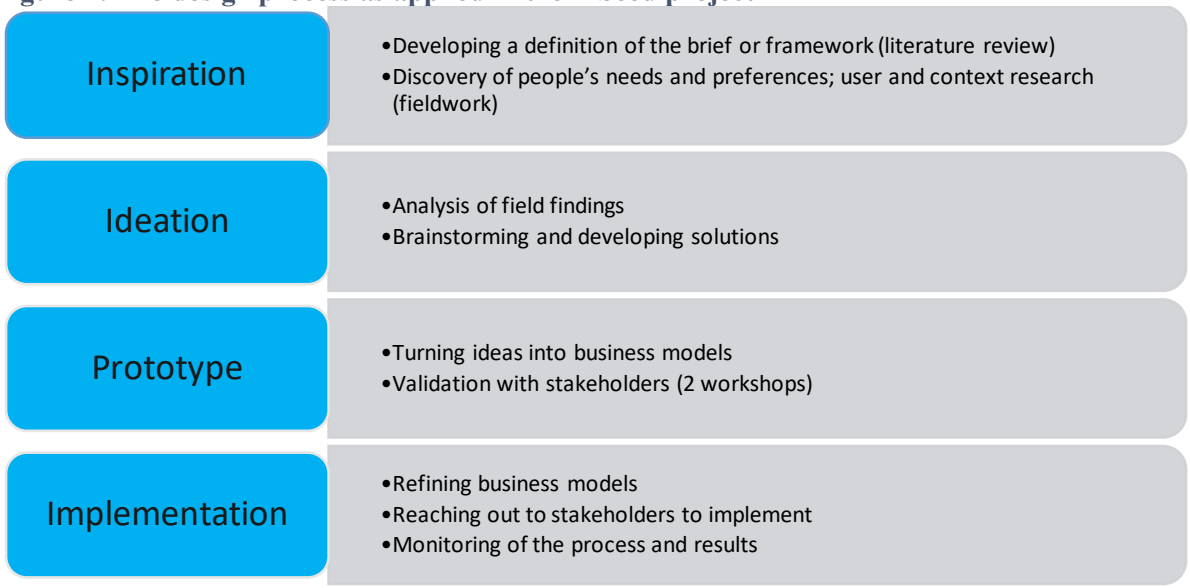
Hoover (2018) explains the difference and relation between design thinking and human-centered design. Where design thinking is an iterative process that leads to the development of products or solutions that will be adopted by the clients or end-beneficiaries, human-centered design is a mindset that overlays design thinking and seeks to ensure that products are actually relevant and beneficial—in the long run—for the people they are intended to serve (Hoover 2018). In other words, human-centered design is a design process based on understanding, through direct observation, of people's needs and preferences (Brown 2008).

The design process includes three (partially overlapping) stages: inspiration, ideation, and implementation (Brown and Wyatt 2010). We have separated prototyping from implementation for a design process with four stages:

1. Inspiration—the problem or opportunity that motivates the search for solutions
2. Ideation—the process of generating, developing, and testing ideas
3. Prototyping—the process of turning ideas into testable products
4. Implementation—the process of putting ideas into practice

Figure 1 provides an overview of these four stages as implemented in the TiSeed project. During the inspiration stage, we conducted desk research (a literature review), followed by user and context research during fieldwork in Ghana. During ideation, we analyzed the data collected during fieldwork and brainstormed potential solutions to come up with four prototypes of business models. Two stakeholder engagement workshops were held to generate feedback on those prototypes. This report will provide the road map for the delivery of these business models.

Figure 1. The design process as applied in the TiSeed project



Source: Adapted from Brown and Wyatt (2010).

For the development of the prototypes, we used the Business Model Canvas (BMC) developed by Osterwalder and Pigneur (2010) to map the identified potential business models.[1] As a tool for describing, analyzing and designing business models, the BMC offers a way to display the business model and has the following nine building blocks: customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structure (Ostenwalder and Pigneur 2010). The BMC tool is increasingly being used to develop business models in rural smallholder settings (e.g., Lundy et al. 2014).

2.2 Desk review

KIT conducted a narrative **literature review** to understand how in other contexts, globally, the issue of lack of access to quality fish seed has been addressed through improved models of seed multiplication and distribution. The aim of this review was to understand the issues being addressed

[1] See https://www.strategyzer.com/canvas/business-model-canvas.

and to gather some initial ideas of possible solutions. We reviewed literature on (1) inclusive business models and (2) seed systems in agriculture and aquaculture. Literature was collected through a targeted online search, and WorldFish provided specific references related to its work on fish seed systems. A total of 52 papers were reviewed, 28 of which were rejected for not making reference to a specific business model. Annex I: Selected literature provides a full list of the papers reviewed and selected. Each of the remaining 24 papers had one or more business models. On the basis of the literature review, we formulated 10 general ideas for potential business models and, after evaluating the models for their suitability for the Ghanaian aquaculture context, discarded two business models during the desk research stage.

Another source of information available before we started the fieldwork was the project's **baseline surveys** conducted during the first six months of the project (Ragasa et al. 2020a; 2020b). These two surveys—one of grow-out fish farmers in the four regions and the other of hatcheries—provided an initial overview of the composition of the sector in Ghana. The farmer survey targeted all active smallholder fish farmers in the four regions, and also included a sample of inactive fish farmers (those that have temporarily closed production but indicated interest in re-starting their fish farms). A total of 479 active tilapia farmers, 124 inactive grow-out farmers, and 37 hatcheries (3 public and 34 private)[2] were interviewed.

The surveys show that, among grow-out farmers, women are underrepresented; of all farmers interviewed (active and inactive) who were either sole owners or managers, only 53 were women (9% of total respondents). In addition, 50 women (9% of total farming households) are involved in the decision making on fish farming (jointly managed by male and female within the household); another 80 households (13%) have at least 1 female family member or hired labor helping in the fish farming and marketing activities (solely managed by man, with female labor). Women contribute 16% of the total person-days of family labor and 5% of person-days of the hired labor (Ragasa et al. 2020a). Moreover, the hatchery survey found 3 women respondents (owners) out of 18 hatcheries, and another 2 hatcheries had female managers (Ragasa et al. 2020b). Therefore, women are engaged in pond fish farming, although to a lesser extent than men. Although many farms are managed jointly by or involve women and men within the household, there are opportunities to involve more women as the productivity and profitability of these farms improve. Doing so will 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.

Youth—defined by Ghana's national youth policy as those aged 15–35 (Ministry of Youth and Sports 2010)—made up about 21% of the farm survey respondents (14% as owners and 24% as managers). This finding means that youth, who represent about 35% of Ghana's total population, are still underrepresented in fish farming.[3] Nonetheless, youth are very much engaged as family and hired labor for fish farms, and more households are using younger members and hiring younger labor. Of the average 35 person-days of family labor per farming household, youth contribute 24 person-days (19 person-days for males and 4 for females) compared to only 11 person-days from older members. Of the average 55 person-days used of hired labor, youth contribute 38 person-days, compared to 17

[2] This excludes 7 integrated hatcheries that do not sell fingerlings but use all fingerlings for their grow-out operations. Of the 37 hatcheries, 18 have hatchery as their main operation and were interviewed in detail, whereas the other 19 have grow-out farms as their main operation and were interviewed mainly on these grow-out farms and only partly on their hatchery operations.

[3] Calculated based on data from: https://www.worldometers.info/demographics/ghana-demographics/#population-pyramid.

person-days from older labor. Youth represent 68% of the total hired and family labor person-days per tilapia growing cycle (Ragasa et al. 2020a).

2.3 Fieldwork

Fieldwork was conducted in Ghana over the period of September 8–20, 2019 for data collection on fish farmers' and hatcheries' challenges and needs. We visited four regions: Eastern, Volta, Ashanti, and Brong Ahafo. Table 1 gives an overview of the activities conducted per region. We used focus group discussions (FGDs) and key informant interviews as the main data collection methods. We conducted FGDs with small-scale farmers, who were identified by the zonal officers from the FC or the regional fish farmers associations. Sampling criteria were region and distance to a hatchery. Although we could not reach sufficient female or youth farmers to conduct separate FGDs with these groups, where possible we had short additional interviews with women and youth to understand their specific challenges. We also conducted interviews with hatchery managers or staff and staff from WRI, FishConnect, and Profish.

Table 1. Fieldwork activities per region

Eastern and Volta region	Ashanti region	Brong Ahafo region	Accra
• 8 farmer FGDs with 27 participants (0 women, 6 youth) • hatchery interviews with 9 staff/managers (1 woman) • 2 public breeding station (ARDEC) interviews with 4 staff (0 women)	• 4 farmer FGDs with 21 participants (of which 6 were farms with hatchery activities) (0 women, 5 youth) • 1 private hatchery interview with 1 owner (0 women) • 1 public hatchery (PAC) interview with 1 staff member (0 women)	• 7 farmer FGDs with 43 participants (of which 4 were farms with hatchery activities) (6 women, 8 youth)	• 2 interviews with private sector start-ups related to fish seed and marketing: FishConnect with 4 staff, Profish with 1 staff (2 women, 5 youth)

Source: Authors' compilation based on the interviews. Note: ARDEC is the Aquaculture Research and Development Centre of the Water Research Institute and PAC is the Pilot Aquaculture Center of the Fisheries Commission in Ghana.

The FGDs had two stages: a first stage in which we explored challenges and opportunities of fish farmers and hatcheries, and a second stage in which we validated these challenges and opportunities, explored potential solutions, and gauged opinions related to ideas on potential business models gained from desk research and during fieldwork. Box 1 provides some of the guiding questions or topics of the interviews.

2.4 Analysis and business model development

After completing the data collection, the team worked on consolidating the findings, such as synthesizing the challenges and opportunities by farm type (cage versus pond). On the basis of this analysis, we developed four potential business models and populated the BMC for these four types with information we had available.

2.5 Stakeholder workshops

At the end of the fieldwork, we organized two stakeholder workshops to validate the fieldwork findings and discuss the four selected potential business models. The first workshop was held in Kumasi on September 19, 2019, for the Ashanti and Brong Ahafo regions. The second workshop was in Akosombo on September 20, 2019, for the Eastern and Volta regions. Participants included farmers, association representatives, hatcheries, regional directors, zonal officers, FC, WRI, IFPRI, and KIT. Both workshops were half-day meetings in which first results of the baseline survey were presented

followed by a presentation of the business model development process and initial results. Subsequently, each business model was discussed in small break-out groups.

Box 1: Fieldwork: Guiding questions

FGDs with farmers

Stage I

Challenges:

- What are your main challenges as a fish farmer? Why?
- What are the specific challenges related to fish seed and extension services? Why?
- What are your current strategies to deal with these challenges?

Preferences and aspirations:

- Why did you move into fish farming?
- How would you rate your job/business on a scale of 1 to 10? Why?
- What is going well for you as a fish farmer? Why?
- What would you like to achieve with fish farming? Where would you like to be in five years' time?
- In an ideal world, what would change? How would you benefit from it? What would be needed to achieve that?

About support services and groups:

- Please tell us about the support you receive or have received for your fish farming? Who have you received support from?
- What do they do well? What can be improved?
- How often do you receive support? Do you get advice when needed?
- Are you a member of an association or (in)formal group? What kind of group?
- What do they do well? What can be improved?

About seed:

- How often do you access seed?
- At what size do you buy the seed and why?
- From where do you get the seed, and how do you decide where you access seed from?
- What would make you buy more seed or buy seed more frequently?
- Do you face any issues when transporting the seed?
- Would you be interested in buying fingerlings from a small-scale nursery?
- Would you be willing to pay a higher price?
- Would you be interested in buying fingerlings 20, growing them a bit, and selling them commercially?
- Would you buy fingerlings from traders?
- Would you trust certification for hatcheries? What would it require for you to trust it?

Stage II

- Validation of challenges and opportunities from Stage I: How can these challenges be reduced? How can the opportunities be seized?
- Gauging of opinions on statements related to possible business models

Topic of interviews with hatcheries

- Characteristics of the business (years in business, species, products, main customers)
- Challenges serving specific types of customers, meeting demand, or achieving quality
- Capacity and constraints to produce and sell more
- Opportunities to expand
- Additional services provided
- Gauging potential of business model ideas
- Opportunities for youth and women

3. Findings: Literature review

3.1 Inclusive business models

What is a business model?

There are many definitions of a business model, but basically "a business model is a simplified and aggregated representation of the relevant activities of a company. It describes how marketable information, products and/or services are generated by means of a company's value-added component" (Wirtz et al. 2016, 41). Thus, a business model describes the rationale of how an organization creates, delivers, and captures value (Ostenwalder and Pigneur 2010). In simpler terms a business model is "what a company does and how they make money from it" (MITSloan 2019). The concept of a business model is closely related to business strategy (designing business models) and operations (implementing business models into organizational structures and systems) (Vorley et al. 2009). It is applicable for any type of enterprise (e.g., for all sizes, levels of formality, and position in the value chain) (Kelly et al. 2015).

Inclusive business models

Inclusive business refers to a commercial relationship between a private company and a group of formal or informal producers whereby both the buyer and the seller generate social, economic, and environmental value in order to sustain long-term profitable interdependence (Lundy et al. 2014). Some emphasize that inclusive business also expands access to goods, services, and livelihood opportunities in commercially viable ways (Jenkins and Ishikawa 2010).

Unlike their predecessors, the Millennium Development Goals, the United Nations Sustainable Development Goals (SDGs) explicitly call on businesses to apply their creativity and innovation to solve sustainable development challenges (IBAN 2018). Others point to opportunity and speak of the untapped market of 2 billion low-income consumers in developing markets. In that sense, drivers are not philanthropic or focused on corporate social responsibility projects, but rather inclusive business is seen as vehicle to future markets (Gradl and Knobloch 2010). Vorley at al. (2009) stress that including smaller-scale producers and processors in value chains can make good business sense. Sourcing from smallholders, however, is not in itself equal to inclusive development. A business model can be considered inclusive only if it results in moving smallholders out of poverty and improving food security (Kelly et al. 2015).

Just as inclusive business lacks a clear definition, so does the term inclusive business models. First, differences exist in how definitions treat the question "inclusive of whom?" Some definitions focus on integration of small-holder farmers, whereas others for example refer to including low-income communities in the value chain (Table 2). Differences also arise in whether inclusivity of the business model should relate only to the operator of the business or if it should also be about enabling low-income customers to access a product or service they were unable to access before. This latter discussion is relevant for the TiSeed project, because our interest is in farmers as customers of seed businesses. These definitions do not elaborate on specific marginalized groups such as women, youth, or ethnic minorities, nor do they engage with the issue that, by definition, business models may be out of reach to the poorest of the poor (particularly in relation to inclusiveness of low-income people as entrepreneurs).

Table 2. Definitions of inclusive business models

Reference	Definition
Lundy et al. (2014)	"Inclusive business models, understood as those businesses in which smallholding producers are involved as providers (or sellers), represent opportunities for economic and social development for both producers and private actors (or buyers). These models possess the virtue of linking actors more effectively, coherently and transparently when a basic business principle is adhered to: both sides (sellers and buyers) must win."
Vorley et al. (2009)	"Here we define inclusive business models as those which do not leave behind small-scale farmers and in which the voices and needs of those actors in rural areas in developing countries are recognized."
SNV and WBCSD (2011)	"An Inclusive Business is an economically profitable, environmentally and socially responsible entrepreneurial initiative, which integrates low-income communities in its value chain for the mutual benefit of both the company and the community. It seeks to improve the livelihoods of low-income populations while increasing returns to the company."
Kelly et al. (2015)	"Inclusive business models promote the integration of smallholders into markets with the underlying principle that there are mutual benefits for poor farmers and the business community."
Vermeulen and Coltula (2010)	"Business models are considered to be more inclusive if they involve close working partnerships with local landholders and operators, and if they share value among the partners. In other words, for a business model to be inclusive it must not only involve a collaborative relationship, but also fair and equitable terms."
Gradl and Knobloch (2010)	"Inclusive business models include the poor into a company's supply chains as employees, producers and business owners or develop affordable goods and services needed by the poor. Here, human and business development go hand in hand. Sustainability, also with regard to natural resources, is inherent in the concept."

Source: Authors' compilation.

In this review we use the definition for inclusive business models formulated by Kaminski et al. (2019): inclusive business models are pro-poor, equitable, profitable business activities that integrate low-income and/or marginalized producers, processors, retailers, distributors, and/or consumers in the value chain and generate positive development outcomes. This definition explicitly also includes models that are inclusive in terms of the types of customers they reach. The term equitable in this context should be understood as inclusive of women, youth, and other marginalized groups, as relevant to the context, and needs to take intersectionality into account.

3.2 Classification of inclusive business models

Several authors have developed a classification of inclusive business models, while others have provided possible examples. Table 3 provides a summary of these categories and example models. Three main conclusions are drawn (Vermeulen and Cotula 2010). First, **no single model is the best possible option for smallholders in all circumstances**. What works best for smallholders while still being attractive to investors is very context specific and depends on tenure, policy, culture, history, and biophysical and demographic considerations. Second, **none of the models is perfectly fair or a holistic solution to rural development**. By their very nature, these agreements link two sets of players—agribusiness and smallholders—that have very different negotiation power. Third, **the detailed arrangements of the agreements are more important than the abstract model** in defining the extent to which an investment shares value with local smallholders.

Table 3. Classification of inclusive business models and examples

Type	Description	Examples (Vermeulen & Cotula, 2010)
Producer-driven models (Kelly et al. 2015; Vorley et al. 2009).	Smallholder production is driven by individual or groups of small-scale producers. Their main objectives are to serve new markets, get better market prices, stabilize their market position, supply larger volumes, increase bargaining power, and increase access to inputs and services. Collective action and effective business organization are critical strategies to increase small-scale producer participation in emerging markets.	**Cooperatives, associations, or groups:** groups of farmers organize to generate collective action, share costs and risks, increase bargaining power, and enhance reliability of collective supply. **Joint ventures**: co-ownership of a business venture by two independent market actors. A joint venture involves sharing of risks and benefits and, often, decision-making authority in proportion to the equity share. **Farmer-owned businesses**: formally incorporated business structures for farmers to pool their assets into entering into particular types of business (e.g., processing or marketing), gain access to finance, or limit the liability of individual members. Such businesses are often owned by cooperatives in order to facilitate business transactions.
Buyer-driven models (Kelly et al. 2015; Vorley et al. 2009).	Smallholder production is driven by off-takers such as processors, exporters, and retailers. Their main objective is to assure supply.	**Contract farming**: pre-agreed supply agreements between farmers and buyers, usually at an agreed date. Often includes pre-financing of inputs, such as seeds, fertilizers, and pesticides, and also provision of technical advice. **Management and lease contracts**: agreements by which a farmer or farm management company works agricultural land belonging to someone else. To provide incentives for the farm management, the contract often entails some form of profit-sharing rather than a fixed fee. **Tenant farming and sharecropping**: management contracts in which individual farmers (often small-scale) work the land of larger-scale agribusinesses or other farmers. In tenant farming the usual arrangement is a fixed rental fee, whereas in sharecropping the landowner and sharecropper split the crop (or its proceeds) along a pre-agreed percentage.
Intermediary-driven models (Kelly et al. 2015; Vorley et al. 2009).	Smallholder production is driven by intermediary actors such as market actors (traders, wholesalers), nongovernmental organizations, or national and local governments. Their main objectives are to supply more discerning customers and (regional) development. Market actors as intermediaries focus on food safety, consistent quality, year-round supply, and innovation at a competitive price. Models of intermediation include service provision, including finance and technical assistance.	**Upstream and downstream business links**: the set of business opportunities beyond direct agricultural production that exist for both agribusinesses and smallholders and small local enterprises.
Public sector-driven models (Kelly et al. 2015).	Smallholder production is driven by government procurement, hospitals, schools, and food aid agencies. For farmers this provides familiar market outlets closer to home and less demanding requirements than the export sector. For governments a driver would be to promote local markets and assure supply of food to public institutions.	

Source: Authors' compilation.

3.3 Seed systems business models review

We reviewed 52 papers on inclusive business models and seed systems in agriculture and aquaculture. The business models in the papers were analyzed and grouped into the 10 business models shown in Table 4. Details on each business model can be found in Table 5, such as details on the value chain actors involved, issues the model addresses, location and species (crop or fish) and the references of the papers. None of the reviewed seed models made specific reference to inclusion of women or youth.

Table 4. Ten potential business models identified in the literature review

Nr.	Model	Description
1.	Contract farming	Small or larger farms are contracted to produce seed or fingerlings. This is mainly done by larger seed businesses or hatcheries that buy the seed or fingerlings. Credit arrangements may also be involved.
2.	Decentralized seed system: community-based models through farmer organizations or groups	Community-based organizations or farmer groups organize around the provision of inputs and services to their members, including seed. To do so, these organizations usually try to establish stronger linkages with public and private actors. Three sub-models are the following: • The groups set up their own nursery ponds. • Members of the group produce seed and sell to their members. • The group gets seed from a supplier (commission agent) and is paid a commission or uses a mark-up price when selling to members.
3.	Decentralized seed system: (small-scale) local hatcheries	This model includes on-farm hatcheries or smaller hatcheries working independently. It may in some cases require low-cost technologies that allow for hatcheries to be set up in more remote locations. Tested technologies include milt bank, cohort breeding system, hapas, or a portable hatchery.
4.	Decentralized seed system: nurseries	Farmers, fingerling traders, or fishermen set up a nursery in a pond, or public water body. They receive fry and nurse this to a larger fingerling size. There are two models: • Single-stage operation where hatchlings are raised until fingerling stage • Two-stage operation such as raising hatchlings to fry and raising fry to fingerlings. When operated close to the homestead they can provide opportunities for women.
5.	Decentralized seed system: rice-field seed production	Stocking of brood stock or fertilized eggs in irrigated rice fields.
6.	Decentralized seed system: seed traders	Instead of hatcheries (or nurseries) selling directly, seed traders are involved. These can be very small players but can also be companies (e.g., in China). In some cases they receive a commission from the hatchery, or they just mark up the price.
7.	Integrated input and service delivery (through public-private partnerships)	Often with support from public sector and/or development projects, private actors (in case of seed they are hatcheries or nurseries) become involved in input supply and other services and extension. They are also known as local service provider (LSP) models.
8.	Quality assurance: formal certification	Formal seed certification through the National Seed Inspection Services.
9.	Quality assurance: alternative models	Alternatives for formal seed certication include the following: • Group based quality assurance: farmers' associations develop quality assurance protocols to assess the quality of seed produced by its members. • Quality declared seed (QDS): an alternative for formal certification which is decentralized and less demanding but yet guarantees a satisfactory level of seed quality.
10.	Seed diversification	Adding other crops or fish species to the business or farm.

Source: Authors' compilation. Note: Business models in the shaded rows were not included in further analysis.

Table 5. Details on each business model

Nr	Model	Value chain actors involved	Issues the model addresses	Location, species (crop or fish)	Sources
1	Contract farming	Seed producers/ hatcheries, nurseries, farmers	• Uncertainty of seed markets • Seed quality • Lack of production capacity of seed businesses	• Burundi, sorghum, beer • China, aquaculture not specified • India, aquaculture not specified • Uganda, tilapia	Brummett 2007a (p.47); FAO 2007 (working group 2); ISSD Africa 2017-1
2	Decentralized seed system: community-based models through farmer organizations/ groups	Breeders, farmers, nurseries, CBOs	• Access to seed • Seed availability • Seed quality • Aligning breeding with local priorities	• Burundi, rice • Ethiopia, sheep • Nepal, silver carp and bighead carp • Nepal, several fish species • Bangladesh, India, Thailand, aquaculture not specified	Bruno et al. 2016 Gurung et al. 2016 ISSD Africa 2017-1 Kassam et al. 2011 Wagle et al., n.d.
3	Decentralized seed system: (small-scale) local hatcheries	Seed producers/ hatcheries, farmers	• Access to seed • Seed availability	• Burundi, sorghum, beans • Tanzania, cassava • Bangladesh, carps and tilapia • Cambodia, Egypt, tilapia • India, Asian catfish and carps • Asia, several species	Apu et al. 2014 Bruno et al. 2016 Das 2002 FAO 2007 (synthesis Asia) ISSD Africa 2017-1 Joffre et al. 2019 Nasr Allah 2012 Siriwardena 2007
4	Decentralized seed system: nurseries	Hatcheries, nurseries	• Access to seed • Seed availabiliy • Seed quality	• Bangladesh, carps • Cambodia, silver barb, tilapia, and carps • Bangladesh, Egypt, Lao PDR, tilapia • Indonesia, grouper • Taiwan, aquaculture not specified • Vietnam, several fish species (e.g., carps)	Fachry et al. 2018 FAO 2007 (synthesis Asia) Islam et al. 2005 Kunda et al. 2014 Lithdamlong et al., 2002 Nasr Allah 2012 Sovanara et al. 2000
5	Decentralized seed system: rice field seed production	Farmers, extension agents	• Access to seed • Seed availability • Quality seed	• Bangladesh, tilapia and carp • Bangladesh, carp	Siriwardena 2007 Barman and Little 2006 Haque et al. 2014
6	Decentralized seed system: seed traders	Seed traders, hatcheries, nurseries, commission agents	• Access to seed • Seed availability • Seed quality	• Bangladesh, carps • Egypt, Philippines, tilapia • Cambodia, China, India, Indonesia, several fish species	Escover et al. 1987 FAO 2007 (synthesis Asia) Hussain et al. 2012 Milwain et al. 2002 Nasr Allah 2012
7	Integrated input and service delivery models	Hatcheries, seed traders	• Access to seed • Seed availability • Seed quality • Access to technical information and other services	• Ethiopia, Nigeria, Tanzania, chicken • Bangladesh, several fish species	Bruno et al. 2016 Kruijssen et al. 2019
8	Quality assurance: formal certification	Government, seed producers, hatcheries	• Seed quality	• Burundi, crops • China, Philippines, tilapia and other fish species	ISSD Africa 2017-2 FAO 2007 (synthesis Asia)

Nr	Model	Value chain actors involved	Issues the model addresses	Location, species (crop or fish)	Sources
9	Quality assurance: alternative models	Community-based organizations, farmers, government	• Seed quality • Access to seed • Seed adapted to local circumstances	• Uganda, potatoes • Tanzania, crops	ISSD Africa 2017-2
10	Seed diversification	Seed producers, seed enterprises, seed buyers (institutional and individual)	• Uncertainty of seed markets • Dependency on a single crop	• Burkina Faso, Liberia, Sierra Leone, millet, sorghum cowpea	ISSD Africa 2017-1

Source: Authors' compilation. Note: Business models in the shaded rows were not included in further analysis.

These models were evaluated for their suitability for the Ghanaian aquaculture context. On this basis, we dropped two models—decentralized seed system: rice-field seed production and quality assurance: alternative models. We dropped the first because rice-field fish production is not common in Ghana. We dropped the latter because one of the other TiSeed project components focuses on formal certification of hatcheries, and we believe that attempting to develop both at the same time would be difficult.

4. Findings: Fieldwork

As indicated in Section 2.3, fieldwork was carried out in September 2019 and gathered, among others, insight into people's challenges related to fish farming. This Section presents the results.

4.1 Farmers

General challenges

Table 6 provides an overview of the challenges mentioned during the FGDs. The number of Xs in the table indicates the number of times that particular challenge was mentioned: one X means the challenge was mentioned once, XX means the challenge was confirmed or mentioned more than once, and XXX means the challenge was mentioned in all groups of that particular region. The following paragraphs detail farmers' perceptions of the issues.

First, farmers noted issues with extreme high rates of fish **mortality** due to the liver and spleen virus in the Eastern and Volta regions. Currently, only cage farmers are affected—with fish mortality rates up to 90% after 3–4 weeks. Farmers are still unclear how to treat the virus and reduce mortality.

The issue of **feed** is mentioned across all four regions. Farmers are challenged by high costs of feed (which make up 80–90% of production costs), a lack of financial resources to pay for feed, and a lack of availability of more affordable locally produced feed. In addition, they often lack information on how to formulate their own feed, or they do not have the equipment needed to produce feed that it is digestible for fish. Floating feed is a particular challenge, although some farmers have found ways to feed tilapia with sinking feed or feed that has insufficient floating capacity. Farmers in more remote areas mention they often travel long distances to purchase feed. Others also mention issues with the quality of feed, in particular when feed is repackaged without proper labeling. Repackaging also causes information transparency issues because it removes information on expiration date and formulation.

Marketing is especially difficult for pond farmers in the Ashanti and Brong Ahafo regions. Because of limited use of feed (because of lack of financial resources), and poor production practices, farmers

are unable to produce fish to market size. Even after 9–12 months, fish reach a weight of only 100–200 grams, whereas market size starts from about 400 grams. Farmers also indicate they lack bargaining power when they negotiate with retailers. For example, a farmer and retailer may agree on a sale, but the retailer may reduce the price after the farmer has harvested the fish, which then forces the farmer to sell at lower prices. Moreover, farmers have no storage facilities to preserve fish if they have no buyers or if they need to allow for negotiating a better price after harvesting. Some blame the unpredictability of markets; others signal that it may be more an issue of lack of planning and marketing skills among farmers.

The farmers in Ashanti and Brong Ahafo also say they experience strong **competition** from cage farmers in the Eastern and Volta regions for tilapia. They indicate this competition is due to the difference in the nature of production between cages and ponds. Cage farming is usually done at higher intensity with higher stocking densities and use of commercial feed. Production volumes are higher and production cycles usually shorter. This means that cage farmers are able to produce more efficiently, and with current production practices they produce larger fish in larger volumes, with a steadier supply—factors demanded by buyers. In addition, cage farmers are generally closer to Accra, where much of the demand for farmed fish comes from. In all four regions, farmers mention that they face competition with others using the Genetically Improved Farmed Tilapia (GIFT) strain, which is illegal but grows faster than the Akosombo strain. In addition, one group in Ashanti mentioned that experiencing competition from foreigners who are able to receive agri-loans with low interest rates, which makes their investments in fish farming cheaper.

In all four regions, farmers mentioned that they lack the **technical know-how** of fish farming. This know-how relates to all aspects of the production process, such as stocking, pond management, feeds, disease management, biosecurity, and so on. In the Ashanti and Brong Ahafo regions, farmers also mentioned a lack of business know-how. This relates in particular to planning—for example, the ability to calculate the feed costs related to a full grow-out cycle at a certain stocking rate in order to make decisions about stocking based on the expected availability of financial resources. Farmers that stock more than their financial carrying capacity will have poor results in terms of growth rate and size. In the Volta and Eastern regions, farmers mentioned that they would like to have better access to information and research on the latest technologies or updates on mortality issues. Farmers in those regions also mentioned challenges related to access to fish health experts (as few exist in Ghana)—which means they rely on the services of veterinarians instead of specialized fish health personnel—and availability of regional labs to test samples. In Ashanti, farmers mention the lack of water quality testing kits, which means they are unable to monitor water quality.

In the Ashanti and Brong Ahafo regions, farmers mention the low number of **technical officers** to provide support. Extension workers usually lack sufficient budget to pay for transport and may therefore visit only farmers who can cover those expenses. In Ashanti, some farmers also alleged that payments were being asked that go beyond transport expenses. Whether or not this is the case, it may mean that some farmers, especially low-income and remote ones, might not always have access to support. In Eastern, Ashanti, and Brong Ahafo regions, some farmers mention that the technical knowledge of extension officers could be improved. It should be noted that many farmers were satisfied with the support being given and often used the phone to access such information.

Some farmers are members of district-level, regional, or national **associations**. Farmers meet and provide support to each other and exchange information, but other activities—such as lobbying for the sector, collective marketing, or purchasing of inputs—are limited. These issues were emphasized most by farmers in Ashanti but were mentioned in all regions. Moreover, some farmers in Ashanti and Brong Ahafo stated that there is a lack of trust in information coming from peer farmers. One farmer mentioned he would only trust information coming from foreign experts. In most FGDs, a few

individuals had more training on aquaculture than others, but they indicated that it is challenging to fully transfer knowledge received in such trainings to other farmers.

Farmers in all FGDs mention that they lack **access to finance**. The tilapia business has low profit margins and high production costs. Few financial institutions will provide loans for aquaculture, and loans available have a high interest rate. There are also no government subsidies in the aquaculture sector.

Last, **other** challenges mentioned by some in the Eastern and Volta regions are theft, poor infrastructure such as roads and electricity, damaged cages in case of strong winds, flooding after heavy rains, and blockage of outflow of the pond. Other challenges mentioned in Brong Ahafo are water shortage during the dry season, predators such as birds or snakes, and lack of equipment.

Table 6. Overview of fish farmers' challenges

Challenge	Volta and Eastern		Ashanti	Brong Ahafo
	Cage	Pond	Pond	Pond
Mortality				
Liver and splean virus causes high mortality (80–90%; after 3–4 weeks)	XXX			
Feed				
High costs of feed (80–90% of costs); lack of affordable local feed	XXX	XXX	XXX	XXX
Long distance to source of feed		XXX		XXX
Low quality of (repackaged) feed			XX	
Marketing				
Low prices for tilapia (indicated as "cheating" women retailers in Ashanti, Brong Ahafo)	X	X	XX	XX
Low prices for catfish		X	X	XX
Lack of storage to preserve fish when there are no buyers			XX	XX
Unpredictable markets				XX
Lack of markets for small size fish / inability to grow fish to market size		X	X	XXX
Lack of planning / active marketing skills	X			XX
Competition				
Competition with cage farmers in Eastern and Volta regions for tilapia			XX	XXX
Competition from foreigners who have low interest rates on agri-loans			X	
Competition with other farmers using illegal but fast growing strains	XX		X	XX
Technical assistance/ support				
Lack of technical know-how	XX	XX	XXX	XXX
Lack of business know-how			XX	XX
Lack of information (research, disease, latest technologies)	XX		X	
Lack of fish health experts (veterinarians instead of specialized in fish)	X			
Low number of technical (government) officers / experts			XX	XX
Technical officers visit only if you pay / no transport		X	XX	XXX
Limited technical knowledge of experts (agric. extension officers/FC)	X	XX	X	
Lack of regional labs to test samples	XX			
Lack of water quality test kits			XX	
Dormant association / lack of organization	X		XXX	X

Challenge	Volta and Eastern		Ashanti	Brong Ahafo
	Cage	Pond	Pond	Pond
Lack of trust in information coming from other farmers			X	X
Financial				
Lack of financial resources / access to finance	XXX	XXX	XXX	XXX
Low profit margins / high production costs			X	XX
Lack of government subsidies	XX	XX	XX	XX
Other				
Theft	X	X		
Poor infrastructure (light, roads)	X			
Strong winds cause damaged cages and escaping fish	X			
Floodings due to heavy rains		XX		X
Water shortage (during dry season)				XX
Predators (birds, snakes)				XX
Blockage of outflow of the pond		X		
Lack of availability of equipment (nets, scale, protective clothing)				XX

Note: X=Mentioned once; XX=Mentioned more than once; XXX=Mentioned in all FGDs .

Seed challenges

Table 7 provides an overview of the challenges that were mentioned specific to seed. The first challenge is the **availability of fingerlings**. Cage farmers in the Volta and Eastern regions indicate that fingerlings are available; however, if farmers require a larger size or a larger quantity, they need to order in advance, which requires good planning. Seed availability issuers reflect some degree of seasonality as many farmers stock at the same time in order to harvest for sales during the end of year festive season, which is when a peak in demand occurs.

For pond farmers in the Eastern region, the challenge is mainly related to **distance** rather than availability of seed. This challenge seems to be particularly caused by a lack of trust in the quality of seed being produced by some of the hatcheries in the vicinity. Some farmers also indicate they lack information on fingerling sources. Distance is also an issue in Ashanti and Brong Ahafo, and is most pronounced in the latter region where, unlike other regions, few private hatcheries have been established because until recently they were discouraged by regional-level fisheries officers. The result is that fingerlings mainly come from Kumasi (in Ashanti), need to be transported over long distances, and become more expensive, even though the Pilot Aquaculture Development Centre (PAC, managed by the FC) sells its fingerlings at a lower price than ARDEC (the Aquaculture Research and Development Centre) and private hatcheries. In Ashanti, some farmers also indicate an issue with timely availability of fingerlings from PAC.

The second seed challenge is the **quality** of fingerlings. For example, lack of uniformity—or differences in growth rates of the fingerlings—is mentioned in all regions. All groups in Brong Ahafo also indicated quality issues as a consequence of incomplete sex reversal, which also 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. Moreover, farmers in Ashanti and Brong Ahafo mentioned poor growth performance of the Akosombo strain and their desire to try out other strains. This obviously is a contentious and well-known issue that results from illegal strains already having entered the country, and the recent mortality issues. In addition, cage farmers in Eastern and Volta state that they have limited knowledge about the quality of fingerlings. Farmers

explain that there are large differences in quality and prices at different hatcheries. They also observe that some hatcheries have poor management practices, so farmers buy from hatcheries located further away because they have more trust in the quality of fingerlings being produced. Some farmers buy from multiple sources to spread the risk. Most farmers consider the relationship with the hatchery important, especially because many hatcheries, particularly those in Eastern and Volta regions, also provide technical advice.

Third, farmers experience challenges related to **transport** of fingerlings. No proper transport with oxygen systems are available in the country, so transport over longer distances may lead to mortality during transport or after stocking. These issues also arise when farmers lack knowledge on how to properly package fingerlings for transport (conditioning, density in the bag, oxygen). Road quality contributes to transport issues, so farmers in the Eastern and Volta regions transport by boat if possible.

Table 7. Challenges related to fish seed

Challenge	Volta and Eastern		Ashanti	Brong Ahafo
	Cage	Pond	Pond	Pond
Seed availability				
Lack of timely available seed (need to order in advance; requires planning)	XX		XX	
Lack of fingerlings available closeby		XX		XXX
Lack of availability of 5 gram fingerlings (only smaller)		X	X	XX
Issues to feed 1–2 gram fingerlings (affects water quality)			X	
Seed quality				
Lack of uniformity in size	X	X	X	XX
Incomplete sex reversal				XXX
Poor growth performance (of Akosombo strain)			X	XX
Lack of knowledge of quality of fingerlings	XX			
Seed transport				
Mortality during transport and after stocking		XX	XX	
Lack of proper transport (with oxygen systems)	XX			XXX
Long distance to hatchery	XX			XXX
Lack of knowledge on how to package				X

Note: X=Mentioned once; XX=Mentioned more than once; XXX=Mentioned in all FGDs.

Seed preferences

The majority of pond farmers in all regions grow both tilapia and catfish (Table 8). Table 8 also indicates the sources of seed according to both the survey and the FGDs. The survey data show that in all regions, some farmers buy relatively smaller fingerlings than they would prefer. One potential explanation is that farmers don't order in advance for a specific size but order fingerlings at the moment they need them and so take whatever is available. As a consequence, some hatcheries aim to sell fingerlings at 5 grams, but they usually sell them earlier when orders are placed.

Table 8. Seed preferences

	Eastern and Volta		Ashanti	Brong Ahafo
	Cage	Pond	Pond	Pond
Species (survey)	Niloticus (98%), Clarias (5%)	Niloticas (86%). Clarias (71%)	Niloticus (84%). Clarias (69%), Heterotis (1%)	Niloticas (90%), Clarias (67%), Heterotis (1%)
Seed sources (survey)	ARDEC (51%), private (34%)	ARDEC (30%), private (29%), Ashaiman (16%), neighbours (9%)	PAC (61%), ARDEC (13%), private (12%), friends (7%)	PAC (33%), private (23%), ARDEC (19%), friends (12%)
Seed sources (FGD)	ARDEC S-Hoint Novi Farm Crystal Lake	ARDEC Ashaiman (brood stock) Private hatchery (Afraim Plains) Local hatchery	PAC Private hatchery (Obouasi)	PAC ARDEC Sunyani Nigeria Cote d'Ivoir
Average fingerling size, in grams, purchased (survey)	1.8	3.1	4.6	5.2
Average fingerling size, in grams, prefered (survey)	2.3	3.5	6.6	7.1
Fingerling size, in grams (FGD)	Larger fingerlings are not available	5 grams	5+ grams	2–5 grams 5–12 grams 5–10 grams
Stocking frequency (FGD)	Mainly staged	1x per year	Staged (monthly, every 2 months, every 4 months)	1x per year 2–4x per year

Source: Authors' compilations.

Gender and youth

As indicated in Section 2.3, we faced challenges identifying women in our fieldwork. Where possible, we asked women additional questions outside of the specific FGDs. From those interviews, we found that women face additional challenges in fish farming in general, due to several inter-related issues, and especially the following:

- Challenges to balance productive and reproductive roles
- Norms and attitudes about women's capabilities of managing a fish farm or being a fish farmer
- Norms, beliefs, and physical challenges related to women being in or on the water when they are menstruating
- Challenges related to physical strength required for certain tasks

Similarly, we asked youth some additional questions. In essence, young men do not face different issues compared to older men, although they may sometimes lack the experience that older farmers have. Fish farming or fingerling production is also not necessarily considered a good career choice for recent graduates, although the two startups we interviewed were exceptions. We also found that younger farmers may at times be more aware of training opportunities and more open to learning new skills. An obvious challenge for young people is gaining access to land and capital to have their own fish farm.

4.2 Hatcheries

Hatcheries mention the following key challenges in their business:

- Quality of the Akosombo strain

- Use of illegal strains and a lack of monitoring of strains being used
- Poor quality of roads (mortality of fingerlings during transport)
- Poor quality brood stock—lack of good brood stock management practices (e.g., inbreeding) at PAC
- Demand for seed from farmers is limited by the following:
    - The recent disease (mortality): demand for fingerlings has significantly dropped as a result (cage farmers)
    - Lack of skills and knowledge among farmers
    - Lack of capacity among extension officers
    - Lack of affordable feed or of capital to pay for feed
- Lack of ability among some hatcheries to meet short-term or large requests for seed
- Lack of ability to raise fingerlings to a larger size
- Lack of proper seed transport vehicles
- Lack of access to hormones for sex reversal
- High costs of feed and electricity
- Lack of fish vaccines

5. Business model prototypes

The analysis of field findings and ideation resulted in the development of four business model prototypes: nursery, local feed mill, seed agents, and local hatchery for tilapia and catfish (Table 9). For each business model, we will present the business model canvas (our 'prototype'), a rudimentary financial model, and the farmer perceptions on the models collected during the fieldwork.

Table 9. Prioritized business models

Business model	Explanation	Issues it addresses
Nursery	Nursery buys fry from a reliable hatchery, transports them to location near other farmers, and grow them to a larger size.	Addresses the need to bring quality seed and technical advice closer to farmers, reduces grow-out period, and reduces mortality risks.
Local feed mill + advice	Local feed mill (or farmer) with pelleting machine and technical knowledge to advise on feed formulation.	Addresses the need of improved access to affordable an quality feed and reliable advice, without having to travel far.
Agents	A technical expert supplies fingerlings; takes care of transport, acclimatizing, and stocking; and provides technical advice.	Addresses the issue of high mortality or costs associatied with transporting of fingerlings and provides technical assistance.
Local hatchery (tilapia and catfish)	A local hatchery obtains brood stock from a reliable source and has good practices in place. It produces local fingerlings for tilapia and/or catfish to sell to nearby farmers and provides technical support.	Addresses the need to obtain access to fingerlings closer to the farms and get access to technical knowledge.

Source: Authors' compilations.

5.1 Nursery

Business model canvas

<table>
<tr><th>Key partners</th><th>Key activities</th><th>Value proposition</th><th>Competition</th><th>Customer segment</th></tr>
<tr><td rowspan="2">• Hatcheries (fry)
• Input dealers (feed)
• ARDEC/ FC / zonal officers (technical support)
• Fish farmers associations (promotion)</td><td>• Establishing facility (pond/ hapas)
• Technical capacity enhancement
• Checking of quality of facilities and processes
• Promotion among farmers</td><td rowspan="2">Nursery that buys fry from a reliable hatchery transports it to location near other farmers and grows it to a larger size (e.g., 10 grams).

This helps to bring seed closer to farmers, reduce the grow out period, and reduce the risks involved related to mortality.

Quality and technical support are important values of the nursery.</td><td>Where there are many hatcheries with undercapacity, nurseries will face competition from them as they can do the same.</td><td rowspan="2">Cage farmers close to and far from hatchery

Pond farmers far from hatchery (Eastern, Ashanti, Brong Ahafo)

Pond farmers close to PAC (Ashanti)</td></tr>
<tr><td>Key resources
• Access to location to set up nursery
• Access to technical knowledge
• Access to good quality fry
• Social network</td><td>Channels
Roll out via pioneering SME, starting small with a farm that already has some inactive hatchery facilities in place.</td></tr>
<tr><th colspan="3">Cost structure</th><th colspan="2">Revenue stream</th></tr>
<tr><td colspan="3">• Variable costs: feed, labor, transport, 10% guarantee, other inputs
• Fixed costs: pond constructions, hapas, equipment, maintenance</td><td colspan="2">• Sales of fingerlings (income per piece sold)</td></tr>
</table>

Financial model

This financial model is based on the variable and fixed costs of a nursery that produces fry bought at 4 grams and sold at 10–15 grams. Estimated survival rate used for the calculations is 73%.

Variable costs (total fingerlings)

	Quantity needed	Unit	Price/ unit	Total
Fry	11,000	pieces	0.15	1650
Fry transport	1	trip	400	400
Feed (starter)	45	kg	19	855
Lime	1	application	150	150
Fingerling transport	1	Trip	400	400
Fuel costs for pump	1	total	80	80
Total variable costs (for 8000 fingerlings)				**3535**

Fixed costs (1 year)

	Unit	Value	Total	Depreciation (yrs)	Total/ year
Pond	1 (40*50m)	9000	9000	20	450
Hapa nets	10	180	1800	0.5	3600
Sowing of hapa (labor)	10	50	500	0.5	1000
Miscellaneous equipment	1	200	200	1	200
Labor	12	300	3600	1	3600
Total fixed costs					**8850**

Potential client base

Region	No. of farms	No. of fingerlings / farm / yr	Total fingerlings all farms / yr	Share of customers	Total fingerlings all customers
Eastern and Volta	70	6000	420000	10%	42000
Ashanti	112	6000	672000	10%	67200
Brong Ahafo	191	3000	573000	10%	57300

The potential client base is estimated based on a number of assumptions related to the number of farms in the region and the average number of fingerlings each of these farms buys. The share of customers reached by the entrepreneur has been set at 10% of the total potential customers. The average number of fingerlings bought by each farmer, which is based on the baseline survey (Ragasa et al., 2020a), is used to calculate potential annual profits.

Potential profit

Region	Variable costs / yr	Fixed costs / yr	Total costs	Profit margin 20%	Estimated business size (GHC)	Feasible price / fingerling
Eastern and Volta	18559	8850	27409	5482	32891	0.78
Ashanti	29694	8850	38544	7709	46253	0.69
Brong Ahafo	25319	8850	34169	6834	41003	0.72

The potential profits have been calculated using the variable costs per fingerling, multiplied by the number of fingerlings that could potentially be sold, minus the annual fixed costs. We then used a profit margin of 20% to assess the price per fingerling that this would amount to, to assess if this is a feasible price that customers might be willing to pay for larger fingerlings. As the real price of fingerlings has been indicated at 0.80 GCH (10 grams) to 1 GCH (15 grams), this means that the model is feasible with this potential client base.

Perceptions on the model

	Eastern and Volta		Ashanti	Brong Ahafo	Hatcheries
	Cage	Pond	Pond	Pond	
Issues	• Low trust in quality • Transport of larger fingerlings is an issue • Will not work now due to the migh mortality • Farmers may not be willing to pay a higher price	• Seed will be more expensive	• Farmers prefer to buy from trusted sources • For catfish, pricing becomes an issue due to cannibalism • Different perceptions of pros and cons of the two species	• Transport or larger fingerlings is an issue • Different perceptions of pros and cons of the two species	• There may be no willingess to pay more among farmers • It would require a proper cost analysis to convince farmers • Transport at larger size is challenging so it would need to be close to farmers
Benefits	• Shorter grow-out period • Better survival rates	• Reduced distance • Less transport • Access to larger fingerlings	• It can be done in earthen pond • Idea supported by the FC	• Shorter grow-out period • Combined with technical assistance • Shorter distance should reduce transport issues and costs	• Reduced mortality • Shorter growout

Source: Authors' compilations.

5.2 Feed mill

Business model canvas

<table>
<tr><th>Key partners</th><th>Key activities</th><th>Value proposition</th><th>Competition</th><th>Customer segment</th></tr>
<tr><td rowspan="2">• Input dealers (feed ingredients)
• ADREC, FC, zonal officers (technical support)
• Fish farmers associations (promotions)</td><td>• Establishing facility
• Technical capacity enhancement
• Checking of quality of facilities and processes
• Promotion among farmers</td><td rowspan="2">A farmer or feed mill that understands the requirements of fish at different grow-out stages and is able to formulate feed and provide technical information on feeding and other pond management practices.

This helps to make feed costs more manageable and provide farmers with another source of technical info.

Customer support is an important value of the local feed supplier.</td><td rowspan="2">Commercial feed products are direct competitors. Price is higher but performance is likely also better.</td><td rowspan="2">Pond farmers (small-scale)

Cage farmers?</td></tr>
<tr><td>Key resources
• Access to location to set up equipment, and do drying
• Access to technical knowledge
• Access to good ingredients
• Social network for promotion</td></tr>
<tr><td>Cost structure</td><td colspan="2">Revenue stream</td><td colspan="2">Channels
Roll out via pioneering SME, starting small with a farm that already has pelleting machines or a feed mill that shows clear interest.</td></tr>
<tr><td colspan="2">• Variable costs: feed ingredients, labor, water, transport of ingredients
• Fixed costs: quipment, shed, maintenance</td><td colspan="3">• Sales of feed or fees on milling and formulating.</td></tr>
</table>

Financial model

This financial model is based on the variable and fixed costs of producing 1 metric ton of feed by a small feed mill.

Variable costs (1 t of feed)

Cost item	Share	Cost	Unit value	Unit	Total
Rice bran	0.10	15	25	kg	60
Maize bran	0.09	15	25	kg	54
Palm kernel	0.20	15	25	kg	120
Soya	0.60	140	60	kg	1400
Vitamins	0.01	20	1	kg	200
Electricity	-	100	1	t	100
Labor	-	90	1	t	90
Water	-	20	1	t	20
Transport of ingredients	-	200	1	t	200
Total variable costs					**2244**

Fixed costs (1 year)

Cost item	Unit	Value	Total	Depreciation (yrs)	Total/ year
Milling, mixing, pelleting equipment	1	18500	18500	10	1850
Shed	1	22000	22000	20	1100
Total fixed costs					**2950**

Potential client base

Region	No. of farms	Kg of feed used / yr	Total kg all farms / yr	Share of customers	Total feed all customers
Eastern and Volta	70	560	39200	30%	11760
Ashanti	112	330	36960	30%	11088
Brong Ahafo	191	170	32470	30%	9741

The potential client base is estimated based on a number of assumptions related to the number of farms in the region and the average amount of feed each of these farms buys. The share of customers reached by the entrepreneur has been set at 30% of the total potential customers. The average amount of feed used by each farmer, which is based on the baseline survey (Ragasa et al., 2020a), is used to calculate potential annual profits.

Potential profit

Region	Variable costs / yr	Fixed costs / yr	Total costs / yr	Profit margin 20%	Estimated business size (GHC)	Feasible price / kg of feed
Eastern and Volta	26389	2950	29339	5868	35207	3.0
Ashanti	24881	2950	27831	5566	33398	3.0
Brong Ahafo	21859	2950	24809	4962	29771	3.1

Based on the potential client base and a customer share of 30%, the business model is feasible at a sales price of 3.0 GHC or 3.1 GHC per kg. Commercial feed has a price of 4.25 GHC per kg, which means that this business model could potentially be feasible, but performance of the feed produced would need to be assessed.

Perceptions on the model

	Eastern and Volta		Ashanti	Brong Ahafo
	Cage	Pond	Pond	Pond
Issues		• Several tried home-made feed but haven't got a good result yet • Need to know the right formulation	• Lack of capital to buy equipment • Would like to test to see if it works • Would not trust other farmers with advice	• No equipment • Need to know the right formulation
Benefits	• Cheaper alternative for commercial feed	• Cheaper alternative for commercial feed • Feed is not always available • There is a mill and one farmer has a pelleting machine	• Cheaper alternative for commercial feed • Feed is not always available now • Some are already producing own feed. • Some plan to produce ingredients for feed	• Cheaper alternative for commercial feed • Feed is not always available • Some are doing it (low capacity)

Source: Authors' compilations.

5.3 Seed agents

Business model canvas

<table>
<tr><th>Key partners</th><th>Key activities</th><th>Value proposition</th><th>Competition</th><th>Customer segment</th></tr>
<tr><td rowspan="2">• Input dealers (feed ingredients)
• ADREC, FC, zonal officers (technical support)
• Fish farmers associations (promotions)</td><td>• Establishing facility
• Technical capacity enhancement
• Checking of quality of facilities and processes
• Promotion among farmers</td><td rowspan="2">A technical expert supplies fingerlings, takes care of transport, acclimatizing, stocking and provides technical advice.

Customer support and reliability are important values of the agent</td><td>Commercial feed producers are direct competitors. Price is higher but performance is likely also better</td><td rowspan="2">All fish farmers, (especially those with limited technical knowledge)</td></tr>
<tr><th>Key resources</th><th>Channels</th></tr>
<tr><td></td><td>• Access to technical knowledge
• Access to good quality fingerlings
• Vehicle
• Social network</td><td></td><td>Role out via pioneering SME, start small with a farm that already has a pelleting machine or a feed mill that shows clear interest</td><td></td></tr>
<tr><th colspan="3">Cost structure</th><th colspan="2">Revenue stream</th></tr>
<tr><td colspan="3">• Time, travel expenses</td><td colspan="2">• Fixed fee, or fee based on number of fingerlings ordered.
• Transport and fingerling costs also covered by farmer</td></tr>
</table>

Financial model

The financial model is based on a premium on the fingerlings bought, and is therefore directly related to the number of fingerlings that are abought by a farmer.

Potential client base

Region	No. of farms	No. of fingerlings / farm	Total fingerlings all farms	Share of customers	No. of customers
Volta and Eastern (cage)	104	10000	1040000	5%	5
Eastern (pond)	60	6000	360000	10%	6
Ashanti	112	6000	672000	5%	6
Brong Ahafo	191	3000	573000	5%	10

The potential client base is estimated based on a number of assumptions related to the number of farms in the region and the average amount of fingerlings each of these farms buys. The share of customers reached by the entrepreneur has been set at different levels for the four regions. The total fee that a seed agent receives from a client in this particular model depends on the number of fingerlings bought by their clients. As in each region the average number of fingerlings bought per farm varies, the total fee received from each client varies also.

Region	Total fingerlings all customers	Fee (10 pesewas / fingerling)	Feasible fee / customer
Volta and Eastern (cage)	52000	5200	1000
Eastern (pond)	36000	3600	600
Ashanti	33600	3360	600
Brong Ahafo	28650	2865	300

The feasible fee per client in Brong Ahafo of 300 GHC may be too low to be attractive to a seed agent.

Perceptions on the model

	Eastern and Volta		Ashanti	Brong Ahafo	Hatcheries
	Cage	Pond	Pond	Pond	
Issues		• Trust	• Not willing to pay additional costs • Trust • Model was tried before but farmers were being cheated	• Not willing to pay additional costs • Trust • Prefers the FC to provide advice and help with stocking	• It needs to be done by people that have the technical knwoledge
Benefits	• Already some agents active	• Willing to pay if it improves farming		• Already some agents active in Côte d'Ivoire • Allows to do other activities (saves time)	• There are already a few agents doing it

5.4 Local hatchery (tilapia and catfish)

Business model canvas

<table>
<tr><th>Key partners</th><th>Key activities</th><th>Value proposition</th><th>Competition</th><th>Customer segment</th></tr>
<tr><td rowspan="2">• Input dealers (feed ingredients)
• ADREC, FC, zonal officers (technical support)
• Fish farmers associations (promotions)</td><td>• Establishing facility
• Technical capacity enhancement
• Checking of quality of facilities and processes
• Promotion among farmers</td><td rowspan="2">A local hatchery that obtains brood stock from a reliable source and has good practices in place produces local fingerlings for tilapia and/ or catfish to sell to nearby farmers. In addition it provides technical support to farmers.

This will help farmers to obtain access to fingerlings closer to their farms and get access to technical knowledge

Quality and follow-up are important values of the hatchery.</td><td>Direct competitors are other hatcheries and nurseries. Farmers that produce their own seed are also not likely to buy fingerlings.</td><td rowspan="2">Cage and pond farmers (small-scale) far from hatchery</td></tr>
<tr><td>Key resources
• Access to location to set up hatchery
• Access to technical knowledge
• Access to finance
• Social network</td><td>Channels
Roll out via pioneering SME, who is already a good fish farmer, has the trust of other farmers, and has facilities in place to do it.</td></tr>
<tr><th colspan="3">Cost structure</th><th colspan="2">Revenue stream</th></tr>
<tr><td colspan="3">• Variable costs: feed, labor, transport, 10% guarantee, other inputs
• Fixed costs: pond constructions, hapas, equipment, maintenance</td><td colspan="2">• Sales of fingerlings (income per piece sold)</td></tr>
</table>

Financial model

The financial model is based on the variable and fixed costs of a hatchery with annual production of 200,000 fingerlings, that are grown to 4 grams.

Variable costs (hatchery with annual production of 200,000 fingerlings grown to 4 grams)

Cost item	Unit cost (GHC/fingerling produced)	Total cost (GHC/year)
Brood stock	0.017	3400
Feed	0.045	9000
Hormones	0.001	244
Fuel	0.015	3006
Transportation	0.024	4800
Electricity	0.017	3346

Cost item	Unit cost (GHC/fingerling produced)	Total cost (GHC/year)
Disinfectants	0.002	367
Operating & maintenance	0.002	360
Hapas	0.004	800
Total	0.127	**25322**

According to these estimates, variable costs are 25,322 GHC/ 200,000 = 0.13 GHC/ piece. This is used as the variable costs to calculate potential profits.

Fixed costs (1 year)

Cost item	Amount	Depreciation (years)	% for hatchery	Annual amount
Hatchery construction	180000	30	0.2	1200
Vehicle	80000	20	0.2	800
Pelleting machine	18500	20	0.2	185
Security (camera)	15000	10	0.2	300
Office	80000	30	0.2	533
Total fixed costs				**3018**

Potential client base

Region	No. of farms	Number of fingerlings / yr	Total fingerlings all farms	Share of customers	Total fingerlings all customers
Eastern and Volta	70	6000	420000	10%	42000
Ashanti	112	6000	672000	10%	67200
Brong Ahafo	191	3000	573000	10%	57300

The potential client base is estimated based on a number of assumptions related to the number of farms in the region and the average number of fingerlings each of these farms buys. The share of customers reached by the entrepreneur has been set at 10% of the total potential customers. The average number of fingerlings bought by each farmer, which is based on the baseline survey (Ragasa et al., 2020a), is used to calculate potential annual profits.

Potential profit

Region	Variable costs / yr	Fixed costs	Total costs	Profit margin 20%	Estimated business size (GHC)	Feasible price / fingerling
Eastern and Volta	5318	3018	8336	1667	10003	0.24
Ashanti	8508	3018	11526	2305	13831	0.21
Brong Ahafo	7255	3018	10273	2055	12328	0.22

The feasible price per fingerling of 4 grams based on a profit margin of 20% is between 0.21 and 0.24 GHC. The actual price of fingerlings of this size is between 0.15 and 0.30 GHC, which is around the feasible price, which means that the business model could be feasible but that costs would need to be managed carefully.

Perceptions on the model

	Eastern and Volta		Ashanti	Brong Ahafo	Hatcheries
	Cage	Pond	Pond	Pond	
Issues	• Fingerlings are currently available, only requires planning • Trust in quality	• Trust: some hatcheries do not have good practices	• Starter feed is not available	• Trust quality of fingerlings from PAC and ARDEC (not from others)	• Would increase compeitition for existing hatcheries • Depends on the number of farmers in a community • Requires facilities and techncial knowledge
Benefits	• Issue is timely availability not general availability • Due to restocking of cages, larger fingerlings are not available now (need to sell earlier).	• Availability of fingerlings near the farmers • Some farmers currently don't know where to buy fingerlings	• Should address issues with timeliness of catfish fingerlings • Some local hatcheries exist, but they have low capacity	• Availability of fingerlings near farmers • Reduces transport issues & costs	• There is an interest and demand for other species • Would reduce risk and vulnerability linked to dependence on just one species

6. Validation workshop

At the end of the fieldwork, we organized two workshops to validate our findings and prioritized business models with relevant stakeholders. The first workshop was in Kumasi on September 19, 2019, for the Ashanti and Brong Ahafo regions combined. The second workshop was in Akosombo on September 20, 2019, for the Eastern and Volta regions.

During the workshop, we presented our findings and the four prioritized business models. Then, we divided the participants in four groups, with each group discussing one of the business models in more detail. Discussions were guided by the following questions:

1. What is your feedback on the business model canvas and the financial model?
2. What would you like to change or add to the business model canvas?
3. Do you think the model would work and for whom? Why (not)?
4. Do you know potential implementers and/or partners?

After the break-out sessions, each group presented a summary of the discussions in the plenary session, after which the other groups could respond and add any other comments. Table 10 and Table 11 provide a summary of feedback on each model from the two workshops, including the main issues or requirements, benefits, and potential implementers and partners.

Table 10. Feedback from workshop, Ashanti and Brong Ahafo

Business model	Issues / requirements	Benefits	Potential implementers and partners
Nursery	• Transportation costs (transportation could be done by somebody else). • Farmers need to undertand that buying larger fingerlings comes with a higher price per fingerling.	• Interest in fingerlings above 10 grams. • It helps to shorthen grow-out periods and brings income for the nursery. • It takes away stress from the hatchery. • Someone in the group is already selling 10 gram fingerlings and this is profitable. • Model is supported by the FC.	• People who are already in hatchery operations willing to also do grow-out. • Farmers who are already into grow-out with enough facilities. • People with managerial skills
Local feed mill + advice	• In some areas there is no equipment • Lack of funds to buy equipment • Challenges with availability of ingredients • High electricity bills • Feed must be tested to ensure quality. • Need for knowledge on the right formula and technical knowledge • Feed mill must be registered and certified.	• If farmers organize and buy in bulk it will decrease costs. • Idea to produce the feed on credit so farmers can pay back after harvest. • Farmers are interested provided that the costs are lower compared to the commerical feed and the quality is good.	• Kenworth Farm in Ashanti: produces floating feed for herself. Interested to expand. • People who already produce feed or already have equipment. • People willing to invest • Feed ingredient suppliers: partner and bargain a lower price to use the ingredients. • Associations: get equipment for the group (question from government support). • Buyers: link selling agents to the feed mill facility so farmers buying the feed can sell their fish.
Agents	• The agent will charge the costs of transportation + a risk allowance so it becomes more expensive • Risk of cheating • Agents need to be recognized as having the required technical knowledge • Agents need to be endorsed by the FC • Agents have distorted incentives as they are paid on the bases of the number of fingerlings • Limit the responsibilities of the agents (not replace the FC) • Receipts to avoid cheating	• There are already some agents actrive • Farmers can require a minimum weight requirements and uniform sizes for fingerilngs. • Groups of farmers could hire one agent together • The agent will condition the fingerlings • The FC only supervises 5% of stocking so there is scope for more people to provid support.	• Hatchery operators may pay agents • Hatchery operators may offer the service of agents to their customers on a commission basis. • Farmers may pay individual agents • This could be an opportunity for the national service personnel since they are already trained.
Local hatchery (tilapia and catfish)	• Training should be done at the participants' own farm and not at other locations with other facilities. • Farmers should be informed about the certification process. • Decentralization of brood stock won't work. It should be specific hatcheries or people to do these activities.		• Assocations can contribute to identify farmers

Source: Authors' compilations.

Table 11. Feedback from workshop, Volta and Eastern

Business model	Issues / requirements	Benefits	Potenial implementers and partners
Nursery	• Lack of financial assistance to invest in the right facilities. • Lack of holding facilities for hatchery opperators • Need ror education and sensitization • It is too risky with the current mortality numbers in the regino.	• It will spread the costs in the value chain • It will help to expand the industry and create more jobs. • It can help to avoid spread of diseases between farms in case of proper biosecurity measures.	• Existing hathcery operators can expand their facilities. • Grow-out farmers that are far away from hatcheries. • Mainly interesting for pond farmers because most cage farmers prefer 1–2 gram fingerlings.
Local feed mill + advice	• Ingredients must be of high quality. Risk of compromising in quality if the farmer bring the ingredients themselves. • Need for knowledge on the right composition of the feed with locally available ingredients. • Propoer transportation and storage of the feed is important to maintain quality.	• Currently the commercial feed is expensive because there is no competition. • Example: yeast (brewery waste product) can be used. • Example: insects instead of fishmeal.	• Establish linkages with suppliers of ingredients. • Government could subsidize the feed for the farmers. • Volta Tilapia is currently in the process to set up fish feed facilitation. • Cycle Farms are producing feed (based on insects). • Input providers • Farmers • Health unit
Agents	• Issues with trust • Need for technical knowledge on biosecurity and fingerling handling • Need for proper transportation and packaging. • Ensure implementation of the FC movement permit • Ensure standardization of transporters & vehicles	• Some hatchery operators already work with agents • Potential to expand it to marketing and sales of harvested fish. • Add stocking to the activities of the seed agent.	• Different roles are possible: agent, transporter, hatchery operators. • S-Hoint has a dedicated transporter • Crystal Lake, S-Hoint agents • Hatchery operators wiling to invest in a vehicle. • Individuals willing to invest in a vehicle.
Local hatchery (tilapia and catfish)	• Hatchery should be certified. • Brood stock must come from a certified source. • Install and improve biosecurity measures. • Proper storage of drugs, feed and other chemicals. • Use of quality feed (high protein) • Good record keeping	• Could help to improve zonation process of approved and non-approved fish farming areas.	• Farmers association • Improve existing hatcheries instead of setting up new hatcheries. • Nucleus hatcheries, linked to certified hatcheries.

Source: Authors' compilations.

7. Concluding remarks and next steps

Over the past decade, Ghana's tilapia farming has experienced tremendous growth in production, but much of that growth has been driven by large-scale cage farmers around Lake Volta. It remains unclear how this growth is and can be made more inclusive of poor and young women and men. This study was conducted to identify major challenges in the fish seed value chain and to analyze different inclusive business models along the chain that can potentially be implemented in Ghana.

The three top challenges noted in the study were high feed costs or lack of affordable local feeds, lack of technical know-how, and lack of capital or financial resources; these challenges are consistent across all pond and cage farmers interviewed. For cage farmers, the Spleen and Kidney Necrosis Virus causing high fish mortality in Lake Volta was also a big issue. Several initiatives have been put

in place to address this issue, including organizing fish vaccinations and FC's efforts toward stricter enforcement of the ban on foreign tilapia strains. Within the TiSeed project, two workshops have been organized for information sharing among stakeholders and a fish health management manual has been developed and will be used for training farmers to improve overall fish health management and biosecurity measures. In terms of lack of financial resources, one has to be careful of introducing distortionary measures and artificial financial support that will not be sustainable in the long term. According to the baseline survey, more than half of farmers reported that they could access credit or a loan if needed, but only a few actually applied for a loan (Ragasa et al. 2020a). More than half of those who did not apply for a loan said they did not need credit, and 28 percent said they did not have access to credit (Ragasa et al. 2020a). Sixteen percent said the interest rate was too high, 10 percent said they did not have adequate collateral, 9 percent said the loan application processes were cumbersome, and 2 percent said there were no lenders available (Ragasa et al. 2020a). It seems that the lack of access to credit and capital is an issue to some farmers, but not to a majority of farmers. The profitability of fish farming appears to be the major and more urgent issue that needs to be addressed to promote real demand for credit and enable repayments. The study also suggests a strong and urgent need to focus on strengthening the technical know-how of farmers to improve productivity and profitability.

Compared to the challenges above, the issue of seed is not as serious, but there are definitely challenges in terms of 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 the other regions. There is some degree of seasonality in seed availability issues as many farmers stock at the same time in order to harvest for sales during the end of year festive season, which is when a peak in demand occurs. Some farmers also indicate an issue with timely availability of fingerlings. For pond farmers in the Eastern region, the challenge is mainly related to distance rather than availability of seed. This challenge seems to be particularly caused by a lack of trust in the quality of seed being produced by some of the hatcheries in the vicinity. Some farmers also indicate that they lack information on fingerling sources.

Farmers in all regions mentioned the issue of fingerling quality, including the lack of uniformity—or differences in growth rates of the fingerlings. All groups in Brong Ahafo indicated that quality issues also arise as a consequence of incomplete sex reversal, which 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. In addition, cage farmers in Eastern and Volta state that they have limited knowledge about the quality of fingerlings. Farmers explain that there are large differences in quality and prices at different hatcheries. They also observe, because some hatcheries have poor management practices, farmers may buy from a hatchery located further away because they have more trust in the quality of fingerlings being produced. Some farmers buy from multiple sources to spread the risk. Most farmers consider the relationship with the hatchery important, especially because many hatcheries, particularly in Eastern and Volta regions, also provide technical advice.

Several issues were also raised by the hatcheries. First, they complained about the decreasing quality of the Akosombo strain, illegal strains being used, and the lack of monitoring of these illegal strains. Second, they reported poor quality brood stock and lack of good brood stock management practices. Third, the high cost of feed and electricity is a major issue reported. Fourth, some of the hatcheries also reported lower demand of fingerlings from cage farmers due to the fish mortality in Lake Volta and poor knowledge and management practices of farmers causing poor farm performance and low profitability.

On the basis of the literature review, field interviews, analysis of survey data, and stakeholder workshops, this study develops four business model prototypes for seed multiplication and distribution to increase farmers' access to and use of quality tilapia seed: (1) **Nursery**, which buys fish fry from a reliable hatchery, transports them to location near other farmers, and grow them to a larger size; (2)

Local feed mill, with pelleting machine and technical knowledge to advise on feed formulation; (3) **Agents**, technical experts supplying fingerlings, taking care of transport and marketing, and providing technical advice; and (4) **Local hatchery**, which obtains brood stock from a reliable source, produces local fingerlings to sell to nearby farmers, and provides technical support. Initial ex ante financial and profitability analyses were undertaken and will be refined according to the actual context in the particular district where the sensitization and pilot-testing will take place. According to these crude calculations, all business models could potentially be profitable, because feasible price levels to make such models profitable are below reasonable prices for the products. These business models have the potential not only to increase farmers' access to and use of quality tilapia seed but also to provide livelihood and income generation along the fish seed value chain.

Stakeholders in the workshop expressed much interest in all of the models, especially in the nursery operation. Per region, we will identify entrepreneurs willing to test one of the four business models. Identification will occur with the help of the fisheries commission and the regional associations. This will be organized through sensitization of hubs of grow-out farmers at the district level, which will be combined with the practical trainings of core farmers being organized by the FC, WRI, and IFPRI under the TiSeed project. The financial models included here are initial estimates based on fieldwork and stakeholder workshops and will be refined according to the actual context in the particular district where the sensitization and pilot-testing will take place.

For sustainability of project outcomes, the TiSeed project plans to work with producers and entrepreneurs who have some capital, have intentionally not targeted artificial financial support, and have instead focused on technical support. The interested entrepreneurs will receive technical support to establish the required facilities. Then the quality of the facilities and processes put in place will be checked. Of the four business models reviewed, TiSeed Project will work with existing small-scale hatcheries and small-scale feed producers to focus on provision of technical support. For nurseries, these are to be set up within the project. The TiSeed project plans to do sensitization, support in their business plan and marketing, technical assistance, and provide free fingerling or some feeds if necessary.

We will monitor the business models after the enterprises are put into place. A monitoring framework will be developed as a separate document. As a start, the main goal is to achieve financial feasibility and sustainability of the business models. Profits over time will be monitored, for example of nursery operation, compared with their original operation (e.g., grow-out farming up to table tilapia). The monitoring should be able to tell whether it would be better for a farmer to grow fish up to 300–400 grams (status quo) or to operate a nursery and sell the fingerling at 10–20 grams to other farmers. An indicator to monitor is the number of nurseries set up and operational within the next two years (remaining project duration).

The second set of indicators would be on the inclusion of small-scale farmers, particularly women and youth. All pond farmers in Ghana are small scale (only the cage farmers are medium to large scale), so we are already addressing the inclusion of small-scale farmers by including pond farmers. Next is to look at the inclusion of women and youth. Indicators to monitor could include the share of businesses owned or managed by women and by youth, and the share of women and youth clients or customers served by these businesses.

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Annex I: Selected literature

Nr.	Reference	Selected (=1)
1	Apu, N. A., Belton, B., Dalsgaard, J. P., Kruijssen, F., and Meisner, C. A. (2014). Bangladesh small and medium-scale aquaculture value chain development: Past trends, current status and likely future directions.	1
2	Barman, B. K., and Little, D. C. (2006). Nile tilapia (Oreochromis niloticus) seed production in irrigated rice-fields in Northwest Bangladesh—an approach appropriate for poorer farmers? *Aquaculture*, *261*(1), 72–79.	1
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4	Brummett, R. E. (2007a). Freshwater fish seed resources and supply: Africa regional synthesis.	1
5	Brummett, R. E. (2007b). Indigenous species for African aquaculture development. In *Ecological and Genetic Implications of Aquaculture Activities* (pp. 229–45). Springer, Dordrecht.	
6	Bruno, J., Rekik, M., Mekkawy, W., Ouma, R., and Okeyo Mwai, A. (2016). Integrated delivery systems of improved livestock and fish genetics.	1
7	Das, S. K. (2002). Seed production of Magur (Clarias batrachus) using a rural model portable hatchery in Assam, India-A farmer proven technology. *Aquaculture Asia*, *7*(2), 19–21.	1
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Nr.	Reference	Selected (=1)
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13	Green, B. W. (2006). Tilapia fingerling production systems. *Tilapias: Biology, Culture, and Nutrition. Food Products Press. Binghamton, NY*, 181–210.	
14	Guerrero III, R. D. (1986). Production of Nile tilapia fry and fingerlings in earthen ponds at Pila, Laguna, Philippines. In *1. Asian Fisheries Forum, Manila (Philippines), 26–31 May 1986.*	
15	Guerrero, R. D. I. (1996). Philippine tilapia farming technologies and their relevance to Africa. In *The Third International Symposium on Tilapia in Aquaculture. Pullin, RS* (pp. 42–45).	
16	Gurung, S. Participatory market chain approach: An unidentified sustainable supply chain model to boost fish nurseries.	1
17	Haque, M. M., Little, D. C., Barman, B. K., Wahab, M. A., and Telfer, T. C. (2014). Impacts of decentralized fish fingerling production in irrigated rice fields in Northwest B angladesh. *Aquaculture research*, *45*(4), 655–74.	1
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21	ISSD Africa (2013). Technical note 1: Promoting integrated seed sector development.	
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27	ISSD Africa (2017). Synthesis paper 2: Effective seed quality assurance.	1
28	ISSD Africa (2017). Synthesis paper 3: Financing seed business.	
29	ISSD Africa (2017). Synthesis paper 5: Access to foundation seed of varieties in the public domain.	
30	ISSD Africa (2017). Synthesis paper 9: The support for farmer-led seed systems in African seed laws.	
31	Joffre, O. M., Pant, J., Somony, T., Chantrea, B., and Viseth, H. (2019). Transforming aquaculture in Cambodia through introduction of improved tilapia.	1
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Nr.	Reference	Selected (=1)
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36	Kelly, S., Vergara, N., and Bammann, H. (2015). Inclusive business models. *Rome: Food and Agriculture Organization of the United Nations*.	
37	Khan, M., and Alam, M. (2003). Technical efficiency of the hatchery operators in fish seed production farms in two selected areas of Bangladesh. *Bangladesh Journal of Agricultural Economics*, *26*(454-2016-36531), 55–70.	
38	Kruijssen, F., Golam, F., Bråten, Y., and Minneboo E (2019). Assessment of the local service provider model in Bangladesh. Penang, Malaysia: CGIAR Research Program on Fish Agri-Food Systems. Working Paper: FISH-2019-10.	1
39	Kunda, M., Harun-Al-Rashid, A., Morshed, F., Islam, A., and Mazumder, S. K. (2014). Production of Tilapia (Oreochromis niloticus) Fingerling in Hapa Using Swim-Up Fry Involving Women in the Haor Region of Bangladesh. *IOSR Journal of Agriculture and Veterinary Science*, *7*, 2319–80.	1
40	Lewis, D. J., Gregory, R., and Wood, G. D. (1993). Indigenising extension: farmers, fish-seed traders and poverty-focused aquaculture in Bangladesh. *Development Policy Review*, *11*(2), 185–94.	
41	Lind, C. E., Brummett, R. E., and Ponzoni, R. W. (2012). Exploitation and conservation of fish genetic resources in Africa: issues and priorities for aquaculture development and research. *Reviews in Aquaculture*, *4*(3), 125–41.	
42	Lithdamlong, D., Meusch, E., and Innes-Taylor, N. (2002). Promoting Aquaculture by Building the Capacity of Local Institutions: Developing Fish Seed Supply Networks in. *Rural aquaculture*, 155.	1
43	Little, D. C., and Hulata, G. (2000). Strategies for tilapia seed production. In *Tilapias: biology and exploitation* (pp. 267-326). Springer, Dordrecht.	
44	Little, D. C., Innes-Taylor, N. L., Turongruang, D., and Komolmarl, S. (1991). Large fish seed for small-scale aquaculture.	
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