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Sustainability of Pond and Cage Fish Farming Systems in the Ashanti, Bono, Eastern and Volta Regions in Ghana

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Master of Science in International Environmental Studies

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Declaration

I, Belinda Pascaline Agyei, declare that this thesis is an outcome of my research and findings.

Sources of information have been cited accordingly, and a reference list has been added. This thesis has not previously been submitted to any other university for the award of any academic qualification.

Signature: 

Date: 15.12.2022

SUSTAINABILITY OF POND AND CAGE FISH FARMING SYSTEMS IN THE ASHANTI, BONO, EASTERN AND VOLTA REGIONS IN GHANA

Belinda Pascaline Agyei

Photo: Aerial view of pond and cage farming systems
Photo credit: Flosel farms, Sogakope, Volta Region, Ghana

''The earth provides enough to satisfy every man's needs but not every man's greed!''

Mahatma Gandhi

ABSTRACT

This thesis analyses the sustainability of pond and cage fish farming systems in 4 out of the 16 regions in Ghana. In Ghana, aquaculture has experienced significant growth due to increased demand for fish protein, which has high nutritional value. However, the development of fish farms has not been free from complex challenges affecting the socio-economic sectors and the welfare of cultured fish. The study uses two conceptual frameworks: the progression of vulnerability (Wisner et al., 2004) and the four pillars of food systems and food security *(Hasselberg et al., 2020)* to analyse and discuss the environmental, socio-cultural and economic factors related to the challenges in aquaculture development and the sustainability of the aquaculture value chain in Ghana from a social science point of view. Therefore, the study explores the fundamental links between aquaculture development in parts of Ghana and the four components of food security: availability, accessibility, utilisation, and stability.

Mixed methods are used to establish that both farming systems can be successful and have the potential to be sustainable in terms of economic profitability and social and environmental viability. However, Ghana's aquaculture sector is still at the infantile stage, and it may be too early to judge its sustainability. The performance of pond and cage systems to meet current and future economic, social, and environmental demands may equally depend on the efficiency of mechanisms put in place to track, manage, regulate, and control the biophysical inputs and outputs to minimise the effects of aquaculture on the environment and society.

Although large-scale cage fish farming has more potential for exporting and supplying fish nationwide, pond fish farming is economically more affordable at the household and local community levels.

However, the lack of trust and information sharing is a social challenge among aquaculturists and other stakeholders. The study recommends that both pond and cage fish farmers get more organised to influence decisions and achieve a common goal to sustain the value chain of fish farming activities. The collaboration and cooperation of stakeholders are necessary to build trust but must be coordinated through establishing a reliable, transparent, and trustworthy governing body to be accountable to and steer the affairs of aquaculture practices.

Dedication

I dedicate this master's thesis to my late mother for her encouragement in my interest in pursuing my education and a new career in environmental studies.

To my father, siblings, my incredibly supportive husband Oheneba Adusei Agyei and our son Jethro Vidal Odum Agyei, thank you for your prayers and encouragement.

To all my friends in Ghana and Norway, colleagues at the Norwegian embassy in Ghana and Doctors without borders, I am grateful for always motivating me to defy the odds.

To God Almighty, my anchor, I thank you for seeing me through.

Acknowledgements

It took encouragement and motivation from people far and near to help me finalize this thesis.

First, I thank all the participants in the study for their time, guidance, and valuable insights. I would specifically like to thank Mr John Domozoro, Technical manager at PBA farms and Emmanuel Tetteh-Doku Mensah, Researcher from the Water Research Institute in Ghana, for their massive support and valuable input in this thesis. I am thankful to the indefatigable staff of the chamber of aquaculture in Ghana, especially the CEO, Jacob Adzikah and Dr Larweh Tetteh, Research Director. Your passion for the cause is inspiring, and I am grateful for always inviting me to the enriching workshops and conferences you organize with various stakeholders in the sub-region.

I am grateful to my former work colleagues at the Royal Norwegian Embassy, especially H.E Ambassador Gunnar Holm, former Norwegian Ambassador in Ghana, and Mia Evelina Kamarainen, senior fishery advisor, for their contributions. Thank you for the valuable contacts you shared and recommendations of crucial study participants that guided my initial data collection.

I was not wrong when I chose Ian Bryceson as my supervisor, a great man with a fantastic personality. His state-of-the-art lectures on Aquatic Marine resource management and how people interact with the ocean inspired my research focus. I am grateful for the assistance and guidance and for being so understanding, patient and supportive throughout the process.

To all who believed in me, prayed for me and encouraged me one way or the other to finish hard, may God richly bless you.

Table of Contents

ACRONYMS

AfCFTA	The African Continental Free Trade Area
AFJ	Aquaculture for Food and Jobs
AST	Akosombo Strain Tilapia
ARDEC	Aquaculture Research and Development Centre
COA Ghana	Chamber of Aquaculture Ghana
CSIR	Council for Scientific and Industrial Research
EPA	Environmental Protection Agency
GIFT	Genetically Improved Farmed Tilapia
ISKNV	Infectious Spleen and Kidney Necrosis Virus
LSA	Large-Scale Aquaculture
MoFAD	Ministry of Fisheries and Aquaculture Development
PPE	Personal Protective Equipment (PPE)
SSA	Small-Scale Aquaculture
WRI	Water Research Institute

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1. INTRODUCTION

Aquaculture referred to in this context as the farming of fish, has earned worldwide recognition in the food production sector for accelerating tremendously in recent years. As articulated in the 2020 edition of the FAO's State of World Fisheries and Aquaculture, there are challenges ahead despite the crucial role fisheries and aquaculture play in improving food security, human nutrition, providing employment (FAO, 2020) and very significantly in fighting hunger, the second SDG goal in the 2030 agenda (FAO, 2018; FAO, 2020). The global contribution of aquaculture to world fish production has increased from 25.7 per cent in 2000 to 46.0 per cent in 2016–18, providing nearly 20 per cent of the average per capita animal protein intake to about 3.3 billion people worldwide in 2017 (FAO, 2020). Aquaculture is dynamic and practised differently in many countries depending on the type of fish cultured, the location of the farming systems and the intensity of the production system, whether the production is extensive, semi-intensive or intensive. There is growing evidence of the positive correlation between properly managed fisheries by dedicated governments and fishery managers showing leadership and consistent increase in stocks above target levels (FAO, 2020). Therefore, when the aquaculture sector is not adequately managed along the value chain from production, processing, distribution, and consumption, various adverse impacts on the economy, environment, and society can emanate from it, leading to questions about the sustainability of the sector.

The concept of sustainability has evolved over the years from the United Nations Brundtland Commission's report that defined it as meeting present needs without compromising those of future generations in the long term (Brundtland, 1987). Since human needs are dynamic and change over time, this concept has had different interpretations by politicians, civil servants, the private sector, industry players, researchers, and farmers. Therefore, one question this thesis attempts to answer is what sustainability really means in aquaculture terms to stakeholders and how it is achieved in the Ghanaian context.

Critics have accused aquaculture of being unsustainable and not environmentally friendly because of biological and physico-chemical ecological impacts (Asmah et al., 2014). Promoting aquaculture developments may influence biophysical factors such as nutrient cycle, poor water quality resulting from feed application, use of antibiotics to treat fish diseases and putrefying wastes from the fish. In addition, biodiversity integrity might be threatened with the

introduction of genetically improved fish strains (GIFS). Research shows a higher risk of fish escapees where biosecurity measures are lacking. Therefore, good governance and streamlined management practices in areas optimal for aquaculture development are crucial to safeguard the ecosystem.

Aquaculture was introduced in Ghana in the 1950s. The benefits of fish farming in providing livelihoods and an income source for many people at the household, national, and international levels cannot be underestimated. Nevertheless, from when aquaculture was introduced in Ghana in colonial times until now, deliberations on whether these benefits are equally shared among aquaculturists and society are nuanced. Over the years, despite recorded progress, research has shown significant challenges related to aquaculture developments, such as fish diseases like the Infectious Spleen and Kidney Necrosis Viral infection (ISKNV) that hit many tilapia farms on the Volta Lake in 2018 and returns on investments. The lack of physical and regulatory infrastructure, no adherence to biosecurity measures, and poor farm management practices contributed to such disasters. In this thesis, we discuss that although there are environmental impacts of aquaculture practices, the environment may also affect the value chain of fish farming in terms of the water level, quality of fish produced, road accessibility for the transportation of goods and services, exposure to pests (rodents, birds, tadpoles).

The Covid-19 pandemic exacerbated the impacts on socio-ecological systems such as fish welfare, storage, market access, deficient infrastructure, electricity supply, and access to funds. For many local settlers along Lake Volta, fishing is a primary source of livelihood. However, with the fast proliferation of cage fish farms on the lake and other businesses in the hospitality sector, such as hotels, cottages, and restaurants, the privatisation of concessions, which often is proposed as a solution for open-access conflicts, may contribute to other social differences between different stakeholders.

Therefore, to assess the state of aquaculture to meet future demands, this thesis follows the principles of the three pillars of sustainability: economic, social, and environmental viability. This study evaluates how sustainable farmed fish production in Ghana is from a social science perspective in the face of challenges related to water quality, fish health management, food safety, and human security. In order to assess the nexus between these, two leading fish production practices are analysed: cage and pond fish farming.

According to Kassam and Dorward (2017), pond fish farms in Ghana operate at a small-scale subsistence level for local communities yet are the dominant production system accounting for 98% of fish farms. Cage fish farms, on the other hand, represent the other 2% comprising Small and Medium Enterprises (SME) and large-scale aquaculture (LSA), i.e. cage farms engaged in the intensive production of tilapia for commercial purposes (Kassam & Dorward, 2017).

In economic terms, cage fish farming seems to be leading Ghana's aquaculture sector, given its contribution to the national GDP and larger scale of production to meet national demand and viability for export and international trade. This study investigates the positive and negative long-term effects of policies and motivation to increase aquaculture production against the contribution to a socially and environmentally more responsible industry that puts nature, fish welfare, and people's health and well-being before wealth creation.

This thesis builds on relevant works done by Ghanaian researchers Asmah et al. (2014) on the implications of cage fish farming practices in the Volta and Lower Volta; Asiedu et al. (2017) with a comprehensive article on the "prospects and sustainability of aquaculture development in Ghana, West Africa" and a baseline study by Ragasa et al. (2022a) with valuable contributions on the implications for accelerating aquaculture developments in Ghana. The FAO's SOFIA 2020 emphasized sustainability put in action, so this thesis aligns with the guidelines provided in chapter 9 of the Code of Conduct for Responsible Fisheries towards sustainable aquaculture development in Ghana.

1.1 Thesis objectives and rationale

This thesis aims to discuss the sustainability of pond and cage fish farming systems in Ghana, notably in the Ashanti, Bono, Eastern regions and along the Volta Lake. These study areas were chosen on three main criteria: the number of fish farming activities observed in these areas, access to a reliable water source and types of fish cultivated.

This thesis focuses on evaluating people's primary motivation to engage in fish farming and how these motivations fit in the discussion of the sustainability of aquaculture developments. The broad range of ecological, economic, and socio-political benefits and impacts of pond and cage farming systems are considered. A focus on fish welfare and a participatory governance

system is essential to inform decision-making and policy formulation in the aquaculture sector of Ghana.

1.2 Research questions

The main research question is: How sustainable are aquaculture systems in Ghana?

Using a case study approach in Ashanti, Bono, Eastern and Volta regions in Ghana, focusing on two essential fish farming systems, cage and pond fish farms, will help answer the research questions. These are areas where most ponds and cage fish farming activities are prevalent.

The following sub-research questions would guide us in addressing the research question:

- *Why do people engage in fish farming?*
- *What are the perceptions on ecological, economic, and socio-political challenges associated with the sustainable development of pond and cage fish farming in Ghana?*
- *What are the salient issues on the welfare of cultured fish in Ghana from production, processing, distribution, and consumption?*
- *What are stakeholders' perceptions of the opportunities, constraints, participation in decision making and their respective contribution towards sustainable aquaculture in Ghana?*
- *To what extent do fish farmers participate in decision-making in matters that affect the current and future state of the aquaculture sector?*

1.3 Structure of the thesis

This thesis progresses in seven chapters. Chapter one introduces the study's topic and objectives to assess how sustainable pond and cage fish farming systems are in Ghana.

Chapter two follows by giving the study's historical and geographical background within the context of fish as food and aquaculture development in Ghana.

Chapter three blends conceptual frameworks and theories of vulnerability and food systems to explain the challenges of the aquaculture sector. The nexus between the concept of sustainability and the factors associated with aquaculture development in Ghana is explored.

Chapter four shows the methodological choices and methods employed, including how interviews were carried out online with 16 stakeholders, including researchers, representatives of fisheries authorities, and fish farmers, followed up with an online survey to reach out to 51 fish farm managers to participate in the study.

Chapter five focuses on the inputs and data collection related to the research questions.

Chapter six discusses the results linked to the literature review as well as the theoretical and conceptual tools referred to in chapter three.

Chapter seven summarises the research and provides recommendations and foci for future related research.

2. BACKGROUND OF STUDY

This chapter outlines the literature reviewed that provides some historical and geographical background of the country and areas under study. It provides background information on how aquaculture was introduced in Ghana and the place of fish in Ghanaian culture. A general account of aquaculture developments in the past three decades in selected areas in Ghana is provided through an overview of the pond and cage production systems in the following regions: Ashanti, Bono, Eastern and along the Volta Lake with a focus on the two main species cultivated Nile tilapia (*Oreochromis niloticus*) and African sharptooth catfish (*Clarias gariepinus*). Throughout the thesis, these species will be referred to as "tilapia" and "catfish", respectively.

2.1 Geographical and historical context

Ghana is heralded as the "Gateway to Africa" (Utley & Smart, 2016,p.8). The country is located in the Gulf of Guinea and advantageously sits along the Coast of Africa. Ghana's population is about 30.8 million people as of 2021, according to the Ghana Statistical Service (GSS, 2021). It has a rich historical background, given that it was one of the hubs during the cross-Atlantic slave trade, peaked in the 18th century and is the first West African country to have gained independence from British colonialism in 1957. Ghana is a peaceful country with a relatively stable economy and a safe arena for foreign and local investments. However, research showed that colonialism positively and negatively impacted African countries. Lange et al. (2006) defined colonialism as the instalment of economic, political, and sociocultural institutions in a colonized area. Although a territory may become "nominally independent", in reality, it may

be subject to micro-management by other foreign powers (Nkrumah & Nkrumah, 1965). Kwame Nkrumah opined that Neo-colonialism is now the new instrument of imperialism. According to him, an independent nation's political policy and economic systems are subject to external supervision and control mainly through monetary assistance to run the State, strategic deployment of civil servants who can influence policies, and the imposition of a banking system that is dependent on the foreign exchange market (Nkrumah & Nkrumah, 1965)

Like most African countries that became independent in the 1960s, Ghana also experienced several consequences that have made these countries and their people “vulnerable” to foreign administration and policies. Degradation of lands for natural resource extraction, destruction and distortion of natural habitat for construction and extensive agricultural practices, capitalism and the concept of monopolies, heavy reliance on importation of goods and services, corruption, introduction of alien diseases to animals and humans, formal education, and science and technology innovations are some of the known footprints of colonialism that still linger on in Ghana.

Figure 2.1-1 New administrative map Ghana with flag 2019 vector image Source: VectorStock (2022)

According to Béné (2007), there are 15 rivers, principally the Black, White and Red Volta and the Oti river covering a surface of 237,870 km²and 12 reservoirs, with the largest being Kpong (36.5 km²). Considering that 10% of the land surface in Ghana consists of inland waters and river systems, there are many opportunities for capture fisheries and aquaculture developments (Doku et al., 2018). Fig.2.1-2 shows that almost 90% of the whole country is suitable for fish farming since the land is well endowed with water resources such as lakes, rivers, seas, dams and dugouts (Amenyogbe et al., 2018; Oteng-Ababio et al., 2017).

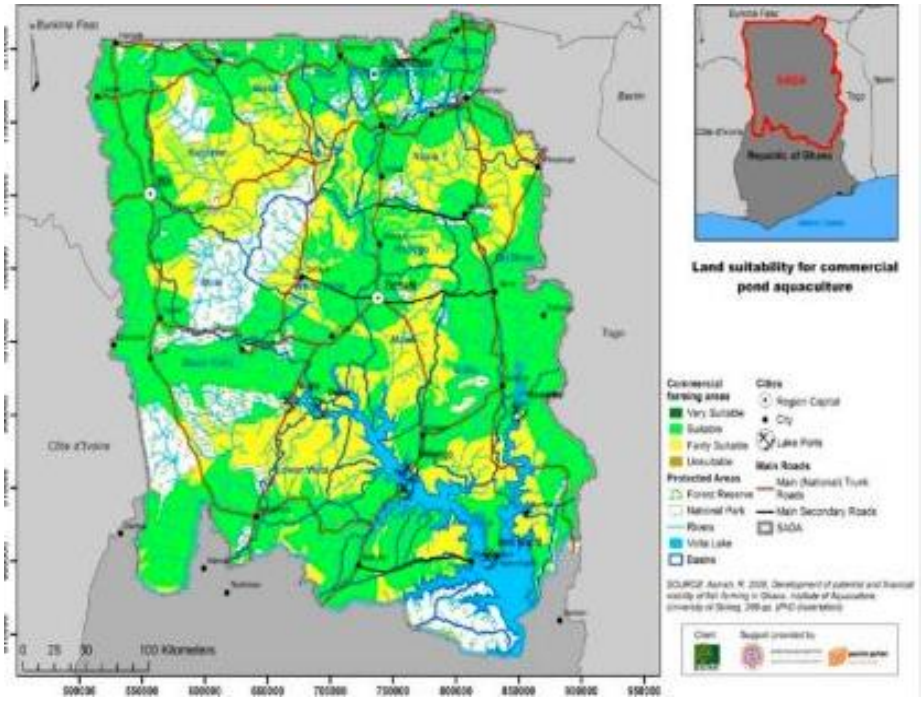


Figure 2.1-2 - Map showing areas in the SADA zone suitable for pond aquaculture. Source: SADA office, Accra (2016) by Oteng-Ababio et al. (2017)

Aquaculture was introduced in Ghana during colonial times in the 1950s (Kassam, 2014). It was a government intervention when, according to FAO, hatcheries were constructed in Northern Ghana in 1953 by the former Department of Fisheries. The aim was to sustain, on the one hand, the culture-based reservoir fishery development programme of the colonial administration and, on the other hand, to supplement the national demand for fish and provide livelihood opportunities by teaching communities along small reservoirs to engage in fish farming (FAO, 2022d). In their handbook, De Graaf and Janssen (1996, p.1) believed that one of the reasons

aquaculture failed to expand in Africa in the 1950s generally was due to the misjudgement by legislators and the "myth" that the primary motivation of fish farmers in rural communities was mainly for food security or a source of protein for their family rather than for income generation. Some of the other reasons they mentioned that contributed to the discouragement of farmers to abandon their fish ponds were the harvesting of small stunted tilapia due to lack of knowledge in husbandry techniques, over-reliance on subsidised extension services and centres that supplied them with fingerlings and other natural limitations.

In the post-independence era and in recent times, aquaculture in Ghana changed with the massive promotion of commercial cage fish farms, especially in Volta Lake, which encouraged commercial investors (Amenyogbe et al., 2018).

2.2 Fish as food and livelihood

Fish is described as a “treasure store of nutrients” (FAO, 2018, p.113), an essential source of food and income for lots of people across the globe (FAO, 2018; Tidwell & Allan, 2001) and, particularly, a vital dietary source of micronutrients in developing countries (Hasselberg et al., 2020). Beyond providing cheaper protein, fish oils and products, fish farming, whether stand-alone or combined with other agricultural practices, has helped create jobs and sustain a livelihood for many (Allison, 2011), including women who are mainly involved in processing and distribution (De Silva, 2019).

The FAO and the World Health Organization (WHO) are leading the United Nations Decade of Action on Nutrition for 2016–2025, which aims to raise awareness about fish's role and ensure it is incorporated into food security and nutrition policy (FAO, 2018). "Putting fish on the table" would mean a closer integration of fish into the debate in alleviating poverty and having both direct and indirect impacts on ensuring Food Security and Nutrition (FSN) for many developing countries battling malnutrition over the years (Béné et al., 2015). Such strategies aim to strengthen and facilitate more robust collaboration between stakeholders concerned with the fish supply chain in countries like Ghana to improve their livelihoods while producing high-quality, nutritious fish for consumers' well-being. Therefore, aquaculture's contribution to

addressing SDG goals 2 (no hunger) and 14 (life underwater) cannot be overlooked in the fight against poverty and ill health.

For more than six decades, the increase in global fish consumption rate was significantly above world population growth, and research showed that the average yearly growth rate of total food fish consumption was 3.1 per cent, overtaking the annual population growth rate of 1.6 per cent (FAO, 2020). Ghana's annual population growth rate is reported to be 2.19% (FAO, 2022c) in 2021, which is higher than the annual global growth rate and justifies the high demand for fish products.

This high fish consumption pattern was mainly accredited to increases in production and a combination of many other factors such as enhanced technologies in processing, cold chain, shipping and distribution; the global income rises that strongly correlate with higher fish and fish products demand, efforts in reducing losses and waste; and increase of fish as a healthier choice for consumers (FAO, 2020).

Asiedu et al. (2017) mentioned that according to FAO (2014,2016), fish consumption per capita in Ghana was estimated at 26 kg, which was higher compared to the world's average (20 kg) and Africa's average (10 kg). Also, fish occupies an important place in the Ghanaian diet and provides an estimated 60% of the animal protein needs for people (Asiedu et al., 2017). The general perception is that in Ghana, high and middle-income consumers patronize more tilapia as high-value fish than low-income consumers who patronize cheaper fish such as catfish and pelagic species like Sardinella (*Sardinella spp*.) from the sea, 'one man thousand' (*Sierrathrissa leonensis*) from inland fisheries (Kassam & Dorward, 2017)

Research has shown that despite rising Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) production, their patronage depends on people's purchasing power. They are perceived to be relatively expensive compared to the imported farmed tilapia from low-cost countries such as China (Amenyogbe et al., 2018) and the small local pelagic fishes such as anchovies. The latter is reported to be people's preferred choice of fish because they are relatively cheaper, available (fresh, smoked or dried) and accessible throughout the year for home meals (Onumah et al., 2020).

Ragasa et al. (2022a) said that, based on the original project proposal of the MoFAD, in order to meet the national demand for fish as food, the government of Ghana implemented the

Aquaculture for Food and Jobs (AFJ) programme, which is an expansion of Planting for Food and Jobs (PFJ) programme. The AFJ had the twin objectives to increase production domestically to 91,000 metric tonnes (mt) in a span of three years (2018 to 2020) and create decent jobs along the value chain to ensure wealth creation among the populace, especially among women and the youth (Ragasa et al., 2022a). Based on their analysis of the programme, there are significant, interrelated components of the AFJ encompassing production, extension service efficiency, market development, and project coordination and management. However, the perception about the performance of the AFJ is that its implementation has been slow, and the main impact is felt in empowering the youth, institutions such as prisons and schools and fish farmers with inputs to increase production (Ragasa et al., 2022a). This exacerbates the challenges in other value chain areas, such as the lack of market development for the fish produced.

The type of tilapia and catfish farmed in Ghanaian waters have been thriving well because their physiology is such that they can withstand a wide range of environmental conditions.

For many years, tilapia production outpaced catfish production in Ghana. However, from 2017-2019 we noticed better performance in catfish production. It is evidenced that the Infectious Spleen and Kidney Necrosis Virus (ISKNV) outbreak was a significant hit on the tilapia farms in 2018, and catfish, having a high growth rate, has proved over time to be more resilient in handling stress and being very well valued in many African countries (De Graaf & Janssen, 1996).

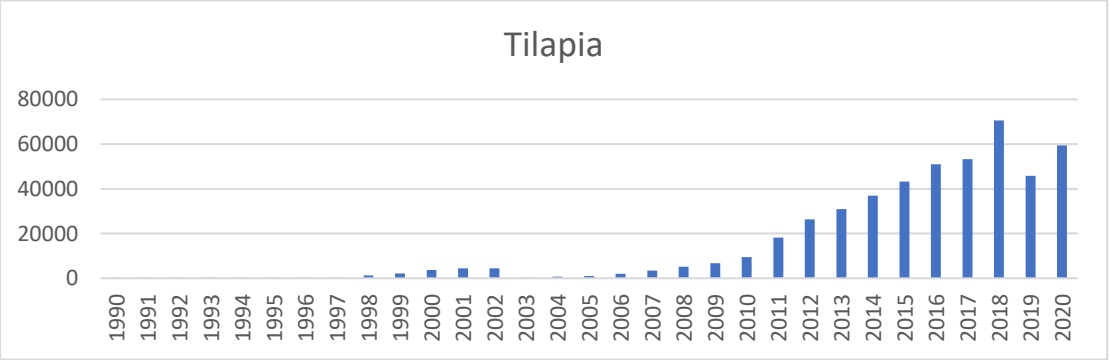


Figure 2.2-1 – Tilapia aquaculture production in Ghana (1990-2020), FishStatJ, FAO Global Fishery and Aquaculture Production Statistics, Source: (FAO, 2022a)

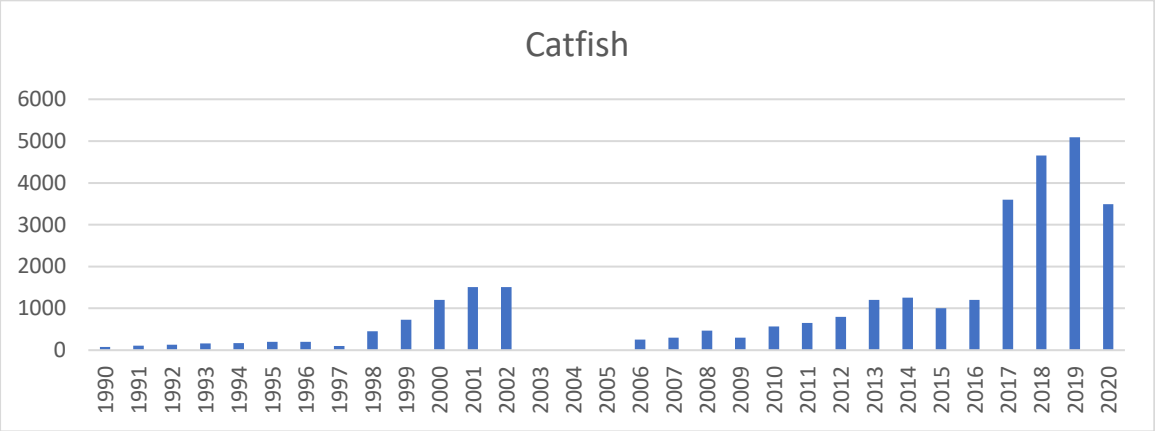


Figure 2.2-2 Catfish aquaculture production in Ghana (1990-2020), FishStatJ, FAO Global Fishery and Aquaculture Production Statistics, Source: (FAO, 2022a)

2.3 Status of Aquaculture Development in Ghana to meet high fish protein demand

Fisheries have played a significant role in supporting the Ghanaian national economy since independence in 1957 (Dabi & Dzorvakpor, 2015) and are estimated to contribute 3 per cent of the total GDP and 5 per cent of the GDP in agriculture (FAO, 2022d).

According to the FAO, Ghana's total inland fishery production is unclear, and it is difficult to determine a definite figure. They estimated the value of Ghana's aquaculture production to be US$ 1.5 million a year, although generally, there is no accurate data and information concerning its contribution to food security, employment, and poverty alleviation in the country (FAO, 2022d). According to the FAO, pond fish farmers operate at a smaller scale, and they practice extensive and semi-intensive aquaculture in contrast with commercial cage fish farmers, who adopt intensive aquaculture practices.

The numbers recorded from 1999 signalled that many people started developing an interest in aquaculture, coinciding with the emergence of the first cage aquaculture farm on Lake Volta at Dodi Asantekrom in the Asuogyaman District, Eastern Region in 1998 (Asmah et al., 2014). New cage farmers rapidly colonised the lake, and intensive aquaculture systems have become until now the backbone of aquaculture in Ghana, accounting for > 90% of fish production (Ramírez-Paredes et al., 2021).

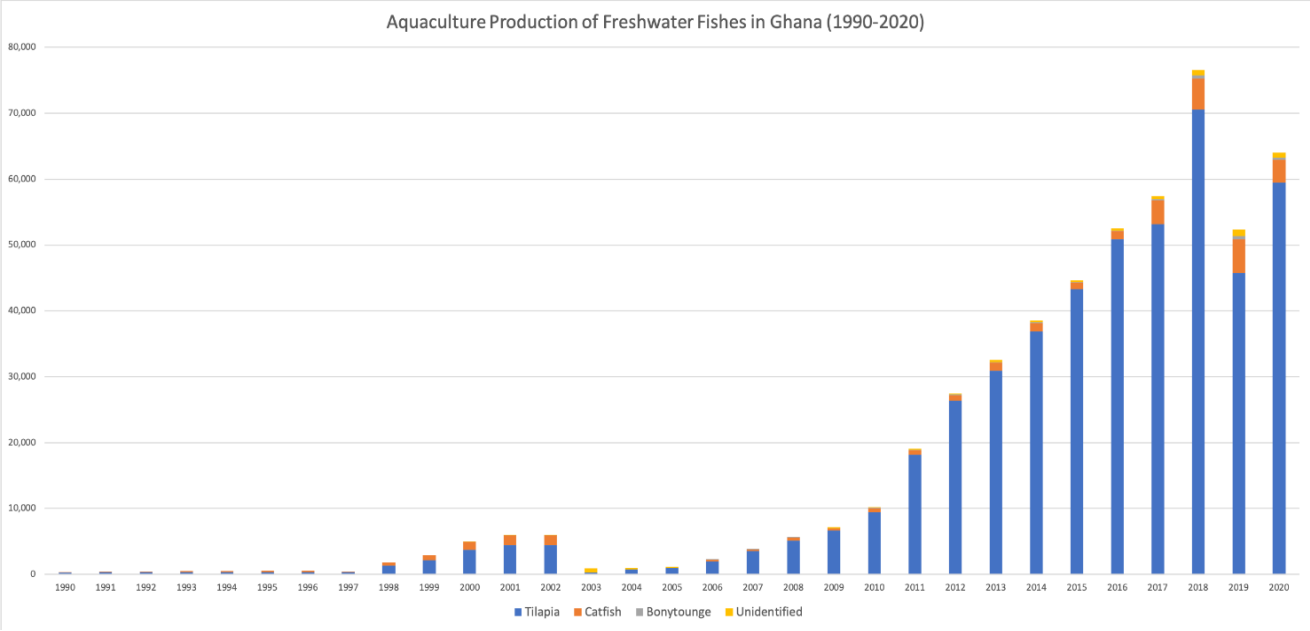


Figure 2.3-1 Proportional contribution of aquaculture production of freshwater fishes in Ghana according to FAO statistics (1990-2020) Source: FishStat J

The main types of fish cultivated are tilapia which constitute over 80 per cent of aquaculture production, while the catfish and bonytongue *(Heterotis niloticus)* constitute the remaining 20 per cent (FAO,2022d).

Official statistics showed that before 1998 (see Fig.2.3-1), domestic aquaculture production was also deficient, probably due to a lack of technical know-how for intensive fish cultivation and using rudimentary tools (Asmah et al., 2014). National Aquaculture yields dropped drastically from 2003 to 2005 because of the ineffectiveness of the sector in dealing with some significant challenges. There was limited access to quality inputs such as fish seed and feed as viable commercial activities to contribute to the development and sustainability of the industry (FAO, 2022d).

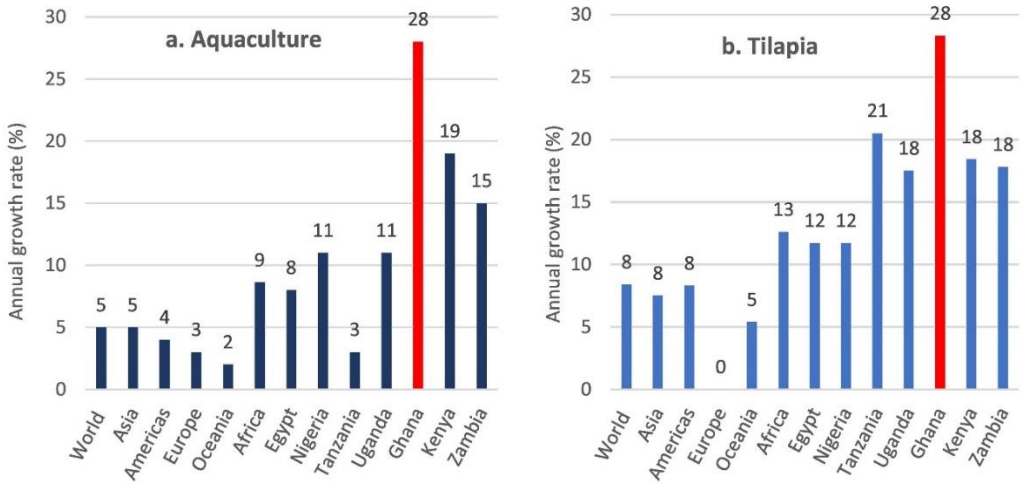


Figure 2.3-2 Annual growth rate in aquaculture and tilapia production, globally and in top-producing countries in Africa (2005–19) source: FAO FishStatJ database, (Ragasa et al., 2022a)

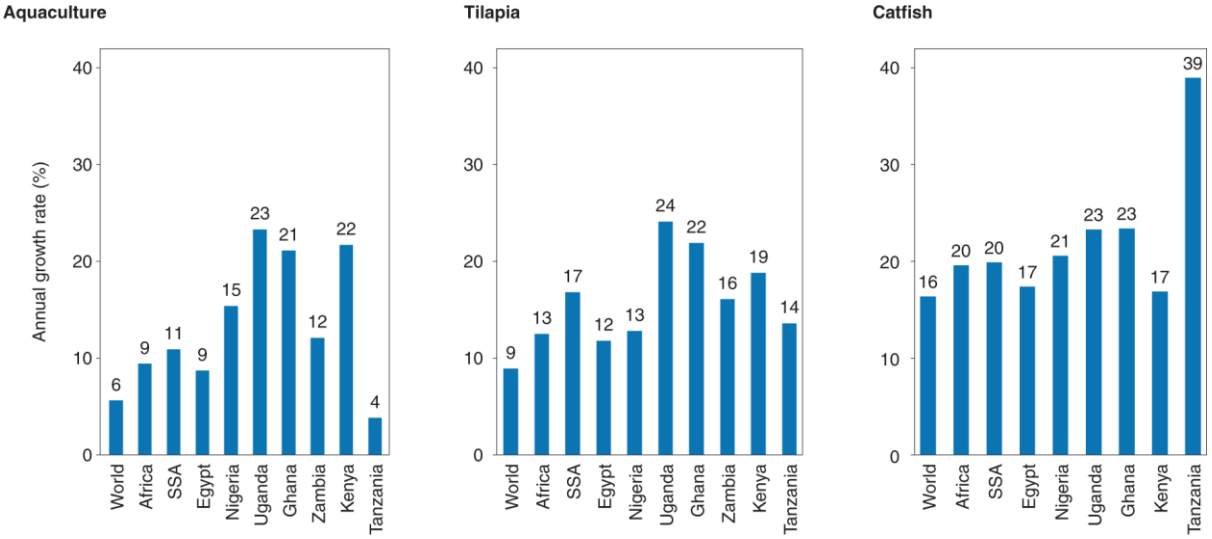


Figure 2.3-3 Annual growth rate in production volumes for aquaculture, tilapia and catfish from 2000-2019 (Ragasa et al., 2022b)

Ragasa et al. (2022a, p.2) explained in Fig.2.3-2 that Ghana's aquaculture, compared to other African countries, expanded "the fastest, at an annual rate of 28% from 2006 to 2019" owing to more research focus and investments on large-scale cage farming around Lake Volta even

though the majority of fish farmers are engaged in pond farming. In Fig. 2.3-3, Ghana is among Africa's top three tilapia and catfish producers.

Between 2013 and 2016, "the national aquaculture production grew from over 32,512 mt/y to 52,470.49 mt/y, representing 11.3% of the national harvest" (Amenyogbe et al., 2018). Total aquaculture production reached its highest in 2018 with 76630 mt/y (FAO, 2022d).

The Ghanaian fisheries sector mainly involves the following: marine capture fisheries (artisanal or small scale; semi-industrial; industrial; tuna fisheries), inland fisheries (freshwater) and aquaculture. Aquaculture production has been growing consistently from 2010-2017 (MoFAD, 2022a) as compared to relatively static inland production (Fig.2.3.4)

In 2017, 70.1% of the fisheries sector was mainly from marine production, while 17.1% represented inland capture production and 13.8% from aquaculture production (MoFAD, 2022b) see Fig.2.3-5

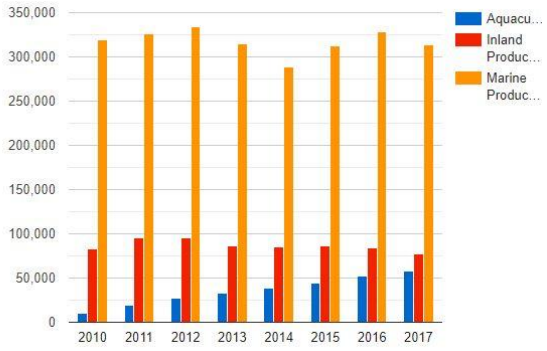


Figure 2.3-4 Fish Production (in Metric Tonnes) By Year (2010 to 2017) Source: (MoFAD, 2022a)

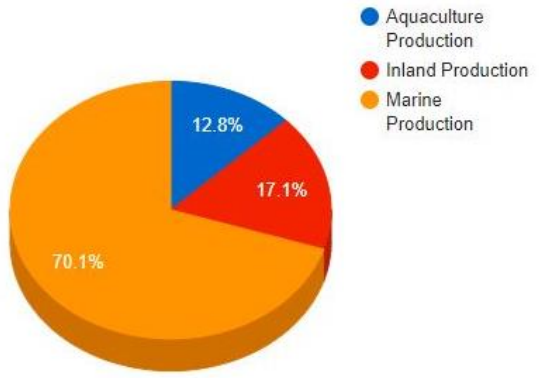


Figure 2.3-5 Fish Production Percentage Contribution by Sector (2017) Source: (MoFAD, 2022b)

The International Food Policy Research Institute (IFPRI) mentioned in a study that this growth was attributed to the presence of government initiatives and support, the development and release of an improved local Akosombo strain (AST) tilapia in 2005, better management practices and technologies in hatcheries and other production systems, and the availability of high-quality feeds locally (Ragasa et al., 2018). For many years the tilapia, for instance, has been one of Ghanaians' most preferred and patronised fish. The economic viability and contribution of tilapia production to national development and fighting food insecurity cannot be underestimated. Following genetic improvement programmes to boost aquaculture production, two main strains from the Nile tilapia (*Oreochromis niloticus*) originating from Africa were introduced in Ghana. The "Genetically Improved Farmed Tilapia" (GIFT) was developed in 1980 by ICLARM, now WorldFish, together with some partners, and the "Akosombo strain" was developed in the years 2000-2003 by a team of Ghanaian researchers from the Aquaculture Research and Development Centre (ARDEC) a branch of the Water Research Institute and the Council for Scientific and Industrial Research (WRI-CSIR) (Ansah et al., 2014; Asmah et al., 2014; Trinh et al., 2021).

Trinh et al. (2021) concluded in their study that the GIFT strain developed in Asia outperformed the Akosombo strain generation 10, constituting the Akosombo selected line (AKOS) and Akosombo control line generations (AKOC) developed in Ghana. According to the Water Research Institute, the GIFT strain developed "*1.6 times faster than the Akosombo strain after 122 days*" (Trinh et al., 2021, p.5). Trinh et al. also observed that the performance of the GIFT strain was attributed to its ability to gather with mouth wide open at the water's surface during feeding times to compete for food, contributing to faster growth performance, survival rate, and resistance to diseases. However, the AKOS performed better than the AKOC, and according to the CSIR-WRI, the harvest period for the Akosombo strain was reduced from eight to six months with a higher survival rate than the unimproved local strains(Trinh et al., 2021). There have been growing concerns about introducing elite strains through these genetic improvement programmes to balance conservation and increase aquaculture production. Asmah et al. (2014) discussed that fish escapees are somehow inevitable and pose a biological threat to conserving the integrity of local species in Ghanaian waters, mainly where biosecurity measures are absent. Therefore, they proposed that it is more prudent to use indigenous species that minimise the risk of gene pollution (Asmah et al., 2014).

The vulnerability of the aquaculture sector was evidenced in late 2018 when production dropped to 52360 mt/y in 2019 (FAO, 2022d), and according to Ramírez-Paredes et al. (2021) from September 2018 to March 2019, many tilapia farms along the Volta Lake were plagued by an infectious spleen and kidney necrosis virus (ISKNV) with very high levels of morbidity and mortality (60%–90%) that affected both vaccinated and unvaccinated tilapia. The results of their study suggested that high production costs and reduced harvests led many farms to halt production temporarily or permanently. The reduction in sales of the primary feed suppliers, such as Ranaan Fish Feeds, by up to 70% and the fluctuation of tilapia market prices due to shortage of production were indicators of the effect of the ISKNV at a larger scale on the aquaculture industry (Ramírez-Paredes et al., 2021)

Further on, the thriving aquaculture sector in Ghana was not spared by the Covid-19 crisis. Fish farmers had challenges accessing inputs and selling their fish, and farmgate fish prices dwindled but started to bounce back by the end of 2020 (Ragasa et al., 2022a).

3. CONCEPTUAL FRAMEWORK AND ANALYTICAL APPROACH

3.1 Vulnerability

The literature on "vulnerability" reveals that the term is rooted in human geography and social sciences. Research has shown that over the last 20 years, there has been a tremendous expansion of the amount and scope of the use of the term in scientific research (Kim et al., 2021). It is commonly mentioned in climate-related research covering significant themes such as *risk, hazard, and disaster management.* It is also prevalent in the discourse of global change and environment and development studies *(Weichselgartner, 2001, p.87).* Recently, the term has also been adopted in other cross-disciplinary research like cyber security, coastal management, and urban planning, for example, in terms of the extent to which a system, people or communities are subjected to attacks and adverse effects of exposure to certain natural or physical conditions (Kim et al., 2021).

Füssel (2007) reiterates the thoughts of Newell et al. (2005) in viewing vulnerability as a "conceptual cluster" in anthropogenic research (Füssel, 2007,p.156). The different perspectives and revolutionary thinking beyond a conventional way of looking at the concept reveal how complex yet relevant this concept is in interdisciplinary research and even within the same field of study. However, there are significant distinctions in the meanings ascribed to

it depending on the context, systems, different epistemological inclinations, and disciplines (Füssel, 2007; Weichselgartner, 2001).

Weichselgartner (2001) describes the concept as a "vehicle" used in different contexts to look at how best to reduce losses caused by natural hazards to achieve sustainability and contribute to the quality of life. However, Adger (2006) gives a more recent view of vulnerability as the degree of exposure to harm and pressures linked to environmental and social change and the capacity to cope or adapt to such perturbations.

Although many attempts to have a universal conceptual framework for vulnerability have proven problematic, it requires a holistic approach to analysing risks in natural or social systems.

Therefore, in discussing vulnerability, it is critical to consider the context, scale (global or local), characteristics of the regions under study (developed or developing), factors contributing to a vulnerable state, the nature of a system, the kind of hazard or threat: biophysical, technological, or social (Füssel, 2007; Weichselgartner, 2001)

A common denominator in the conceptualisation of vulnerability is the recognition that beyond natural factors, there are socially constructed or socio-political and economic processes that propel a vulnerable state.

The second edition of the influential book "At risk" by Wisner et al. (2004) throws more light on the perspectives of vulnerability by criticising the ideological, cultural myth that associates the vulnerability of people with poverty or being in a bad situation. It questions natural disasters and other social processes that make people vulnerable in the face of universal environmental changes and economic globalisation. It suggests that extreme natural occurrences can only be referred to as a disaster when a group of people are exposed to such (Wisner et al., 2004). Therefore, in discussing disasters, natural hazards and human action cannot be decoupled; it is a complex mix of the two *(Wisner et al., 2004).* In addition to natural triggers, the way social systems operate can make some people more vulnerable and prone to disasters than others*. (Wisner et al., 2004)*.

One significant contribution to the literature is that the risk society often creates new risks in providing security, making a system and people more vulnerable *(Wisner et al., 2004)*. It

elucidates the importance of culture or cultural settings and how a blend of traditional knowledge and modern science can make a system resilient or vulnerable. Often, vulnerability may be described as the opposite of resilience, given that the concept does not have a comprehensive theoretical grasp of ecological processes compared to its grounding in social and political theories. The combination and complementarity of the two concepts, as prescribed by Adger (2006), could be interesting. Adger (2006) illustrates the relevance of the combined effect of vulnerability, resilience and adaptation on social-ecological systems in the face of climate change. He presents several challenges to frame the concept of vulnerability to encompass the social aspects using measurement methods that include "perceptions of risks and vulnerability". Adger contributes to the discussion by pointing out the importance of efficient governance systems in focusing on equitable participation in decision-making and adaptive solutions at different scales to mitigate risks and promote resilience.

Based on Adger's views, this thesis propels that vulnerability may go beyond defining weak systems and could be viewed in how individuals think, act or perceive their surroundings and how their motivations can expose them to harm.

Furthermore, in analysing socio-ecological processes in the sustainability of aquaculture production in Ghana, this thesis seeks to analyse the sustainability of the fish farming systems from a social science perspective. Therefore, to assess the vulnerability of the management of fish farming systems in Ghana to current and future changes as well as hazards, it is worth checking the environmental, economic and social factors that could lead to a striking disaster in the thriving aquaculture sector in Ghana and provide adaptive measures to mitigate such impacts.

Therefore, the Pressure and Release (PAR) model by Wisner et al. (2004) is the analytical framework used to assess "the progression of vulnerability" related to cage and pond farming systems. The book explains that vulnerability results from the interconnection of three interlinked processes: "the root causes, dynamic pressures and unsafe conditions". A disaster occurs when there is a clash between these three processes and natural hazards that sometimes are beyond human control. The sustainability of the aquaculture sector depends on mitigating these factors by avoiding a potential clash with different hazards that could lead to a disaster or the collapse of the fish farming systems. The PAR model describes disaster as the meeting point between hazards and vulnerability: Risk= Hazard x Vulnerability (R=HxV).

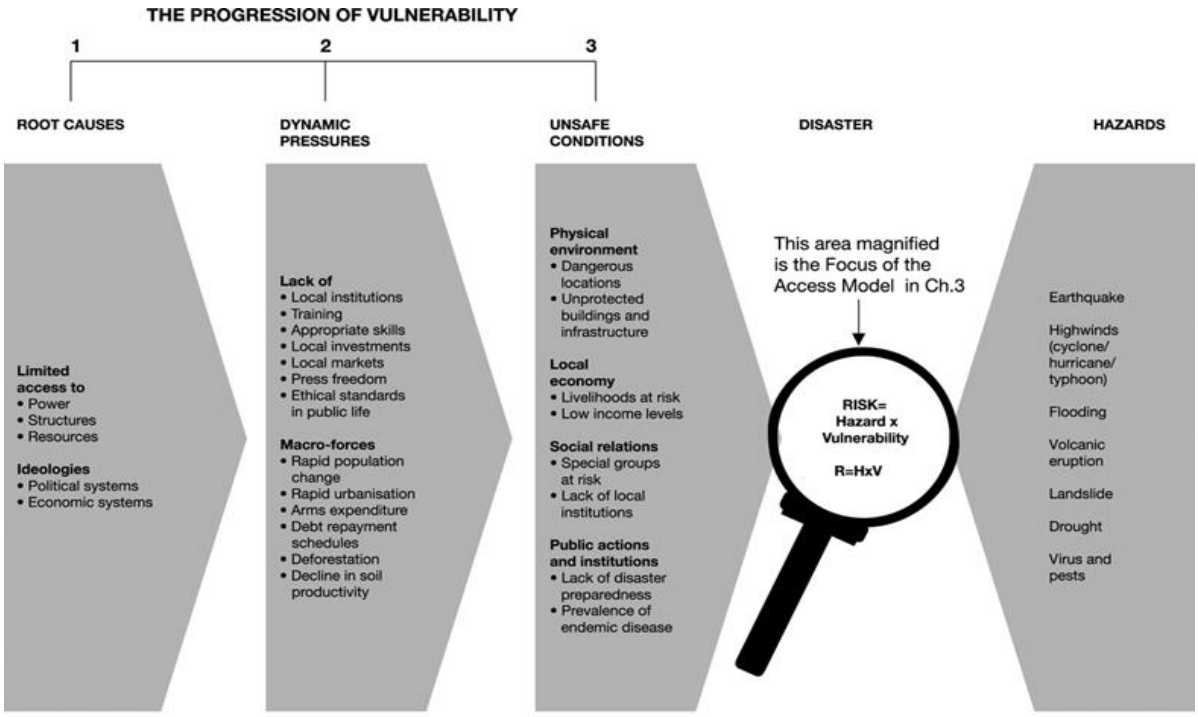


Figure 3.1: Pressure and Release (PAR) model: the progression of vulnerability (Wisner et al., 2004, p.51)

3.2 Food security, Food systems and Fish as food

The FAO's SOFIA (2018) suggests that when there is food security, "*all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life*"(FAO, 2018, p.113). Research shows that the concept of Food security originated about 45 years ago in the era of global food crises, and owing to its complex "multidimensional and multifaceted operational construct", its definition has since then evolved with over 200 interpretations (Berry et al., 2015; Smith et al., 1993). However, the above widely adopted definition stems from the Rome Declaration on World Food Security in 1996, which involves three essential dimensions at different levels: availability (national), accessibility (household), and utilisation (individual) (Peng et al., 2019). In 2009, it was further developed to include the concept of vulnerability and stability as short-term indicators of the capacity of food systems to withstand shocks that are either natural or anthropogenic (Berry et al., 2015) and affect the dimensions mentioned above over time (Peng et al., 2019).

More recently, this widely accepted definition of food security has been further expanded by the High-Level Panel of Experts (HLPE) to include the notions of agency and sustainability explicitly in explaining the concept (HLPE, 2020). According to the HLPE, "agency" is about all people's ability to access enough needed nutritious food and their capacity to partake in policy processes and decision-making concerning their choice of what they should eat and produce. Furthermore, sustainability is reflected in the time frame whereby "at all times" presumes the short, medium, and long-term processes and implications.

According to the FAO, the multidimensional actions required shall encompass the improvement of food systems governance and inclusive and responsible investments in different areas such as agriculture, rural communities, health and education, empowerment of small-scale producers and reduction of risk through strengthening social protection mechanisms.

This thesis was inspired by Norad's policy formulation on the Fish for Development programme (FfD) published in September 2019, and the content developed by NORGHATI (the Norway-Ghana Tilapia initiative) in 2015 was based on the concept of "fish as food" and how Ghana could learn from Norwegian aquaculture best practices. This thesis seeks to contribute to the discussion on food security, nutrition, and sustainability. It, therefore, attempts to link the perceptions of the introduction of aquaculture as an intervention for food security with the deficiencies in the supporting systems tailored at different levels described from production, processing, distribution, and consumption. However, the emphasis is on the socioeconomic, political and ecological factors as elaborated in the proposed conceptual framework (Fig. *3.3*) by Hasselberg et al. (2020), which will be elaborated in the discussion part.

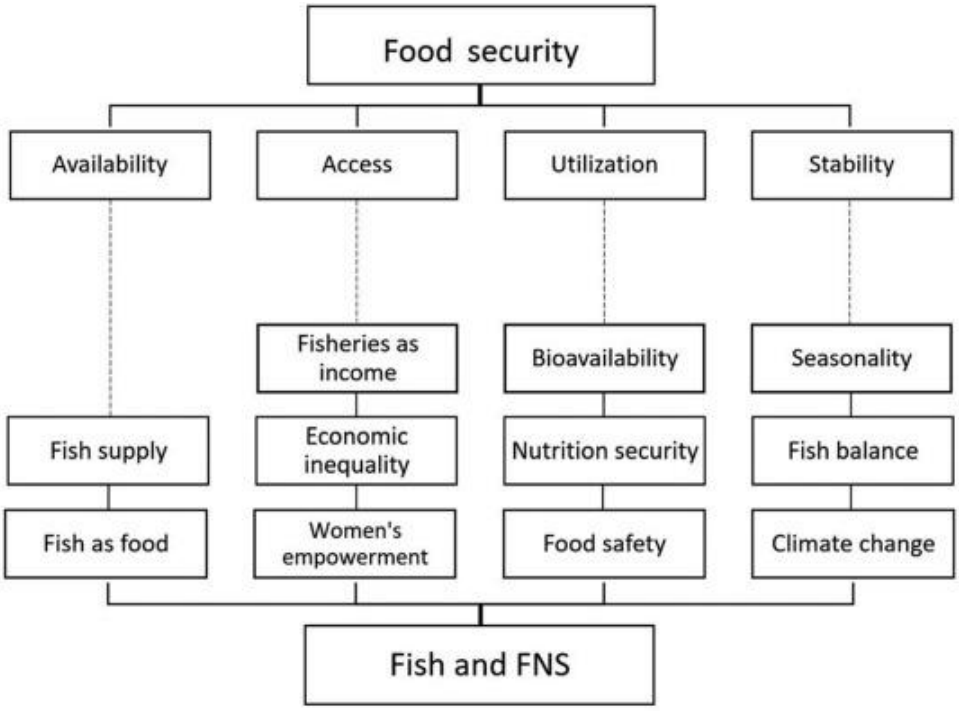


Figure 3.3: Conceptual framework for the review article, the four pillars of food security (FAO, 2006) and selected focus areas related to fish and FNS in Ghana by Hasselberg et al. (2020)

4. METHODS

This chapter presents the approaches to conducting this research. Subsection 4.1 introduces the research strategy, design and study area. The sample selection process is explained in subsection 4.2. In subsection 4.3, data collection methods are presented. Methods for data analysis are shown in subsection 4.4. The chapter ends with an explanation of the study's limitations, ethics and trustworthiness in subsection 4.5.

4.1 Research strategy, design, and study area

4.1.1 Research strategy: mixed qualitative and quantitative

A mixed method strategy was applied to address the research questions of this study for triangulation and verification of claims. It is an approach used as a simple shorthand to represent studies that combine quantitative and qualitative research in a single project (Bryman, 2016, p.635).

Qualitative and quantitative data design, collection and analysis follow a unique framework since they respectively involve *epistemological commitments* and are distinct *paradigms* (Bryman, 2016, p.636).

The first stage of this empirical work involved a qualitative approach because it was a more natural enquiry process to allow an in-depth understanding of fish farming activities from a sociological viewpoint.

The research questions in this inductive approach facilitated learning from the direct experiences of informants and stakeholders while collecting personal accounts of various activities from production, processing, distribution, and consumer preference. The focus was to identify the salient issues affecting pond and cage aquaculture, group them into major themes and understand how the informants made meaning out of sustainable aquaculture practices in line with the main research question.

The second step involved a quantitative approach to test the main concepts deduced from the interactions with participants and the relevant literature reviewed.

The major themes that ran through the interview sessions were grouped into four modules to develop the online survey. The aim was to assess the sustainability of pond and cage fish farming with a significant focus on social, economic, environmental, and political aspects:

Module A- General information about the business

Module B- Fish Production, Input, Output, Storage, Cost

Module C- Fish Welfare

Module D- Level of participation in decision-making.

However, merging the results of both methods contributed to having a complete and reliable dataset for analysis. Bryman (2016) explains that completeness is better achieved when quantitative and qualitative methods are combined. According to him, "*the gaps left by one method (for example, a quantitative one) can be filled by another (for example, a qualitative one)"(Bryman, 2016, p.644)*

The objective of the triangulation of qualitative and quantitative data sets collected at different points and from several participants was to confirm the factors affecting pond and cage fish farming as prescribed in the literature. It also helped evaluate similar conclusions regarding new knowledge, such as the lack of trust among stakeholders for a sustainable aquaculture sector. It contributed significantly to the validity of qualitative and quantitative findings so that they could be verified or "mutually corroborated." Although there is a possibility of failure to

corroborate during triangulation, this process in mixed methods research helps to cross-check results from the two methods employed and increases confidence in the findings by using different ways of measuring a concept (Bryman, 2016).

4.1.2 Research design: exploratory sequential design and embedded design

In carrying out this study, a mixed methods research design was done to collect qualitative and quantitative data at different points in time. The findings were analysed, integrated, and conclusions were drawn in a single study to address the research questions (Tashakkori & Creswell, 2007). Bryman cited four out of six research designs that Creswell and Plano Clark (2011) distinguished and are commonly used in social research: "Convergent parallel design", "Exploratory sequential design", "Explanatory sequential design", and "Embedded design" (Bryman, 2016, pp.638-639).

Thus, the research in this thesis followed an "*exploratory sequential design*", whereby qualitative data were gathered first and subsequently guided the design of an online survey based on sub-research questions to collect quantitative data. According to Bryman (2016), there are two aims to using "exploratory sequential" designs in research. Firstly, the researcher makes hypotheses from the investigations to develop research instruments like a questionnaire to collect data for quantitative assessment. Secondly, quantitative research is carried out as a follow-up to qualitative findings to allow the scope and generalizability of the qualitative data being assessed (Bryman, 2016).

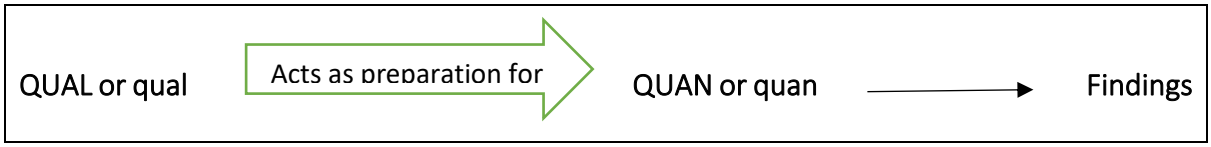


Figure4.1-2: Exploratory sequential design based on Creswell and Plano Clark's (2011) basic methods design (Bryman, 2016, p. 639)

The research questions were based on general concerns derived from the literature reviewed regarding the sustainability of aquaculture worldwide.

The nature of the research questions was open-ended and thus required an in-depth investigation that would generate significant themes such as motivation, vulnerability, fish welfare, associations, cooperatives, and participation in decision-making. The themes derived from the interview notes served as a preparation to formulate specific quantitative sub-research questions to follow up on the key findings or interpretations of the qualitative data.

For instance, the first research question sought to understand why people engaged in fish farming. During the interactions with the participants, it was deduced that different motivations depended on the types of cultivation system, location and the species farmed.

The level of associations and correlations between the variables were established to debunk, complement or validate the claims made by the participants.

4.1.3 Study areas

This work's initial focus was on fish farming activities in the Volta and Brong Ahafo regions, where most farms were perceived to be predominant. However, during the research, it was identified that the government of Ghana had carried out some zonation exercises and demarcated the country into 16 administrative regions, initially ten regions. The significant change was in the Brong Ahafo region, which was now divided into three (3) distinct regions, i.e., Bono, Bono East and Ahafo regions. However, fish farmers and Extension service Officers (ESO) from these three areas who participated in this study were classified under the Bono region covering the Sunyani section, where most ponds and small-scale aquaculture were sited. The names Brong Ahafo and Bono were used interchangeably based on the literature review and the outcome of this study.

The zonation exercise revealed inconsistencies regarding the actual location of cage farms and the regions in which they operate. The Volta Lake cut across some regions from south to northern parts of Ghana, and the fact that most cage fish farm systems were found around the lake did not imply that they were located in the Volta region, as one may be tempted to believe. The regional location of the cages was determined by where the people mainly launched their activities. For example, the location of the office building, cage, warehouse or storage place would determine the fish farm's operation area.

Considering these facts, the scope of the study expanded to include a case study of operational farms in the Ashanti region, Bono region, Eastern region and along the Volta Lake. These are the main areas in Ghana where pond and cage farming systems are predominant. While tilapia and catfish pond fish farms were predominant in the Ashanti and Bono regions, cage systems intensively producing tilapia were more present in the Eastern and along the Volta Lake in the Volta region. Asiedu et al. (2017) noted that these four regions accounted for around 86% of aquaculture production in Ghana (27, 450.56 tonnes) based on MoFAD (2013).

These study areas were classified into regions and numbered in alphabetical order: Ashanti (1), Bono (2), Eastern (3) and Volta (4). The maps below were generated by Ragasa et al. (2020) in the IFPRI/WRI household survey and hatchery assessment (2019). Their study involved 55 farmers without GPS coordinates of their fish farms (2 farmers in Ashanti, 10 in Brong Ahafo, 29 in Eastern, and 14 in Volta). Therefore, this thesis used it as a baseline study for the selected areas to contact the farms mentioned in their research.

Pond fish farming was commonly practised in the Ashanti and Bono regions (Fig. 4.1-3a, 3b). In contrast, cage fish farming was more prevalent in the Eastern region and along the Volta Lake (Fig. 4.1-3c,3d). Therefore, these regions were selected based on their varied and significant contribution to aquaculture development in Ghana (Fig.4.1-3e).

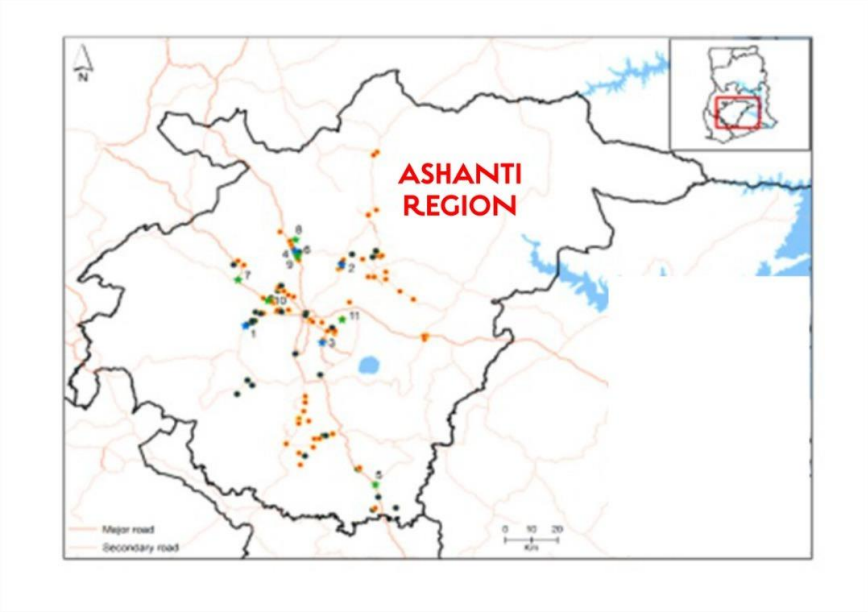


Figure 4. 1-3a: Location of pond fish farms in the Ashanti region adapted from Ragasa et al. (2020)

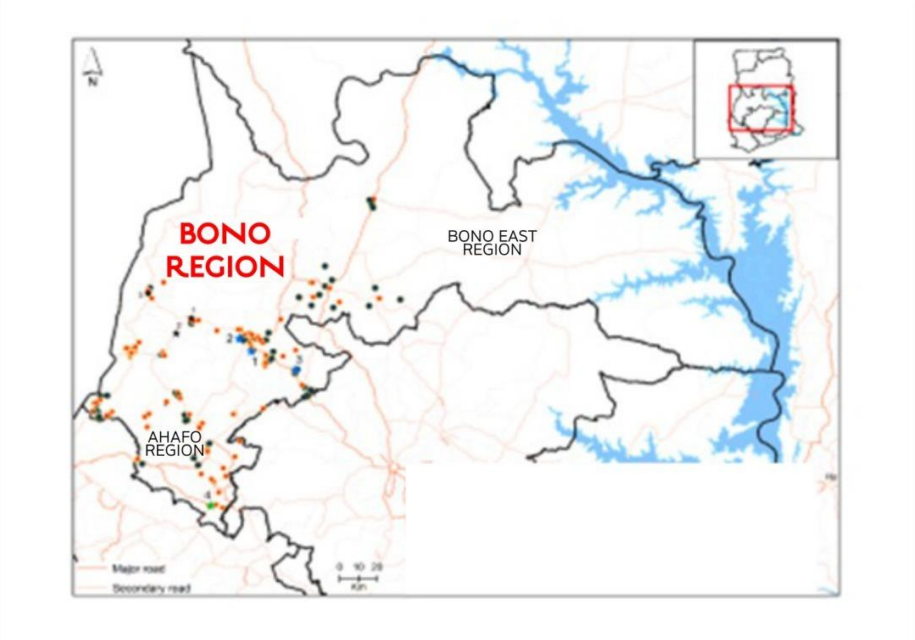


Figure 4. 1-3b: Location of pond fish farms in the Bono region adapted from Ragasa et al. (2020)

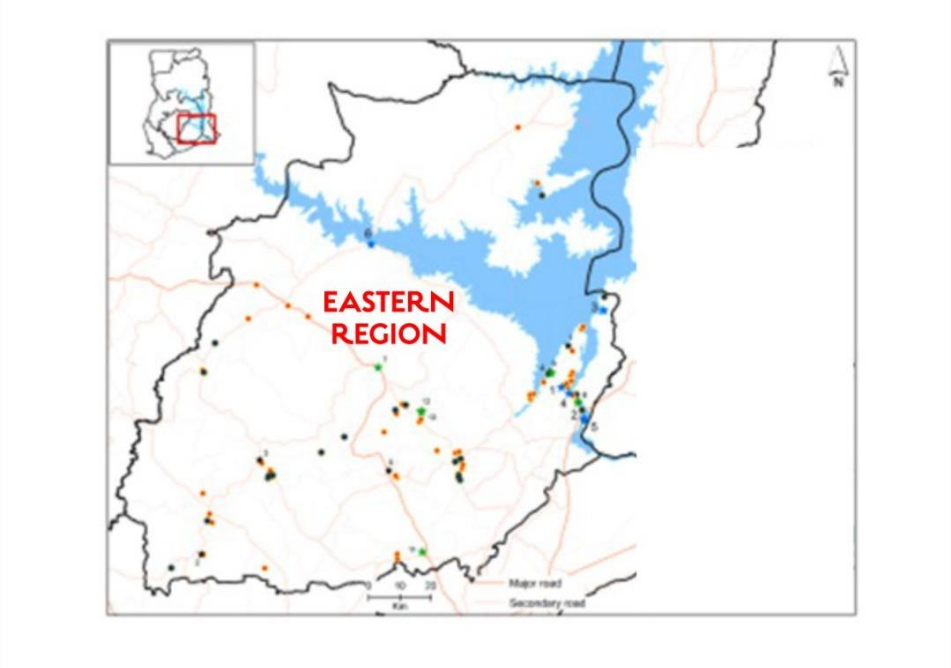


Figure 4. 1-3c: Location of cage and pond fish farms in the Eastern region adapted from Ragasa et al. (2020)

Figure 4. 1-3d: Location of cage fish farms in the Volta region adapted from Ragasa et al. (2020)

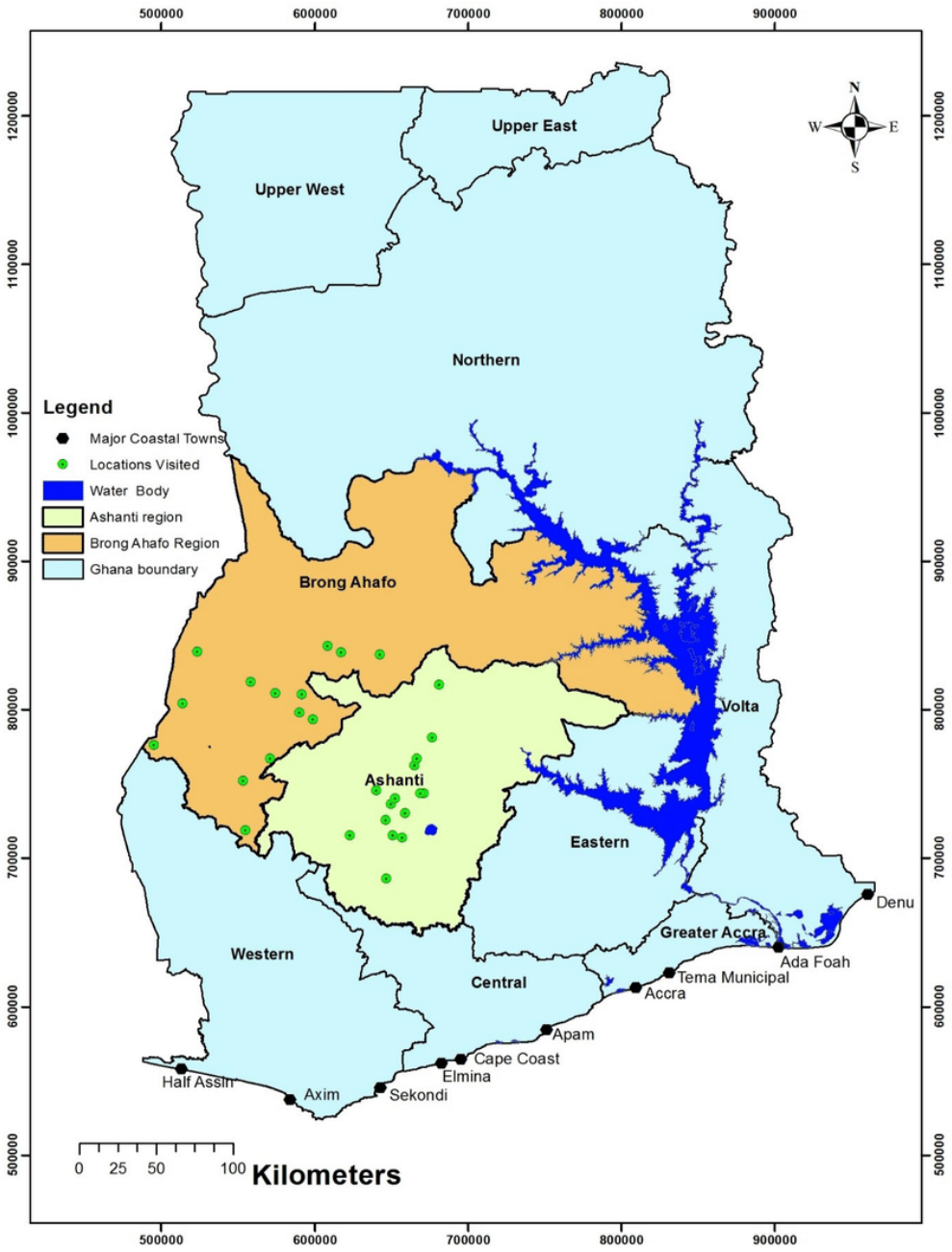


Figure 4. 1-3e: Map of Ghana showing the Volta Lake and study area. Source: Asiedu et al. (2018)

4.2 Sample selection approach

A sample is a part of a larger population, in this case, pond and cage fish farmers, researchers, the private sector, and government authorities representing some of the stakeholders in Ghana's aquaculture sector.

This thesis follows a mixed method strategy that requires sampling schemes that fit the exploratory sequential design. This means that sampling was done for qualitative and quantitative studies. In total, 16 participants participated in the qualitative study, and 51

respondents participated in the online survey for the quantitative study. Interviews included views related to farmed tilapia and catfish from hatcheries to grow-out farms from pond and cage fish farmers, researchers, civil society, academia and consultants from the fisheries commission

Qualitative sampling design.

A non-probability sampling method was employed because it was easier and more convenient to get in touch with relevant stakeholders in the aquaculture sector in Ghana through online platforms, given the limitations to travel for fieldwork. The target population were to have a certain level of knowledge and experience that fit into the study.

A purposive sampling design was adopted to learn more about the opinions and experiences of stakeholders across the aquaculture value chain in Ghana to gather a varied range of data regarding pond and cage fish farming in the selected regions. Therefore, the first 3-day hybrid Aquaculture conference for the West African Region from 14-16 May 2021 gathered major stakeholders who shared their views on the state of aquaculture in Ghana and other countries in the sub-region. The Chamber of Aquaculture Ghana (COA Ghana) organised the conference and workshops in collaboration with the Department of Marine and Fisheries Sciences of the University of Ghana (UG). Field notes taken during the sessions were beneficial in drawing the study plan and contributed to building a network of relevant study participants. The aim was to get people's experiences, suggestions, and visions for a viable aquaculture sector as they deliberated on remedies and mitigation options for the various challenges.

I purposefully contacted key respondents: high officials, industry players, academia, pond and cage fish farmers and relied on snowball sampling to get recommendations from those interviewed to help identify and recruit other potential participants for interviews (Bryman,2016) and fish farmers to fill the online survey for the quantitative study. In this thesis, fish farmers refer to farm owners and managers.

A list of operational and non-operational fish farmers in the Brong Ahafo region was collected from a Ghanaian researcher, Dr Asiedu Berchie, a Fisheries and Aquaculture scientist from the University of Energy and Natural Resources in Ghana, who did a similar study with two other researchers using the Sunyani Fisheries Zone as a case study to look at "*Prospects and sustainability of aquaculture development in Ghana, West Africa*". However, since the data was

just relevant to one region under study, contact details of Extension Service Officers (ESO) from the Ashanti, Bono, Eastern and Volta regions were obtained to reach out to farmers in those areas for further investigations. Three ESOs were interviewed. They also recommended and encouraged other fish farmers to participate.

Quantitative sampling design

The research objectives required varied information from different actors to have a holistic picture of the aquaculture sector in Ghana using the four regions as a case study. Since there were limitations to carrying out in-depth interviews with fish farm managers, the online survey was designed explicitly for fish farmers primarily on the field who were believed to have on-the-ground insights into the salient issues affecting pond and cage fish farming activities. Random sampling was conducted to reach only "active" or operational fish farms. The online survey link was shared with participants at the first hybrid conference organised by the Chamber of Aquaculture Ghana in May 2021. The process was slow, as only ten fish farmers filled out the online form between May 2021 and April 2022. Having had the chance to network with some of the participants and extension officers in the different regions under study, they were contacted to help push the online questionnaire to active fish farmers they knew or provide their contacts to call them and administer the questionnaire on the phone. Forty-one fish farmers were contacted between May and August 2022. In total, 51 fish farmers (N=51, Ashanti region: n=10; Bono: n=17; Eastern: n=18; Volta: n=6) participated in the online study. Although generally, it was a relatively small sample size of the population and generalisation of results might not be possible, the integration of the results from the relatively larger quantitative sample and the outcome of the interviews carried out contributed to discovering new trends on the one hand and confirm what is captured in most literature reviewed on the other hand.

4.3 Data collection and Research execution: online questionnaire, interviews, and secondary data: Literature review, Stakeholders' consultations, interviews

This section describes the process of collecting primary and secondary data from relevant stakeholders in the aquaculture value chain in Ghana. Sixteen interviews were conducted in English, and two others were conducted in Twi (Akan). The online survey was in the English language.

Primary data

The Chamber of Aquaculture Ghana (COA) was the first point of contact for up-to-date information regarding the industry to identify the gaps and establish the study's relevance.

A semi-structured questionnaire-based interview, tailored for four different groups of stakeholders, was designed for the data collection of primary data gathered through zoom, followed later by an online survey using the Nettskjema developed by the University of Oslo (UiO), opened between May 2021- August 2022.

The first round of interviews involved the private sector and civil society, notably the COA Ghana, Fisheries Commission, WRI and a representative of the Norwegian Embassy in Ghana to provide insights on donor cooperation, in this case, Norad, on their "Fish for Development programme". The questionnaire included open-ended questions on participants' perceptions about the sustainability of aquaculture in Ghana, opportunities and general factors affecting pond and cage farming, and the future of aquaculture.

The second round involved people from academia: UG Legon, Norwegian Veterinary institute, and researchers in water quality and fish health. Open-ended questions were asked on the management of farming systems in Ghana, general concerns and perceptions about the sustainability of aquaculture, fish diseases, fish health, and the role of academia in ensuring sustainable practices across the aquaculture value chain.

The third round of interviews involved extension service officers from the Ashanti, Bono, Eastern and Volta regions. Open-ended questions were asked about the role of the Fisheries Commission and extension service officers, general perceptions of fish farming activities in their localities, the role of associations, and the challenges and opportunities for sustainable fish farming in their regions.

Lastly, only Three fish farmers were interviewed thoroughly using the semi-structured interview questionnaire to get their views on the challenges, opportunities, production system, routines, satisfaction levels, and association membership.

The online survey was limited to fish farmers and farm managers since their voice was missing in the qualitative process. Their voices would be captured in the quantitative study as questions

asked in the survey were dichotomous, ordinal, nominal and numerical based on the principal themes derived from the initial coding process of the interviews.

Direct calls to selected participants were made and using the semi-structured interview questionnaire to guide conversations with the few fish farmers that were reachable and other stakeholders from academia, government, notably fisheries commission, WRIC, private sector organisations (COA Ghana), International cooperations (Royal Norwegian Embassy on behalf of Norad) among others.

The strategy involved ESOs and the COA Ghana sharing the survey link with operating farmers registered with their outfits. However, collecting online data in Covid times seemed appropriate but presented many challenges. Most fish farmers had no internet connection, and some complained of expensive data bundles. Thus, I followed up with the extension officers I contacted earlier for an interview to request the contact of the fish farmers. A total of 13 respondents who participated were the contacts from the Bono Regional Fisheries Commission office and six others from the Ashanti Regional Fisheries Commission office. Eight other respondents were contacts from the Eastern Regional Fisheries Commission office. I called the respondents and filled out the online questionnaire on their behalf by reading out the questions to them.

This benefited the study as it offered the opportunity to ask leading questions, clarify ambiguous responses, and identify gaps in how the questionnaire was designed.

Secondary data

The selection of secondary data was a continuous process that involved scanning and selecting relevant articles and reports on global sustainable aquaculture. Most articles and reports related to aquaculture in Ghana were used, and these were works done by Ghanaian researchers in collaboration with partners in international cooperation.

The official websites of the Ministry of Fisheries and Aquaculture Development, the FishSite, the Water Research Company and the FAO were instrumental in getting relevant information and figures for both qualitative and quantitative data.

Training manuals were developed in 2020 by the stakeholders in the TiSeed Project, which aimed at helping small-scale cage and pond fish farmers with technical and practical guidance on the quality production of tilapia seeds for higher yields.

Insights from the "Farmers' manual on small scale tilapia cage fish farming in Ghana"(Agyakwah et al., 2020a) and "Farmers' manual on small-scale tilapia pond farming in Ghana" (Agyakwah et al., 2020b) were used as well to analyse responses from the interviews.

Official publications, scientific reports from the FAO database and a statistical tool (Fishstat J) were consulted for data on tilapia and catfish production and demand. A review of relevant scientific articles and reports using the keywords: "sustainable aquaculture", "Aquaculture Ghana", "*Oreochromis niloticus*", "*Clarias gariepinus*", "cage and pond fish farming", "fish welfare", "Fish disease treatment", "aquaculture in Bono region", "aquaculture in Ashanti and Eastern regions", "aquaculture in Volta Lake", "fish feed."

4.4 Data analysis

Qualitative content analysis was utilised to construct the meaning of texts (Bryman, 2016) and identify different actors and systems in the fish farming sector. The interactions with different stakeholders allowed me to discover the participants' worldviews through their personal experiences of success stories, bad events, and concerns regarding the sustainability of aquaculture in Ghana. Therefore a narrative analysis was appropriate since it has to do with "*how a protagonist interprets things*" and how the researcher can go about "*systematically interpreting their interpretations*" (Riessman, 1993, p.5)

Out of the 16 interviews, only eight were thoroughly transcribed and sent to the respondents for validation or correction to ensure the participants' views were captured clearly.

Bryman (2016, p.385) said that "*respondent validation*" is a process that requires the researcher to share an account of the outcome of the study with the respondents for corroboration. Two participants (1 fish farmer and 1 researcher) reverted with corrections and clarifications on their submissions. The data collected and transcribed were stored in a protected folder awaiting analysis. However, summaries and coding of the discussion with all participants were a continuous process to generate relevant themes regarding pond and cage farming systems in the areas of study, as shown in appendix 5.

Preliminary qualitative analyses were done while taking the data (Grbich, 2012) and transcribing the interviews. For every 1hr interview, an average of 6hrs was dedicated to its transcription. Thirty-nine themes were generated to guide the online survey design and were coded in numerical values classified in ordinal, scale, and nominal units of measurement in the software used for the analysis.

Perceptions of stakeholders on their participation in decision-making and the factors affecting the welfare of the fish at production, processing, distribution, and consumption were analysed qualitatively based on the literature reviewed and interviews.

Quantitative data collected from the survey were entered into Microsoft Excel software (2013) to run basic descriptive statistics to generate graphs to analyse the motivation for engaging in fish farming in the Ashanti, Bono, Eastern and Volta regions arranged in alphabetical order. The results from the survey were arranged in clusters based on the location of the farms.

IBM SPSS Statistics Data Editor (version 26) was used to generate crosstabulation and correlation tables to assess the relationship and association between socio-economic and environmental factors affecting the choice of production systems and the types of species cultivated. Correlation analysis was also done to assess satisfaction levels in the survival rate, sales, fish profitability and patronage of the different species cultivated.

4.5 Assessment of study Limitations and trustworthiness

The Covid-19 pandemic disrupted my initial plan to travel to Ghana for primary data collection and how the research should be conducted due to travel restrictions. Also, a series of life events accounted for the delay in writing and postponement of my thesis submission. I took a break in data collection for close to 1 year to proceed on a study and maternity leave from July 2021 to June 2022. It is hard to say that the blessing of a child posed limitations to the study, but it certainly affected my health and energy level and drained me as a research student.

Getting clearance from the NSD to carry out interviews and an online survey took about two months after all ethical guidelines were reviewed and accepted before going on sick leave. Since I could not be physically present in Ghana to collect data, informed consent forms and information about the study were sent via email to participants after confirming participation in an online interview. Although most did not return the signed consent forms, they gave verbal approval and acknowledged they were familiar with the study and interview. Two participants

(1 farmer and 1 researcher) requested to view the interview transcription before giving final approval to quote them in the thesis.

While some participants had no computer or smartphone access, others were concerned about having internet data to fill out the online questionnaires. Therefore, I used Skype for direct calls using the contact list of managers of operational fish farms in the areas under study, especially Bono and the eastern regions, to fill out the online form. It was very time-consuming and exhausting, but necessary to validate and have reliable data to process.

Internet connection was relatively poor in some areas of Ghana, so interviews took longer than expected. The length of interviews varied between 45mn- 1h30mn depending on the times we had to reconnect and repeat questions and answers. This also affected the amount of time spent on the transcription exercise.

Knowledge gathered during interviews, and a few survey responses influenced my thinking that all pond fish farmers may face the same issues regardless of their geographical location. However, results cannot be generalised because of the small sample size and the non-probability sampling design employed for qualitative research, which has a higher risk of sampling bias and weaker inferences than probability sampling.

Initially, the study aimed to compare pond fish farms in the Bono region and cage fish farms along Lake Volta. I wished to get as many fish farmers as possible to partake in the online survey. However, getting respondents was particularly challenging due to many factors. Even though the online survey was open two months before my leave, I only got ten respondents, which was not enough. The low participation from pond fish farmers influenced me to add pond operators in and around the eastern and Ashanti regions. Thus, the need to keep it open until 31 August 2022. However, I only got 51 respondents in the end.

Also, four fish farmers (3 from the Eastern region and one from Bono) were interviewed via WhatsApp and skype calls; unfortunately, these were not recorded and stored due to the media used. The language used was a mixture of English and Twi (Akan). However, even though the salient points were jotted down, not everything was fully captured, especially with the two fish farmers who only spoke Twi (the local Ghanaian dialect), which I am not too fluent in.

One of the significant bottlenecks was that most fish farmers were not members of any association or not registered with the Fisheries Commission. So, getting access to a list of all operational fish in the areas under study was relatively unsuccessful. The sampling was based only on a few recommended fish farmers from ESOs in the respective regions, which presented some limitations to generalising findings.

The survey could not differentiate the type of fish farm the respondents were operating, whether hatcheries or grow-out farms. The study only categorised the farming systems as ponds and cages. I believe the sample framework could have been better in terms of the representativeness of the population. Only two women were interviewed, and the online survey did not specify gender, age and income information as the main focus was on perceptions of what sustainable aquaculture meant to pond and cage fish farmers.

Trustworthiness

Bryman (2016) states that trustworthiness is used to assess a study's credibility, transferability, dependability and confirmability.

Regarding credibility, only a few industry players and pond fish farmers were engaged in in-depth interviews. The study had to rely on other researchers' findings and official reports to fill in the knowledge gap, which might have influenced this research in how the survey was administered to confirm some findings. However, the triangulation process contributed to the confidence that the results obtained from the study were consistent with what the different actors view as salient issues about the sustainability of pond and cage fish farming in Ghana. The results can be transferable because the study involved and reflected participants' perceptions from all four regions in the case study.

The data-gathering process was consistent with the guidelines from the NSID, and the template for informants' consent was discussed with the thesis supervisor. A pilot test was conducted with one fish farmer who studied aquaculture in school and one from the Chamber of Aquaculture in Ghana. The same participants were used to test the online survey, and their contributions helped reframe some questions to avoid ambiguities and assess the dependability and validity of the study. A codebook based on the major themes identified was created and used for the survey data. As part of the methods, fish farmers and researchers who participated in this study will be contacted again and provided feedback on the results. A

summary of the results and key points discussed will be drafted and sent via email to key participants with the hope that some of the recommendations can inspire them and help them in their line of business. A copy of the thesis shall be sent after submission to the Chamber of Aquaculture, which was instrumental in helping me gather data to refer to fish farmers about the study's results.

5. RESULTS

This chapter presents the primary data findings from the interviews and online surveys. Subsection 5.1 is a presentation of the culture systems studied. The motivation for engaging in fish farming and the choice of production systems are mentioned in subsection 5.2. Issues about the sustainability of ponds and cage systems of production are highlighted in subsection 5.3. Stakeholders' opinions about fish welfare were expressed in subsection 5.4. An account of perceived opportunities for the sustainability of aquaculture in subsection 5.5. The chapter ends with a summary of the results in subsection 5.6.

The fish farmers, farm managers, extension service officers, researchers and other stakeholders in the aquaculture sector consented to be interviewed, and some willingly shared pictures to use in the thesis to illustrate their views. The authors of the pictures, both from primary and secondary sources, were duly acknowledged.

5.1 Culture practices

Different opinions on the choice of fish culture practices were raised in the study. There were two major fish farming systems in the areas under study: cage and pond systems.

A cage fish farmer mentioned that cage culture was more capital-intensive than pond culture, which is why pond fish farms were more prevalent in rural areas. However, pond fish farmers had many more responsibilities. The extension service officer for the Bono region stated that: "*in pond culture, everything is regulated by the farmer*"**.** Pond fish farmers were to ensure they got clean water, and the wastewater or effluent had to be treated so as not to pollute the environment. The fish farmers' duties were to ensure the supply of quality water and water treatment, acquire quality fish seed and feed, harvest and acquire adequate storage facilities, sales, distribution and transportation of the fish harvested and stored.

a) Cages

Images of Cage fish farms on the Volta lake

Image 1: Cage farm with galvanised pipes, metal drums and nylon nets source: Asmah et al. (2014,p.39)

Image 2: Cage farm on the Volta lake Credit- Golden Tilapia Farmers, Akateng

b) Ponds

Images Pond fish farms in the study areas

Image 3: Polyculture of Nile tilapia (Oreochromis niloticus) and African catfish (Clarias gariepinus) pond fish farm in Konongo farm. photo credit: Mrs Sarpong

Image 4: Tilapia pond farms in Sogakope. Photo credit: Flosel farms

The survey showed that 55% of the respondents operated pond fish farms, while 41% operated cage fish farms. The other 4% represented two respondents from the Bono region who claim to have a different farming system, but each was rearing tilapia and catfish, respectively. The ESO in Bono mentioned that apart from earthen and concrete ponds, some fish farmers have set up trampolines for rearing fish in this area.

Most cage fish farms could be found along the Volta Lake that ran through the Eastern and Volta regions, while pond fish farms were more present in the Ashanti and Bono regions.

Count

		Type of farmed fish			
		Tilapia	Catfish	All the above	Total
Farming system used	Cage	19	1	1	21
	Pond	6	19	3	28
	Other	1	1	0	2
Total		26	21	4	51

Table 5.1a: Crosstabulation of cage systems and fish cultured

Cage fish farmers were more into tilapia cultivation. The interviews and literature reviewed revealed that the type of tilapia cultivated in Ghana was mainly the Akosombo strain tilapia (AST), an improved version of the Nile tilapia (*Oreochromis niloticus*).

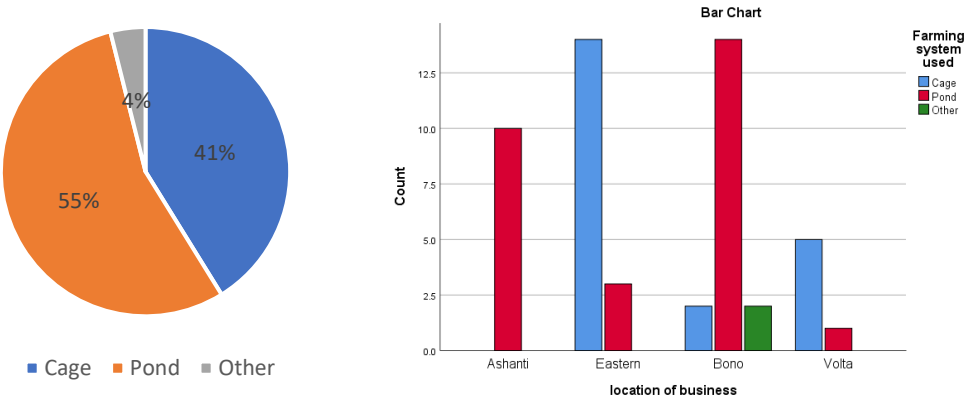


Figure 5.1c: Crosstabulation of the location of the business and Farming system used

		Farming system used			
		Cage	Pond	Other	Total
location of business	Ashanti	0	10	0	10
	Eastern	14	3	0	17
	Bono	2	14	2	18
	Volta	5	1	0	6
Total		21	28	2	51

Table 5.1b: Crosstabulation of the location of farms and farming system used

Ponds were smaller unit culture systems commonly referred to as small-scale aquaculture used to rear fish domestically. Some examples were hapas, tarpaulins which were collapsible ponds, and concrete tanks. The ESO for the Bono region mentioned that people from the Bono region did more of earthen pond culture. The survey showed that only two respondents from the Bono region were into cage farms and other fish farming systems, while fourteen respondents were operating ponds. The main types of fish cultivated in the ponds were catfish and tilapia. However, catfish was the most popular fish cultivated in earthen ponds. Of the 28 ponds surveyed, 19 were into catfish production, while six cultured tilapia. However, three respondents stated they operated a polyculture system whereby tilapia and catfish were reared in the same ponds.

Image 5: Harvesting of fish in a hapa pond, source: SARNISSA photo competition winner- photo credit: Prince Ofori

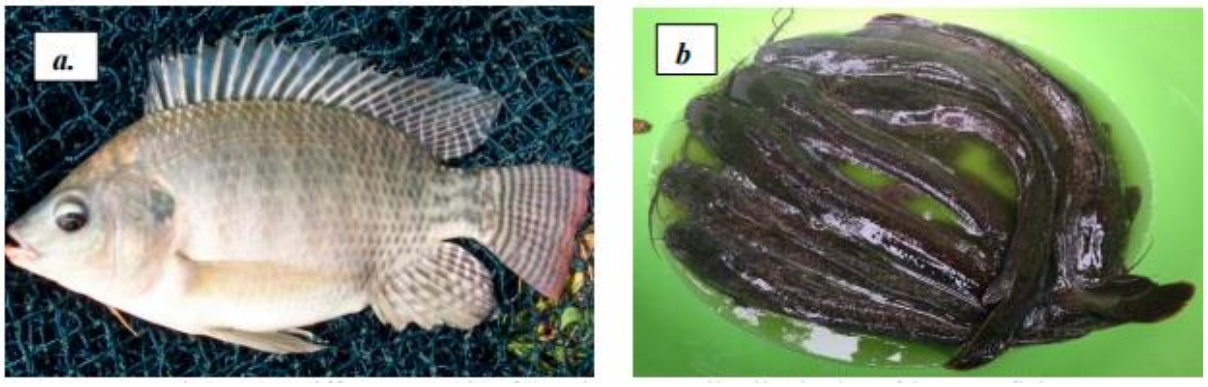


Image 6: Species farmed a=Nile tilapia (Oreochromis niloticus) b= African catfish (Clarias gariepinus) Source: (Agyakwah et al., 2020a, p.6)

		Type of fish farmed			
		Tilapia	Catfish	All the above	Total
Farming system used	Cage	19	1	1	21
	Pond	6	19	3	28
	Other	1	1	0	2
Total		26	21	4	51

Table 5.1c: Crosstabulation of pond systems and fish cultured

5.2 Motivation for engaging in Fish farming

The study showed that most small-scale fish farmers were primarily motivated to engage in aquaculture because it provided livelihood or food for their families. The economic aspects of business profitability came in secondary.

> *"Pond culture brings aquaculture to the people's and rural communities' doorsteps on a subsistence level. Cage culture is more capital intensive than pond culture."*
>
> (Interview-participant 12, ESO, Bono region).

Some respondents studied aquaculture in school and pursued it as a business or recreation. However, only three out of sixteen participants interviewed were not university graduates, among whom a woman and mainly operated pond fish farms in Bono and Ashanti regions, respectively.

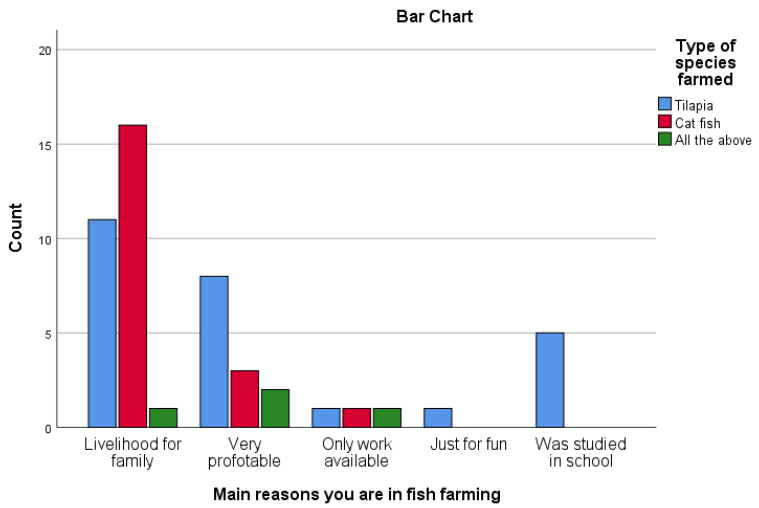


Figure 5.2-1: Motivation for engaging in fish farming

"I have been doing this for five years and love it. I do not intend to stop. We rear other animals as well, like cattle and goats. When my husband started doing it, it was for pleasure, and then we realised it could be a profitable business because people were patronising it. So, we buy our fingerlings from Ofinso. We rear catfish and tilapia, but we are more into catfish production because they buy more catfish than tilapia". (Interview-participant 15, fish farmer from Ashanti region)

"*Our farmers need much training. They have an idea that aquaculture is like cocoa farming and galamsey (an illegal mining term used in Ghana). The perception is that there is much money in it."* (Interview-participant 13, ESO, Ashanti region)

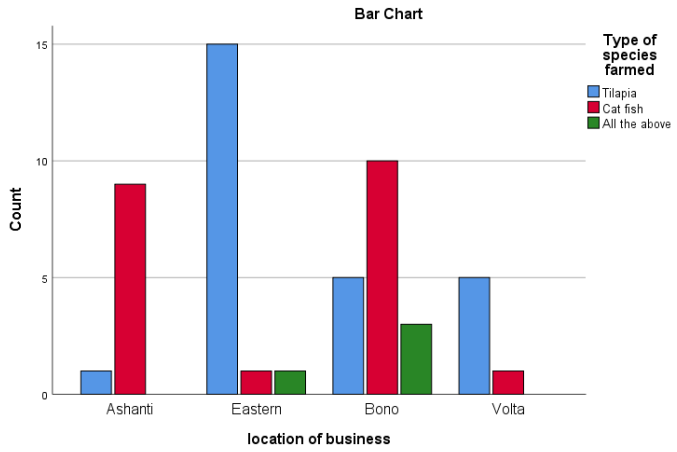
Count

		Type of fish farmed			
		Tilapia	Catfish	All the above	Total
Main reasons for going into fish farming	Livelihood for family	11	16	1	28
	Very profitable	8	3	2	13
	Only work available	1	1	1	3
	Just for fun	1	0	0	1
	Was studied in school	5	0	0	5
Total		26	20	4	50

Table 5.2-1: Crosstabulation of motivation for going into fish farming and choice of farmed fish

Small-scale pond fish farmers in the Ashanti and Bono regions cultivated more catfish than tilapia as opposed to commercial cage fish farmers in the Eastern and Volta regions, who were into an intensified tilapia production system.

Of the seventeen respondents from the Eastern region, fifteen fish farms produced tilapia, while only two strictly did catfish and polyculture, respectively. In the Volta region, five respondents were into producing tilapia, and only one fish farm was rearing catfish. Three fish farms in the Bono region ran a polyculture system; ten reared catfish in ponds, and five produced tilapia. In the Ashanti region, nine fish farmers were rearing catfish, and only one respondent was into tilapia farming.



		Type of farmed fish			
		Tilapia	Catfish	all the above	Total
location of business	Ashanti	1	9	0	10
	Eastern	15	1	1	17
	Bono	5	10	3	18
	Volta	5	1	0	6
Total		26	21	4	51

Figure 5.2-2: Crosstabulation of the relationship between the location of the business and the type of farmed fish

Table 5.2-2 below shows that respondents' satisfaction level with the type of species cultivated was beyond average. There were two missing data; only one fish farmer cultivating tilapia and five farmers producing catfish stated their dissatisfaction with cultivating those species. According to respondents from the Eastern and Volta regions, tilapia was more profitable and marketable and would sell faster than catfish.

Cage fish farmers interviewed also opined that tilapia was more profitable than catfish, which was why they ventured into the production of tilapia.

On the other hand, pond fish farmers believed that catfish production was more profitable than tilapia production.

The study showed that the location, survival rate and consumer preferences were significant factors affecting the fish farmers' motivation to cultivate tilapia or catfish.

Crosstab

Count

		Sales				
		very satisfied	Quite satisfied	Satisfied	not satisfied	Total
Farmed fish	tilapia	4	11	10	1	26
	catfish	2	8	5	4	19
	All the above	1	2	1	0	4
Total		7	21	16	5	49

Table 5.2-2 Crosstabulation of the relationship between the level of satisfaction and the farmed fish

Correlations

		Fish profitability	Patronized fish	Survival rate of fishes	Satiffaction with the growth of fishes	Sales
Fish profitability	Pearson Correlation	1	.589**	.176	.205	.310*
	Sig. (2-tailed)		.000	.236	.171	.034
	N	49	49	47	46	47
Patronized fish	Pearson Correlation	.589**	1	-.183	-.024	.110
	Sig. (2-tailed)	.000		.213	.872	.456
	N	49	50	48	47	48
Survival rate of fishes	Pearson Correlation	.176	-.183	1	.293*	.567**
	Sig. (2-tailed)	.236	.213		.045	.000
	N	47	48	49	47	48
Satiffaction with the growth of fishes	Pearson Correlation	.205	-.024	.293*	1	.225
	Sig. (2-tailed)	.171	.872	.045		.128
	N	46	47	47	48	47
Sales	Pearson Correlation	.310*	.110	.567**	.225	1
	Sig. (2-tailed)	.034	.456	.000	.128	
	N	47	48	48	47	49

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 5.2-3: Correlation between fish profitability, patronization, survival rate, growth satisfaction and sales

5.3 Sustainability of Pond and Cage fish farming in Ghana

Beyond peculiar challenges affecting pond and cage fish farms, the survey and qualitative study results showed common factors affecting both fish farming systems. This section examines perceptions on ecological, economic, and socio-political challenges and prospects associated with the sustainable development of pond and cage fish farming in the Ashanti, Bono, Eastern and Volta regions.

5.3.1 Challenges and opportunities in pond fish farming in the Ashanti and Bono regions

- Types and location of ponds

This study's most common types of ponds were earthen ponds. Of the 51 respondents in the four focus areas studied, 28 fish farmers managed ponds representing 55% operating pond farms located mainly in the Bono region (14 pond farms or 27.4%), followed by the Ashanti region (10 pond farms or 19.6%). Fish farmers constructed them on their family lands or properties. A fish farmer said during his interview, "*I am operating the fish farms on my land, which I inherited from my father.*" (Interview-participant 3, pond fish farmer)

On average, some of the fish farmers interviewed while administering the survey revealed that they operated a minimum of two fish ponds cultivating tilapia and catfish separately or adopted a polyculture system whereby catfish and tilapia were reared in the same pond. The survey showed that 3 out of 28 pond fish farms produced catfish and tilapia in the same pond. The reasons for engaging in tilapia or catfish farming were based on consumer or market preference, taste, management of stocking density, and growth rate, among others.

> "*I am cultivating tilapia and catfish… but now I am switching to catfish, which tastes much better than the tilapia. Tilapia has too many bones. I started by putting ten catfish into the tilapia pond to control the tilapia population. The catfish was feeding on the tilapia fingerlings. I learned this tip when I attended a training in Akosombo*" (Interview-participant 3)

Some of the ponds were located on farms or near farms where pesticides and other heavy agrochemicals are used.

"*When it rains heavily, some of these chemicals are washed into the ponds and cause a high mortality rate in fishponds*" (Interview-participant 3).

The topography and size of the ponds determined the intensity of the fish-culture practices in these areas. Most fish farmers operated an extensive production system, relying primarily on natural resources for farm management.

"*We have about eight earthen ponds size 100x100 and currently operate with three ponds, each stocked with 2000 catfish. However, some of them die along the line. We see several dead fish floating on the surface of the water. Since the feed and fingerlings are expensive, we thought of nurturing the fingerlings. Sadly, after two weeks of hatching, they die. We invited an expert, and they found out that it is due to the water's acidity and PH level. We learned that it is not helping and that not all waters are suitable for hatching. So, for now, we stopped hatching for about two months*." (Interview-participant 15, pond fish farmer- Ashanti region)

According to the ESO in the Bono region, when someone wished to start a pond fish farm, the Fisheries Commission had a crucial role in ensuring a thorough initial assessment of the land's topography and its ability to hold water was done adequately.

He mentioned that one of their primary duties was to check and ensure a reliable water source or water inlet to rear the fish. The land's topography was assessed by checking its slope, which would facilitate the drainage system by gravity. In setting up pond culture, it was paramount to ensure that its construction was cost-effective by ensuring that the fish produced could be sold on time at a reasonable price to avoid losses. The ESO for the Bono region also said, "*we try to eliminate any factor that would lead to high production cost from the onset*." The approaches to avoid high production costs were through the performance of site inspections by selecting good sites and building good ponds for fish production to ensure the sustainability of the pond culture.

- Access to quality water and water management

Groundwater was the primary source of ponds in the Bono and Ashanti regions. Discussions with a fish farmer and ESOs revealed that fish farmers would dig ponds on family lands in water-

locked areas. In such instances, the fish farmer was solely responsible for ensuring water quality and water treatment so that the ponds were ready for fish farming. However, most fish farmers did not have the prerequisite knowledge, skills, and abilities to construct and manage fish farms. ESOs were consulted only when the fish farmer faced difficulties and sought help.

> "*I need a reliable pumping machine to ensure that the water is changed frequently*" (Interview-participant 3, pond fish farmer)

Well-constructed ponds, bearing in mind the inlets and outlets of water, could prevent these agrochemicals runoffs or overflow from farms from affecting the fishpond. However, some of these chemicals could still get into the ponds.

A fish farmer operating a tilapia and catfish pond said that he used poultry manure in some white plastic bags floating on the pond's surface, serving as a source of nutrients to the phytoplankton (Fig. 5.3.1). He mentioned he learned this tip during training in October 2020, organised by the TiSeed project, on how to construct a pond and feed the fish. According to him, the green-coloured water indicated enough oxygen and that the fishes were healthy. On the other hand, when the water turned very green and smelling, it meant there was a problem.

Image 7: Use of manure to fertilize a pond farm in the Bono region. Photo credit: fish farmer participant interviewed

The ESO for the Bono region confirmed this by stating it was not wrong when the water was green. The water turned green because of the production of plankton, i.e. algae, the primary food for the fish. However, an awful smell or a stench of dead fish from the pond indicated poor water quality, and the fish farmer was responsible for changing or treating the water. He equally confirmed that some farmers used chicken droppings to fertilize the water to get enough nutrients for the algae to photosynthesise. The fish farmers would tie the chicken droppings to the walls of the ponds so that when they decayed, the plastic bags got blotted. Once the bags began to sink in the water, they would take them out.

- Low quality of fingerlings

According to a consultant from the Fisheries Commission, pond farmers were one of the groups of fish farmers responsible for selling fish of inferior quality as fish seeds.

Some fish put in a pond would naturally grow faster than others. The pond fish farmers tended to harvest the big ones and sell them. Those with stunted growth were left behind and sold as fish seeds. However, technically these do not meet the requirement of fish seeds.

> "*Fish seeds are supposed to be produced from a hatchery through the proper protocols*". (Interview-participant 6, retired Fisheries Commission officials)

The supply of good seeds was one factor that affected pond and cage aquaculture, and this demonstrated how it could emanate from a fishpond.

> "*You tell them you want the shooters or jumpers, which grow faster so you can harvest them after six months. However, you end up having a mix, i.e., different sizes. Some fingerlings are already matured, costing between 20 pesewas to 1GhC. Therefore, we must segregate the fish according to their size and weight to avoid cannibalism and feed them adequately*." (Interview-participant 15, pond fish farmer in Konongo, Ashanti region)

5.3.2 Challenges and opportunities of cage fish farming in the Eastern and Volta region

This study showed that most cages operating on the volta lake, along the Eastern and Volta regions, were systems of production that mostly retained the Akosombo strain tilapia (AST),

an improved version of the Nile tilapia (*Oreochromis niloticus),* in a confined area at a higher density than observed with the pond systems in the Ashanti and Bono regions.

Freshwater cage fish farming provided many opportunities in terms of economy of scale but equally presented ecological and social challenges.

The site location and design of cages on Lake Volta contributed to the welfare of fish cultured in their natural environment with a constant flow of fresh water, metabolic waste disposal, and protection from invasive species. However, water being a conductor was the means through which most cage fish farms were prone to fish diseases resulting from viral and bacterial infections.

Various concerns about the water quality and social conflicts between stakeholders of the volta lake catchment areas were raised.

- Multiple uses of the lake and social conflicts among stakeholders

The study revealed that the Volta Lake provided ecosystem goods and services not limited to cage fish farmers but equally benefited other stakeholders in the leisure and tourism industry, local indigenes, and government institutions such as the Water Research Commission.

The ESO for the Akosombo centre said: "*the lake is an open-access natural resource. It is not only meant for cage fish farmers. So, before cages were set up on the lake, there were fishermen who were local indigenes and used the lake as the primary source of their livelihood. There has been some friction between fishermen and cage fish farmers as the former perceived that the latter was taking over their fishing grounds*" (Interview-participant 14).

It was reported that other fishes in the lake were attracted by the feed droppings around the cage fish farms, causing them to migrate towards the cages. According to her, the fishermen were usually in a dilemma since it was against the law to get into somebody's concession. Some fishermen risked going close to the cages to fish with their canoes. The fish harvested were sold at a lower price to the same target market. Such happenings usually triggered social conflicts between cage farmers and local fishermen.

On the other hand, one of the consultants from the Fisheries Commission mentioned that on the Volta region side of the lake, the water and sewage corporation had an intake point somewhere near Kpeve. Fish farmers were located very close to the intake point. The number

of operations there affected the water quality drawn by the water and sewage corporation. Conflicts between the two parties arose when the state compelled the fish farmers to move from there. According to the Fisheries Commission consultant, many fish farmers on Volta Lake did not have environmental permits and were operating illegally, so they usually did not have a say when kicked out. He assumed that if the fish farmers were already the first to rightfully operate on the section of the Volta Lake under contention, the water and sewage corporate would have looked for another place to lay their pipes.

This study revealed that to acquire a license to operate in Volta Lake, the fish farmer had to get permits from different entities, which was a hectic and relatively costly process. The process of getting the license to operate a fish farm shall be expanded in the discussion section of this thesis.

Although this study did not probe further on the issue of which of the two parties, fish farmers or the water and sewage corporation, were the first to be there, the consultant's submission confirmed the reality of the open-access dilemma and perceptions of an ecosystem approach to fisheries and aquaculture management and the power exerted by government in such issues. He said: "it does not matter who got there first because the state can acquire your property at any point in time and order the fish farmers to move and give them some compensation."

- Overstocking densities

Interviews with academic researchers and ESOs revealed that cage fish farms that produced the locally improved Akosombo strain tilapia were overstocking their farms with fingerlings. The perception of most fish farmers was that the more fish stocked, the more profit they might get.

A cage fish farmer from the Eastern region (Interview-participant 8) confirmed the above view and said: "If *you have 5000 fishes in a 25 cubic cage, that will be overcrowding the ecosystem. So, oxygen may be in short supply, and the fish can die."*

The study showed that the perception of overstocking fish in semi-intensive and intensive production systems was directly linked to the feed conversion ratio in grow-out systems. The

feed conversion rate, as explained by the fish farmer (Interview-participant 8), was the amount of feed needed to produce the desired weight of fish based on market demand, which determined the price they would sell the harvested fish: FCR= feed used / fish weight obtained. For instance, it is unsustainable for a fish farmer to use 2kg of fish feed to produce 1kg tilapia.

The consultant from the Fisheries Commission gave a scenario by comparing managing a fish farm to a poultry farm. He said:

> *"When your chicks are ready, the more you keep them, the more you spend money feeding them, which constitutes a loss to your operations. It is the same in fish farming. When the fish are ready, and you cannot sell them, the more you feed them, the more you spend money. You will be lucky if they keep on gaining weight. However, you lose money if the feeding does not help them grow and put on weight."*

Apart from the economic downside of overstocking fish in production systems, research has shown that there are high risks of disease outbreaks affecting the welfare of the fish.

5.3.3 Common factors that affect the sustainability of pond and cage fish farms in the study areas

The survey showed that there were numerous factors affecting the aquaculture sector in Ghana. 3 out of 51 participants omitted to respond to the question. The figure below indicated that 13 out of 48, representing 27% of the total respondents, opined that lack of knowledge about different fish diseases, in general, was the most common factor affecting cage and pond fish farmers in this study. Ten respondents representing 20.8% of the results, were of the view that in addition to the lack of knowledge in fish disease, the lack of government support, the lack of trained fish veterinarians, the lack of adequate infrastructures such as laboratories, research centres, the lack of regulations and the importation of foreign illegal fish or fingerlings were among the significant factors affecting the sector as a whole (Fig. 5.3-3a)

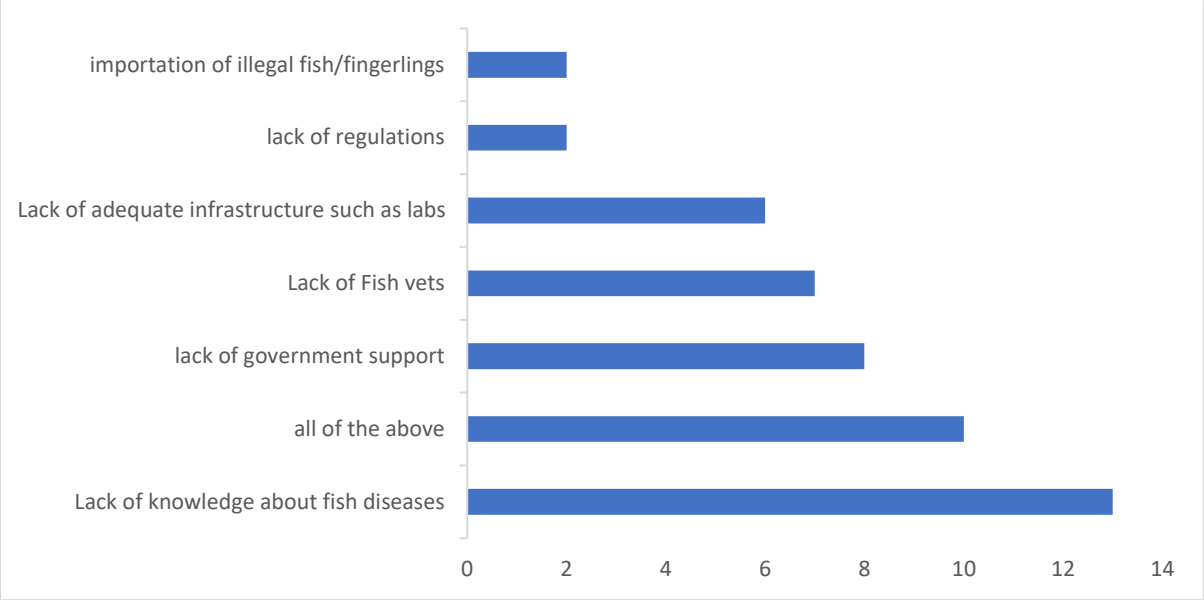


Figure 5.3-3a- Key factors affecting the sustainability of aquaculture systems in Ashanti, Bono, Eastern and Volta regions

Other factors mentioned during the interviews with different stakeholders were:

- Economic factors

- *Lack of sufficient capital:* fish farming was viewed by fish farmers operating both systems of production as capital-intensive and a high-risk investment in the event of a disaster. Fish farmers would need quite a substantial amount of money to start and sustain a fish farm. Cage fish farmers viewed installing cages and acquiring the right equipment (nets, materials) as substantial technical investments. Therefore, many cage fish farms in Volta Lake collapsed when they were not allowed to operate or experienced losses due to disease outbreaks. For pond fish farmers, the most significant investment was access to quality and treated water to rear fish. Pond fish farmers also had challenges with mass production because, unlike cage fish farmers, they had a lower capacity to buy fingerlings in large quantities and mostly adopted extensive aquaculture relying more on nature to rear the fish.

- *Limited access to insurance cover:* The CEO of the Chamber of aquaculture said that some of the fish farmers operating on a bigger scale had some insurance covering their fixed assets, such as buildings, machines, and vehicles. Traditional insurance companies provided the insurance product. However, insurance coverage for biomass was unavailable, and small-scale fish farms were mostly uninsured. The Chamber of Aquaculture and Ghana Agricultural Insurance Pool had been piloting aquaculture insurance products to cover biomass. Few fish farmers had been participating in the pilot project. If successful, the aquaculture insurance product will be rolled out to all fish farmers.

- *High costs of fish feed*: the feeds were available but relatively expensive. A private sector participant mentioned that the feed cost was high and took up to 60 % of the production cost (interview-participant 1, private sector).

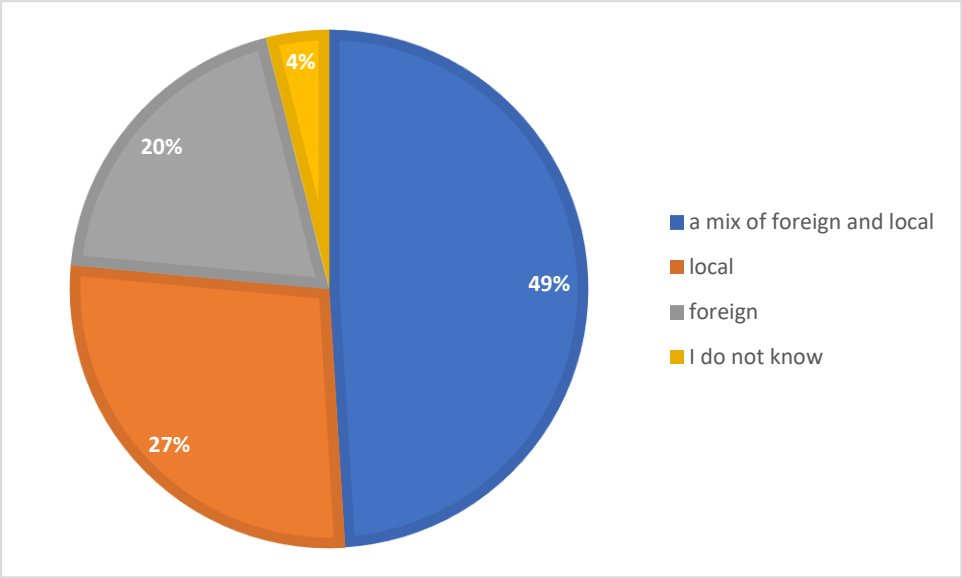


Figure 5.3-3b: Fish feed types used by fish farmers

Fish farmers who practised semi-intensive and intensive aquaculture systems depended on more feed supplements for their fish. Therefore,49% of the fish farmers used a mix of local and foreign feed, 27% used local feeds from rice bran, maize, and 20 % used exclusively foreign feeds. The most common foreign feed fish farmers in Ghana used were the Raanan fish feed (Israel), Aller Aqua feeds (Denmark), and Cycle farm feeds (France). Fish feed production plants were set up in Ghana and strategically located in areas where fish farms were operating to

enable quick access to their products at competitive prices. Aller Aqua, for instance, was said to be located close to Volta Lake, where many cage fish farms produced tilapia intensively. However, access to fish feed for farmers in the Ashanti and Bono regions was more challenging. Most informants believed that the price of foreign fish feed was relatively high, and although some were willing to pay, the quantity and quality of fish harvested affected their sales profit. The quality, however, accounted for the majority of the choice of fish feed used by fish farmers.

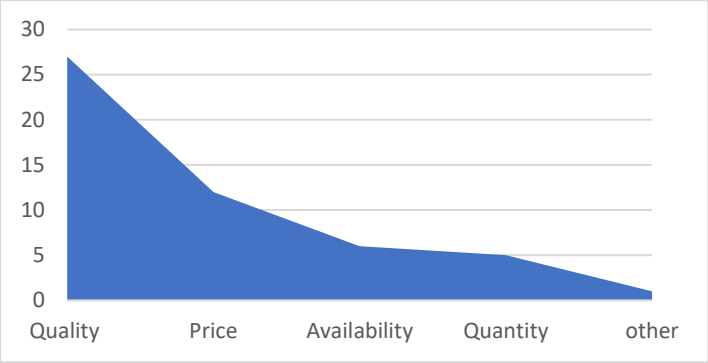


Figure 5.3-3c: Factors affecting the choice of fish feed used by fish farmers

- *The marketing system*: farmers usually did not have much control over fish prices. "*The women would go to the farms, play some tricks, and get the fish at their proposed prices (bargaining system)*", said the ESO from the Bono region. Fish farmers should have more control over the prices of the fish they produce. The few big players who had the economics of scale could fix prices themselves. However, the small players had no choice but to sell at the prices imposed on them by the fishmongers, middlemen or market women. A fish farmer from the Ashanti region said:

  "When you go on the net, it looks good and promising. Catfish prices are pegged between Ghc 13 and Ghc 15 per kilo. In reality, the market women buy it at Ghc 6. So, I realised we are just throwing money away." (Interview-participant 16)

- *Tilapia importation*: Although the importation of tilapia has been banned in Ghana to encourage the local production and growth of pond and cage systems, it appeared to be a common practice in Ghana, where people still managed to bring in tilapia fish seeds from overseas. According to the consultant from the Fisheries Commission (Interview-participant 6), imported tilapias were cheaper than those produced locally

because imported tilapias appeared bigger and fatty, had more flesh and were more appealing to the Ghanaian consumer than those produced locally. The importation of fish also affected the local farmers because they could not compete in terms of cost or affordability. Local businesses were at risk of collapsing due to the flux of imported fish seeds and products in the Ghanaian market.

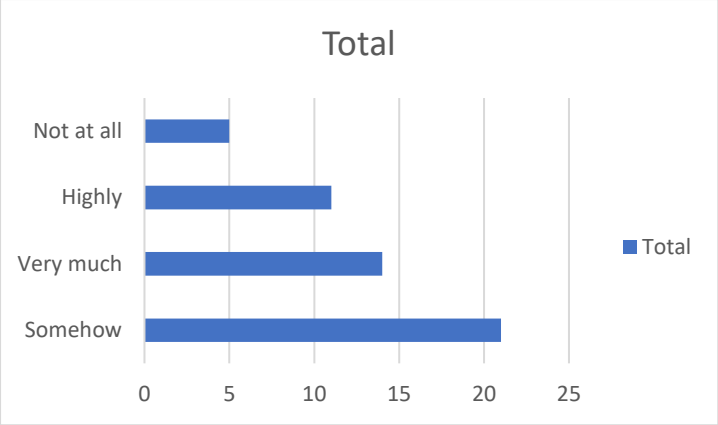
- Socio-political factors

- *The lack of enforcement of regulatory and monitoring policies:*
  "*Diseases like the ISKNV viral infection were things we imposed on ourselves because we do not abide by regulations. People want to be forced to comply."* (Interview-participant 6, University lecturer)

The ESO for the Ashanti region mentioned that prior to starting a fish farm, whether pond or cage, the fish farmers must have acquired permits from the Environmental Protection Agency (EPA), a document that states the right of access and usage of water from the Water Resources Commission (WRC) and an Aquaculture permit from the Fisheries Commission (FC). However, the consultant from the Fisheries Commission and other ESOs mentioned that many farmers operating cages and ponds do not have the required documentation for running their operations.

However, the institutions that must enforce the rule of law have proven inefficient due to a lack of cooperation and collaboration with fish farm managers.

- *High level of mistrust among stakeholders*: according to informants in the study, some fish farmers would not cooperate in providing data or records about their production history. Other fish farm managers would not allow authorities on their premises in order to carry out ad-hoc inspections. Fish prices at farmed gates varied and were often not disclosed as it was a tool for competition among fish farmers, mainly within the same locality.
- *Political nepotism*: the online survey showed that most fish farmers believed that political nepotism affected the stability and sustainability of the aquaculture sector in Ghana (Fig. 5.3.3d).



Row Labels	Count of q40_Political_Nepotism
Somehow	21
Very much	14
Highly	11
Not at all	5
Grand Total	51

Figure 5.3-3d: The extent to which political nepotism affects aquaculturists in Ashanti, Bono, Eastern and Volta regions in Ghana

The issue of nepotism arose during the interviews with various stakeholders as perceptions of the challenges farmers encountered to acquire licences and permits to operate were raised. Some informants mentioned it was sometimes challenging to get all documents from one place, and the application treatment most often depended on "whom you know". Some fish farms belonged to politicians or their relatives and high-ranked society officials. Some did not have permits to operate and would go unpunished when found faulting because they knew someone in power. Another issue was "passive employees" recruited into offices, taking big salaries without performing their duties adequately, and going scot-free. Such occurrences were seen as demotivating factors to collaborate with regulatory bodies.

- Environmental factors

Poor water quality was identified as a common challenge in both systems, though they operated differently and had different access to water sources. The location and zonation of fish farm sites and how the arms were constructed played a pivotal role in human and environmental interaction.

Land-based pond fish farms were mainly dugouts or artificial settings like trampolines filled with groundwater or from rains and streams to cultivate fish. The study showed that anthropogenic activities in the vicinity, such as run-offs from agricultural farms, management of hotel and restaurant businesses, tourist attraction sites and activities on the lake, and land degradation at construction sites, had an impact on the quality of water for fish production. However, in the case of ponds, higher stocking density meant a higher concentration of animal

waste (defecation debris, remains of dead fish, undissolved fish feed) that built up at the bottom and polluted the water when not changed over time. It was found that pond fish farmers had more considerable challenges in treating the polluted water before releasing it to nature. The lack of knowledge of fish farm waste management, water effluent treatment and the lack of supervision from regulatory bodies in ensuring the right thing was done contributed to the depletion of ecosystem integrity and disease spread.

A researcher from the Water Research Institute of the Council for Scientific and Industrial Research (WRI-CSIR) was contacted to give his perceptions about the challenges of the aquaculture sector in Ghana. He mentioned that his institution was involved in Environmental Impact Assessment (EIA) and laboratory analyses for water quality assessment to test its suitability for aquaculture development. One of the challenges faced by most aquaculture farmers was the lack of adequate facilities for certain water quality analyses, how water samples were fetched and sent to the laboratory and bad road networks. There were factors to consider for a good sample, notably the place and the way the samples were collected, ensuring the sample's integrity was maintained until ready for analysis. The quality of analysis depended on adequate instruments and human resource availability.

He mentioned that most of the water samples lost their integrity by the time they reached their lab, and that was due to several factors, such as:

- inadequate storage practice: when samples were collected in the wrong containers, exposing the water to light, there was a higher probability that photosynthesis would keep occurring and other organisms might develop.

- failure to label and tag samples with IDs, unreadable tags, and undated samples were causes of mix-ups or loss of samples.

- Storage was a significant challenge: most samples were kept frozen for more extended periods or transported without ice which caused a degradation of the sample

He said that, ideally, the samples should be analysed the same day they were collected or transported with ice.

5.4 Fish farmers and other stakeholders' opinions about the welfare of fish cultured

Speakers at the first 3-day hybrid Aquaculture conference for the West African Region from 14-16 May 2021 on the state of aquaculture in Ghana and other countries also raised similar concerns. The lack of knowledge on fish diseases was linked to the lack of trained veterinarians in Ghana and the low investment in biosecurity measures which exposed pond and cage farms to viral and bacterial disease hazards. Fish farmers interviewed equally confirmed they needed more training and education on fish health. Most fish farmers expressed willingness to pay for fish health services when they realised their fish were sick and experienced high fish mortality rates.

> *"We invited an expert, and they discovered that it is due to the water's acidity and PH level. We learned that it is not helping and that not all waters are suitable for hatching. So, for now, we stopped hatching for about two months."* (Interview-participant 15, pond fish farmer, Ashanti region)

> *"We tend to resort to foreign expert vets who can provide the fish disease report. It is a slower process, more expensive, but because they provide us with vivid reports, we have trust and confidence in them, and we think it is worth investing in that*." (Interview-participant 8, cage fish farmer, Eastern region)

These services were usually expensive as they engaged foreign fish health services because of the lack of available fish vets in Ghana, the time factor and the process of getting proper expert feedback. The fish farmer from the Eastern region (Interview-participant 8) said only three vets were available at the Fisheries Ministry with inadequate diagnostic resources. Fish farmers who need urgent help would have to engage them on a "private consultancy level", and usually, they did not get reports from these vets to get to know the real issues or diseases that affected their farmed fish.

The survey showed that most fish farmers sought help when they observed that their fish were sick (Table 5.4; Fig. 5.4). However, many fish farmers would try traditional water treatment methods using antibiotics, chemical disinfectants, and salt to treat the fish and water as a first step to salvage the situation. When the health of the fish was eventually affected, vaccination was the solution provided mostly after seeking professional help.

		treatment_Type					
		Use of antibiotics	disinfect with chemical	preventive methods such as vaccination	I do seek professional help	I do nothing	Total
Farming system used	Cage	5	4	2	7	2	20
	Pond	3	1	3	11	7	25
	Other	0	0	1	0	0	1
Total		8	5	6	18	9	46

Table 5.4: Crosstabulation count of the relationship between the farming system used and treatment type

The study revealed a knowledge gap about fish diseases and health management. According to the ESOs, some cage fish farmers and academic researchers interviewed, the ISKNV viral infection and spread of fish disease in cage fish farms that affected most tilapia cage farms in 2018 were attributed to the illegal infiltration of imported fish in the Ghanaian waters from a particular Chinese farm in Asutuare.

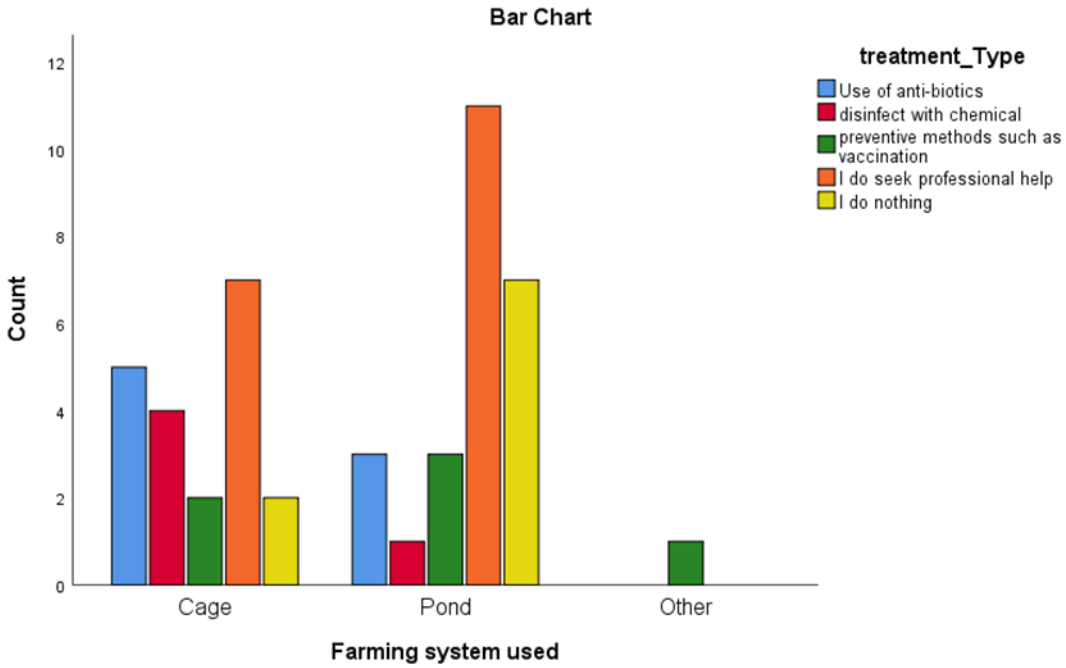


Figure 5.4: Fish disease treatment types in ponds and cages

Pond fish farmers interviewed, on the other hand, mentioned that they were not affected by the ISKNV viral infection and usually did not need to vaccinate their fish. However, they were mainly dealing with bacterial and fungal infections. Some fish farmers "overused" antibiotics to treat their fish which in some instances led to antibiotic resistance. One fish farmer said some of the unknown causes of the fish sickness would lead them to use google or YouTube videos to find DIY solutions to care for their fish. Consultants were only engaged to step in when the situation got out of hand.

Significant concerns were raised regarding the welfare of cultured fish in Ghana along the value chain from the production, processing, distribution, and consumption of fish products.

Some informants perceived the government's intervention to mitigate the ISKNV viral infection in 2018 as reactive governance to address the high fish mortalities.

> *"The government is interested in where there is money and has not demonstrated responsibility in making the aquaculture sector sustainable. If they were doing a quarter of what they did for the oil industry, the aquaculture sector would be telling a different story now. The government got interested in the aquaculture industry during the ISKNV*

outbreak because it became a public health scare" (Interview-participant 8, cage fish farmer, Eastern region)

We have structural political governance issues that need to be addressed. According to a participant interviewed in the study, "*the most important thing is government's engagement and priority to the sector and provide the infrastructure and technical expertise. So far, the government is not having this as a priority*".

A participant in the study claimed that before the dead fish in Volta Lake could be disposed of, some fishmongers and local people living near the affected cage fish farms harvested the dead fish for personal use or put it in the market for sale. The fact that they believed it was nature blessing them with free fish showed the lack of awareness about fish diseases and the threats these dead fish could pose to human security and food safety. It equally revealed the weakness in surveillance, monitoring and regulatory bodies regarding the aquaculture sector.

- Overstocking

Overstocking or high stocking densities was identified as a critical issue, as respondents' perception was that the more fish stocked in a pond, the more yield they would get.

According to the ESO in Bono, regarding pond fish farming, there was a limit to the stocking density, i.e., the number of fingerlings put in the pond compared to the size of the pond. For cages, the stocking density could be between 50-150 fish/meter cube, provided all the conditions were met in terms of oxygen level and space. While on the other hand, in the ponds, the stocking density for tilapia was 3-6 fish per meter square. The main difference was that the stocking density with cage fish farming was higher than in ponds. Therefore, the perception for most fish farmers was that if it is for business, the best option is to go with cage fish farming in terms of tilapia production instead of ponds to make more profit and sustain the industry.

According to an informant from the Norwegian Veterinary Institute, overstocking caused the fish to be stressed as they would compete over food, oxygen, and space. Although farm managers provided quality feeds to the fish, there were reports of abrasions on fish skin and numerous mortalities. Some pond fish farmers would think their fish suffer from bacterial

diseases and decide to treat the fish with antibiotics. Overstocking was instead identified as a threat to the welfare of the fish and, in such instances, provided a conducive environment for viral infections to spread faster in the case of cage fish farms.

5.5 Perceived opportunities for the sustainable aquaculture industry in Ghana

> "*Aquaculture is a multi-disciplinary and multi-actor enterprise that requires all stakeholders' involvement for the industry to survive*" (Interview-participant 11, Norwegian Veterinary Institute).

The informant from the NVI further likened the aquaculture industry to a football team and illustrated that as many players played different roles on the field, the main aim of running with the ball was to score a goal and lead the team to win the match. In the same way, teamwork from aquaculture stakeholders will make the achievement of a sustainable sector possible.

Therefore, to bridge the gap between academia and industry, scientific and technological innovations must be promoted in alignment with local knowledge and individual preferences.

The outcome of research must shape the modus operandi of industries and other stakeholders to achieve sustainability in these times of high uncertainties.

The government introduced some interventions to create employment and allow people to be trained in aquaculture. Training and capacity building emerged as recurring themes when participants were asked to comment on the government's initiatives. Much funding has gone into training human resources in production and farm management best practices. However, little was said about the transfer of knowledge, skills and abilities of the beneficiaries to benefit the aquaculture sector.

1. Training on best management practices, fish health

The ESO from the Bono and Ashanti regions confirmed that farmers were mainly trained on husbandry practices, which were considered the best management practices on their farms

> "*We have veterinary doctors who oversee the health of most fish produced on farms to ensure that the fingerlings are healthy. The farms must be clean following biosecurity protocols supervised by vet officers*" (ESO, Bono region).

2. In 2020, the government introduced a flagship national programme called "Aquaculture for food and jobs" to provide employment and create avenues for these trainees.

The Fisheries Commission established aquaculture facilities for groups, associations, and institutions such as the prison services and the second cycle institutions. There is also one group called Eagle youth group located in Wenchi; they were given ten ponds the size 300-meter squared. We gave them about three hundred bags of feed.

In the Bono region, the Commission sponsored a senior high school called Doma Secondary school with four earthen ponds, fingerlings, and feed for their first production. Students from the school would learn from the farm depending on their skill set. The initiative would train a whole value chain of persons with entrepreneurial skills like business students, technical skills from the agriculture and science department, processors, and post-harvest people from the home economics department. The initiative to train the youth at a tender age was strategic because it would offer practical career guidance for these students before tertiary education. They would have basic knowledge and hands-on practical experience in Agro-business, business administration, technical skills, and ethical principles.

3. TiSeed (Tilapia Seed project) was looking to develop an improved quality tilapia seed or fingerling to distribute to farmers. The ARDEC championed the TiSeed project under the CSIR.

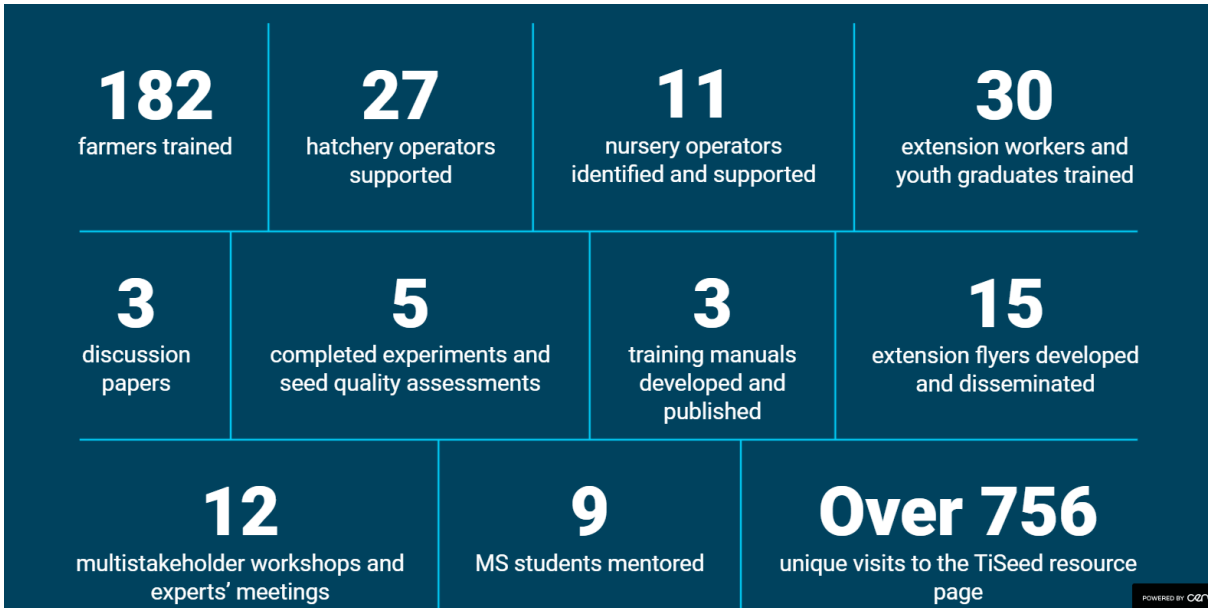


Figure 5.5: TiSeed by the numbers. Source: (IFPRI, 2022)

3. Extension service delivery- to provide technical backstopping to stakeholders in the aquaculture sector, supporting and ensuring that fish farmers understand their job, the dos and don'ts, and explaining salient issues the sector faces to researchers.

5.6 Summary of results

From a social science perspective, the sustainability of fish farming systems in Bono, Eastern, Ashanti region and along the volta lake depends on the role, decisions and commitment of different institutions and stakeholders.

The government institutions, private sector and other stakeholders in the aquaculture value chain may not have balanced interests and effective interaction to ensure that their present actions and motivation do not affect the legacy of the aquaculture sector for the future generation. There was a perception that the Ministry of Fisheries and Aquaculture Development in Ghana did not have an adequate budget for its operation and mainly relied on investments and international cooperation funds. The fisheries commission's role was to ensure proper and regular assessment of safety and security threats, risks, and vulnerabilities to minimise the risk of fish diseases and the collapse of fish farms that threaten food and human security and livelihoods.

On the one hand, fish mortalities were attributed to algae blooming, untreated water related to the amount of fish feed that sank to the bottom and the high amount of manure and fertilisers from other agricultural practices that ended in the pond. On the other hand, low-quality fish seeds and high stocking densities accounted for fish losses in ponds.

Perceptions on the reasons why the sustainability of pond culture has become problematic are as follows: the price of feed, quality of seed and marketing are the main challenges that affect pond culture in Ghana.

- The feed price: "the feed is costly and keeps increasing day in and day out."
- The quality of seed, i.e., fingerlings, the breed of fish or the genetic make of the fish:

In Ghana, the type of tilapia cultured is referred to as the Akosombo Strain Tilapia, which, compared to Western and Asian countries and even in Egypt, the type of tilapia they culture grows faster than the Akosombo strain.

However, currently, they have introduced the "GIFT" tilapia strain (Genetically Improved Farmed Tilapia, which "is of a higher quality in terms of growth than the Akosombo strain", according to the ESO, Bono region. He further explained that *"this is a challenge because the fish feed is expensive, and you are obliged to feed the stock regularly. The fish might not grow in time and in the desirable weight to sell faster at a price you want."*

Therefore, the fish farmer will use more feed, spend more money, and still compete with the attractive and fatty GIFT strain on the market.

The pond fish farmers suffer more than the cage fish farmers because they operate on a small scale and do not have the capital and naturally conducive environment to operate on a large scale as the cage fish farmers do.

The central perspective from the FC officers is that academics focus more on the quality of the seed, while the fish farmers are more worried about the price of the feed.

> *"If you ask people from academia and genetic scientists, they might tell you that their major issue is the quality of seeds or fingerlings before they mention the price of the feed. However, people like us spend most of our time with the farmers, and we speak their language. So, if you should ask a farmer: what is the major challenge you face? He will tell you that the feed is killing them because the price keeps increasing daily."*

Cage fish farmers are big investors and can buy the fish feed in massive quantities "between 100- 1000 bags because they have the capital": "they buy the feed in containers". Therefore, they prioritise getting quality seeds or fingerlings to meet market demand and satisfaction in record time.

On the other hand, *"pond fish farmers buy 2 or 3 bags to feed the fish. The highest they can go is to buy an average of 30 bags of feed".* Procuring fish feed becomes more expensive. Thus, their primary issue is the price of feed.

- Marketing: Pond fish farmers are the ones who have issues with marketing because

> *"Most small-scale farmers do not even have a business plan and just jump into it. Sometimes they construct the pond and start the fish farm before coming to the commission for advice then you realise they did not do it well. However, for a good*

extension service, you must primarily encourage the farmer because he has already pumped in money, and then you correct him."

In a nutshell, there is much work to do if the aquaculture sector aims at sustainability. As a participant passionately described the state of the aquaculture sector and said:

> *"The whole thing is to exploit the African market. We need to grow and explore new markets within the African market. We need to add value to the product. Africa is a massive continent with a vast potential market. We can expand if we do things right. How many of our farmers are meeting their production targets? Why are we underproducing? It is not only fish feed. How is management done? We should not be complaining about hunger in Africa. We can get so much in one season and the next. "* (interview-participant 7)

6. DISCUSSION

Figures 6.1-1 and 6.1-2 serve as a checklist for assessing the progression of the vulnerability of aquaculture systems management in Ghana, notably pond and cage fish farms. In this discussion chapter, the Pressure and Release model by Wisner et al. (2004) is used as a reference point to identify the root causes, dynamic pressures, and unsafe conditions that exacerbate hazards and create a conducive pattern for disasters.

Ghana's thriving aquaculture sector has experienced a series of disasters between 2012 and 2018, such as viral disease outbreaks that affected the livelihood and survival of fish farming businesses. Such occurrences threaten food security and human security as the lack of implementing biosecurity measures affects food safety. An adaptation of the conceptual framework for the review article, the four pillars of food security (FAO, 2006) and selected focus areas related to fish and FNS in Ghana by Hasselberg et al. (2020) are used to discuss the importance of implementing several aspects of biosecurity measures at all levels of food systems along the value chain of the aquaculture sector and the long term sustainability of producing fish as food in Ghana.

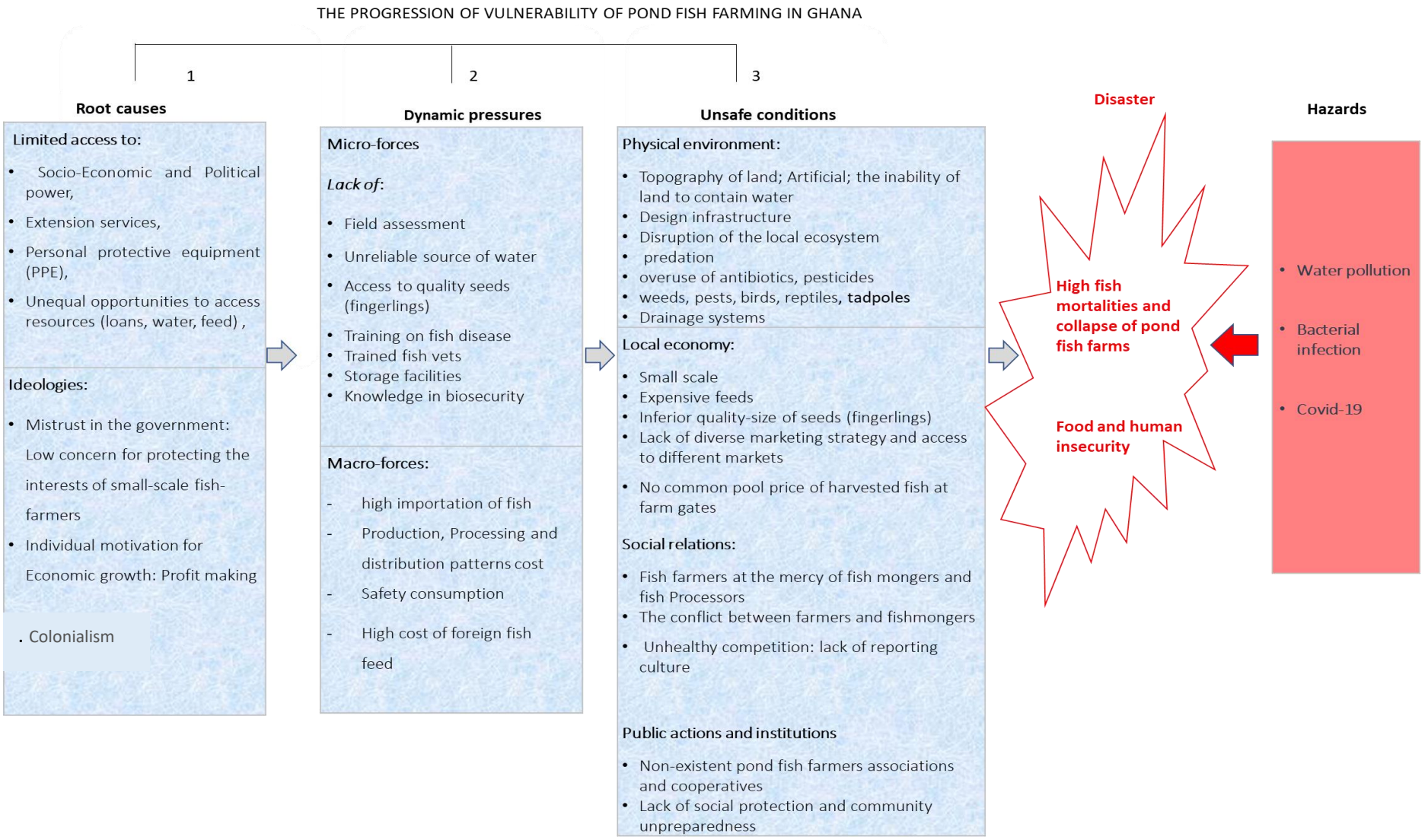


Figure 6.1- 1: Progression of the vulnerability of pond fish farming system in Ghana

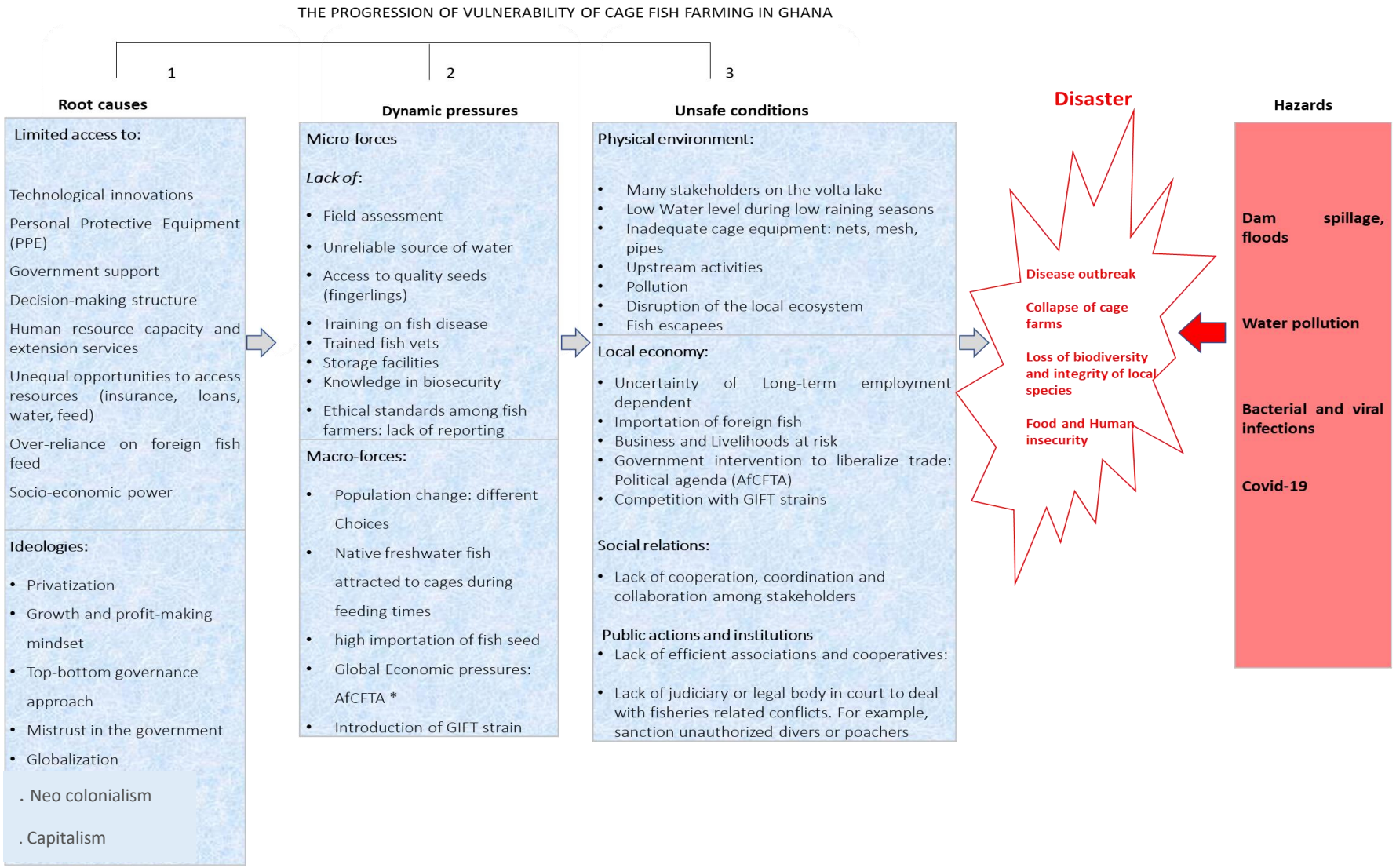


Figure 6.1- 2: Progression of the vulnerability of cage fish farming system in Ghana

6.1 Ecological, economic, and socio-political factors associated with the sustainable development of pond and cage fish farming in Ghana

The concept of sustainability is perceived differently by stakeholders such as researchers, government, civil society, the private sector, investors, and fish farmers, to name a few.

For governments and politicians, the concept of sustainability is a political issue which shapes policy-making in a globalised world to attain a balanced- sheet of economic growth, social well-being and environmental stability in the short, medium and long term (Heinrichs & Biermann, 2016).

In the 1995 code of conduct for responsible fisheries, sustainable development is defined as "*the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in agriculture, forestry, fisheries sectors) conserves land, water, plant, and animal resources, is environmentally non-degrading, technically appropriate, economically viable, and socially acceptable*'' (Frankic & Hershner, 2003, p.522-523).

In this section, an attempt is made to narrow down the concept of sustainability to what it means in aquaculture terms in the Ghanaian context.

- <u>Ecological and Environmental hazards</u>
- Implications of location and territorial fish farm sites

The water research institute commissioned a study to assess the water quality and primary productivity characteristics of Volta Lake in Ghana (Karikari et al., 2013). On the one hand, the results indicated a low concentration of nutrient levels in Volta Lake, which indicated that the Lake was not eutrophic. On the other hand, the lake's pH level, average value temperature and dissolved oxygen were suitable for aquatic life. Therefore, Lake Volta could accommodate more cages without pressure.

However, recent concerns raised by the Fisheries Commission's ESO for the Akosombo centre showed that many anthropogenic activities following an increase in the number of settlements

around the lake were affecting the water quality and, by extension, the quality of fish produced by the cage fish farms.

The runoffs from farms that use pesticides and large amounts of fertilizers end up in water bodies in the vicinities. Research has shown that human waste and throughput from anthropogenic activities are significant sources of nutrients and life for other organisms like aquatic species. The excessive amount of nutrients in the ponds originating from the farm practices and feeds not consumed by the fish can cause algae blooms preventing plants from having access to direct sunlight, which is necessary for photosynthesis and survival. Although it has been acknowledged that nutrients runoffs from agricultural farming practices may cause eutrophication in water bodies, research has equally shown that the stocking density, content of fish feeds and fish farming practices in terms of the quantity and frequency of feeding times equally contribute to the potency of eutrophication in ponds. Folke et al. (1994) argued that the intensive monoculture of salmonids in cages, for instance, bears high environmental costs. To them, this type of throughput production system relies heavily on inputs of natural resources and ecological services. Considering the number of resources collected and used from large areas and the amount of concentrated waste generated and released back into the environment, the sustainability of a monoculture system of production is arguable.

A pond fish farmer has more responsibilities in ensuring a constant supply of quality water, water treatment, procuring fish seed and feed, harvest and storage, sale, and distribution. Pond fish farmers are to ensure they get in clean water, and the wastewater or effluent must be treated in order not to pollute the environment. However, most of the pond fish farmers operate on a small scale, on their lands or backyards. Therefore, some farm owners may not know the consequences of their actions when they discharge polluted water into nature without treatment. The inefficiency of monitoring and regulatory bodies in these rural areas does not help hold the farmers accountable for such hazardous actions.

In the case of cage culture, fish farmers benefit from having access to a larger flowing water body, and the fish are in their natural habitat. The Volta Lake is an entire system that goes beyond the borders of Ghana and "*flows into neighbouring countries Burkina Faso, Togo, Mali, Benin, and Ivory Coast*" (Ghansah et al., 2016, p.206). Regarding the ecological impact of cage fish farming, the challenge lies in controlling potential water pollution or disease spread

upstream that trickles down to those downstream. Vulnerable people find it more challenging to bounce back and reconstruct their livelihoods when hit by a disaster making them more susceptible to the consequences of subsequent hazards (Wisner et al., 2004). Therefore, in assessing the environmental impact of cage farms, it is worth noting that the risk factor in cage fish farming is higher than with the pond farms regarding water system control, the scale of impact of disease outbreaks, fish escapees, predation, and competition.

Managing waste and water effluents from land activities was also recorded as affecting Volta Lake's water quality. There have been reports of illegal small-scale mining activities referred to as “galamsey” on and near water bodies such as the Black Volta river affecting the water quality (Bowan & Tingan, 2020), polluting many rivers and contaminating freshwater fish. Research has equally shown that indigenous settlers around the lake have agricultural farms near the Lake Volta, and with the use of insecticides and pesticides, there is a high probability of fish being affected. Most of the communities around Volta Lake are rural areas deprived of good roads for the transportation of goods and services, waste disposal and treatment facilities, toilets, and other sanitary facilities. The standard means of transport is by canoe or small boats on the volta lake (van Zwieten et al., 2011).

Frictions and tensions between cage fish farmers, indigenous fishermen, and hotel and restaurant owners were prominent. As observed by Karikari et al. (2013), beyond the primary objective of Volta Lake to generate electricity to supply Ghana and neighbouring countries, the Lake provided other ecosystem goods and services. The Lake was a source of drinking water, transportation, fishing and recreation to stakeholders in the Volta Lake, for example, FC, WRI, VRA, hotels, resorts, local fishermen and settlers whose interventions and activities might affect water quality.

The lack of preventive, monitoring and control mechanisms to reduce exposure to such hazards threaten the sustainability of cage fish farming at the social and environmental level.

- Inferior quality of fingerlings

Some fish seed producers provided low-quality fish seeds or fingerlings. The ESOs, Fisheries Commission consultants and academic researchers equally raised concerns over Ghana's high fish importation culture to meet the national fish protein demand.

- Socio-Economic and political factors

De Graaf and Janssen (1996, p.1) stated there was a "*myth*" that the primary motivation of fish farmers in rural communities was mainly for food security or a source of protein for their family rather than for income generation. However, the survey's results showed otherwise that it was not a myth. Fish farming in Ghana is acknowledged as the cheapest source of animal protein for local communities. However, its success depended on access to quality water, fish seed, fish feed, and good management practices that impacted fish's growth, patronage, and profitability. These factors are some of the root causes that dictate the motivation of fish farmers to pursue aquaculture.

The location and concentration of fish farms also exacerbate the lack of attention on the welfare of farmed tilapia and catfish in Ghana. Access to quality water is paramount to the cultivation of quality fish. Most pond fish farmers in Ashanti and Bono regions used groundwater to rear their fish in an artificial concrete or earthen pond. Therefore, pond farmers had an enormous responsibility to ensure clean, well-oxygenated water at the right temperature for the fish to grow normally. Cage fish farmers also had water quality concerns, although they benefited from a larger flowing water body like the Volta Lake. The participants in the study revealed that various anthropogenic activities around the Lake and the concentration of legal and illegal cage fish farm operations in some parts of the lake were the sources of social conflicts among the lake beneficiaries aside from the health hazards they posed to both human and animal biomass.

The ESO for the Akosombo centre explained that the tensions between the cage fish farmers and the indigenous fishermen were a classic example of an open-access problem. There have been growing concerns about such open-access conflicts since it is challenging to manage or govern the movement of fish in water bodies. Cage fish farmers felt insecure as poachers threatened their business, and the movement of motorised canoes caused the caged fish to be stressed and affected their feeding patterns. There are laws governing the Aquaculture industry in Ghana, namely the Fisheries Act 625, 2002; Fisheries Regulations, 2010 (Agyakwah et al., 2020a; Agyakwah et al., 2020b). In addition, as shown in the results chapter, the fish farmer is required to have three main permits before starting operations: an environmental permit from the Environmental Protection Agency (EPA), rights to water usage from the Water

Resources Commission (WRC) and an Aquaculture permit from the Fisheries Commission (FC). However, these laws, regulations, policies, and requirements are often not respected. The results showed that some cage fish farms on lake Volta and pond fish farmers operated without a license. Policies on managing fish farming activities in Ghana might not achieve the intended goals because they are mainly imposed on the fish farmers without considering whether the latter understand the implications of their actions. The interactions with stakeholders from academia and the industry players revealed that fish farmers who failed to provide such documentation were mainly due to the heavy bureaucratic procedures and lack of implementation of regulatory measures from the Fisheries Commission.

Therefore, an ecosystem approach to aquaculture management is necessary, whereby the government and relevant stakeholders adequately address occupancy issues. Avoiding social conflicts by ensuring the cages are appropriately located in designated areas in the lake and everybody has room to operate.

Economic constraints

Cost of production

Good nutrition for farmed fish in Ghana must be considered to produce high-quality fish to meet the protein needs of the people. The frequency and types of feed given to the fish are crucial determinants of the quality of fish produced.

Participants in this study mentioned that fish feed represents almost half the production cost, making farmers who practice a semi-intensive or intensive aquaculture vulnerable and less competitive in the market due to the high prices of locally produced fish compared to imported fish. Therefore, most farmers mix foreign and local feeds for their fish to optimise output and break even. Also, the Covid-19 pandemic exacerbated the fish feed industry's vulnerability among other aquaculture value chain sectors. The lockdowns and movement restrictions presented several limitations in accessing goods and services, reducing demands on farmed fish such as tilapia from hotels, restaurants and the tourism industry at large (Ragasa et al., 2021). Fish feed producers such as Aller Aqua and Ranaan, the leading foreign feed producers and distributors in Ghana, recorded low sales due to the restrictions and low demand from fish

farmers who had low capacity to purchase due to reduced operations and challenges in selling their fish. Ragasa et al. (2021) also mentioned that tilapia prices are relatively higher than other fish and animal protein types in Ghana. So, in the event of economic hardships, consumers tend to switch to cheaper options. Many fish farmers that started with tilapia cultivation switched to farming catfish. Cost of production in terms of FCR, change in consumer preference, and greater satisfaction in the growth rate of catfish compared to tilapia during the same production period account for the shift in focus of production.

Economy of scale

In terms of economic profitability, cage fish farmers are predominantly the leading fish farming system. They are doing business, employing many people, and impacting the economy. There is a whole value chain from production to distribution: those involved in the production, go-betweens or intermediaries who pick and distribute to market women right down to the consumer. It has a broader value chain impacting more people and national GDP. The cages on the volta lake make up almost 90% of tilapia production in Ghana, while the sector is dominated by ponds representing 98% of fish farms in Ghana (Kassam & Dorward, 2017). So, according to Kassam and Dorward, 2% of fish farms produce 90% of tilapia, which appears to be the preferred fish for high and medium-income earners.

Meanwhile, pond fish farms operate on a smaller scale and cannot produce much compared to cages. One of the challenges impeding large-scale pond production is that the pond is an artificially created system whereby the fish compete for food, oxygen, and other physical and chemical factors. The pond fish farmer who engages in aquaculture for subsistence must compete to meet all these requirements. However, the fish might not be able to grow as big as those in the natural water system. The cage fish farmer's primary responsibility is to feed the fish well and adhere to well-established Standard Operating Procedures (SOPs). The ESO from the Bono region said that if all environmental factors are right, the fish will grow bigger and healthier.

6.2 Nexus between sustainability of farming systems, the welfare of cultured fish, biosecurity, human security and food security

- Dynamics of production systems

Regarding the production systems, the study focuses on ponds and cages representing culture systems on land and freshwater, respectively. In Ghana, pond and cage systems of fish farming are the most common forms of cultivating fish.

This study focused on Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*), the most preferred species by farmers and consumers.

The intensive system of cultivating fish would determine the types of feed needed to ensure direct feeding of the fish for optimal growth. For instance, extensive system practices involve natural waterways containing larvae or juvenile fish harvested over time. Usually, organic fertilisers (manure), inorganic, i.e., chemical fertilisers or a combination of both are indirectly utilised to boost nutrients such as nitrogen (N), phosphorous (P), magnesium (Mg), potassium (k) and carbon that are crucial for natural food production (Phytoplankton growth) to increase productivity (Edwards, 1993).

In semi-intensive systems, farmers tend to add supplementary feeds towards the end of the culture cycle when the fish reach their adult stage with higher competition over natural food resources. On the other hand, other farmers combine fertilizer and feed inputs throughout the cycle to maximise the output of a grow-out farm.

However, the systems of operation and how they are managed present challenges that threaten the success of aquaculture in Ghana. Managing fisheries and aquaculture in Ghana has a long history of ups and downs. Sometimes due to environmental conditions beyond human control and other times due to anthropogenic activities. The sector's vulnerability was proven during the major ISKNV outbreak in 2018, whereby a large percentage of cage fish farms were affected and eventually had to fold up.

Loosed policies on fish importation, reliance on fish feed subsidies, the ineffective zonation of regions and demarcation of cage fish farm concessions, and conflicts of interest among stakeholders played a significant role in making pond and cage fish farming vulnerable.

Economically and socially, farming systems were threatened by several factors: the high cost of feeds, low quality of fish seeds or fingerlings, heavy reliance on importation of goods and services, low ratio of extension service officers to the number of existing fish farms, lack of trained fish veterinarians, lack of knowledge in fish health and biosecurity measures.

Environmental challenges were mainly the location of fish farms, zonation of concessions and risks of being exposed to fish escapees and invasive species that threaten the integrity of the local AST in the Ghanaian freshwater ecosystem.

- Sustainability of the production of *catfish* vs *tilapia*

This research shows that fish farmers preferred the two types of fish cultivated in Ghana, tilapia and catfish, because they quickly adapt to different environments.

Tilapia can quickly adapt to different environments in freshwater or brackish water. Tilapia's herbivorous nature allows the specie to feed on plankton and phytoplankton and can survive in cages or ponds.

Because of their anatomy and peculiar characteristic as airbreathing fish, catfish can be reared in clear water but equally in muddy waters where they can find their primary food source. Catfish are omnivorous predators that can feed on insects, zooplanktons, worms, smaller fishes and other organisms (De Graaf & Janssen, 1996) and survive for many years in different environments, whether inland or in pond settings. Most pond fish farmers preferred to rear catfish than tilapia because it was less demanding in terms of foreign feeds. Most fish farmers could mix locally made feeds from wheat or rice brans, maize, or corn husks with foreign feeds they buy from feed manufacturers such as Ranaan feeds, which appeared to be the most common.

Catfish are described by study participants as fleshier than tilapia and have more value-adding properties. They can feed on earthworms, plankton, and algae, among others. According to the findings, some pond farmers in the Bono region believe cultivating catfish is more cost-efficient than tilapia as they are a more robust and resilient specie. They are less prone to diseases and equally thrive in varied habitats, from flowing streams to muddy ponds, sluggish rivers, or lakes.

According to the FAO statistics, catfish production has steadily increased since 2015. The ISKNV outbreak caused tilapia farms' production to dwindle from 70,628 mt in 2018 to 45,750 mt in 2019. Catfish production, on the other hand, thrived steadily. Therefore, catfish's resistance to viral infections seems higher than tilapia.

The catfish business has experienced a significant increase in recent years in Ghana. Chains of restaurants and cottages that introduced a new culture of "point and kill" are currently the trend. Customers can point to the size and weight of fish they want for pepper soups, grills, and kebabs. People have become more creative in putting fish on the table with a broader range of tasty meals.

Smoked catfish is particularly a delicacy for many people in Ghana. Smoking has been the most famous traditional way to add value to catfish for decades in Ghana. Smoking was also a way to preserve the fish harvested. Women are mostly more involved in the smoking of catfish than men. However, concerns about the risk of intoxication and food contamination during the smoking process have led government and fisheries authorities to develop innovative projects to ensure food safety and curb the impact of smoking catfish on the atmosphere and humans.

Image 8: Women's engagement in the catfish value chain in the Bono region Photo credit: Emmanuel Mensah, Senior researcher, CSIR Water Research Institute, Ghana. TiSeed project

Most times, biosecurity measures are neglected, affecting the fish's health and trickling down to consumers later.

Key stakeholders such as academia, government agencies, feed producers and industry players must come together with viable solutions for a proper balanced nutritional diet for the fish. More research should be channelled towards funding innovations for feed production that meet the right consistency of protein, carbohydrates, fats, minerals, and vitamins for complete or supplementary affordable diet options for tilapia, given that they are herbivores that mainly feed on planktons or algae. Feed production could be locally made with readily available farm products such as corn or groundnut husks and vegetable oils while strictly adhering to biosecurity measures to ensure optimal growth and health of cultivated fish.

The species cultivated may be resilient, but if the management and operations systems are weak and vulnerable, it might cause a collapse of the aquaculture sector in Ghana.

Therefore, new fish species should be explored to diversify the types of fish cultivated, use internally generated funds to develop feeds locally, and invest in feed production skill-sharing among the fish farmers.

- Fish welfare: disease control, fish health management and biosecurity measures

The lack of knowledge about fish diseases and the type of treatment used by fish farmers indicated the degree of vulnerability and susceptibility to disease spread and high fish mortalities. Not all diseases or conditions require vaccination. In the case of ISKNV disease spread in 2018, the quantum and rate at which the fish were dying and the number of cage fish farms that were affected, leading to most businesses folding up, was a clear case of viral infection that required vaccination as a measure to mitigate the impact on the industry. The government intervened and offered massive free vaccination programmes to salvage the situation. However, since the vaccination was done manually and the number of trained professionals was limited, large-scale fish farms that could afford the services would get their fish that survived vaccinated and could bounce back in business.

The Norwegian Veterinary Institute investigated tilapia mortality in Ghana following the ISKNV outbreak in Ghanaian waters. One of the significant challenges they faced was the lack of required diagnostic centres in Ghana, and samples for bacteriological analyses had to be kept chilled due to a lack of functional incubation facilities to be transported to Norway, where lab diagnostics and analyses were conducted at the Norwegian University of Life Sciences (Veterinærinstituttet, 2018).

Similar challenges are encountered when the Water research Company (WRI) of the CSIR (Council for Scientific and Industrial Research) is to conduct analyses of water quality within Ghana. According to a participant from the WRI, poor storage facilities exposed the samples of water to light, allowing photosynthesis and the development of organisms such as chlorophyll a. Also, the participant in the research made mention of freezing samples for a more extended period which gives a clear indication that more education is needed on how water samples or disease samples should be done, kept, and transported under the right conditions to preserve the integrity of the water samples for adequate diagnosis and control. The lack of coordination between fish farmers who need the services of institutions like WRIC is sometimes problematic. Proper communication channels and feedbacks are necessary to follow the correct procedures in ensuring that the welfare of fish and biosecurity measures are adhered to adequately. Regulators, fish farmers and consumers should be concerned about the procedures involved in the fish farm's production, harvest, processing, and distribution.

Sometimes the way fish is processed, for example, through smoking, the fish tends to lose vital nutrients and can cause serious health problems to consumers. Standards are often set to meet exportation requirements. The standards for local consumption must equally be set and respected.

Biosecurity protocols go beyond using PPEs or keeping the farm site clean, as advanced by some participants. Many factors should be considered. Prior consultation for selecting the appropriate location of a cage or pond fish farm is needed to ensure that concessions are not too close to each other. Regular visits by extension service officers and regulatory bodies should be part of the routine for disease prevention and health controls. Such follow-up visits are crucial to help report fish mortalities and update the list of bacterial and viral pathogens of fish diseases in Ghanaian waters to inform policy directions. Investing in aquaculture engineering, science, and technology to segregate different generations and limit fish-stocked relocation is also paramount.

- Food security, food safety and human security

The concept of food security has developed over the years. The High-Level Panel of Experts (HLPE) includes the aspects of agency and sustainability in a recent review of the widely accepted definition by the FAO.

Figure 6.2-2: The six dimensions of food security in its current definition source:(HLPE, 2020, p.10)

Therefore, this study argues that fish is food and should align with the HLPEs' description of the processes involved in food systems. According to the HLPE, a food system, as shown in Fig. 6.2-2, "*gathers all the elements (environment, people, inputs, processes, infrastructures, institutions) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the output of these activities, including socio-economic and environmental outcomes"* (HLPE, 2017, p.23; HLPE, 2020, p.11).

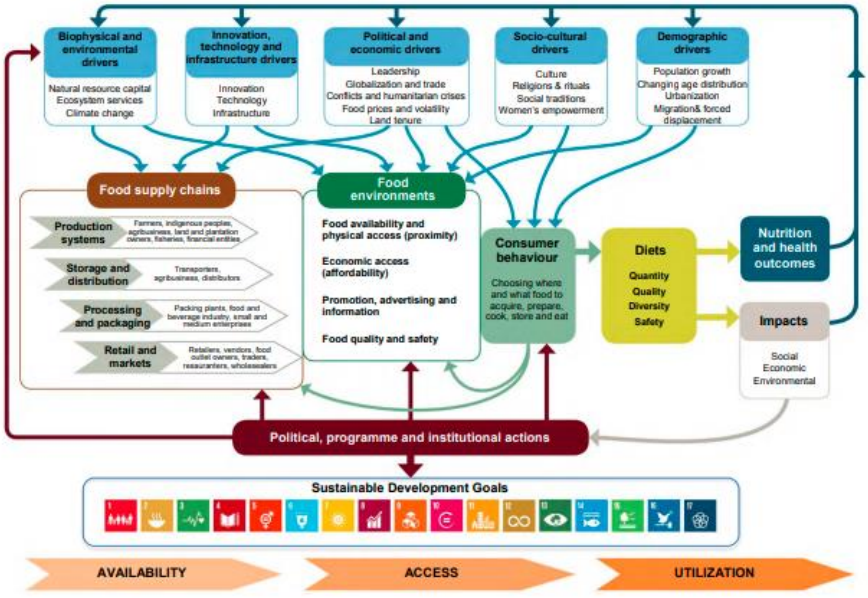


Figure 6.2-3: Conceptual framework of food systems for diets and nutrition Source: (HLPE, 2017, p.26)

In alignment with the UN Sustainable Development Goals (SDG) 2 and 14, the aim of developing the aquaculture sector in Ghana is to contribute to improving food nutrition, hunger eradication, poverty reduction and, to some extent, human security. This thesis suggests that when food security is achieved, it contributes to human security and wellness. Balancing food security and employment opportunities in the blue economy can be achieved through the sustainable use and conservation of water resources.

- Fish supply chain in Ghana

The fish supply chain implies the processes involved in producing, storing, processing and selling fish products to make them available for people. In other words, the activities and actors involved from the production to the consumption of fish products in Ghana. Some essential factors to consider are how fish products are stored to avoid fungal development or food rots and how waste is efficiently managed or recycled to contribute to food safety and human security. Research has shown that edible fish oil can be produced out of fish by-products, therefore, allowing the development of another type of market in line with food security, employment, poverty alleviation, and other social interventions. Therefore, based on the HLPE (2017) framework on food systems, the following drivers, "biophysical and environmental; innovation, technology and infrastructure; political and economic; Socio-cultural; demographic", greatly influence the availability, accessibility, and utilization of fish products.

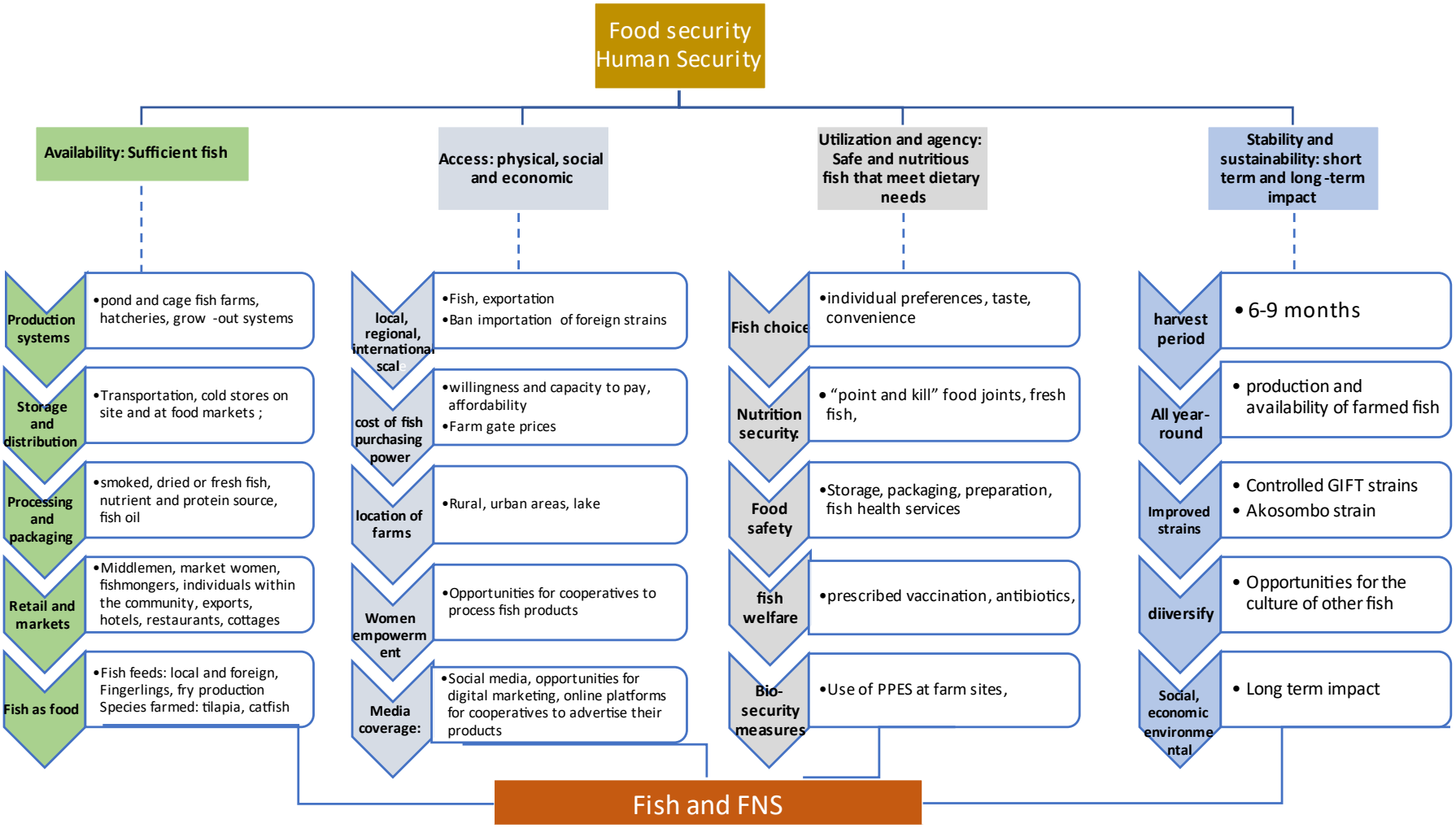


Figure 6.2-4: Conceptual framework of the nexus between human security, the pillars of food security as reviewed by HLPE (2017) and the sustainability of the value chain of fish as food and FNS in Ghana adapted from Hasselberg et al. (2020)

Against this backdrop, pond culture in Ghana arguably has more potential than cage fish farming and could be the future of aquaculture. Regarding accessibility, pond culture systems are prevalent in rural communities where individuals and groups can rear the fish in their backyard, process it, sell it, and make money for themselves. The responses from the majority of pond fish farmers revealed that most of them did not need storage facilities for the fish they produced. They know when they will harvest adult fish, and the market women or customers place their orders and buy them as soon as they are harvested. The lack of specific amenities, such as stable electricity for cooling the fish, makes it a practical adaption system for the fish farmers to run their businesses. However, the challenge lies with when the purchasing power of customers drops, like during the Covid-19 pandemic. The more the fish grows, the more feed is required leading to a higher feed conversion ratio (FCR) and the more expensive it is to keep the business running. It is similar to operating a poultry farm: the more chickens multiply, the more feed they require and the riskier the investment gets when threatened by diseases. Farmers reported that they had to harvest the fish, smoke them, dry them to sell later, and use some fresh and processed fish to feed their families. From this angle, a small pond fish farm is possibly more viable subsistence for a family or group than a large-scale farm.

On the other hand, Ghana's government initiated its flagship programme, "Aquaculture for food and jobs". Below are the objectives presented by Ragasa et al. (2022a) from the MOFAD, 2018 original project document :

1. To encourage the private sector through economic incentives to increase investment in commercial fish farming
2. To promote small-scale fish farming
3. To support institutions, such as schools, prisons, or the military, that have the potential to produce fish
4. To support existing and new entrant fish farmers with inputs, with a focus on youth
5. To strengthen extension services, as well as fish health and environmental management, and
6. To develop fish markets and provide marketing assistance to fish farmers.

Some informants in the study revealed that the AFJ project had known slow progress, and as of 2020, it has focused on supporting youth associations and institutions with inputs, facilities, and training to start or expand their production. However, the focus on scaling up the

production of cultured tilapia and catfish indicates that the government is skewed towards the intensification of fish farming in Ghana, which would positively impact GDP and economic growth. However, the impact of intensified systems of culture on the environment and society raises concerns about the sustainability of the aquaculture industry if care is not taken. Governments sometimes fail to look at the bigger picture and the long-term effects of their policies and interventions. One of the issues in developing countries like Ghana is the failure to recognise and be honest about the root problems that must be addressed.

The government must set the right priorities to balance the increase in production with food safety measures to achieve food security and human security. As mentioned, many tilapia cage farms on Volta Lake were affected by the ISKNV disease that hugely impacted livelihoods and the national GDP in 2018 and 2019. Reports have it that this has become endemic in Ghanaian waters, necessitating control mechanisms by enforcing biosecurity measures, better management practices to safeguard the water quality and more investments in educating and training students and farmers in matters related to sustainable aquaculture.

6.3 Opportunities for a sustainable aquaculture industry in Ghana

The future of aquaculture in Ghana presents many opportunities. Policymakers, fish farmers and other actors must focus on producing more fish with less energy, less water, less land and, by extension, lower carbon footprints and emissions. The role and importance of using science and technology for innovative engineering solutions in the aquaculture industry cannot be undermined. The same opportunities for agricultural engineering and development projects must also be given to the aquaculture sector for more innovative, cost-efficient production systems. A diversification or shift in production systems such as ponds, cages and tanks to aquaponics and Recirculatory Aquaculture Systems (RAS systems) is currently being explored in Ghana. In early 2022, the new Ghana National Aquaculture Centre and Commercial farm was commissioned to be built over two years, a project worth 9.8 million euros aiming to train and equip over 300 entrepreneurs in the aquaculture sector targeted at the youth and university graduates who express interest in aquaculture to produce 50,000 metric tons of fish in the next five years (Magazine, 2022)

Image 9: Site plan of the new National Aquaculture Center And Commercial Farm in Amrahia, Ghana. Photo credit: Aquaculture magazine, Source: (Magazine, 2022)

Although there is scanty research on the financial viability of aquaponics in the subregion, it plays a role in developing "integrated food production systems" and can be commercially advantageous in regions that present challenges with access to quality water (Goddek et al., 2015). Aquaponics allow for rearing fish and cultivating vegetables in water on the same farm.

Such interventions and investments are laudable. However, when the aquaculture sector lacks facilities to handle diagnostics of fish diseases and a skilled workforce in the sector, there are concerns about whether the country or the sector is prepared and ready for such high-tech solutions such as the RAS, which might require constant electricity supply and skilled aquaculture technicians to run the operations.

At the governance level, there are lessons to be learned from other countries, such as Norway, that have experienced various health and environmental challenges related to the farming of salmon. Over the years, Norway has built resilience in the aquaculture sector through science, technology, and a network of competent resource persons that would facilitate knowledge sharing and collaboration among stakeholders.

For instance, the potential for using remote sensing and GIS applications has not been fully tapped (Falconer et al., 2020). Stakeholders can benefit from such applications to investigate, monitor, and analyse environmental stressors for the management and planning of the aquaculture sector.

The potential to diversify the types of fish farmed is also an avenue to explore. The concentration has been predominantly on producing tilapia and catfish that occupies vast lands and water territories with a higher impact on the environment when not done correctly. However, there are opportunities to cultivate other types of fish and aquatic food, such as shellfish, that are nutritious with lower carbon footprints.

Research has shown a gap between population needs and local capacities for fish production in Ghana. When unexpected crises such as Covid-19 occur, it creates even more considerable uncertainties that enlarge the gap between needs and resource capacities. Over-reliance on imported goods and services such as foreign feeds and access to foreign laboratories for fish disease diagnostics in the event of a disease outbreak in cage fish farms, for instance, makes

the aquaculture industry very vulnerable to low production, high fish mortalities, and business collapses. Such occurrences were evidenced by the ISKNV viral infection that affected most cage farms on Volta Lake in 2018.

Structural and functional governance is deemed necessary as different stakeholders in the spirit of co-ownership come together and intervene at different levels to mitigate the risks. It is, therefore, essential that strong networks are built and are guided by **principles such as commitment, trustworthiness, transparency, and accountability** for thriving businesses to attract investors and secure livelihoods at the local and national levels. Given the number of stakeholders in the aquaculture industry with varied motives and goals, they all must work together to improve the state of aquaculture in Ghana.

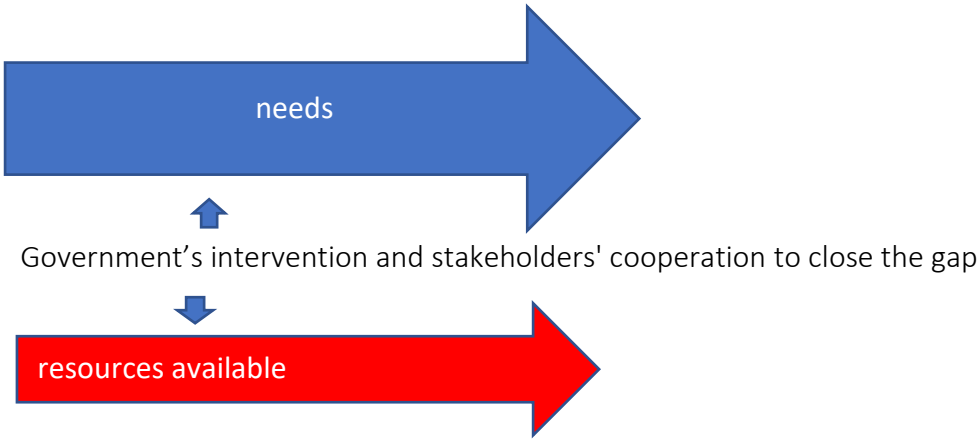


Figure 6.3-1: the role of government and stakeholders in closing the gap between available resources and needs

Government can use policy instruments to reduce the gap between needs and supply. Specific interventions, such as:

- *A one-stop shop for acquiring relevant permits* to operate a fish farm
- *enforcing the ban on the importation of fish*
- *imposing heavy sanctions* on perpetrators of illegal smuggling of foreign fish seeds into Ghanaian waters
- *Review the zonation of Volta Lake* to avoid social conflicts by ensuring the cages are appropriately located in designated areas in the lake and everybody has room to operate.

- *Establishment of more laboratories and research centres locally* to avoid expensive and delayed diagnostics of fish diseases. Some academic researchers said the government had started such an initiative by constructing laboratories in Koforidua, Takoradi and Accra. These test centres were due to be completed in 2021.
- *Implementing capacity-building programmes to train fish veterinarians*: Recently, there have been programmes proposed by lecturers at the University of Ghana in collaboration with other universities and development cooperation bodies. One such programme is the AQUAHEM project, a capacity building in aquatic and environmental health funded by the Norwegian Agency for Development Cooperation, Norad. Scholarships are offered to qualified and competent students at masters and PhD levels at partner universities, including the University of Ghana (UG), the University of Science and Technology (KNUST), the University of Development Studies (UDS), the University of Lagos (UNILAG), the Norwegian University of Life Sciences (NMBU) and the Norwegian Veterinary Institute (NVI). This collaboration would encourage more research and education to mitigate the disastrous effect of fish diseases affecting the sustainability of aquaculture in sub-regional countries like Ghana. There are opportunities to equally include programmes on fish feed development using local natural resources, developing aquaculture engineering programmes to embrace new technologies in fish production, vocational training and entrepreneurship programmes for small-scale producers and cooperatives to add value to their products for local and export markets, among other opportunities.
- *Develop Aquaculture Insurance plans*: some traditional insurance companies provide insurance covers for personal and fixed assets to large-scale fish farmers. Extending and expanding insurance policies to cover biomass and benefit small-scale fish farmers equally is vital. The aquaculture industry is dominated by small-scale fish farmers who mainly produce fish for livelihoods or local consumption and as a source of income. Any hazard that can hinder the production flow of the small-scale farms could have dire consequences on several rural communities that depend on fish farming for their livelihood and survival. Support from government and public authorities such as the Fisheries Commission to provide aquaculture insurance plans for assets and biomass in the event of a disaster to support affected fish farmers in recovering from a disaster would be a step in the right direction. Such interventions could foster trust and cooperation that are vital to sustaining the aquaculture industry in Ghana.

6.4 Building trust for stakeholders' participation and contribution in decision-making in matters that affect the current and future state of the aquaculture industry

Multi-stakeholder partnerships are vital to the sustainability of aquaculture in Ghana. According to Professor Nunoo, during the opening ceremony of the first hybrid aquaculture conference for the west African region, it is of great essence to create a platform that brings together the government, civil society, development partners, industry players at all levels, fish farmers and all relevant stakeholders and actors in the aquaculture value chain. Strategies to enhance production and productivity and mitigate the sector's marketing challenges must be coherent and inclusive.

Research has shown that a hybrid of economic and non-economic factors has led Ghana to be a low-trust society (Asante, 2014). However, this research suggests four pillars to consider from the social aspect of sustaining pond and cage fish farming: building trust through empowerment, cooperation with other stakeholders to achieve one's goal, coordination between different institutions and stakeholders and collaboration with all stakeholders to achieve a common goal.

The following recommendations are vital to the survival of any business-like aquaculture and mitigating risk impacts.

- Make aquaculture attractive to different actors such as students, researchers, and investors by nurturing an informed citizenry that knows the benefits or prospects of aquaculture developments and the effects of improper fish farming practices.
- Value addition of fish products using fish processing technologies. For example, new ways to smoke the fish and package it to make it attractive
- customers should have varieties of options in how to enjoy fish products: smoked, grilled, fried, dried, salted, or fresh. Emphasis should be laid on safe packaging, storage, and transportation to avoid contamination that could have adverse health implications for consumers.
- Resource governance and multi-stakeholder partnerships: reporting yields and sharing knowledge and expertise. For instance, when fish farmers agree on standard market prices for their fish at farm gates, they will avoid being at the mercy of middlemen and

market women who take advantage of the weak collaboration among fish farmers. Collaboration instead of unhealthy competition is vital.

- Establish strong institutions for monitoring and regulating the sector. The laws governing the licencing of fisheries activities must be translated into local languages for the fish farmers, like those in the rural areas, to understand what is at stake. Compliance with fisheries and aquaculture regulations depends on the level of interpretation and understanding of the laws by the concerned. However, as stated in Ghana's Fisheries regulations LI 1968 of 2010, English is the medium of communication that the master or second officer of a fishing vessel must have good command over the English language in writing, reading and speaking (*Ghana Fisheries regulations L.I 1968*, 2010). By extension, these rules may apply to pond and cage fish farmers.

  Given that majority of fish farmers operate small-scale systems, not everyone had the opportunity to benefit from formal education. Therefore, rules and regulations governing aquaculture should be translated into local Ghanaian dialects to ensure that people understand the implications of their actions and what is required of them. The challenge, in this case, is that there are many local dialects in Ghana. The country is divided into 16 regions, and each region speaks a particular dialect. Therefore, translating regulations, laws and decrees in local dialects may be beneficial but can also cause a loss of vital information or increase the chances of ambiguous meanings attributed to some concepts.

  The efficiency of information dissemination is facilitated when farmers are willing to be part of associations.

- The private sector must lead with developing local businesses and adding value to our local products. The government's role is to put legislation and incentives in place to guide the private sector in promoting local businesses. Cooperation between the private and public sectors is, therefore, fundamental in the quest to help the aquaculture sector thrive sustainably. In this regard government's aquaculture development strategy must be aligned and coherent with the needs of the industry following a series of disease outbreaks, such as The ISKNV viral spread and the novel Covid-19 pandemic that had a heavy toll on the aquaculture value chain in Ghana. Lessons learned from these must therefore guide policies and frameworks for

aquaculture development. Although the AFJ programme is a laudable instrument, the focus at this stage must be on enforcing strong environmental standards before, during and after production systems are established as startups or grow-out systems rather than a fixation on growth and development first and then fixing the problems later. The system of governance of the aquaculture sector must adopt a more proactive approach than reactive in the face of multiple threats and hazards.

The way forward

Building trust to reduce risk through empowerment

The establishment of a governing body to be accountable to is vital. This body must be transparent and trustworthy.

The chamber of aquaculture is an example with the sole aim of advocating sustainable aquaculture practices through partnerships and building a solid network among stakeholders. Encouragement and endorsement from government authorities through active participation in conferences, workshops, meetings, and other social activities organised by these associations are essential to building trust among different actors.

When farmers see that the government is working hand in hand with the private sector, listening to recommendations and engaging stakeholders in the development of the sector, trust is built on accountability and results.

Cooperation with other stakeholders

The lack of reporting and sharing information among fish farmers and other stakeholders represents a significant flaw in the aquaculture industry in Ghana. Some Fish farmers who do not observe due diligence in farming practices can put others at risk and are vulnerable to disease spread linked with the discharge of polluted water in the environment. If a farmer is aware of his or her cultivated fish suffering from a certain kind of disease or infection, it is morally right to inform other fish farmers in the vicinity to take precautions. Instead of unhealthy competition among fish farmers, the duty of care must be inculcated through

training programmes and formal education. Practitioners can act individually to achieve personal goals but should think institutionally and responsibly to make the system work.

Coordination between government institutions and stakeholders

The government's intervention in the mass vaccination programme later in 2019 is seen as reactive governance seeking to address the ISKNV spread as it posed threats to human and food security. The MoFAD and Fish health directorate are carrying out the exercise through the Fisheries commission, and the project depends on government funding. There is ongoing research to evaluate the effectiveness of such interventions, but farmers report less mortality than in previous years.

A paradigm shift is necessary so that licences and permits for operation are obtained by facilitating a functional network of stakeholders that must replace the rigid bureaucracy.

Collaboration among stakeholders

Forming efficient associations and cooperatives must be encouraged to foster networking with other farmers, producers, distributors, researchers, veterinary institutions, fish veterinarians, and government officials who would help protect their shared interests, such as affordable fish feed. Therefore, reporting yields will be standardized, pool prices will be uniform, and data presented to the governing bodies such as FAO, world bank can thus be trusted for research purposes.

University and research institutes such as KNUST are encouraged to produce innovations and partner with the private sector to commercialise local products to reduce the overreliance on fish products and feed imports. Bridging the gap between academia and industry promotes scientific and technological innovations in alignment with local knowledge and individual preference.

The outcome of research must shape the modus operandi of industries and other stakeholders to achieve sustainability in these times of high uncertainties. Collaboration among stakeholders is key to addressing the challenges the aquaculture industry faces.

A concerted effort between the government, primary producers of feeds and seeds and academia is needed to regularize the prices of both fish feeds and seeds to make them more affordable and accessible to all fish farmers.

The common interest in sustaining the industry should be to ensure enough cultured fish to meet the deficit in fish production for food security in the country.

Both pond and cage fish farmers need to make a deliberate attempt to have a united front. Coming together to support each other through associations and cooperatives will help conflict management, resolution and prevention between farmers and market *women who seem to dominate fish marketing activities.* (De Silva, 2019)

7. CONCLUSION

7.1 Concluding comments

The study looked at how "sustainable" pond and cage fish farming systems were in 4 out of 16 regions in Ghana: the Ashanti, Bono, Eastern and Volta regions. The thesis concludes that although aquaculture in Ghana has been thriving in recent times compared to when it was introduced in the colonial era, it is relatively too early to assess its sustainability. The understanding and application of the concept of sustainability are nuanced. While a government's policy instrument may measure it within a span of five to thirty years, a fish farmer may look at it from the perspective of the time frame between stocking and harvesting of the fish and their level of satisfaction with the growth, sales and performance of the fish cultured. The pillars of sustainability, i.e. economic, social and environmental viability, are measured in the long term and over a more extended period. Therefore, the success or failure of operating pond and cage fish farming systems in Ghana may not necessarily mean these systems are sustainable or unsustainable.

Most of the findings in this thesis were consistent with global trends regarding the motivation for engaging in fish farming and the challenges associated with aquaculture development. Although fish farmers are motivated to engage in aquaculture for livelihoods and job opportunities, they are all in it to make a profit and see investment returns.

Intensified large-scale cage fish farms were mainly run by the private sector, contributed more to the national GDP and presented more potential for international trade and export opportunities. Small-holder Pond fish farmers represented the majority and operated ponds at community and local levels for their livelihoods, contributing to food security and jobs for people in the rural parts of the country. Starting and maintaining a pond fish farm may be capital intensive; however, in the long run, pond farms have a lesser impact on the

environment and contribute to community well-being at the local and national levels. For this reason, governments in developing countries have for many years benefited from funds from donor countries to help small-scale fish farming, primarily in rural areas, to achieve the SDG goals to alleviate poverty and hunger by 2030. Despite the funding and donor help received over the years, numerous factors threaten the viability of pond and cage fish farming. The factors affecting the aquaculture sector ranged from bacterial pathogen and viral fish diseases, lack of knowledge on fish health management, poor fish farm management practices, seasonal poor water quality, and illegal imports of foreign tilapia strains. This study presented the unique and complex threat factors in the operational pond and grow-out cage fish farms. Nevertheless, the lack of knowledge about handling fish diseases and poor water quality emerged as the top issues that require better governance solutions.

This thesis used the conceptualisation of the progression of vulnerability, as proposed by Wisner et al. (2014), to argue that the success and sustainability of the aquaculture industry in Ghana largely depend on addressing socio-political root causes to reduce exposure to risks and disasters. The adapted conceptual framework from Hasselberg et al. (2020) showed the nexus between human security, the pillars of food security as reviewed by HLPE (2017) and the sustainability of the value chain of fish and food nutrition system in Ghana. It suggests that the stability (short term) and sustainability (long term) availability, access and utilization of fish as food would largely depend on individual choices and active engagement in ensuring that safety measures are followed in the process of production, processing, distribution and consumption of fish products. Biosecurity protocols and policies will not be efficient and beneficial until people get to know, understand, develop an interest and work together to achieve a common goal to sustain the aquaculture value chain.

Aquaculture must look attractive for the youth to embrace it and motivate people to think and act more altruistically. Beyond the economic incentives, environmental stewardship and social responsibility must be the guiding principle of stakeholders. Good governance, cooperation in collective action, private-public partnerships and adherence to management best practices by all stakeholders are central to securing the future of aquaculture in Ghana.

The lack of accountability nurtures distrust among stakeholders. This study suggests the government's support for establishing an independent, trustworthy and accountable governing body. Such an institution must be led by competent and qualified people endowed

with scientific and local knowledge to stir the affairs of Ghana's aquaculture industry and promote information sharing through building networks, training and education of students, fish farmers, and feed producers, among other stakeholders. This body may also serve as a" one-stop- shop" with satellite branches in the 16 regions, where licensing, certification schemes, and expert advice on how to start and sustain a fish farm can easily be accessed. Henceforth, researchers ought to be accountable to fish farmers by providing thorough feedback and reports to educate them on the issues affecting their business, especially concerning diseases and fish welfare. Fish farmers must be willing to share information about possible risks with their fellow farmers for them to make informed decisions and prevention to avoid disasters from occurring. A culture of reporting yields must be nurtured among farmers to regulate fish prices at farm gates to protect the fish farmers' interest and promote healthy competition. Above all, the government should be more proactive in allocating a decent budget for aquaculture development in Ghana, get more involved in matters related to aquaculture at all levels, and provide the necessary policies, the human resource and infrastructure needed to monitor, regulate, and control the aquaculture industry to prevent it from disasters. I believe a sustainable aquaculture sector should not be over-reliant on foreign aid. Instead, a sector that can achieve its goals by responsibly using the available resources and able to diligently direct investment funds to address pressing needs and where both the private and public sector work hand in hand to secure there is enough quality fish as food for future generations.

7. 2 Further research

This research did not discuss the Government of Ghana's (GoG) membership of the AfCFTA as initially planned because it is a relatively new topic in Ghana, and most participants did not have much insight into it. As a member of the AfCFTA, the government aligns its trade policies to be more liberal and inclusive to promote the free movement of people, goods, and services within the African continent. The aim is to redress and strengthen the Ghanaian economy through trade liberalisation and to attract more investments and skill forces from within and outside the continent. However, following the impacts of Covid-19, it is unclear if some industries, such as the aquaculture sector, are prepared enough to compete with other economies within the African sub-region concerning standardisation and high taxes on fish

feed products which are mostly imported. Nigeria and Egypt are part of the African Union (AU) and, according to the FAO, are giants in aquaculture production. Therefore, further investigation into the impact of the AfCFTA on Ghana's aquaculture industry is recommended to evaluate how economic policies can make or break a thriving industry.

The discourse on the sustainability of aquaculture in Ghana cannot be complete without mentioning gender equality and the role women and children play in running the industry. One of the limitations of this study was that only three out of sixteen participants interviewed were women, and the online survey did not require the gender of the participants. The literature reveals that men were more involved with management and production operations while women were primarily engaged in fish product processing, sales, and distribution. Further research on doing a comparative study of the impact of leading roles of women and men in governance positions in the aquaculture industry may contribute to the importance of inclusive aquaculture governance systems. Ghana is a good case study as the current Minister of Fisheries and Aquaculture Development, and the president of the Ghana Aquaculture Society are both women.

Also, two participants in higher authorities raised concerns about recent reports on child labour and trafficking in the aquaculture industry. Due to the sensitivity of this matter, fieldwork would be more appropriate to investigate such claims.

These topics could not be explored in-depth within the scope of this thesis due to the time limitation and lack of data from the relevant sample population.

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Appendix 1- Information for participants

Thank you for considering to participate in this study. Below, you will find information about the purpose of the study and describes your contribution and your rights as a participant, if you agree to take part.

1. Research topic

"Sustainability of pond and cage aquaculture development in Bono/Ahafo regions and the Volta lake in Ghana

2. Research objectives

This research aims to highlight and discuss sustainable best practices in pond and cage aquaculture developments in Ghana. The area of study is delimited to aquaculture activities in the Bono region, Ahafo region, and Volta lake. The reason for choosing these areas is based on 3 main criteria: type of fish cultivated, level of access to a reliable source of water and the number of fish farming activities observed in these regions.

I am particularly interested in discussing the social and political impacts of aquaculture development in Ghana, the interaction among the various actors in the cultured fish or aquaculture value chain (production, processing, consumption) in the Bono region, Ahafo region and settlements around the Volta lake in Ghana.
I also seek to discuss the main challenges the industry faces and highlight possible solutions proposed by the participants and governing bodies.

A structured questionnaire, informal or semi-structured interviews are the main tools used to collect the data.

Participation

You are humbly encouraged to take part in this research conducted by Belinda Pascaline Agyei from the Norwegian University of Life Sciences (NMBU). The purpose of this study is as stated above to assess the sustainability of pond and cage aquaculture industry in your region. This study will contribute to the completion of my master's thesis by June 2021.

This is a voluntary exercise, and should you decide, with your free-will to contribute in this research, you will need to sign the participation consent form. This is after I have answered any follow up questions to your satisfaction.

This study consists of an ☐**online survey** or ☐ **interview** that will be administered to individual participants. You will contribute with answers to a series of questions related to the sustainability of the aquaculture industry in your region.

The interviews shall be carried out online via zoom, skype, WhatsApp video/audio calls (with end-to-end encryption) or any other means which may be suitable to you as a participant in this study.

The interviews shall be recorded and ethics regarding data protection and anonymity shall be adhered to.

3. **Time required**

Participation in this study will require roughly 10 minutes to fill the survey and roughly a maximum of one (1) hour of your time for the online interviews.

4. **Risks**

Only minimal risks associated with everyday life and the tightening of measures against the COVID-19 spread are perceived to delay data collection. However, since most of the interviews and surveys will be carried out online, we can cooperate in making flexible time to achieve our goals.

5. **Benefits**

Our common interest is to be active players in ensuring the sustainability of the aquaculture sector in Ghana in general. Thus, your views and voice truly matter.

6. **Confidentiality**

The results of this project will be coded in such a way that your identity as a participant will not be attached to the final form of this study. As a researcher, I only have the right to use and publish non-identifiable data.

However, while individual responses are confidential, collective data will be presented representing averages or generalizations of all answers from various participants. The collected data will be stored in a secure location accessible only to me as the main researcher. Upon completion of the study, all information gathered regarding individual respondents with their answers (including audio/video recordings during interviews) will be destroyed.

Participation & Withdrawal

Your participation is entirely voluntary. You have the right at any point in time to withdraw your participation without any consequence.

For any further information, questions, suggestions or concerns regarding this study, kindly **contact**:

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Norwegian University of Life Sciences (NMBU)

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Appendix 2- Information letter for pond and cage fish farmers

Are you interested in taking part in the research project

"Sustainability of pond and cage fish farming systems in the Ashanti, Bono, Eastern and Volta regions in Ghana "?

This is an inquiry about participation in a research project where the main purpose is to discuss the sustainability of the pond and cage aquaculture systems in the Ashanti, Bono, Eastern and Volta regions in Ghana. In this letter, we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project

This is for a master's thesis which aims to highlight and discuss sustainable best practices in pond and cage aquaculture developments in Ghana, notably in the study areas. The reason for choosing these areas of study is based on three main criteria: type of fish cultivated, access to a reliable water source, and the number of fish farming activities observed in these areas.

I am particularly interested in the interaction between the various actors and stakeholders in the aquaculture value chain (production, processing, distribution and consumption) in Bono and the Volta lake in Ghana.
I also seek to discuss the industry's main challenges and highlight possible solutions proposed by the participants and governing bodies in line with adaptive policy frameworks involving the participation of major stakeholders in the industry.

Data will be collected through online interviews via zoom or skype using a semi-structured questionnaire format. A personalised link to the zoom meeting shall be sent to selected participant (s) via email, and only those invited shall be admitted to the meeting room.

Who is responsible for the research project?
The University of Life Sciences, NMBU is responsible for the project.

Why are you being asked to participate?

You are being asked to participate in this research study because someone in the aquaculture industry or academia recommended you. We look forward to getting information from fish farmers, governing bodies, academia, major aquaculture industry players such as feed producers/manufacturers, processing industries, customers/retailers, NGOs, or diplomatic representatives in Ghana who may be coordinating projects in the fish industry.
Your participation is highly valued and appreciated as it will contribute to the analysis of policies regarding the aquaculture industry and add to the discourse on the sustainability of aquaculture: benefits, challenges/vulnerabilities, threats, prospects.
Your personal views and perspectives are sought to better guide recommendations for the sustainability of the aquaculture industry.
The purpose of this study is as stated above, to assess the sustainability of the pond and cage aquaculture industry. This study will contribute to completing my master's thesis by August 2021.
This is a voluntary exercise, and should you decide, with your free will to participate in this research study. You will be asked to sign the consent form below once all your questions have been answered to

your satisfaction.

What does participation involve for you?

If you choose to take part in the project, this will involve you attending an online interview with the student researcher Belinda Pascaline Agyei. Confirmation of attendance shall be sent via email, and a personal meeting shall be created via zoom, allowing the invited participant(s) access. It will take approx. 1 hour for the online interviews. The interview is centred around questions about the governance and management of fish farms; Fish health and welfare; government policies and interventions for sustainable aquaculture systems in Ghana; education and training; perspectives about the future of aquaculture, among others. Your answers will be recorded electronically, and your personal views are very important to the study.

Participation is voluntary
Participation in the project is voluntary. If you choose not to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your privacy – how we will store and use your personal data
We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

- The researcher, Belinda Pascaline Agyei (Student) and thesis supervisor Ian Bryceson from the Norwegian University of Life sciences, NMBU will have access to the personal data
- No unauthorised persons can access personal data. «I will replace your name and contact details with a code. The list of names, contact details and respective codes will be stored separately from the rest of the collected data"
- The data shall be stored on Nettskjema research server for the online surveys and zoom is used for the audio-visual interviews which shall be locked away/encrypted and stored safely.
- The interviews shall be recorded and ethics regarding data protection and anonymity shall be adhered to.

What will happen to your personal data at the end of the research project?
The project is scheduled to end on 15 August 2021. Personal data, including any digital recordings shall be kept no longer than 6months after submission of the project for verification, follow up or future research, after which it shall be deleted.

Your rights
So long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and

- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your consent.

Based on an agreement with the Norwegian University of Life Sciences, NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?
If you have questions about the project, or want to exercise your rights, contact:

- *Norwegian University of Life Sciences, NMBU* via Belinda Pascaline Agyei (Student) or Ian Bryceson (project supervisor
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Yours sincerely,

Belinda Pascaline Agyei
(Student)
Tel: +4797383325
Email: beow@nmbu.no

Consent form

I have received and understood information about the project ***Sustainability of pond and cage fish farming systems in Bono and the Volta Lake in Ghana*** and have been given the opportunity to ask questions. I give consent:

- To participate in:

☐ Online Survey
☐ Interview via zoom

- For information about me/myself i.e., my name, business name, location to be published in a way that I may be recognised

- For my personal data to be stored after the end of the project for verification, future research purposes

I give consent for my personal data to be processed until the end date of the project

---

(Signed by participant, date)

Appendix 3- Consent form to participate in research

Topic: "Sustainability of pond and cage fish farming systems in Ashanti, Bono, Eastern and Volta regions in Ghana"

Researcher: Belinda Pascaline Agyei, Student, Norwegian University of Life Sciences (NMBU), email: beow@nmbu.no / bowusu2000@gmail.com

Note: **Participation in this research is voluntary.**

Date: …….

Name (Optional): ……

☐ I have read and understood the study information dated or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.

☐ I freely accept to be a participant in this study and understand that I have the right to skip questions I am not comfortable to answer and that I can withdraw from the study at any time up until May 2021, without having to give a reason.

☐ I agree with the interview/focus group being ☐audio recorded ☐video recorded

If you are participating in a focus group interview:

☐ I agree to maintain the confidentiality of the focus group discussions

☐ I understand that the information I provide will be used for a Master's thesis research and that the information will be anonymised.

☐ I agree that the information I provide can be quoted in research outputs.

If you don't mind your name being used in quotes:

☐ I agree that my real name can be used for quotes.

☐ I don't want my name to be assigned to quotes, it should be anonymised

☐ I understand that any personal information that can identify me – such as my name, address, will be kept confidential and not shared with anyone

☐ I consent that information I provide can be deposited in a data archive so that it may be used for future research.

X _____ X _____

Belinda Pascaline Agyei
Student/Researcher

Name:
Research participant

Appendix 4- Semi-structured interview guide

Duration: 45mn- 1hour

Background information

Where is your work located (Please Specify the region):

Where do you work (name of organisation)

Number of years/months working with the company

What is the capacity of the fish farm

How many employees are working there

How often do you keep records of harvests: daily-monthly-yearly

How long has the fish farm been in existence

Income range

In my opinion, the main factors that affect the aquaculture industry the most:

1.
2.
3.
4.
5.

Others:

Where do you get your fish feeds from

How many times do you feed the fish

Do you get government support

Do you benefit from any subsidies

How do you dispose of the waste

What are the daily routines in the management of the fish farm

Main losses of fish stocks in the past 5 years have been due to:

1. Fish diseases
2. Lack of technology and adequate infrastructure
3. Lack of experts to treat disease outbreaks
4. Lack of access to vaccines
5. Lack of proper training
6. Other (please specify):

What has been the cause of the main diseases affecting the fish

How often do you vaccinate the fish in your pond/cage?

- very often
- often
- once a year

what technique do you use to vaccinate the fish?

- Manual vaccination
- Automated vaccination system
- Other: (please specify)

How important is the quality of feeds for fish to you

Are you concerned with the ability to provide enough feeds for the fish at every stage of their development?

Are you concerned about the quality of feeds given to the fish

Do you get your fish feeds from different sources

where do you buy your fish feeds from?

- A local company in Ghana
- A foreign company in Ghana
- Imported from overseas
- Imported from another African country

who do you buy your fish feeds from? (providing the company name is optional)

how satisfied are you with the services of the company you buy fish feeds the most from?

- Very satisfied
- Satisfied
- Not satisfied
- I don't know

Do you think your fish farming business will thrive in the next 10 years?

- Yes
- No
- I am not sure

If your answer is no or not sure, what could be the factors that would affect the sustainability of your business:

- Strict regulations
- Environmental factors
- The high cost of feeds
- Fish Diseases
- High level of competition
- Lack of government support
- All of the above
- Other factors than what is stated above (please specify)

who are the main customers?

Do your customers have a role to play in the type of fish they want produced and processed for their consumption?

- Yes
- No
- Sometimes
- Never

The fish produced is mainly for:

- Local consumption
- Export
- Industry processing
- Drying

Which of these issues do you think need urgent government intervention:

- Enforcement of regulations
- Subsidies for fish feed
- Quality of fish feed
- Establish more fish laboratories to control fish disease outbreak
- Training and capacity building of fish farmers
- Training and capacity building of fish scientists
- Standardization of the aquaculture sector

How would you like to see Ghana's Aquaculture sector under the African Continental Free Trade Area (AfCFTA)?

- Liberalised (allow other countries to bring in cultured fish)
- Restricted (ban on imported cultured fish)

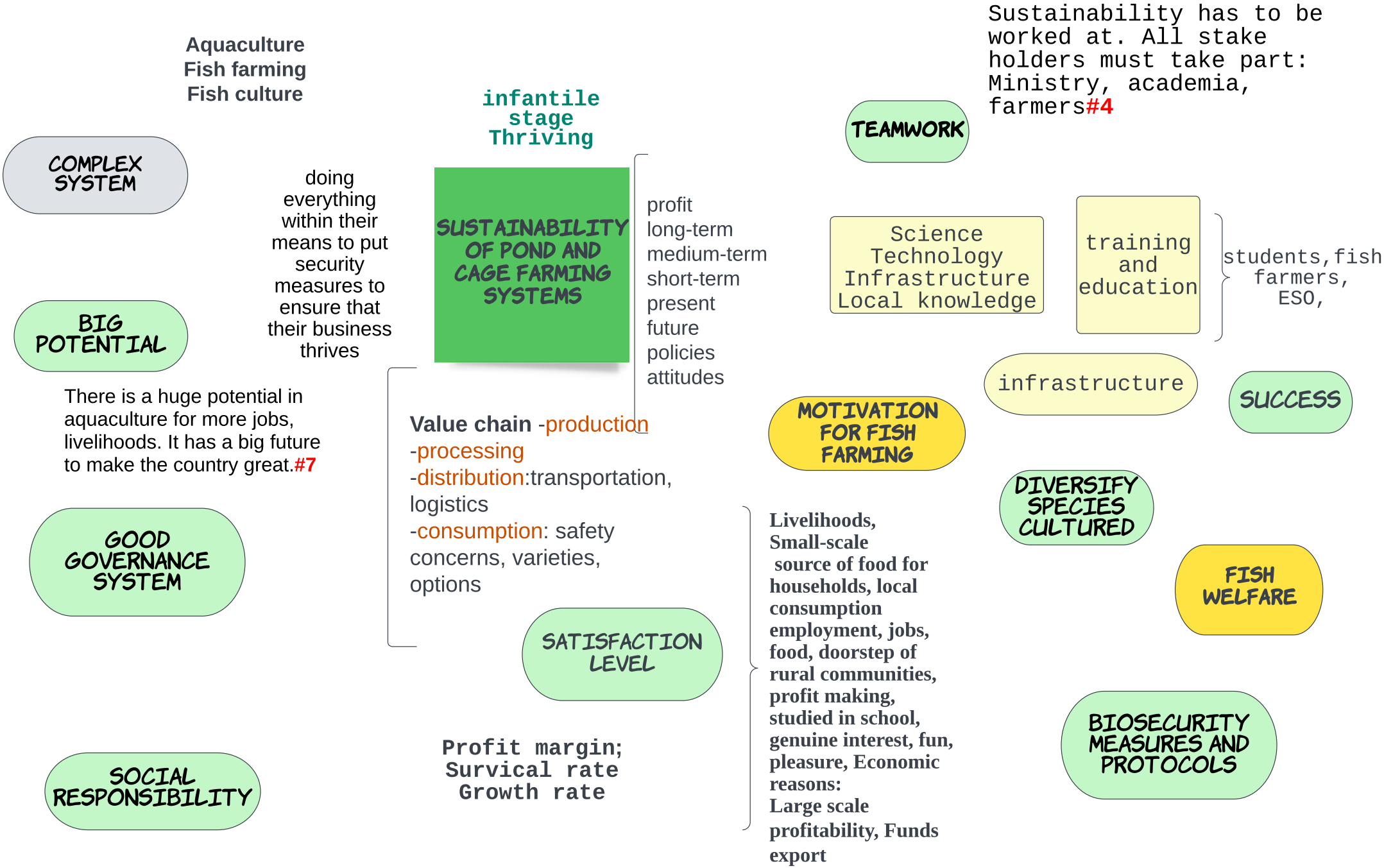
Do you think the Aquaculture sector in Ghana can thrive on its own without international cooperation?

- Yes
- No
- Not sure

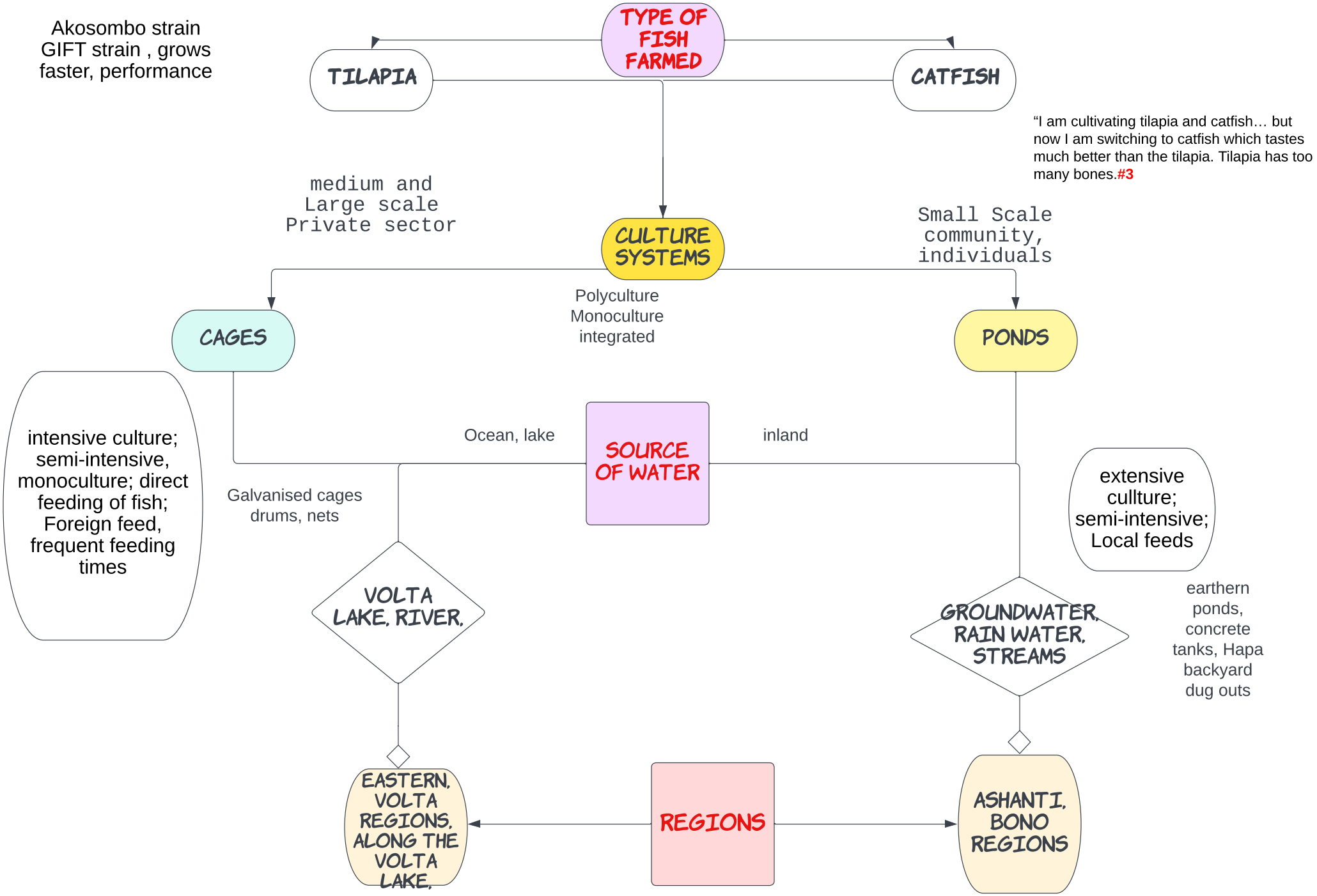
Is fish waste treated and recycled in your company?

-

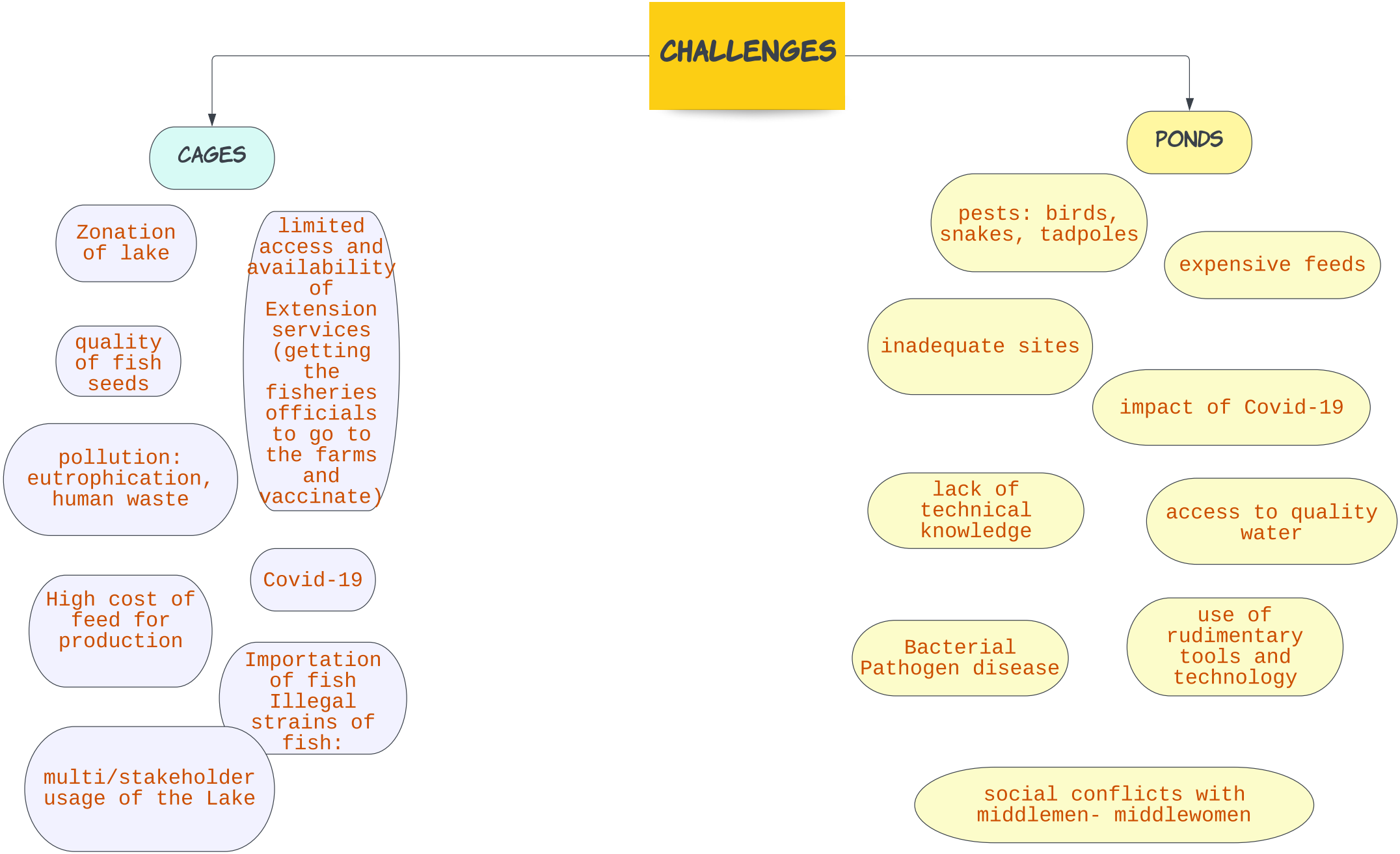
Appendix 5a- Coding and mapping of themes



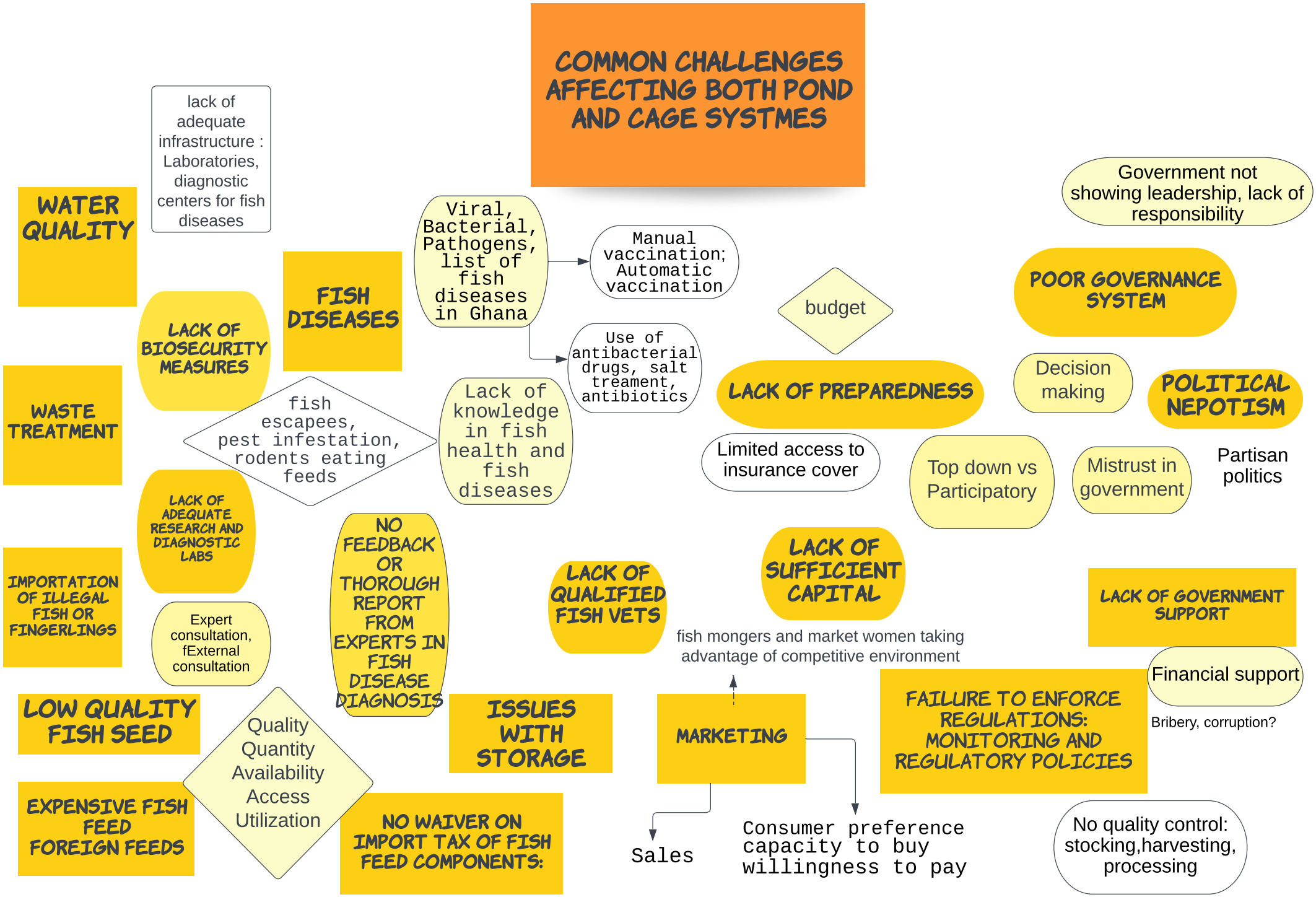
Appendix 5-b Coding and mapping of themes



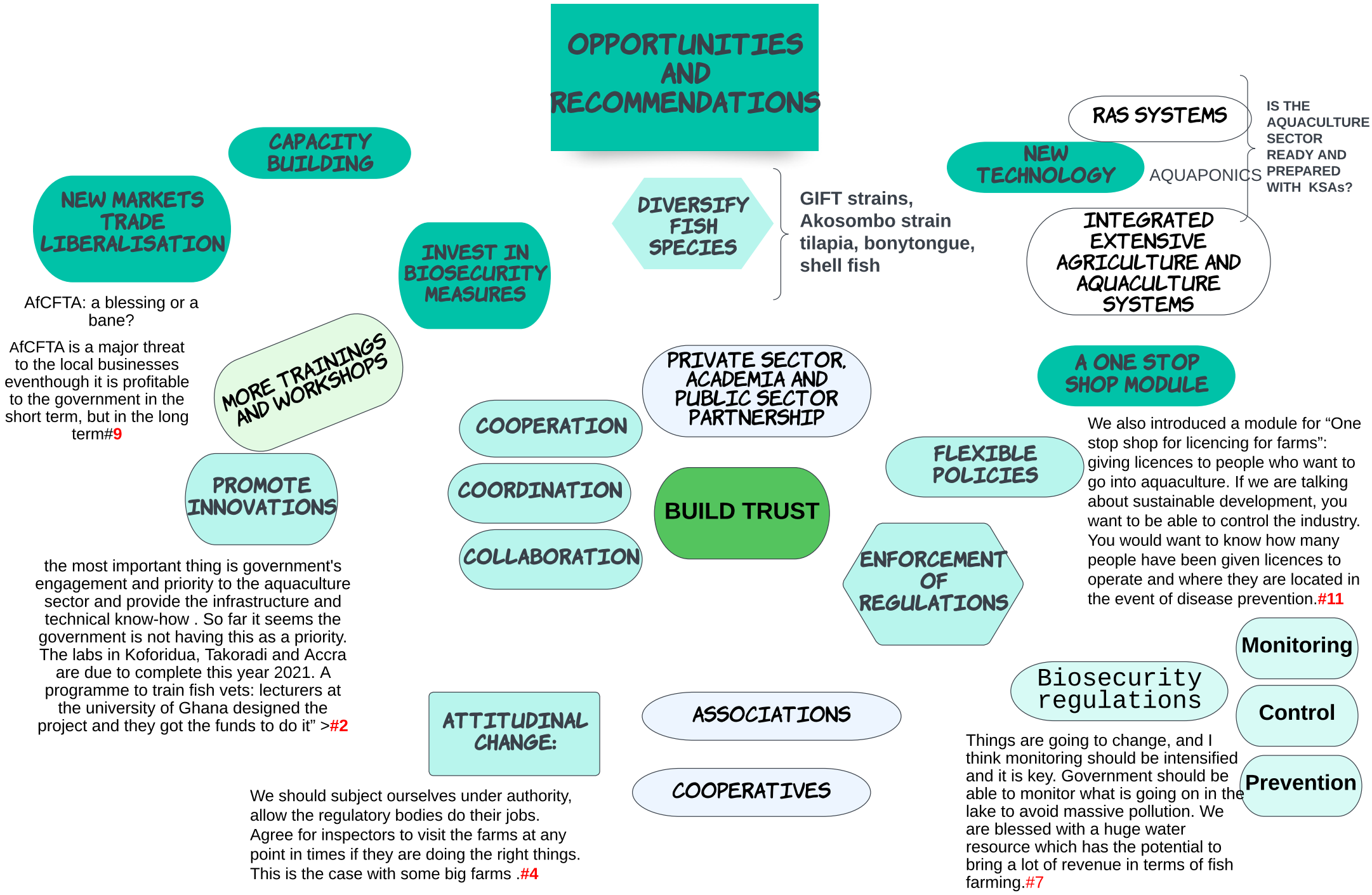
Appendix 5c- Coding and mapping of themes



Appendix 5-d Coding and theme mapping



Appendix 5-e Coding and mapping of themes



Appendix 6- Online Questionaire: Sustainability of pond and cage fish farming systems in Ashanti, Bono, Eastern and Volta regions in Ghana

Module A. Business Identification

Code	Item	Response
A1 A2	**Location**	
A3 A4	**Region**	
A5 A6	**Type of fish farming** (Pond; cage; if other please specify)	☐ Pond ☐ Cage ☐ other (please specify)……
A7	**Number of employees**	
A8	**Current quantity of fish stock (how much fish do you have in stock)**	
A9	**Farm size (space)**	
A10	**Number of years in operation**	
A11	**Name of respondent /business**	
A12	**Is your business registered with the fisheries commission?**	☐ Yes ☐ No ☐ I am not sure ☐ I prefer not to say
A13	**Are you a member of any aquaculture association in your area or elsewhere**	☐ Yes (Please specify the name of the association) ☐ No (please comment on reasons) ☐ I am not sure (please comment on reasons) ☐ I prefer not to say
A14	**What is the main reason why you are into fish farming?**	☐ it provides livelihood for my family ☐ it is very profitable ☐it is the only work available ☐ I do it just for fun because everyone else is doing it ☐ it is what I studied in school

A1 (Bono, Ahafo, Brong), A2 (Volta lake), A3 (Bono, Ahafo, Brong regions), A4 (Volta region, Ashanti region etc); A5 (pond) A6 (cage) A7,A8 and A9 (Small Scale or Big scale aquaculture)

Appendix 6- Online Questionaire: Sustainability of pond and cage fish farming systems in Ashanti, Bono, Eastern and Volta regions in Ghana

Module B. Fish production, Input, output, storage, cost

Code	Item	
B1	**What type of fish do you cultivate**	☐ Tilapia ☐ Catfish ☐ Carps ☐ All of the above ☐ Other type of fish (specify): ……
B2	**What type of fish sells <u>better</u>?**	☐ Tilapia ☐ Catfish ☐ Carps ☐ All of the above ☐ Other type of fish (specify): ……
B3	**Type of fish sells <u>faster?</u>**	☐ Tilapia ☐ Catfish ☐ Carps ☐ All of the above ☐ Other type of fish (specify): ……
B4	**What type of fish you cultivate requires more feed?**	☐ Tilapia ☐ Catfish ☐ Carps ☐ All of the above ☐ Other type of fish (specify): ……
B5	**How many times do you feed your fish?**	☐ Once a day (morning/afternoon/ evening) ☐ Twice a day (morning and afternoon/ Morning and evening/ afternoon and evening) ☐ 3 times a day (morning, afternoon and evening) ☐ More than 3 times a day ☐ It depends (please comment): ……..
B6	**How much does a bag of fish feed cost?**	
B7	**What brand of fish feed do you use?**	☐ Foreign (specify with name of product) ☐ Local (specify with name of product) ☐ I am not sure

Appendix 6- Online Questionaire: Sustainability of pond and cage fish farming systems in Ashanti, Bono, Eastern and Volta regions in Ghana

B8	**Do you know the content and composition of the fish feed you use?**	☐ Yes ☐ No ☐ I am only told it is the best and I trust the content ☐ I am not sure
B9	**What is the basis of your choice of fish feed you use?**	☐ Price (It is affordable / relatively expensive) ☐ Quality (it is good, and the fish like it) ☐ Quantity (it is cost-efficient) ☐ Availability (it is always available in the market) ☐ Accessibility (I can find it easily) ☐ Other (specify)
B10	**How often do you harvest your fish?**	☐ Every day ☐ At least once a week ☐ More than once a week ☐ Once a month ☐ More than once a month ☐ Other (specify)…….
B11	**On a scale of 1-5, how satisfied are you with the <u>QUANTITY</u> of fish you harvest?**	☐ Very satisfied (1) ☐ Quite satisfied (2) ☐ Satisfied (3) ☐ Not satisfied at all (4) ☐ I don't know (5)
B10	**On a scale of 1-5, how satisfied are you with the <u>QUALITY</u> of fish you harvest?**	☐ Very satisfied (1) ☐ Quite satisfied (2) ☐ Satisfied (3) ☐ Not satisfied at all (4) ☐ I don't know (5)
B11	**On a scale of 1-5 how satisfied are you with the <u>SALES</u> of fish you harvest?**	☐ Very satisfied (1) ☐ Quite satisfied (2) ☐ Satisfied (3) ☐ Not satisfied at all (4) ☐ I don't know (5)
B12	**Do you have space for storage of fish harvested?**	☐ Yes, I have more than enough space ☐ Yes, I have space, but it is not enough ☐ No, I have never had storage space because I don't need it ☐ I used to have storage space but not anymore
B13	**Where do you sell your fish?**	☐ Within the same community ☐ Outside the same community

Appendix 6- Online Questionaire: Sustainability of pond and cage fish farming systems in Ashanti, Bono, Eastern and Volta regions in Ghana

	(Please tick possible answers)	☐ In other regions ☐ I do export ☐ I do not sell: The fish harvested is processed and consumed by members of my household
B14	**Who are your customers?**	- - -
B15	**Do you engage in any kind of agricultural activity close to your fish farm?**	☐ Yes ☐ No ☐ Not yet
B16	**Approximately how much of your total household income is from selling farmed fish?**	☐ Almost all ☐ Most of it ☐ Some of it ☐ a small amount ☐ None
B17	**How often do you keep records of the following:** - **amount of fish produced and sold** - **amount of fish feed used,** - **amount of time spent in feeding and caring for the fish** - **number of deaths and survival rate of the fish** - **Other routines: specify**	☐ Everyday; ☐ most of the time; ☐ sometimes; ☐ never ☐ Everyday; ☐ most of the time; ☐ sometimes; ☐ never ☐ Everyday; ☐ most of the time; ☐ sometimes; ☐ never ☐ Everyday; ☐ most of the time; ☐ sometimes; ☐ never ☐ Everyday; ☐ most of the time; ☐ sometimes; ☐ never

Appendix 6- Online Questionaire: Sustainability of pond and cage fish farming systems in Ashanti, Bono, Eastern and Volta regions in Ghana

Module C. Fish welfare

Code	Item	Response
C1	**Has your farm been affected by any disease in the last 5 years?** *If you answer No, please skip question C2, C3*	Yes No
C2	**What kind of disease?**	
C3	**What treatment did you use?**	
C4	**How often do you vaccinate your fish**	
C5	**At what stage in the production do you vaccinate your fish?**	
C6	**How expensive is the treatment of fish against diseases?**	Very expensive Expensive Affordable Free of charge
C7	**Who does the vaccination?**	☐ Mass vaccination programmes by the fisheries commission ☐ I do it by myself with the help of my local staff ☐ I pay external services
C8	**In your opinion, what is the main factor that affects fish welfare in the aquaculture sector in Ghana**	☐ Lack of knowledge about fish diseases ☐ lack of fish veterinarians ☐ Lack of adequate infrastructure such as laboratories ☐ Lack of government support ☐ Importation of illegal fingerlings ☐ Lack of regulations ☐ inappropriate fish feeds ☐ Other (specify)……..

Appendix 6- Online Questionaire: Sustainability of pond and cage fish farming systems in Ashanti, Bono, Eastern and Volta regions in Ghana

Module D. Decision making and level of participation

Code	Item	Response
D1	How often do you participate in decision making regarding the welfare, price and production cost of farmed tilapia catfish etc.	☐ All the time ☐ most of the time ☐ sometimes ☐ never
D2	Do you determine your own prices?	Yes No It depends (specify)
D3	**How often do you take part in a training need analysis for capacity building?**	
D4	**Do you think you need training and capacity building to manage your fish farm more efficiently?**	Yes, Very much needed Yes I need training but I don't have the funds Yes I need training but I don't have time No, you do not need education/training to run a fish farm No, I am not interested Other reason?.....
D5	**How efficient is the aquaculture association in your locality?**	Very efficient Efficient Somehow efficient Not efficient at all Not functioning
D6	**How satisfied are you with Government support in the fish farming industry?**	☐ very satisfied ☐ satisfied ☐ not satisfied at all
D7	**To what extent do you think political nepotism affect the stability and sustainability of the aquaculture industry**	☐ Highly ☐ very much ☐ somehow ☐ not a all

Appendix 7- Brief profile of participants interviewed – semi structured interviews

Order of interviews	Participants	Sector	Level of education
Interview 1	Mr B. Asiedu	Academia	graduate
Interview 2	Mr J. Adzikah	In the private sector, fish farmer-cage	graduate
Interview 3	Mr Amosa	Fish farmer- pond	Form 4
Interview 4	Dr Addo	Academia	graduate
Interview 5	H.E G. Holm	International cooperation	graduate
Interview 6	Dr Koranteng and Mr Awity	Consultants-Fisheries Commission	graduate
Interview 7	Dr Duodu	Academia	graduate
Interview 8	Mr J. Domozoro	Fish farmer- pond and cage	graduate
Interview 9	Mr Isaka Tetteh	Private sector	graduate
Interview 10	Mr E. T.D Mensah	Researcher	graduate
Interview 11	Dr K. Cudjoe	Academia-veterinary institute-Norway	graduate
Interview 12	Mr H. Dzamefe	ESO Bono region	graduate
Interview 13	Mr Richard	ESO Ashanti region	graduate
Interview 14	Mme Janet	ESO Eastern and Volta region	graduate
Interview 15	Esther	Fish farmer -pond	unknown
Interview 16	Mr Ike	Fish farmer- pond	graduate

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