THE NEXUS BETWEEN GOOD AQUACULTURE MANAGEMENT PRACTICES, SURVIVAL RATE OF FINGERLINGS, AND THE EFFICIENCY OF FISH FARMERS IN GHANA

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DECLARATION

I, Munkaila Lambongang, do hereby declare that this research work submitted to the University for Development Studies, is my own work towards MPhil Agricultural economics and that all materials used in this work have been duly acknowledged.

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I hereby declare that this dissertation has been prepared and presented in accordance with the guidelines for supervision of thesis set forth by the University for Development Studies.

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ABSTRACT

While aquaculture development is considered an important growth point for the Ghanaian economy, an understanding of the practices that contribute to its productivity growth is less understood in the Ghanaian context. To be specific, the role of good aquaculture management practices (GAMPs) in improving survival rate, technical and profit efficiencies in aquaculture production in Ghana has received less attention. This study employed data from the Tilapia Seed Project and developed three measures of good aquaculture management practices to examine their effects on survival rate, technical and profit efficiencies. Afterward, the determinants of GAMPs were analyzed using Poisson regression and multiple linear regression models. Then, a fractional regression model was used to determine the effect of the GAMPs on the survival rate of fingerlings, while the stochastic frontier analysis was used to examine the effect of GAMPs on the technical and profit efficiencies in aquaculture production. The findings indicate that Ghanaian aquaculture farmers moderately engage in good management practices and that having access to credit, technical advice, in-house training and asset ownership are the major factors with positive influence on the uptake of GAMPs. With the survival rate of fingerlings, the higher the cost of chemicals used, the higher the survival rate of the fingerlings. The results further show that GAMPs as well as technical advice and feed usage significantly reduce the levels of technical inefficiencies among aquaculture farmers. GAMPs also reduce the level of profit inefficiency among the farmers. Based on the findings, the study recommends that credit be made available to farmers as this can help in the utilization of GAMPs and subsequently increase survival rate, technical and profit efficiencies. It is also important that extension advice from the Fisheries Commission be scaled up and enhanced as it particularly increases the uptake of GAMPs.

DEDICATION

I dedicate this work to the almighty God, the German Academic Exchange Program (DAAD) and the entire Lambongang family for showing me love and their hearty affiliation in the success of my life.

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CHAPTER ONE

1. INTRODUCTION

1.1 Background

Fish is an important source of animal protein consumed by both poor and wealthy households in both rural and urban areas throughout Ghana. Fish consumption provides up to 60% of Ghanaians' animal protein needs (FAO, 2016; Michael et al., 2019). Evidence shows that Ghana's per capita fish intake in 2020 was around 25kg, greater than Africa's current level of 10.5kg and the world's current level of 18.9kg per annum. Approximately 75% of Ghana's domestic fish production is consumed within the country (FAO, 2016; Hasselberg et al., 2020; Onumah et al., 2020). With regards to regional differences in consumption, Eastern Regional households spend the largest share (32.7%) of their food budget on fish, with the least being Greater Accra (19.5%) (Ansah et al., 2020). Furthermore, fish accounts for 22.4% of overall food expenditure in Ghanaian households, with 25.7% in impoverished households (Onumah et al., 2020).In addition, while Ghana's domestic fish consumption demand is around 720,000 metric tons, the country's yearly fish supply is just 400,000 tons, creating a huge shortfall of up to 320,000 metric tons of fish and its products each year (Akuffo et al., 2020; FAO, 2016). In Ghana, the aquaculture sector employs a large number of people. In Ghana's marine capture fisheries, roughly 135,000 people are employed, and 2.6 million people, including spouses, children, canoe carvers, input providers, and close relatives, rely on them for survival (FAO, 2016). Apart from the primary fishing activity, the postharvest industry offers a diverse range of livelihood opportunities. Full-time work to seasonal engagement in various phases of the fish postharvest chain are examples of such opportunities. Processing and trading, storing, loading, packing, loading and offloading, and shipping fresh and processed fish and fish products are only a few examples (Frimpong and Adwani, 2015).

It is even more critical to develop the aquaculture sector in Ghana because evidence suggests that aquaculture employed approximately 33% of all people involved in fish production in 2015 (Meijer et al., 2015) and is expected to grow to 52% by 2025, with the vast majority of jobs being generated in low-income countries (Kaminski et al., 2020; Pauly and Zeller, 2019). However, with population growth reaching unsustainable levels and rising food insecurity, Ghana's declining fish supply from catch fisheries is insufficient to meet the protein needs of the growing population (Rurangwa et al., 2015).

Despite the fact that aquaculture in Ghana has the potential to bridge the gap between the quantity demanded of fish and the quantity supplied, and even to produce more than the domestic demand for export, natural water bodies such as River Bosomtwi, Lake Volta, and others, which have been instrumental in fish production until now, face a variety of challenges, ranging from pollution due to small-scale illegal mining (galamsey) to low water levels that threaten fisheries (Rurangwa et al., 2015). Despite these difficulties, aquaculture continues to be the most promising means of closing the growing gap between production and demand for fish (Amenyogbe et al., 2018). However, in order for aquaculture to achieve significant growth and to realize its full potential, the development of Ghana's aquaculture must be re-examined.

In Ghana, poor quality and erratic supply of fish seed available for stocking is among the significant constraints to successful aquaculture development among producers. According to Siriwardena (2007), Small-scale aquaculture operations in rural areas account for the majority of freshwater aquaculture production. Nonetheless, the availability of technology, the need for fish seed, and the development of low-cost breeding and seed production methods provide rural poor people with chances to get involved in the fish seed supply chain. Fish seed supply, as a vital fundamental ingredient for effective aquaculture, has a significant role in the provision of food and income, and hence in the achievement of the Sustainable Development Goals (SDGs).

Though fish seed plays a crucial role in successful aquaculture production and growth, the effect of good aquaculture management practices (GAMPs) cannot be overlooked as a critical component to the survival and sustainability of aquaculture ventures. GAMPs in this study comprise the various management practices that can be used or applied by farmers to enhance the efficiency and sustainability of aquaculture businesses. Previous studies have identified feed management, stocking density, the use of fertilizer, water cleaning measures like sediment removal, and water exchange as good management practices in aquaculture production (Hukom et al., 2020; Mohanty et al., 2018). Besides, using salt and lime have been considered very pertinent in aquaculture production as it helps to decrease harmful gases, disease prevalence and mortality rate (Prodhan and Khan, 2018; Rahman et al., 2020b; Sharker et al., 2014). That notwithstanding, this study considers other indicators of GAMPs that relates to sanitation and hygiene measures such as maintenance of good hygiene in the changing room of the employees, written sanitation and hygiene plan, written pest control plan, availability of space for the appropriate storage of drugs, disposal of sediments, appearance of the environment, the presence of other animals around the fish farm environment, especially fish ponds. Also, other management practices relating to record keeping such as water quality records, waste records, feed records, layout records, harvest records, sales records and stocking records are those considered in this work. These management practices are particularly important because research has indicated that fish diseases such as tilapia lake virus outbreak that occurred in 2018 were likely caused by poor management practices such as poor water quality management in some sections of Lake Volta (Kuebutornye et al., 2020).

According to Pauly and Zeller (2017), increasingly, aquaculture is being used as a source of protein, and its percentage of world fish output is expected to increase in the future years, particularly in developing countries. Increasing and maintaining aquaculture production in underdeveloped nations, on the other hand, is dependent in part on the adoption and utilization of modern farm technologies or methods. Even though using new farm technologies in poor economies like Ghana has the potential to provide immediate economic benefits to the households that adopt (El-Shater et al., 2016; Mathenge et al., 2014) the question that remains is, how? Improved aquaculture technology adoption could provide direct economic advantages to households in the form of higher production and, as a result, favorable income effects. Several studies in developing nations have looked at the influence of better agricultural technologies and improved management practices on household welfare (Coromaldi et al., 2015; Mathenge et al., 2014; Minot, 2006).

According to Ansah et al. (2014b), however, even though the total impact of pond aquaculture on receiving waters in Ghana is presently minimal, better management practices for nutrient and effluent management should be widely adopted by fish farmers in the near future, particularly as the number of fish farms and the intensification of existing farms increases in Ghana. The application of best management practices in the fish farming industry necessitates strategies that balance profitability and efficiency (Ponzoni et al., 2007). Research has also indicated that the amount of nutrients, water, sediments, and oxygen demand from ponds into receiving water bodies are all affected by nutrient and effluent management strategies (Ansah, 2014). Beyond the possible environmental benefits, changing nutrient and wastewater management practices has economic ramifications. Therefore, the essence of investigating the effect of various management techniques like water quality management, sanitation management, and records keeping on aquaculture production.

During the past decade, the tilapia farming industry in Ghana has undergone enormous expansion and production. However, large-scale cage growers in the Lake Volta region have been responsible for much of the expansion (Kruijssen et al., 2020; Ragasa et al., 2020). Consequently, in February 2019, a three-year program called Accelerating Aquaculture Development in Ghana via Sustainable Nile Tilapia Seed Production and Dissemination (TiSeed) was launched with the goal of making aquaculture more accessible and financially profitable (Ragasa et al., 2020). The project has a focus on youth and women small-scale farmers. Besides, as part of the project objectives, it is expected that at the end of the project, about 400 small-scale cage and pond farmers including women and youth in the pilot regions, including the Volta, Eastern, Ashanti, and Brong Ahafo regions, will have improved and monitored tilapia seed quality, increased productivity by 20% for cage and 15% for pond, and reduced fingerling mortality rate by 50% (Kruijssen et al., 2020).

However, since the inception of the project, there has not been any significant evaluation of how good aquaculture management practices influence the survival rate of fingerlings. Evidence points to challenges for growing aquaculture in Africa, such as feed quality and availability, storage, and transport (El-Sayed, 2013), but there has been less emphasis on the importance of good aquaculture management practices. This study, therefore, seeks to unravel the influence of good management practices on the survival rate of fingerlings and the technical and profit efficiencies of farmers.

1.2 Problem statement

According to reports from the Fishery Directorate of Ghana, several constraints affect the expansion of aquaculture in Ghana (Beyens et al., 2018). Among these include a lack of an adequate supply of seed, a scarcity of high-quality fish seed, as well as suitable feeds (Asiedu et al., 2016; Cobbina and Eiriksdottir, 2010). Inadequate investment from the private sector and limited information concerning the profitability of aquaculture are also listed as part of the challenges (Cobbina and Eiriksdottir, 2010; Kassam and Dorward, 2017)**.** But the management practices engaged by farmers can also influence the productivity and sustainability of the aquaculture industry. Despite the fact that Ghana's aquaculture farming has seen tremendous growth in production, which has resulted in increased incomes for the industry and animal protein for consumers, recent losses in the Lake Volta region highlight the pertinent challenges Ghana faces in securing and expanding upon that growth (Ragasa et al., 2018b). Aside from that, fish is particularly perishable after harvesting because it requires adequate preservation and storage to extend its shelf life and maximize its nutritional value **(**Setsoafia et al., 2017). Consequently, the profitability of artisanal fishermen has suffered, and serves as a disadvantage for people to engage in fish farming and its related businesses. But because farmers' profits are already dwindling due to the numerous challenges, proper management practices are necessary to ensure better productivity and improved incomes.

So, the Tilapia seed (Tiseed) program comes at an opportune time, given Ghana's major issues in the aquaculture sector, which has enormous promise in terms of assuring food security and employment creation while also reducing poverty. Despite the fact that previous research on the characterization of fish farming practices and the performance in Ghana (Ragasa et al., 2020), as well as on inclusive business models for access to high quality fish seed and technical support **(**Kruijssen et al., 2020)**,** those focusing on survival rate and efficiency in Ghanaian aquaculture have not considered the effects of GAMPs. However, GAMPs have the potential to increase the productivity and efficiency of fish farms. For instance, there is evidence that good feeding method applied to fingerlings before stocking has the potential to increase the survival rate of fingerlings (Jha et al., 2015). Also, the addition of drugs and other bacteria agents helps to prevent the activities of water-borne bacteria. This helps to prevent fish diseases and deterioration of water quality during transit and for that matter ensures the survival rate of fingerlings (Rajts and Shelley, 2020). Besides, good record keeping of the weather, quantities of feed and fertilizer used, water quality management, and monitoring fry activities enables the early detection of problems and getting solutions when problems arise (Goddard, 2012; Rajts and Shelley, 2020). All these practices can eventually lead to the improvement of the efficiency of aquaculture farms. Therefore, understanding the factors that enhance the uptake and utilization or application of GAMPs and how this influences the survival rate of fingerlings and farmers' efficiency is a necessary first step towards the sustainability of the aquaculture industry in Ghana.

1.3 Research questions

The main research questions this thesis address is "what are the determinants of good aquaculture management practices and their influence on the survival rate, technical and profit efficiencies of fish farmers in Ghana?" The specific research questions to address this main question are as follows:

1. What factors determine good aquaculture management practices among fish farmers in Ghana?
2. To what extent do good aquaculture management practices affect the survival rate of fingerlings/fish seed in Ghana?
3. What is the effect of good aquaculture management practices on the technical and profit efficiencies of fish farmers in Ghana?

1.4 Research objectives

Corresponding to the main research question, the main research objective is to examine the determinants of good aquaculture management practices and how good aquaculture management practices influence the survival rate, technical and profit efficiencies of fish farmers. The specific research objectives are as follows:

1. To examine the determinants of good aquaculture management practices used by fish farmers in Ghana.
2. To determine the effect of good aquaculture management practices on the survival rate of fingerlings/fish seed in Ghana's aquaculture farming.
3. To evaluate the effect of good aquaculture management practices on the technical and profit efficiencies of farmers

1.5 Justification of the study

A number of factors support the significance of this study. First and foremost, as the importance of aquaculture in Ghana's economy grows, it is necessary to understand the factors that can influence the adoption of good aquaculture management practices by fish farmers, such as good water quality management, proper sanitation, and biosecurity measures, as well as appropriate record-keeping. Secondly, it is necessary to investigate and document the impact of management strategies on the survival rate of fingerlings. Considering that fingerlings are the most essential inputs in aquaculture production, a thorough understanding of management-related aspects that can improve their survival will go far in assisting the development of the aquaculture industry. Finally, the study fills a knowledge gap for researchers and policymakers regarding the relationship between effective aquaculture management techniques and the technical and profit efficiencies of farmers.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview of Ghana’s aquaculture sector

Aquaculture is profitable throughout Ghana because of the abundance of rivers, dams, seas, and dugouts that the country has to offer (Amenyogbe et al., 2018). In view of such favorable environmental and institutional factors as ideal topography and climate, sufficient human resources, and an abundance of natural water bodies, the industry's participants can look forward to a promising future. Also, higher demand for fish is another important factor that makes aquaculture a viable venture in Ghana. In just a few years, Ghana has grown its aquaculture industry at a remarkable rate (Rurangwa et al., 2015). The country's colonial administration, led by Britain, initiated Ghana's marine aquaculture by building the country's first hatcheries in 1953. At the same time, the government wanted to establish a culture-based fishery development program to bolster the local population's taste for fish and increase the local economy and subsequent welfare of the population (Crentsil and Ukpong, 2014). Following the country's independence in 1957, the government implemented a plan to install fishponds in all of the country's irrigation systems, with a particular emphasis in the northern region. The program aimed at turning 5% of government-built irrigation dams into fish farms, since it is possible to expand fish farm populations by expanding irrigation dam populations (Amenyogbe et al., 2018).

While modern production led to the launch of many cages in Lake Volta due to the gains made, recent decades continue to witness a massive increase in production, resulting in the quick addition of many cages. Since the entrance of commercial investors into the aquaculture sector, the overall nature of the industry has also changed in Ghana (Kassam, 2014; Mensah et al., 2006).

Unquestionably, aquaculture is a relatively new industry in Ghana, but it is growing rapidly across the country, particularly in the Ashanti, Central and Eastern areas of the country, as well as in the Volta and Western regions. In these areas, most farmers employ comprehensive fish culture methods that include dams, dugouts, ponds, and reservoirs (Mensah et al., 2006). The overall aquaculture production in Ghana is dominated by commercial fish farmers (who account for just about a quarter of the total production) who use intensive systems, accounting for around 75% of total aquaculture production in Ghana. In the central and southern portions of the country, pond culture systems are used extensively, and they cover the vast bulk of operations in that region (Frimpong and Adwani, 2015).

Despite the fact that the tilapia production technique has evolved in recent years, the vast majority of tilapia is still raised intensively in cages, notably in Lake Volta, as a result of the transformation (Kassam and Dorward, 2017), this has already started to change and the quantity of intensively cultured tilapia is beginning to decline (Asiedu et al., 2017). Approximately 90% of all farmed fish in Ghana are maintained in cage culture systems, with the other 10% raised in ponds or other open water environments (Amenyogbe et al., 2018). Cage farming is primarily on Lake Volta, and it experienced rapid expansion between 2010 and 2016, with the number of companies involved growing at an annual rate of 73% (Ansah et al., 2020).

Records suggest that Ghana's first cage fish farm was built in the year 2001 (Kaunda et al., 2010). The bulk of the farms, on the other hand, do not have their own hatchery facilities and instead rely on the purchase of fingerlings from other hatcheries for their operation. The majority of the time, medium-scale farmers obtain their fingerlings from large-scale farmers and other big sources such as the Water Research Institute and the Aquaculture Research and Development Centre at Akosombo in Ghana (WRI-ARDEC). Aside from that, they rely on the WRI-ARDEC in

Akosombo for technical advice on good management techniques and procedures (Antwi-Asare and Abbey, 2011). When it comes to numbers, the majority of farms use a cage system (Amenyogbe et al., 2018). More than half of all cage farms are in Ghana's Eastern Region, namely in the Asuogyaman District, with the majority of smaller-scale cage farms being between Akosombo and Kpong Dams (Amenyogbe et al., 2018).

Cage farms, which are classified medium-sized or smaller, may be found in places like Kpeve in the Volta Region's South Dayi District, Akuse in the Lower Manya Krobo District, as well as Akrusu in the Eastern Region's Upper Manya Krobo District (Kassam, 2014). Because most aquaculture takes place near irrigation sites, dams, and reservoirs, extensive or culture-based aquaculture are common in Ghana's Northern, Upper East, and Upper West regions. A good number of commercial farmers in Ghana employ cage culture systems, with only a handful using earthen ponds (Rurangwa et al., 2015). Tilapia, known is the dominant and preferred fish type for both aquaculture as well as consumers in Ghana (Ragasa et al., 2018a). With the present production of about 52,000 tonnes, Tilapia species alone account for over 80% of the farmed fish harvest (Amenyogbe et al., 2018) while Catfish (*Clarias gariepinus)* and *Heterobranchus* species constitute the remaining 20% of farmed species. In addition, the populations of *Heterotis niloticus*, tiger prawn (*Penaeus monodom*) and silver carp have all been selectively bred for experimental purposes (Amenyogbe et al., 2018).

The majority of Ghana's subsistence fish farmers feed their fish with maize bran, wheat bran, rice bran, as well as other cereal brands that are easily accessible on the local market (Doku et al., 2018). Only a few farmers use commercial feed, which is pricey in comparison. Despite the fact that a commercial feed mill was created in Ghana in 2011, farmers continue to import commercial feeds because the mill is unable to meet farmer demand. The high price of fish feed in Ghana is a prominent indicator of the high cost of aquaculture production (Asiedu et al., 2017).The cost of constitutes about 70% of the total production costs, with imported feeds alone accounting for the additional 30% cost above domestically manufactured feeds (Kobayashi et al., 2015). The Ministry of Fisheries and Aquaculture Development has regulated the import of farmed fish, particularly flash-frozen tilapia, in order to boost aquaculture growth. Finally, the Ghana National Aquaculture Development Plan (GNADP) was formed by the Ministry with the goal of expanding aquaculture productivity (Adanu and Adanu, 2016).

The initiative's overall objective is to improve the practice, direction, and evolution of aquaculture as a viable business activity, as well as its execution, which is expected to cost $85 million. The initiative's anticipated cost is $85 million. All of the plans listed above were developed in collaboration with the Food and Agriculture Organization of the United Nations (FAO), which served as the foundation for the National Aquaculture Strategic Framework (NASF) and the Ghana National Aquaculture Development Plan (GNADP), both of which are geared toward the advancement and management of Ghana's aquaculture industry (Doku et al., 2018).

2.2 Types and characteristics of aquaculture in Ghana

Depending on the type of culture, there are ponds, pens, and cages to choose from. In aquaculture, pond culture, or the rearing of fish in natural or manmade basins, is the most ancient method of raising fish. Over the years, the practice has extended to virtually every region of the world, and it is now used to culture a diverse range of species in freshwater, brackish water, even marine environments (Singh and Lakra, 2011). It is mainly done in stagnant waters, although it can also be done inflowing streams, particularly in highland areas where running water is available.

Growing fingerlings or fish seed to marketable size in ponds using water from rivers, plain rain water or irrigation canals is known as running water fish cultivation (Hossain, 2014). For the fact that running water fish cultivation involve regular change of water and substantial stocking of the cultivated species, the system is similar to intense culture. The constant flow of water is beneficial to fish culture because it provides abundant dissolved oxygen and washes away waste products and feed that is not consumed (Boyd, 2012).

The benefits associated with using pond culture include have been highlighted as follows. Pond culture requires low technical knowhow and can coexist with other farm crop operations, it also requires minimal labor, and non-productive farmland can also be converted and used as fish production ponds. Findings of Hiheglo (2011) conclusively proves that pond aquaculture will be the cornerstone of Ghana's fish farming industry in future, perhaps due to the diverse advantages that come with the use of ponds for fish production. However, some disadvantages of using pond culture have been highlighted to include land availability and expenditure involved in pond construction. There may also be requirement for ponds renovation every 8 to 10 years as well as difficulty in keeping track of fish inventories. Also, fish may be subject to predators and pathogens. While managing the fish, it may also be necessary to make adjustments to account for changes in weather, temperature, and water quality (Boyd and Tucker, 2012).

Cage and pen culture is the practice of raising fish in fixed and floating net enclosures held by bamboo, wood, or metal frameworks and put in sheltered, shallow sections of bodies of water such as lakes, rivers, and estuaries. Fish pen/cage culture is a more recent development compared to fish pond culture, which has a 4000-year historical background (Baluyut and Balnyme, 1995; David et al., 2019). In at least two countries, cage culture appears to have developed independently of one another: first, in Kampuchea, located in South East Asia, where fishermen in and around the Great Lakes region maintained Clarias spp. and other commercial fish in bamboo or rattan cages or baskets, and second, in Indonesia, where bamboo cages have been used to grow Leptobarbus hoeveni fry as early as 1922 (Baluyut and Balnyme, 1995). Since that time, cage culture has expanded to over 35 nations across Europe, Asia, Africa, and the Americas (Beveridge, 2008). Pen culture is believed to have originated in Japan's Inland Sea region within the early 1920s (Husen, 2019), and was used by the People's Republic of China within the 1950s for rearing carps in freshwater. It was first used to culture milkfish in the shallow, freshwater in the Philippines in the 1970s (Husen, 2019). It has since been successfully expanded to include tilapia and carp production.

Cage culture's appeal may be due to its greater flexibility when it comes to siting the structures as compared to pen culture (Jhingran, 2015). Cages, for example, can be erected in bays, lagoons, straits, and unprotected coasts, as long as they are protected from high monsoonal winds and violent waves. Floating cages can also be installed in deep reservoirs, rivers and canal systems, or even deep mining pools that could not be used for culture due to harvesting difficulties (David et al., 2019). Pen and cage culture have, on the other hand, experienced rapid expansion in recent years, particularly in the last two decades, owing to dwindling ground resources for fish farming and increasing awareness of their advantages over the traditional pond culture, such as their potential application in various types of open water bodies, including coastal waters, protected coves as well as bays, lakes, rivers, and ponds; and their accessibility in different kinds of open water bodies, including coastal waters, protected coves and bays, lakes, and rivers (Granada et al., 2016).

Also, pen and cage culture yields are often high, depending on the productivity of the water body and whether or not additional feeding is used. The advantages of cage culture include the following: good customer acceptance, great tolerance to a wide variety of climatic circumstances, disease resistance, quick supply of fingerlings for stocking, and ease of culture and maintenance. However, because of its site-specific constraints, its progress, and adoption as a popular technology have been limited. Cage culture is exclusively used commercially in the Philippines, Indonesia, and China (Beveridge, 2008). Also, in terms of cost, cages are expensive not just because of the expense of the structures themselves, but also because a reasonably balanced diet must be purchased to feed the animals (Amenyogbe et al., 2018). Mostly the area in which pens are introduced presents some challenges. For the most part, this is attributable to two primary factors. When the water reduces, the temptation to remove the pens may be weak, and therefore the pens should be built high that even if the water retreats, the pens will still be visible (Hiheglo, 2011). But when fishermen also fish at the pen sites, they can to sell their tilapia and/or catfish at reduced prices, thus depriving fish farmers of the opportunity to sell their products at desired prices (Asiedu et al., 2017). Though water availability in cages or pens limits the usage of water for other users, it may be useful in situations when it is costly to provide water to other users. As a result, the sole concern in Ghana currently is to get a remedy for the problem of water levels fluctuation (Asmah et al., 2021). As such, a technological approach to improve a plankton bloom's density, for example, by using cow manure, may be rather useful (Asiedu et al., 2017).

2.3 Importance of the aquaculture sector in Ghana

Ghana's aquaculture industry makes significant contributions to the country's economy. At the current rate of fish production via aquaculture, Ghana is producing 52,470.49 metric tonnes of fish in each year (Asiedu et al., 2017). Whether one reside in a rural location or a major urban setting, fish is the most common source of animal protein in Ghana.

In terms of employment, Ghana's dependence on the aquaculture sector for its livelihoods amounts to approximately 10% of the total population (Amenyogbe et al., 2018). According to Aggrey-

Fynn (2001), fish is the only protein source whose life span can be reliably and economically prolonged by the use of low-cost technical processes like smoking, salting, and drying that are easily available even in isolated marketplaces. It is estimated that there are over 140 distinct species of fish living in Lake Volta, which employs approximately 300,000 people who live within the lake's catchment area (Asiedu et al., 2016). The aquaculture industry is a key major employer, food security, poverty alleviation, and a source of foreign exchange in many developing countries, particularly in Africa. When examining the issue from a gender perspective, it becomes clear that the aquaculture business is quite important; however, although men are primarily involved in cultural activities, women are more involved in post-harvest operations such as processing and trading (Béné et al., 2016). There has been a rise in the demand for fish and fish products because of population growth. Additionally, as the number of fish caught by fishermen is not adequate to fulfill the increased demand for fish, new fishing areas must be explored to suit the public's needs (Mensah et al., 2021). As a result, ensuring the expansion of aquaculture is vital and cannot be ignored as a strategy to fill the gap between fish demand and supply in Ghana. In addition, it is crucial to increase aquaculture to make up for the country's shortfall in fish production and to produce more fish for export.

2.4 Challenges in the aquaculture business

After several years of aquaculture development in Ghana, the country is still grappling with fundamental difficulties, as is the case in many other African countries. As a starting point, Ghana's aquaculture industry suffers from a limited grasp of the aquaculture investment process. Additionally, there is little evidence on the economic performance of the aquaculture industry, which makes it difficult for people to participate in the field (Amenyogbe et al., 2018). This is a major challenge because fish is a major protein source for a majority of Ghanaians and for that achieving the Sustainable Development Goals (SDG2) of ending hunger and poverty requires that emphasis be placed on the aquaculture sector as it can help in the alleviation of poverty and achievement of food security. So, the needed information concerning aquaculture's economic profitability must be made available to stimulate investment in the sector especially the youth.

More crucially, the low supply of improved feed and fingerlings has been a historical barrier to the progress of aquaculture in Ghana. This is because the quality of fingerlings is a major determinant of the progress of any aquaculture enterprise. Closely related to fingerlings is fish feed. Feed has to be a major factor in every aquaculture business but insufficient and low-quality feed is dwindling growth in the aquaculture sector. In fish farming, there is proof that producers have failed because they have suffered large losses as a result of the use of poor-quality seed and feed (Kassam, 2014).

Another major challenge confronting the aquaculture sector is insufficient extension services. Though agricultural extension agents play a major role in terms of information dissemination to farmers, the current extension farmer ratio in Ghana does not guarantee consistent and successful information dissemination to farmers. As the number of extension agents is limited, the information on improved technologies and other efficient production decisions that farmers would have been privileged to obtain are denied them. This phenomenon has led to a reduction in output and productivity, and can also lead to negative implications on household welfare.

Other obstacles to the expansion of aquaculture include a lack of a cohesive policy, a scarcity of rigorous need-based research combined with inadequate funding, and a lack of focus on aquaculture marketing across a wide range of institutions (Munguti et al., 2014). Indeed, advances in fish culture systems, such as raising cage and pond productivity, introducing new efficient systems, and building a sustainable mechanism for production and distribution of pond inputs, are difficulties that still need to be addressed in the Ghanaian aquaculture industry (Amenyogbe et al., 2018).

As a result of the growing interest in fish farming that has been sparked by the Ministry of Fisheries and Aquaculture Development, new problems such as environmental degradation, biosecurity, and the spread of diseases have arisen, which must be addressed through appropriate management practices in order to reduce their negative impact on farmers' livelihoods. The preservation of water quality is one of the most severe challenges faced by fish growers. The decomposition of fish fecal waste can sometimes cause dissolved oxygen levels to rapidly fluctuate, causing damage to the delicate gills of the fish and resulting in additional difficulties. This is especially true in shallow water. Unfortunately, many farmers are unable to meet these obstacles on their own and should be given the necessary assistance (Yavuzcan Yildiz et al., 2017).

2.5 Potentials for aquaculture development in Ghana

The rise of cage aquaculture is more consistent than that of pond aquaculture. This is because vertical input supply integration, local aqua feed production, quality fingerling production under controlled conditions for safety, form the foundation of a significant cage farming sector (Rurangwa et al., 2015). Ghana is capable of seizing this opportunity to join the ranks of other global giants. Overexploitation of catch fisheries in Ghana's natural waters has been widely noted. However, the beacon of hope for alleviating the strain of fish shortages is aquaculture. It is impossible to overstate Ghana's vast aquaculture potential (Asiedu et al., 2017), since aquaculture is gaining popularity, particularly among the youth.

The successful development of sustainable fish farming depends on the successful packaging of aquaculture as a practical investment opportunity, in which potential investors see the possibility for financial reward (Amenyogbe et al., 2018). Research has indicated that the marine sector provides the most lucrative opportunities and should thus be given particular attention. Other agricultural approaches, such as integrated fish production, can, however, be used in conjunction with this. However, collaboration and the establishment of ties between industry actors, such as farmers and the government, are required in order to allow the sharing of information and ideas. Small farmers must also be linked to local, urban, regional, and worldwide markets through proper mechanisms for them to get value from their investments. Farmers must also be educated and equipped to accept new aquaculture technologies through rural extension initiatives (Obiero et al., 2019). Besides that, governments must continue to make more efforts to create an environment that encourages private sector investment in vital areas such as feed and finance.

To fully respond to local aquaculture, specific and realistic policies should be tailored, rather than unrealistic initiatives. Extension Services must provide information on water quality to farmers. These courses should provide participants with hands-on experience in topics such as water quality testing and the procedures to follow in order to maintain a healthy aquatic habitat for fish. Because Ghana has only one recognized fish feed company that generates only a fraction of the required quantity, around 80-90% of the country's fish feed is imported each year. As a result, it is a major area of interest in which private firms might make investments (Amenyogbe et al., 2018). The promotion of value addition in the fisheries and aquaculture sectors, as well as the enhancement of livelihoods in fishing communities, must be implemented. According to Ghana's Fisheries and Aquaculture Sector Development Strategy, value addition in the aquaculture production chain is essential to minimize post-harvest losses, lower handling costs, and generate higher-value products (Akande and Diei-Ouadi, 2010). Fish infections represent a significant threat to the viability of the aquaculture industry in Ghana; therefore, there is the need for the government and other stakeholders to work together to do research and educate farmers on disease control and prevention (Hiheglo, 2008).

2.6 Adoption of Innovations

According to Pianka (2016), Roger developed a typology of innovators based on a scale of "innovativeness," describing five types of innovators based on the average time it takes for an innovation to be adopted within a community. Rogers looked at how people adopted several technologies, from boiling water to cell phones. Individuals who can operate under conditions of great risk and uncertainty, as well as those who are ready to tolerate periodic setbacks, are referred to as "innovators." These people tend to act as gatekeepers in their communities, and they frequently think outside of the local system and its limits.

Innovators are the first to adopt new technology, yet they make up a small percentage of all adopters (2.5%) (Pianka, 2016). Individuals that serve as role models and initiate change in their communities are referred to as "early adopters." When they adopt a concept, these early adopters give it their “stamp of approval.” They are more integrated into the social structure than the innovators, and they have the most influence in a community when it comes to their views on innovations. Early adopters, according to Rogers, are more logical and capable of accepting an innovation earlier than later adopters, implying that they are more efficient at determining the most efficient path to achieving a given goal. They do not need to see the idea in action to understand how valuable it is.

The "early majority" is a group of people who adopt innovations somewhat ahead of the average person in a system. These folks, unlike early adopters, do not hold “opinion leadership” roles in their communities, but they do communicate with others in the system regularly. They frequently spend more time debating whether or not to adopt an idea before acting. The "early majority" accounts for roughly a third of a system's users. Rogers' "late majority" group will be slightly slower to accept a new technology than the typical member of a local system (Cheng et al., 2004). The "late majority" accounts for roughly a third of all adopters.

Finally, "laggards" are the most conservative group of all those who adopt new technology. The laggards, like the innovators, are partially cut off from their social system. They're said to be wary of change and resistive to new ideas. This group accounts for around 16% of all adopters (Lundblad, 2003). Diederen et al. (2003) further divide “laggards” into two groups: “late adopters” and “non-adopters.” The term “late adopter” refers to people who accepted an innovation but were not among the initial 25% of possible consumers of the innovation. Non-adopters are persons who did not adopt any new technology. But an individual's social position is frequently positively connected with his or her level of innovation on a broad level. Individuals that are attempting to achieve a higher social position have been proven to be more inclined to adopt innovation, maybe adopting it as a means of reaching that status.

2.7 Empirical literature on the determinants of good aquaculture management practices

The challenges facing Ghana's aquaculture have become serious following a decade of enormous expansion in production (Ragasa et al., 2018b). The findings of the 2019 baseline study carried out by the International Food Policy Research Institute (IFPRI) and the CSIR-Water Research Institute (CSIR-WRI) highlight the vulnerabilities of farmers. Although it is difficult to continue farming if the productivity and profitability are low, poor sanitation and biosafety precautions and ineffective aquaculture management practices seem to be preventing some farmers from making the best out of their aquaculture business (Mensah et al., 2021).

In Ghana's six primary aquaculture producing areas (Eastern, Volta, Ashanti, Bono, Bono East, and Ahafo), 182 farmers, 15 commercial hatchery operators, and 30 zonal officials got training on optimal aquaculture techniques under the TiSeed initiative in July and August 2020 due to the importance of proper management practices in the aquaculture industry. Each two-day session included presentations by CSIR-WRI, IFPRI, and Fishery Commission (FC) experts on crucial themes, as well as field trips to nearby "model" farms. Farmers were divided into clusters for training, with 20–30 farmers instructed in each cluster and ten clusters conducted across the six regions. Farmer issues such as pond and cage preparation before stocking feeds and feeding, water quality management, harvest, and marketing plans were also addressed by facilitators in turn (The Fish Site, 7 September 2020, at 1:50 pm).

Training and technical support on good aquaculture management practices are important since there is a need to increase aquaculture production to meet the excess demand gap of the increasing population. To buttress the point, productivity is mostly determined by the effective use of various farm inputs and management methods. However, feed is one of the most important components in fish production, accounting for roughly 70% of overall costs (Khan et al., 2017; Prodhan and Khan, 2018). Besides feed, the effect of fertilizer in increasing the phytoplankton level in the pond cannot be overlooked. However, another crucial ingredient that boosts aquaculture productivity is high-quality fingerling (Khan et al., 2021). Therefore, there is the need for farmers to take extreme caution when stocking fingerlings since overcrowding makes fish species more susceptible to diseases, reduced growth, and death.

Diverse water cleaning methods, such as sediment removal and water exchange, help maintain good water quality, lowering dangerous gas levels, reduce illness, and mortality rates (Xiao et al., 2019). Aquaculture productivity is also affected by culture systems such as monoculture and polyculture. Evidence shows that farmers in industrialized countries follow the appropriate aquaculture management practices regulations, whereas farmers in developing nations are unable to use all of the management practices (Prodhan and Khan, 2018). But the adoption of aquaculture management practices is dependent on the availability of information, access to information, the provision of appropriate extension services, and training (Prodhan and Khan, 2018).

Furthermore, differing socioeconomic features of the producers may influence management practices adoption.

Past evidence on the adoption of aquaculture technology has also shown that the adoption of aquaculture management practices was strongly influenced by education, training, and extension contact (Amankwah and Quagrainie, 2019; Kazal et al., 2020). Sujatha et al. (2015) investigated factors influencing non-traditional Sericulture adoption of silkworm and mulberry rearing technologies and realized that farming experience, education, and extension service all had a significant impact on new technology adoption, regardless of holding size. Swathi Lekshmi et al. (2011) discovered that in scientific shrimp farms, adoption was high in harvesting, conditioning, sterilizing, liming, as well as feed management. Also, Jain et al. (2009) found a significant linkage between the adoption and ownership of infrastructure, emphasizing the importance of strengthening infrastructure development to boost agricultural technology adoption. In addition, Karunathilaka and Thayaparan (2016), Kumar et al. (2018), and Amankwah and Quagrainie (2019) among others, investigated the adoption of better technology in several aspects of agriculture and aquaculture.

The desire to accept aquaculture or new aquaculture-related innovations has also been found to be strongly correlated with income. Aquaculture is more likely to be adopted by individuals with more financial resources, according to studies (Agbamu and Orhorhoro, 2007; Cleaver et al., 2018). For example, Agbamu and Orhorhoro (2007) discovered that income level had the strongest link with concrete ponds and polyculture systems adoption in Delta State, Nigeria. Roussy et al. (2017) also found that the percentage of household income generated by farming was a strong predictor of the adoption of optimal management techniques among crawfish producers.

The adoption of innovation has also been found to be correlated with access to information and familiarity or knowledge of the innovation (Bosma et al., 2012). An assessment of the learners' needs should be undertaken before the commencement of training activities, according to a study of a fish culture training program in Nigeria (Aphunu and Ajayi, 2010). This would allow the training to be tailored effectively. The authors of the same study found that practical abilities connected to innovation are more important than theoretical knowledge. Adequate communication with fisheries extension agents has also been demonstrated to be a key element in deciding whether or not to adopt (Cleaver et al., 2018).

The lack of familiarity with innovation, according to Joffre et al. (2019), was the second most important reason why optimal management practices were not adopted. Miyata and Manatunge (2004), investigated Indonesian farmers' intentions to embrace floating net aquaculture after their farms were relocated due to dam building, and found that "learning from others" was the most essential component in making the decision. This agrees with some who have stated that better access to reliable aquaculture information could help the aquaculture business in the United States (Chu et al., 2010). The adoption decision equally appears to be influenced by self-identification as producers who identified as early adopters were more likely to embrace best management practices in the Louisiana crawfish sector than those who identified as late adopters, according to Nyaupane and Gillespie (2011). They also discovered that those who considered themselves to be risk-averse were less likely than those who did not.

Commercial fishers are well-known for being early adopters of new technology and innovation (Pianka, 2016)). In the context of commercial fishing, there appears to be a large negative link between age and innovation adoption (Cleaver et al., 2018). That is, one would expect younger fishermen to be more likely to adopt innovations than older fishermen. Also, membership in a political group correlate favorably with the adoption of innovation in the New England finfish business, in part because knowledge about innovations is exchanged at these organizations' meetings. Membership in these groups may also have an impact on the political environment, ensuring that members' success in the business continues (Abu and Akinrotimi, 2012a).

Increased adoption is also linked to higher education levels (Kumar et al., 2018). Dewees and Hawkes (1988) discovered that education is particularly crucial when it comes to the adoption of sophisticated technologies, like electronic fish-finding equipment for mid-water trawlers. However, Pianka (2016), found no evidence that one group of fishermen routinely accepted innovations ahead of others, owing to the diverse needs of each potential adopter.

However, in Ghana, research on the adoption of GAMPs and its association with the survival rate of fingerlings and efficiency of farmers is still inadequate or almost non-existent. As a result, this research is critical in supporting aquaculture industrial participants to understand the need of using appropriate management practices in their operations to enhance output and productivity.

2.8 Fish seed systems and survival rate of fingerlings

To achieve long-term fish production under increasingly variable conditions, effective and well-functioning seed systems are required. Any suggestion for improvement necessitates a thorough understanding of the current seed system's status and performance (Shikuku et al., 2021). For these reasons, it is critical to understand how fish seed systems work.

To begin with, seed systems have the ability to either maintain or decrease the quality of the seed that is dispersed. Among the most essential aspects of fish seed quality are the following: genetics (strain purity and improvement), sanitary (absence of illnesses), and physiological characteristics (survival rate). It has been shown that degeneration, or a loss of quality along specific dimensions, has a detrimental effect on yield (Shikuku et al., 2021). Therefore, knowing the effects of seed systems on quality is crucial for providing moral justification for increasing the production of genetically modified fish seeds on a large scale. Second, it is becoming widely acknowledged that creating a long-term economic case for value chain actors is a critical component of successful agricultural innovation scaling initiatives (Woltering et al., 2019). This fundamentally needs a study of seed production and distribution profitability and cost-effectiveness. Third, seed systems evolve over time as a result of corporate incentives, technological advancements, biophysical considerations, socioeconomic factors, and institutional issues (Maredia et al., 1999). Although our knowledge of such change factors and their interactions across fish seed systems is far from complete, it is essential for the creation of cost-effective fish seed distribution systems.

Basing on the tilapia seed system in Bangladesh as a case study Shikuku et al. (2021) analyzed the status and performance of tilapia seed dissemination models; and identified constraints and entry-points to delivering quality fish seed or fingerlings to farmers. The findings have policy and investment implications for increasing fish seed systems' capacity to deliver high-quality seed with desirable features to farmers in Bangladesh on a timely and sustainable basis.

According to Amankwah and Quagrainie (2019), the production of high-quality and quantity fingerlings has been one of the primary issues facing Nigeria's aquaculture industry's progression and development. Due to a lack of fish seed, many fish farms in the country have failed to operate efficiently. Many technical issues arise during seed production, whether in a pond or a hatchery.

The lack of and bad management of broodstock, incorrect feed, and feeding methods, and poor record-keeping of all induced spawning operations are among the most serious challenges (Amankwah and Quagrainie, 2019; Fagbenro et al., 1993). Fish seeds are critical to the success of fish farms. They serve as the foundation for successful aquaculture (Abu and Akinrotimi, 2012a). The most essential mechanisms that impact fish development in the culture medium are the quality seed from recognized farms and fish feed (Abu and Akinrotimi, 2012b). However, when it comes to improving seed supply, it is important to remember that small hatcheries in both rural and urban areas are critical and the need to institute measures to support their existence and sustainability.

2.9 Efficiency in aquaculture production

The ability of a company to produce more with the same resources, or the same amount with fewer inputs, is measured by technical efficiency (TE). A firm with a TE of 1.0 creates the greatest number of outputs from the smallest number of inputs (Schøyen and Odeck, 2013). The publication of Farrell's key article on production efficiency in 1957 resulted in the creation of numerous methods for assessing productivity and efficiency, the two most commonly employed in aquaculture being stochastic frontier analysis (SFA) and data envelopment analysis (DEA) (Iliyasu et al., 2014).

To estimate efficiency scores, the SFA uses econometric methodologies, which are used in conjunction with a parametric method (Aigner et al., 1977). There is a significant advantage to using this technique in that it has only two error terms: one that accounts for the existence of technical inefficiency in production and another that accounts for random effects outside of the control of firms, such as disease outbreaks, natural disasters, floods, and many other natural disasters. Additionally, SFA enables the testing of hypotheses in the presence of technical inefficiency. The most significant disadvantage of SFA is that the functional form and distribution assumptions of the two error factors must be unambiguously described for the model to be valid (Coelli and Battese, 1996).

The Cobb-Douglas (linear in logs) and Translog functions are the most often applied functional forms (quadratic logs). However, while the Cobb-Douglas functional form requires only a few parameters to be estimated and is straightforward to comprehend, it assumes that all decision-making units (DMUs) have identical production elasticities and substitution elasticities that are both equal to one. Yet, the Translog functional form is more versatile and has fewer restrictions on production and substitution elasticities; however, it needs an estimate of numerous parameters, which makes it harder to comprehend the results and can sometimes result in multicollinearity (Iliyasu et al., 2014).

Data Envelopment Analysis (DEA) is a nonparametric methodology that makes use of linear programming approaches to solve problems (Charnes et al., 1978). The fundamental advantage of this strategy is that it does not necessitate the specification of a functional form in advance. Although DEA has received much praise for its ability to capture the effects of measurement errors and stochastic noise in data, it has received some criticism because it cannot capture the effects of uncontrollable factors such as natural disasters, environmental problems, disease outbreaks, and climatic changes in data. Another disadvantage of DEA is the potential susceptibility of technical efficiency (TE) to fluctuation in the sample size and composition (Coelli, 1998; Iliyasu et al., 2014).

The bootstrapping approaches established by Simar and Wilson can be used to mitigate the DEA's weaknesses (Swathi Lekshmi et al., 2011). Selection between the two ways to measure technical efficiency has been arbitrary in most empirical investigations, with data availability and researcher preference being the primary factors determining which methodology is used (Wadud and White, 2000). Nevertheless, empirical investigations in agriculture have revealed that the choice of estimating approach has a significant impact on technical efficiency scores, which have been demonstrated to be significant (Ogundari et al., 2012). Iliyasu et al. (2014) conducted a meta-analysis of data from 36 technical efficiency articles on aquaculture and found that the DEA model usually yield higher Mean Technical Efficiency (MTE) scores compared to the SFA technique. They presume that because the DEA is deterministic, it does not consider the random noise. And recommended that studies in the future should consider using bootstrapping DEA to minimize this setback. This is because the lesser the noise, the closer the MTE estimated from these two approaches will be. They researchers also found out that the Cobb-Douglass functional form yield higher MTE indices than the Translog model.

Oluwatayo and Adedeji (2019) indicated that in Nigeria, catfish is critical to the country's aquaculture industry's long-term viability, as they can survive in a variety of culture systems and environments, grow quickly, and have a high fertility rate, with improved fry survival and adaptation to supplemental feed for farmers to make the most out of their investment through profit. But resources must be used optimally and efficiently to attain economic optimum output and consequently profitability. Any agricultural enterprise's profitability is enhanced by the efficiency with which inputs are utilized. Fish producers' ability to adapt to new technologies and achieve sustainable production is determined by their technical efficiency.

Efficiency studies, according to Jarzębowski (2013), assist governments in determining the extent to which they can increase output by improving efficiency with the present resource base and technology. Many African farmers, as noted by Ajao (2012), continue to use low-yielding agricultural technology, resulting in low production. Furthermore, it is sometimes stated that the essential question for agricultural policymakers is whether the agricultural sector can be made more efficient by attaining more production with existing input levels or attaining current output with less input consumption than is currently observed. Identifying the productive behavior and its components is a crucial step in resolving this question.

The economic theory revolves around the concept of efficiency. The goal of production economics theory is to optimize, which implies efficiency. Researchers and policymakers have long acknowledged the importance of efficiency in raising agricultural productivity. It is no wonder, then, that the analysis of farm-level efficiency in developing nations has received a lot of attention (Ogundari et al., 2012). Much of this work is based on the assumption that if farmers are not making efficient use of existing technology, efforts to enhance efficiency are more cost-effective than introducing new technologies to increase agricultural yields (Oluwatayo, 2008). In general, fish farming as an industry has challenges such as a scarcity of fishing inputs (fingerlings and feed), growing trawling costs, insufficient production of cultivable fish species fingerlings, and a shortage of least cost-effective feed for fish culture, to name a few (Oluwatayo and Adedeji, 2019). So, efforts should be made to identify factors that can enhance efficiency for farmers to be able to make the best out of their investments.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1 Conceptual framework

The stochastic frontier profit function was used to develop the conceptual framework in figure 1 below, based on production theory. The framework was organized in expectation of feedback and influence mechanisms in terms of farm-level efficiency. The main focus is on how input-output transformation, affects the efficiency and survival of fingerlings taking into consideration GAMPs to proffer appropriate policy recommendations. In aquaculture production, the production elements (cost of fingerlings, farm size, cost of maintenance, cost of chemicals, labor cost, cost of lime, cost of drugs, cost of transport, etc.) were used as inputs in the aquaculture production activities. With the outcome of the production activities of the fish farmers, it was required that as a farmer used more of the inputs, outcome in terms of the quantity of fish harvested will increase, however, overuse of the inputs could also have a detrimental effect on the quantity of output produced. Optimality, therefore, becomes a critical component in determining the degree of inputs to be used. The efficiency of a farmer as well as a farmer’s decision to utilize the knowledge on GAMPs was assumed to be influenced by socioeconomic and institutional factors. Age, household size, level of education, gender, male manager, and male owner among others were expected to influence a farmer's efficiency, the utilization of GAMPs, and the survival rate of fingerlings. Also, the institutional factors included and were expected to affect the dependent variables are access to credit, access to extension personnel, technical support, group membership among others. Therefore, it is expected that when farmers are efficient, it will lead to improvements in their level of production, this will translate into better incomes and general improvement in the welfare of the farmers.

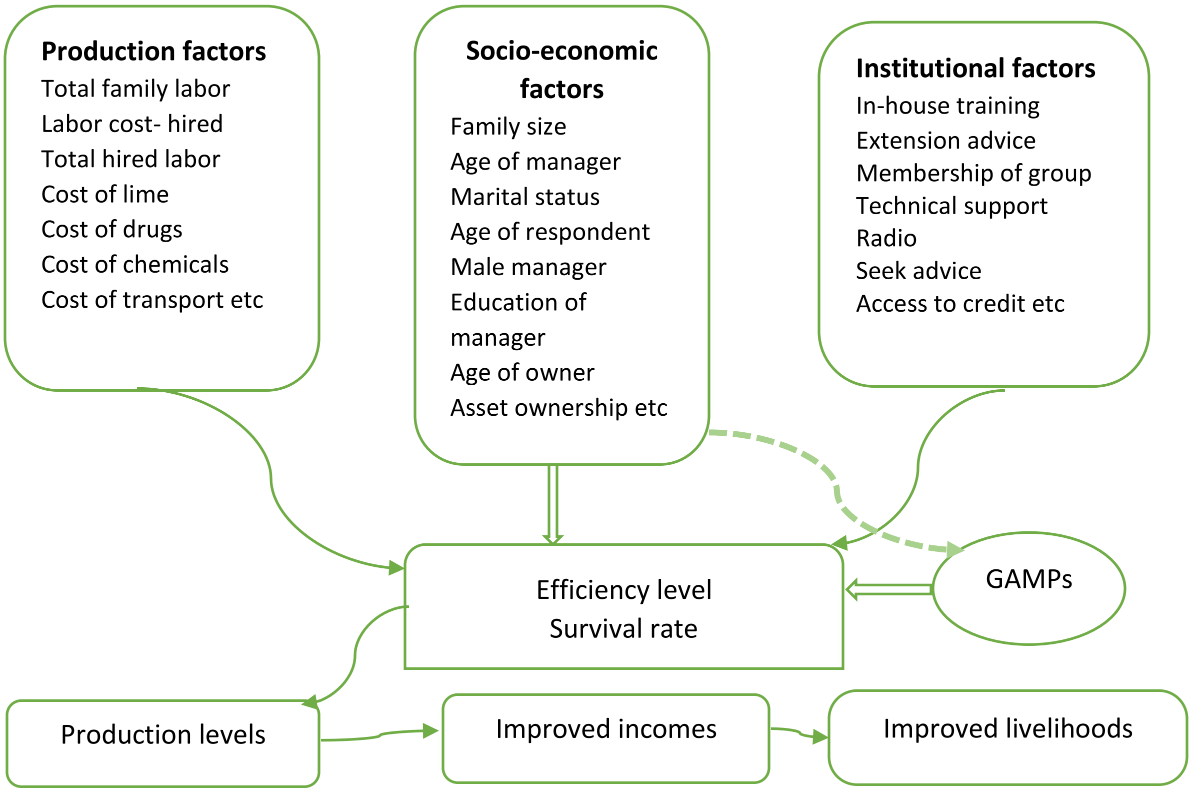

Figure 1: Conceptual framework of the factors that influence the utilization of GAMPs and the efficiency of farmers

3.2 Theoretical framework of the stochastic production function

Profit maximization is the goal of every rational fish farmer; even the non-commercial producers seek to get the maximum output possible from the limited resources available. The production function is mostly employed in studying the technical relationships linking inputs and outputs, where inefficiency in production may be recognized easily. When the farmer's actual level of production falls below the maximum frontier level with a given amount of scarce resources, he is deemed technically inefficient (Tsionas and Kumbhakar, 2004). The approach of measuring technical efficiency among subsistence farmers has several shortcomings, especially in settings like Ghana, where farmers who are faced with varying resource endowments and varying prices are examined (Ali & Flinn, 1989). Studies have shown that evaluating farmer productivity solely on technical efficiency criteria usually overlook other economic goals of decision maker (Ansah et al., 2014a). This is because technical efficiency only addresses how to produce but does little on how much to produce. Studies that only use technical efficiency as a sole measure of productivity have received several criticisms. This is because input levels are in most times endogenous, and thus the estimation of a cost or profit function rather than a production function reduces the level of endogeneity (Adesina and Djato, 1997). The larger concept of economic efficiencies, such as profit efficiency, is a more acceptable approach in measuring efficiency under these conditions (Berger and Mester, 1997b). This is because rather than relying only on technology, farmers optimize their operations based on market prices and competition. In general, technical efficiency refers to a firm's ability to maximize output for a given set of inputs, whereas allocative efficiency refers to the firm's ability to employ inputs in the best possible proportions given their prices and production technique. (Khan, 2012). The stochastic frontier model enables one to measure farm level technical and economic efficiency using Maximum Likelihood Estimation. A stochastic model originally was pioneered by Aigner and Chu (1968) who proposed a composed error term. Following the specification, stochastic production frontier can be written as:

$$Y_i = f(x_i, \beta)\, e^{\varepsilon_i} \qquad (1) \quad i = 1, 2, \ldots\ldots\ldots\ldots N$$

where Y_i is the fish output for the ith farm, x_i is a vector of k inputs (or cost of inputs), β is a vector of k unknown parameters, ε_i is an error term. The stochastic production frontier is also called "composed error" model, since there are two error components: stochastic random error component and that of the technical inefficiency component as follows:

$$Y_i = f\,(x_i, \beta)\ \exp v_i - u_i \qquad (2)$$

where Y_i represents tilapia output, which is measured in kilograms, x_i represents the quantity of input used in the production, v_i represents random errors assumed to be independent and identically distributed $N(0, \sigma_v^2)$ and u_i represents the technical inefficiency effects assumed to be non-negative truncated of the half-normal distribution $N(u, \sigma_u^2)$

The truncated-normal distribution is a generalization of the half-normal distribution. The truncation obtains it at zero of the normal distribution with mean μ, and variance, σ_u^2.

So, this study employed both technical and profit efficiency methods to study input output relationship among the aquaculture producers. The technical and profit efficiencies of the farmers have thoroughly been discussed in sections 3.5.4.1 and 3.5.4.2 respectively under the methodology.

3.3 Study area

The study covered the six regions of Ghana that fall within the Tiseed project area. These regions include Ashanti, Brong Ahafo, Bono, Bono East, Eastern, and Volta regions. These regions are are the major fish producing regions in the country. The mean annual rainfall pattern within these regions ranges between 895mm–1506mm with mean annual temperature between 260C–270C. A list of farmers developed in collaboration with the Fishery Commission (FC) and extension officers from these regions was used.

3.4 Source of data and survey instrument

The data employed for this study was obtained from a cross-sectional household survey of smallholder fish farmers in Ghana jointly led by the International Food Policy Research Institute (IFPRI) and CSIR-Water Research Institute (WRI) of Ghana from May to June 2019 as part of the Tiseed project implementation. Multistage sampling technique was employed in the selection of the households. In the first stage, Ashanti, Brong-Ahafo, Bono, Bono East, Eastern, and Volta regions were purposively selected because of the smallholder aquaculture activities and earthen pond utilization in these regions. Farmers from these regions also took part in training led by the Fisheries Commission (FC) as part of the Tiseed project. In the second stage, the survey teams started a purposeful selection with the list of fish farmers from FC. A total of 479 active small-scale tilapia farmers were identified and interviewed by means of a questionnaire. The household survey instrument covered modules on cage or pond sizes and characteristics, costs and constraints in production, and socioeconomic indicators.

3.5 Method of data analysis

3.5.1 Assessing the determinants of good aquaculture management practices

To assess the determinants of good aquaculture management practices, multiple linear regression, and Poisson regression models were used. Three separate indices were generated from the management practices data for analysis. The use of the three different indices for good aquaculture management practices is to ensure that outcomes from the models do not depend on the measure of GAMPs, thus serving as a robustness test. Before discussing the models in detail, the next section discusses how the three indices of GAMPs were generated.

3.5.2 Measures of good aquaculture management practices

The first measure of GAMPs was derived by a simple scaling method, where a simple sum was made of the good aquaculture management practices used by the fish farmers. Farmers were asked to indicate whether they undertake a number of identified good aquaculture management practices, and each had a response of yes or no. In the end, this resulted in a count variable, with some fish farmers using no GAMPs.

The second and third measures of the GAMPs index were based on the use of factor analysis (FA) and principal component analysis (PCA), respectively. The purpose of FA is to represent each independent variable as a linear combination of a smaller set of common factors. Given the observed variables $m_1, m_2, m_3..........\,...m_k$, with a common factor or latent variable measuring the continuous utility obtained from using good aquaculture management practices represented by F, the variables (indicators) may be expressed in a linear relationship in terms of F as:

$$X_i = \alpha_{ij} F_j + U_i \quad (3)$$

The extended form of the factor model is also specified as;

$$X_1 = \alpha_{11} F_1 + \alpha_{12} F_2 + \alpha_{13} F_3 + \alpha_{14} F_4 + ...\alpha_{1m} F_m + U_1 \quad (4)$$

$$X_2 = \alpha_{21} F_1 + \alpha_{22} F_2 + \alpha_{23} F_3 + \alpha_{24} F_4 + ...\alpha_{2m} F_m + U_2 \quad (5)$$

$$X_v = \alpha_{v1} F_1 + \alpha_{v2} F_2 + \alpha_{v3} F_3 + \alpha_{v4} F_4 + ...\alpha_{vm} F_m + U_v \quad (6)$$

where, X_i are the items/variables/indicators, F_j are the latent continuous factors, U_i represents the variable uniqueness, α_{ij} is the loadings of any variable X_i on any factor F_j, $i = 1, 2, 3, ..., v$ (v = number of items/variables and $j = 1, 2, 3, ..., m$ (m = number of factors). After running the factor analysis, the GAMPs index is then generated for subsequent analysis. In the FA, the eigenvalue of a factor is obtained by summing the squared loadings of all variables of that factor, as in:

$$\sum_{i=1}^{v}(\alpha_{ij})^2 = \alpha_{1j}^2 + \alpha_{2j}^2 + \alpha_{3j}^2 + \alpha_{4j}^2 + \ldots + \alpha_{vj}^2 \quad (7)$$

Hence, the retained factor became the utilization decision

With PCA, the data is first centered on the averages of each variable within a data matrix of n variables and m samples. This ensures that the data is centered on the origin of the primary components while having no effect on the data's spatial relationships or variances along with the variables (Holland, 2008; Reid and Spencer, 2009). The linear combination of the variables X_1, $X_2, \ldots X_n$, yields the first principal component P_1.

$$P_1 = a_{11}X_1 + a_{12}X_2 + \ldots a_{1n}X_n \quad (8)$$

or, in a form of matrix notation as; $P_i = a_1^T X$

The first principal component is generated to account for as much variance in the dataset as possible. By choosing large values for the weights a_{11}, $a_{12}, \ldots, a_{1n}$, one may make the variation of P_1 as large as possible. In order to account for this, weights are calculated under the restriction that their sum of squares equals one (Holland, 2008), that is,

$$a_{11}^2 + a_{12}^2 + \ldots + a_{1n}^2 = 1, \quad (9)$$

The second main component is determined in the same method as the first, with the exception that it must not have any correlation with the first principal component and account for the next greatest variance as shown in equation (8).

$$P_2 = a_{21}X_1 + a_{22}X_2 + ...a_{2n}X_n \quad (10)$$

Each of these steps must be completed several times until a total number of primary components equal to the number of variables has been identified. This means that all of the original information has been accounted for, and the sum of all of the variances of all of the primary components will equal the sum of all of the variances of all of the variables. Adding all of these changes of the original variables into the principal components results in a total of:

$$P = XA \quad (11)$$

Scores are calculated as linear combinations of the original variables and the weights a_{ij} for each individual observation in this new coordinate system of the main components. The rth sample's score on the kth component, for example, is calculated as:

$$P_{rk} = a_{1k}x + a_{22}x_{r1} + ...a_{2k}x_{r2} + ... + a_{nk}x_{rn} \quad (12)$$

However, when it comes to data reduction, PCA uses a method that involves creating one or more index variables from a larger collection of measured variables. It accomplishes this by combining a group of variables in a linear fashion (essentially a weighted average) (Abdi and Williams, 2010).On the other hand, FA takes a whole different approach to data reduction. It is a model for calculating the value of a latent variable (Brown, 2015). A single variable cannot directly measure this latent variable (for example, intelligence, social anxiety, and application of GAMPs).

The PCA and FA are very much similar in the following ways; both are techniques for data reduction as they allow capturing of the variance in variables in a smaller set, they are run in the same manner with the outputs looking much similar, the steps taken to run them are the same for example, extraction, rotation, interpretation, and choosing the number of components or factors.

Irrespective of all these similarities, the fundamental difference between them is that PCA is a linear combination of variables, whiles FA is a measurement model of a latent variable (Santos et al., 2019). Whiles PCA seeks to explain as much of the overall variance in the variables as possible by analyzing all observed variance, whereas FA simply looks at the common covariance between the variables (Schneeweiss and Mathes, 1995). This means that when the original variables are sufficiently correlated, PCA is performed. When we assume a latent trait, FA is most appropriate.

3.5.3 Assessing factors that influence good aquaculture management practices

From the activities in section 3.4.2, the indexes of good agricultural management are further modeled to examine the factors that influence the use of those management practices. The indexes derived from the FA and PCA generate a continuous variable, which can be assessed using the multiple linear regression model. Equation (11) below is a general specification of the econometric models used for analyzing the factors that influence GAMPs.

$$F = xb + \varepsilon \qquad (13)$$

From the left-hand side, F =index generated by FA or PCA and denoting the dependent variable (GAMPs), x =vector of independent variables, $b =$ coefficients to be estimated which measure the effect of the factors affecting GAMPs, and ε =error term associated with the measurement in both equations.

The empirical model can be written as;

$$F = b_0 + b_1X_1 + b_2X_3 + b_3X_4 + b_4X_6 + b_5X_7 + b_6X_8 + b_7X_9 + b_8X_{11} + b_9X_{12} + b_{10}X_{13} + b_{11}X_{16} + b_{13}X_{18} + b_{12}X_{20} + b_{13}X_{23} \qquad (14)$$

A second model to model the count version of the good aquaculture management practices is based on the Poisson distribution because the data is a count. The Poisson regression model, which is a special case of the Generalized Linear Models (GLM), is suitable for the estimation of count data

(Greene, 2001). Consider a count variable, K which counts the number of times that a certain event occurs during a given time period. The Poisson regression model explain this count variable $K_i$using explanatory variablesX_i, for $1 \leq i \leq n$. This p-dimensional variable X_i contains characteristics for the ith observation. The variable, K follows a Poisson distribution with parameter λ if and only if $p(K = n) = \frac{exp(-\lambda)}{n!}$ (15)

for $n = 0,1,2, \ldots\ldots$ Poisson variable: $E[K] = \lambda \; and \; Var[K] = \lambda$

The conditional mean function using a linear combination of the explanatory variables is shown below: $E(K/x_i) = \mu = exp(X_i\beta) + u_i$ (16)

$K(k = 0 - t)$ represent the number of good aquaculture management practices utilized by a farmer.

where X_i represents a vector of independent variables that can influence the utilization of GAMPs, β represent a vector of parameters to be determined, K_i is the count of good aquaculture management practices.

3.5.4 Examining the effect of good aquaculture management practices on the survival rate of fingerlings

The effect of good aquaculture management practices on the survival rate of fingerlings was assessed by employing a fractional regression model (FRM) due to the nature of the dependent variable. Since the right representation of the conditional mean Z is an important assumption for the regression model to be valid, the fractional regression model (FRM) developed by Papke and Wooldridge (1996) helps to deal with dependent variables defined on the closed interval [0, 1].

The fractional regression assumes a functional form for Z that imposes the requisite constraints on the values of the dependent variable:

$$E(Z/X) = G(X\beta), \quad (17)$$

where $G(.)$ is a known nonlinear function that meets the condition $0 < G(.) < 1$. x represents a vector of explanatory variables that can influence the survival rate of fingerlings including any of the three indices generated from the aquaculture management practices and β represents a vector of parameters to be estimated. Papke and Wooldridge (1996) suggested possible specifications for the non-linear function, any cumulative distribution function usually applied to model binary data. However, the widely used ones are the Logit and Probit functional forms, in addition to the Log-Log and the Complementary Log-Log specifications. In addition, based on the Bernoulli log-likelihood function, the same authors propose the estimation of FRM using a quasi-maximum likelihood estimator of θ, given by $\sum_i (z\, log(G(x_i\theta)) + (1 - z_i)\, log\ (1 - G(x_i\theta)))$ (18)

However, the properties of the estimator can be seen in Papke and Wooldridge (1996) and Ramalho et al. (2010). The general specification of the survival rate model is given by equation (18) as follows:

$$Z = \beta_o + \alpha x + \gamma m + e \quad (19)$$

where Z = survival rate of fingerlings, x = a vector of other explanatory variables that are hypothesized to affect the adoption of GAMPs, m = aquaculture management practices, α and λ are a set of coefficients to be determined, e = error associated with the model

3.5.5 Assessing the technical and profit efficiencies of farmers

3.5.5.1 Technical efficiency of farmers in aquaculture production

The stochastic production frontier (SPF) methods have been widely used in many industries, including agriculture, to model input-output relationships and to measure the technical efficiency of individual farmers. These methods have also been applied to compare the performance of farmers under different technological regimes. According to Aigner et al. (1977) and Meeusen and van Den Broeck (1977). The stochastic frontier production function is expressed as;

$$Y_i = f(x_i, \beta) + \varepsilon_i \qquad (20)$$

were $i = 1, 2, 3, 4 \ldots\ldots\ldots N$

$$\varepsilon_i = V_i - U_i$$

where Y_i is the output level of the *ith* farmer in kilograms, X_i is the vector of the input level used by the *ith* farmer, β are the unknown parameters to be calculated, and ε_i denotes the stochastic composite error. It is presumed that the two elements of the error terms are identically distributed. The component V_i is an asymmetrically distributed error term that captures production variance due to factors outside the domain of the farmer, U_i is a one-sided error term that captures the inefficiency of the farmer. Therefore, Technical Efficiency is specified as;

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{f(x_i;\beta)\,exp(v_i - u_i)}{f(x_i;\beta)\,exp(v_i)} = exp(-u_i) \qquad (21)$$

where Y_i is the observed output of the *ith* farmer and Y_i^* is the unobserved output. Technical efficiency takes a value between 1 and 0. Thus $0 \leq TE_i \leq 1$. If $U_i = 0$, then the production firm is 100% efficient and if $U_i > 0$, then there is some inefficiency on the part of the farmer. To estimate the determinants of TE, this study considered (Battese, 1995).

The empirical Cobb-Douglas production function for determining the factors affecting the output levels of *ith* fish farmer is specified as;

$$ln\, Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta\ _3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_9 + \beta_7 X_{10} + \beta_8 X_{11} + \beta_9 X_{13} + \beta_{10} X_{13} + \beta_{11} X_{14} + \beta_{12} X_{16} + \beta_{13} X_{18} + \beta_{14} X_{19} + \beta_{15} X_{20} + \beta_{16} X_{21} + \beta_{17} X_{22} + \beta_{18} X_{25} + \beta_{19} X_{26} + \beta_{20} X_{27} + \beta_{21} X_{28} + \beta_{21} X_{29} + \beta_{22} X_{30} + \beta_{23} X_{31} + \beta_{24} X_{38} + \beta_{25} X_{39} + \beta_{25} X_{40} \quad (22)$$

The model assessing the determinants of technical inefficiency is also specified as;

$$U_i = \alpha_0 + \alpha_1 X_{38} + \alpha_2 X_{39} + \alpha_3 X_{40} + \alpha_4 X_3 + \alpha_5 X_{11} + \alpha_6 X_{11} + \alpha_7 X_{16} + \alpha_8 + \alpha_9 X_2 + \alpha_{10} X_{15} \quad (23)$$

3.5.4.2 Profit efficiency of farmers in aquaculture production

Profit efficiency, according to Berger and Mester (1997b), has the ability to detect errors in the production process on both input and output sides. The farmer is deemed profit inefficient if he or she fails to operate on the profit frontier; otherwise, the farmer can be termed as profit efficient and can be able to earn the maximum permissible profit from the given resources. Because the pace at which agricultural inputs are converted into outputs varies depending on agro-inputs, technology, environmental circumstances as well as labor availability, it also influences how profitable the production will be in the end.

Given the output level (L), the farmer has the aim of maximizing profit at a least cost. Assuming the output price is represented by p, w is the vector of input prices and a are the fixed factors. Following the work of Ansah et al. (2014a), this study focuses on the area used in fish production in meters as the fixed factor, therefore profits (π) can be maximized by adjusting output levels (L) and the levels of input (x, a ,) in their respective quantities. Considering the stochastic production theory proposed by Aigner et al. (1977), it means that the stochastic profit function of the ith is expressed as;

$$\pi_i = f(p_i, w_i, a_i)\, exp(v_i - u_i) \qquad (24)$$

With the frontier profit function denoted by:

$$\pi_i^* = f(p_i, w_i, a_i)\, exp(v_i) \qquad (25)$$

The v_i, s are independent errors, identically distributed with a mean of zero and a constant variance (σ_v^2). Also, v_i is present due to random factors that normally go beyond the farmers' control, such as measurement errors and climatic conditions. They u_i, s are non-negative random variables that are the farmers' characteristics that prevent them from attaining the maximum profit specified by the frontier (Battese and Coelli, 1992). The profit inefficiency is represented by a non-negative random variable with values that ranges within the interval of 0 and 1. Also, u_i possess a non-negative half-normal distribution. The u_i and v_i behave in a way that is consistent with stochastic frontier functions. Therefore, the profit efficiency of the ith farmer is termed as the factor by which the profit level of the farmer is lesser compared to the frontier profit (Battese and Coelli, 1992). Given the profit frontier (PE) model expressed by equation (19), the PE can be calculated from equation (23)

$$PE = \frac{\pi_i}{\pi_i^*} = \frac{f(p_i, w_i, z_i)\, exp(v_i - u_i)}{f(p_i, w_i, z_i)\, exp(v_i)} = exp(-u_i) \qquad (26)$$

In efficiency measurement based on the stochastic profit frontier, two types of functions are specified based on two key assumptions. These assumptions depend on whether market forces are considered or not. With that, one can generally consider the standard or alternative profit functions (Ansah et al., 2014a). The profit gained from running on the profit frontier is calculated using the standard profit function, which takes farm-specific prices and factors into account. It assumes that inputs and outputs markets are perfectly competitive. With the standard profit function, when the input price is given (w) and the output price (p), profit can be maximized by the farm enterprise by adjusting inputs-output use in the production process. The equation (24) shows the expression of the standard profit function and the logarithmic form is expressed in equation (25)

$$\pi = f(p, w, z; v, u) \tag{27}$$

$$ln\, \pi = ln\, f\, (p, w, z; v, u) \tag{28}$$

The variance of the errors σ_v^2 the profit inefficiency effects σ_u^2 and the variance of the model σ^2, are shown in equation (26)

$$\sigma^2 = v^2 + u^2 \tag{29}$$

which measures the total variance which can be attributed to profit inefficiency. However, Battese and Coelli (1995) computed gamma (γ) from equation (27) which quantifies the inefficiency in the variance of the residuals.

$$\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2} \tag{30}$$

with $0 \le \gamma \le 1$

The assumption in equation (25) is that farmers have no market power. But in most smallholder settings, there are imperfect markets and different farmers are faced with different prices depending on their ability to negotiate (Ansah et al., 2014a). In this instance, the amount of output produced is used in place of the output price in the standard profit function, which result into the alternative profit function, as indicated by Berger and Mester (1997a) and elaborated in equations (28) and (29).

$$\pi_{alt} = \pi_{alt}(y, w, z; v, u) \quad (31)$$

$$\pi_{alt} = \pi_{alt}(y, w, z) + (v - u) \quad (32)$$

The alternative profit equation shows how farm households can achieve the highest attainable profit base on their levels of output as compared to output prices. Those in favor of the alternative profit function argued that the alternative profit function reduces scale bias, that is holding output fixed and determining farmers' capacity to generate more profit (Ansah et al., 2014a).

3.5.4.3 Empirical Model

Berger and Mester (1997b), adopted the Cobb-Douglas functional specification of the alternative profit efficiency model. With this model, the output is fixed while the prices of output vary as expressed in equation (30).

$$ln\, \pi_i = \alpha_0 + \sum_{j=1}^{4} \alpha_j \, ln\, w_i + b_1 \, ln\, y_i + b_2 \, ln\, a + (v_i - u_i) \quad (33)$$

The Cobb-Douglas functional form specification of the alternative profit function for the fish farmers is:

$$ln\, \pi_i = \beta_0 + \beta_{1X_1} + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_{16} + \beta_8 X_{18} + \beta_9 X_{23} +$$

$$\beta_{10} X_{25} + \beta_{11} X_{31} + \beta_{12} X_{34} + \beta_{11} X_{35} + \beta_{12} X_{36} + \beta_{13} X_{37} + \beta_{14} X_{38} + \beta_{15} X_{39} + \beta_{16} X_{40}$$

Table 1:Model variables and their hypothesized effects

Variable	Symbol	**Description**	***Models and a priori* expectation of variables**			
HOUSEHOLD CHARACTERISTICS			GAMPs	Survival rate	Technical efficiency	Profit efficiency
Hired labor cost	X_1	Hired labor cost			-	_
Total family size	X_2	The number of people with the same cooking arrangement			+	_
In house training	X_3	In-house training for staff (=1)	+	+	+	_
Region	X_4	Region of a respondent	+/-	+/-	+/_	+/_
Area	X_5	Area of land used for fish farming in meters	+		-	_
Harvest	X_6	Amount of fish harvested in tones				+
INDIVIDUAL CHARACTERISTICS						
Asset ownership	X_7	Amount of assets owned by a household	+			
Marital status	X_8	Marital status of a respondent	+			
Age of manager	X_9	Age of the manager in years	+	+	+	
Marital status	X_{10}	Marital status of a respondent (1=married)	+	+	+	
Male manager	X_{11}	Whether a manager is a male (=1)		+	-	
Education of manager	X_{12}	The educational level of manager in years	+			
Age of owner	X_{13}	Age of the owner in years		+	-	
Male owner	X_{14}	Whether the farm owner is a male (yes=1)	+	+	-	

Owner-manager	X_{15}	Whether the owner is the same as the manager (yes=1)	+	+		
ACCESS TO INFORMATION						
Advice FC	X_{16}	Whether a farmer received advice from a fishery extension agent (1=yes)		+	+	–
Frequency of advice	X_{17}					
Technical advice	X_{18}	Whether a farmer received technical advice on aquaculture production (1=yes)	+		-	+
Frequency of extension visits	X_{19}	Number of times a farmer had extension visit		+	+	
Membership of group	X_{20}	Membership of association (1=yes)	+		-/+	
Other support	X_{21}	Whether a farmer received any other support apart from training and technical support (1=yes)			+	
Radio	X_{22}	Whether a respondent get access to fish farming information on radio	+	+	+	+
Seek advice	X_{23}	Whether a farmer sought advice and technical support since he started (1=yes)		+		+
FINANCIAL CAPITAL						
Tilapia income	X_{24}	The amount of household income supplied by the tilapia business		+		

Credit	X_{25}	Whether farmers applied for credit (1=yes)	+	+	-	+
PRODUCTION INPUTS						
Fertilizer	X_{26}	Whether a farmer uses fertilizer or not (1=yes)		+	-	
Lime	X_{27}	Whether a farm manager uses lime or not (1=yes)		+	-	
Chemicals	X_{28}	Cost of chemicals (GH₵)		+	-	
Feed	X_{29}	Cost of feed (GH₵)		+	-	
Transport	X_{30}	Cost of transport (GH₵)			-	
Electricity	X_{31}	Cost of electricity (GH₵)			-	_
Fuel	X_{32}	Cost of fuel (GH₵)		-		
Drugs	X_{33}	Cost of drugs (GH₵)		-		
Lime	X_{34}	Cost of lime (GH₵)		-		_
Disinfectant	X_{35}	Cost of disinfectant (GH₵)		-		_
Maintenance	X_{36}	Maintenance cost (GH₵)		-		_
Fingerling's cost	X_{37}			+		-
Index by scaling	X_{38}	Index generated by the sum of all management practices		+	+	+
FA	X_{39}	Index of GAMPs generated by factor analysis		+	+	+
PCA	X_{40}	Index of GAMPs generated by principal component analysis		+	+	+

NB: *a blank means that the variable does not appear in that model.*

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

This chapter focuses on the results of the study. Section 4.1.1 dealt with the summary statistics of the survey respondents. This include their educational status, marital status and location characteristics. The socio-demographic characteristics are discussed in section 4.2. This also include household assets, access to information, fish production characteristics, and access to financial resources. Section 4.3 contains discussion on the determinants of good aquaculture management practices, whiles 4.4 deals with the effect of the management practices on the survival rate of fingerlings. The effect of the management practices on technical and profit efficiencies is in section 4.5 and 4.5 respectively.

4.1 Summary characteristics of the farmers

4.1.1 Educational status of the farmers

In the context of good aquaculture management practices, the attainment of formal education may be important in relation to the types of management practices used by farmers as well as the efficiency of using those management practices. In the sample used for this study, the results show that only a few of the survey respondents (8.31%) had no access to formal education. Of the respondents who had access to formal education, the highest number of them had primary or Junior High School level of education (42.19%), followed by university or polytechnic level of education (23.42%), Senior High School level of education (22.43%), and postgraduate level of education (3.65%). Minot (2006) noted that education creates the platform and paves a way for entry into extra employment activities, for farmers to make efficient investments in their farms. The high level of education among the fish farmers in Ghana could enhance farmers' uptake and application of GAMPs since education broadens an individual's understanding of issues with regards to technologies that can help them maximize their gains. Also, access to education can lead to improvement in the quality of labor and the ability to utilize improved farming methods could be enhanced (Hyuha, 2006). On the other hand, a low level of education could also affect utilization due to inadequate understanding and wrong perception of better technologies and improved aquaculture practices.

4.1.2 Marital status of respondents

Most of the household heads were married (83.58%) at the time of the data collection, while the remaining 16.42% were distributed into single household heads (12.44%), divorced household heads (1.82%), and widowed household heads (2.16%). All else equal, married household heads who have children may have the advantage of family labor over the unmarried. This labor availability can improve an individual's ability to utilize the GAMPs.

4.1.3 Locational distribution of fish farmers

The data contains fish farmers who were located in the Brong-Ahafo (39.17%), Volta (6.94), Eastern (28.76%), and the Ashanti regions (25.12%). It is important to note that during the empirical analysis, respondents from the Volta and Eastern regions were combined due to the relatively low number of respondents from those two regions.

Table 2:Distribution of fish farmers by education, marital status and location

Educational status of respondents	Frequency	Percentage (%)
No formal schooling	50	8.31
Junior High School/Primary School	254	42.19
Senior high school	135	22.43
University/Polytechnic education	141	23.42

Postgraduate degree	22	3.65
Total	602	
Marital status of the respondents		
Single	75	12.44
Divorced	11	1.82
Married	504	83.58
Widowed/widower	13	2.16
Total	603	
Location of the respondents		
Ashanti	152	25.12
Brong-Ahafo	237	39.17
Volta	42	6.94
Eastern	174	28.76
Total	605	

4.2 Socio-demographic characteristics of the survey farmers

The individual characteristics described in this section are presented in table 3 below. The mean age of a farm manager was reported to be about 47 years while that of the aquaculture owner was about 51 years. This means that on average, a farm manager is younger than the owner, but they all fall within an active age bracket. Therefore, they can have the strength and ability to contribute well to the agricultural sector development through proper utilization of efficient technologies, such as the GAMPs considered in this study. The interesting aspect of this distribution is that about

75% of the owners doubled as managers of their own farms. With this distribution, it is expected that most of the farmers will utilize GAMPs since they manage their own businesses, and any benefits of good aquaculture management can be expected to accrue to them. The average family size of a household is about 6 persons. Thus, on average each household had about 6 persons at the time the data was collected. The relatively high household size may prove to be useful as it creates easy access to family labor to undertake GAMPs. Besides, the larger the household size, the higher the number of mouths to feed which can stimulate the utilization of GAMPs. As labor is an important factor in every agricultural enterprise, the cost of labor has a major influence on farmer's production decisions. The average cost of labor was about GH₵ 4.04, but the large standard deviation of GH₵ 4.35 implies that farmers incurred relatively heterogeneous wage costs on the farm. The low average wage is not also surprising because of the high unemployment situation in most developing economies such as in Ghana, where businesses take advantage of the abundant supply of labor and pay disappointingly low wages.

The results also show that about 92% of the fish farms are owned by males with the remaining 8% being owned by female household heads. This limited representation of women in aquaculture enterprise ownership is not surprising because, is pertinent to realize that women are often less involved in the actual production but mostly responsible for the cleaning and processing of fish after harvest. Research has also shown that, while in the production sphere women are usually assist in most activities, the situation is entirely different in the consumption sphere where women are exclusively responsible for all the tasks involved (Agbebi et al., 2016). Also, studies have shown that women aquaculture producers often face challenges such as lack of access to information, inadequate knowledge on aquaculture production, and land tenure issues, which limits access and control over resources (Agbebi et al., 2016; Huggins, 2014) and therefore may hinder their participation in the production chain.

Closely related to the ownership of farms, the results indicate that about 93% of the farm managers were males. Due to the level of involvement of men in aquaculture activities especially in the production stage, men could possess the abilities to better manage farms than their female counterparts. Also, the ability of women to work as better farm managers could be impeded by challenge in acquiring production inputs such as fingerlings. Also, women mostly depend on men for production tools in their activities. Besides, inadequate technical knowhow due to low level of education is another major factor that retards women's ability to act as farm managers.

4.2.1 Household assets and aquaculture production characteristics of farmers

The results show that only about 27% of the respondents have access to in-house training while the majority have not received any form of in-house training. The low percentage of fish farmers having access to in-house training is somewhat worrying because such training can help both employees and managers to acquire appropriate on-the-job skills for proper and efficient management of their fish farms. Due to the important role assets could play in the uptake of new agricultural technologies, data was taking on households' assets to determine if there is a relationship between assets and uptake and utilization of GAMPs. Among the assets that were considered include ownership of a pickup, motorbike, bicycle, refrigerator, TV, generator, water pump, water tank, livestock, poultry, among others. The summary statistics showed that on average, a household owns about 5 assets, some owning nothing and others owning up to 16 different kinds of household assets. Though the standard deviation is about 3, depicting a smaller disparity of assets ownership among the farmers, the minimum value of 0 makes the outcome less appealing, since it is a sign that some households do not own any of the assets under consideration.

Juxtaposing the mean value of 5 to the maximum asset value of 16 brings to bear the lesser access to assets in the study population.

Research shows that poor households can use information and communication assets like radios, cellphones, and televisions to access useful information on good farming technologies that might otherwise be unavailable or prohibitively expensive (Shuck, 2014). Besides, market prices, agricultural extension services, financial services, are just a few examples of the information that households can access through the use of these communication assets. Also, asset ownership has been shown to boost people's psychological and emotional health, aside from its ability to increase social standing in many communities around the world (Kratzer and Kato, 2013). Access to assets could also boost farmer's confidence, encouraging them to take chances and invest in new technologies that can promote their well-being as in the utilization of the GAMPs.

In terms of pond size, the minimum area of land (in square meters) a farmed pond occupied was about 4.459, with a maximum of 8000 square meters. Also, the statistics show that the average area of land used for aquaculture activity is about 751.489 square metres.

4.2.2 Summary of fish production characteristics

The mean quantity of fish harvested across the 4 surveyed regions was in the 2019 production season 884.61 kg, with some farmers harvesting nothing (zero catch) and others harvesting as high as 42,500 kg. The larger value of the standard deviation (2214.28 kg) gives the impression that there was a great variation in the quantity of fish harvested among the farmers. From this harvest, an average amount of GH₵ 11697.62 is obtained as profit when the revenue obtained is offset by the price of feed, seed, labor, and other costs. Some fish farmers experienced negative profit (loss) of GH₵-44,410 while others gained as high as GH₵ 637,116 of profit from the aquaculture enterprise in the production season under consideration. Thus, while some of the farmers made huge losses in their fish enterprises, others gained massively. Though several factors can account for the losses, it would not be out of place to imagine that training farmers on GAMPs could help minimize the losses. Again, the high standard deviation in profit of GH₵ 36,329.771 means that there is a great disparity in the levels of profits obtained by fish farmers in Ghana. This calls for appropriate measures to reduce the disparity and hence the need to find out the source (s) of the losses and inefficiencies among the farmers.

The survival rate of fingerlings was measured in percentages and computed as the total number of fishes harvested divided by the total number of fingerlings cultivated. The result indicates that the mean survival rate of fingerlings is about 87%, with a minimum of 7.1% and a maximum of 100%. Though the mean survival rate looks encouraging, the deviation of 13% from the complete survival of fingerlings presents a cause for worry as it is an indication that farmers are experiencing lower levels of fingerling survival, which consequently affects enterprise turnover.

Table 3: Summary statistics of variables used in the regression models

Variable	Mean	Std. Dev.	Min	Max
Outcome variables				
Harvest	884.616	2214.281	0	42500
Profit	11697.616	36329.771	-44410	637116
Survival rate	0.870	0.168	0.071	1
Household assets and aquaculture production characteristics				
In-house training	0.27	0.444	0	1
Household assets	4.97	2.738	0	16
Area	751.49	1001.449	4.459	8000

Socio demographic characteristics of respondents				
Age of manager	46.87	13.717	19	91
Total family size	6.177	4.423	1	40
Hired labor cost	4.043	4.352	5	53.76
Owner Manager	0.751	0.433	0	1
Male owner	0.925	0.263	0	1
Male manager	0.935	0.246	0	1
Age owner	50.762	13.247	20	99
Access to information				
Technical advice	0.489	0.5	0	1
Advice from fishery commission	0.786	0.41	0	1
Access to information from radio	0.762	0.426	0	1
Frequency of extension visits	2.309	4.87	0	70
Membership of a group	0.549	0.498	0	1
Financial capital				
Credit	0.174	0.38	0	1
Production inputs				
Cost of disinfectant disinfectants	14.915	257.984	0	6000
Cost of chemicals	16.703	52.043	0	600
Cost of transport	116.689	224.524	0	2000
Cost of electricity	42.959	318.141	0	6000
Cost of lime	10.271	99.422	0	2100
Cost of maintenance	0.155	0.507	0	7

Cost of fuel	76.614	360.426	0	5000
Cost of drugs	7.433	91.815	0	2000
Fingerling cost	1047.992	1722.565	14.367	17884.615
Quantity of feed (kg)	831.063	2588.599	0	52275

4.2.3 Access to information

With access to information for aquaculture production, while 48.9% of the respondents got technical advice from other extension officers to manage their aquaculture activities, 78.6% of them accessed information from the fisheries commission. These statistics indicate that the level of access to information is generally good especially concerning the number of farmers who could access information from the Fisheries Commission. This level of information and knowledge gained through extension services should inevitably be a motivation for farmers to use GAMPs. The results also indicate that about 76% of the survey respondents obtained aquaculture information via radio. This means that quite apart from the information they obtained through extension agents and Fisheries Commission, a good number of them had information through radio which can also influence their level of understanding and utilization of GAMPs in their fish farming activities.

Apart from access to extension services, the frequency of extension visits is another important factor worth considering. The results show that the average number of visits received by a fish farmer in the 2019 production season was about two times. But the high standard deviation suggests that the number of extension visits received by the farmers was very heterogeneous. So, appropriate measures are needed to help improve the number of extensions visit that farmer receive as it can influence their decisions to practice or take up new technologies.

Membership of a farmer-based organization or non-governmental organization is important because farmers learn new ideas from their colleagues during group meetings. The results from the survey indicate that about 55% of the survey respondents belong to a farmer-based organization or a non-governmental organization, and for that matter possess the necessary platform to learn from their peers with regards to efficient methods of production.

4.2.4 Financial capital

Credit is an important factor in every business endeavor, and many researchers have identified access to credit as among the main motivating factors influencing an individual's engagement in agricultural production (Kumar et al., 2010; Rehman et al., 2017). Despite this important role that credit plays, the summary statistics show that only 17.4% of the respondents got access to formal credit for their aquaculture production, with the remaining 83% not having access to any form of credit. This is an indication that access to agricultural credit remains a major challenge in Ghana. While the reasons for this low access was not directly evident from the data, research shows that high collateral requirements or higher interest rates often serve to demotivate farmers from accessing production loans. For instance, Prodhan and Khan (2018) found that difficulty in accessing credit was the main problem that made the maintenance of large aquaculture farms difficult.

4.2.5 Production inputs

In aquaculture production, several inputs are involved. Usually, depending on the type, the common inputs involved are fingerlings, disinfectants, lime, drugs, chemicals, feed, fertilizer, and electricity among others. In the data analyzed for this research, the results show that among these production resources, fingerlings were the most expensive, costing an average of about GH₵ 1,048 per kilo during the 2019 production season. The high cost of fingerling is understandable because in an aquaculture enterprise fingerling is the major production input that must be acquired before any decision is made on the other inputs. Therefore, it is not surprising that the average cost of fingerlings is greater than all the other inputs that were used in the production process. Closely related to the costs of fingerlings was the cost of transportation, which cost about GH₵ 117 on the average. The higher average cost of transportation could be related to the delicate nature of fingerlings that requires a very efficient mode of transportation. Among the remaining inputs, costs of maintenance were the lowest, with an average of about GH₵ 2. The small average cost of maintenance could mean that the farmers in the study context spend relatively less capital in maintaining their ponds and cages.

4.3 Determinants of good aquaculture management practices

As discussed in chapter three, two different statistical models were used to examine the factors that influence good aquaculture management practices. The Poisson regression model was used for the count measure of the GAMPs, while multiple linear regression was used for the continuous measures of the GAMPs obtained through factor analysis and principal component analysis.

It can be observed from Table 4 that while the estimated pseudo-R-squared value of the Poisson model is modest (0.10), the overall significance of the model, as indicated by the Wald chi-squared value of 250.56, is satisfactory. In the multiple linear regression models, the R-Squared values of 30.6% and 32.8% with their corresponding p-values of 0.000, support the fact that the independent variables explained a good amount of the variation in the dependent variable.

It is evident from the data shown in Table 4 that out of the 23 explanatory variables that were included in the models, 16 of them are statistically significant and contribute to explaining the variation of GAMPs among the farmers. An interesting aspect of the results is that both the Poisson regression and multiple linear regression models agree on the significance and direction of the explanatory variables, affirming the robustness of the results in this study.

Access to credit, for instance, is statistically significant and contributes positively to good aquaculture management practices in both the Poisson and multiple linear regression models, *ceteris paribus*. Thus, there a significant difference in the uptake and use of GAMPs between farmers who have access to formal credit and those without access (Abate et al., 2016; Lambrecht et al., 2014). Thus, fish farmers who had access to credit had higher rates of using GAMPs. It has also been established that the adoption of improved practices requires an extra cost to be incurred by farmers and therefore, having better access to credit can enhance utilization by providing producers with the necessary capital for investment (Kazal et al., 2020).

All else equal, the results show that farmers who received technical advice from the Fisheries Commission or other extension agents also adopted the GAMPs as evident in the Poisson regression model as their counterparts who did not receive extension information. The finding on technical advice in increasing the utilization of GAMPs confirms the findings of deGraft-Johnson et al. (2016) and Mensah-Bonsu et al. (2017) as well as Kazal et al. (2020), who also observed a positive effect of extension advice on the adoption of aquaculture management practices. The direction of the coefficient indicated that the likelihood that farmers who had technical advice would adopt a higher number of improved practices is statistically significant 1%. In addition, the importance of technical advice cannot be underestimated because the adoption of new technologies requires some degree of technical knowledge, and direct contact with extension officers increase the acquisition of relevant knowledge in that regard. Therefore, it will be of benefit to increase the number of extension staff in rural areas to increase the levels of adoption of these practices (Kazal et al., 2020).

Also, the results show that farmers or managers who conduct in-house training for their employees used more GAMPs as compared to their peer farmers who did not have any form of in-house training arrangement for their employees. This finding is consistent with the work of Kabir and Rainis (2015), who found that training positively influenced the adoption of improved aquaculture management practices. This could also be as a result of the fact that training is one major way of empowering farmers with knowledge, which is a prerequisite for better farming performance, and as well helps farmers to diversify their knowledge and understanding of the essence of engaging more of the improved management practices. Besides, farmers can gain knowledge on different improved management methods from agriculture training programs introduced by the government and other non-governmental organizations (Begume et al., 2020; Prodhan and Khan, 2018). Salazar et al. (2018) and Mantey (2019) equally found similar results and offered recommendations on the importance of education and training on household technology adoption decisions.

Table 4: Determinants of good aquaculture management practices

	Model 1	**Model 2**	**Model 3**
	GAMPs by scaling	**FA**	**PCA**
Variables	Coefficient	Coefficient	Coefficient
Credit access	0.113**	0.291**	0.715***
	(0.0446)	(0.127)	(0.275)
Technical advice	0.193***	0.0845	0.283
	(0.0403)	(0.108)	(0.233)
In-house training	0.171***	0.627***	1.424***

	(0.0420)	(0.117)	(0.253)
Age of manager	-0.005***	-0.000695	-0.00336
	(0.0015)	(0.004)	(0.009)
Primary/Junior high school	0.262***	0.236	0.446
	(0.0823)	(0.198)	(0.430)
SSS_SHS	0.384***	0.563***	1.189***
	(0.0849)	(0.206)	(0.448)
Polytechnic/university	0.420***	0.683***	1.483***
	(0.0856)	(0.209)	(0.453)
Masters/PHD	0.576***	1.025***	2.243***
	(0.110)	(0.285)	(0.619)
Second quintile	-0.0498	0.102	0.268
	(0.0561)	(0.150)	(0.325)
Third quintile	-0.0463	0.0416	0.0479
	(0.0626)	(0.164)	(0.355)
Fourth quintile	0.0201	0.256*	0.564*
	(0.0566)	(0.152)	(0.330)
Fifth quintile	0.0122	0.250	0.628*
	(0.0596)	(0.160)	(0.346)
Owner and manager	-0.0709	-0.314**	-0.644**
	(0.0481)	(0.131)	(0.285)
Frequency of extension visits	0.00305	0.0159*	0.0258
	(0.0032)	(0.009)	(0.020)

Male owner	-0.0371	-0.0954	-0.113
	(0.0699)	(0.185)	(0.401)
Membership of a group	0.0741**	0.00160	0.0574
	(0.0377)	(0.101)	(0.219)
Brong_Ahafo	0.0784	-0.282**	-0.524*
	(0.0519)	(0.139)	(0.302)
Volta/Eastern	0.140**	-0.159	-0.321
	(0.0632)	(0.168)	(0.365)
Area	0.0335*	0.0801*	0.152
	(0.0180)	(0.048)	(0.105)
Divorced	0.148	-0.0777	-0.364
	(0.157)	(0.386)	(0.838)
Married	0.125**	0.0952	0.198
	(0.0586)	(0.161)	(0.349)
Widowed/widower	0.228*	0.212	0.518
	(0.135)	(0.344)	(0.745)
Radio	0.0603	0.224*	0.473*
	(0.0429)	(0.118)	(0.255)
Constant	1.694***	-0.547	-1.320*
	(0.128)	(0.332)	(0.721)
Log likelihood	-1094.882		
Wald chi square	243.07***		
Pseudo R2	0.10		

LR test (α = 0)	0.000***		
Observations	415	355	355
R-squared		0.307	0.328

*** p<0.01, ** p<0.05, * p<0.1, denote significance at 1%, 5% and 10%

The age of a farm manager has an inverse relationship with the utilization of GAMPs at 1% significance level, *ceteris paribus*. The results indicate that a year increase in the age of a farm manager will lead to a decrease in the likelihood of utilization of GAMPs. This negative association of age and good aquaculture management practices could imply that older farmers may not be ready to accept improved practices, which is in line with the findings of Ofuoku et al. (2008), Ofuoku et al. (2011) as well as Kazal et al. (2020). This result also brings to bear that in an attempt to increase the utilization of GAMPs, emphasis should be placed on training younger farmers since the emphasis on experienced farmers may not be as good compared to focusing training efforts toward the youth.

All other factors held constant; farmers' educational level influence their decisions to utilize aquaculture management practices. This is partly because educated farmers have the advantage of participating in different workshops seminars and for that matter can appreciate the need for the utilization of good management practices. Education also helps to improve an individual's understanding of new technologies which can help facilitate their uptake (Rehman et al., 2016). Similarly, the outcome of this research is in line with the work of Prodhan and Khan (2018), where education had a significant positive effect on adoption level, for instance, highly educated farmers had a greater likelihood of adoption as compared to the less educated ones. Begume et al. (2020) also found results similar what is reported in this thesis on the influence of education in the adoption of improved aquaculture management practices.

With regards to the effect of asset ownership in the utilization of GAMPs, quintiles were generated by the use of PCA and included in the estimation as binary variables. Quintiles are statistical values of dataset that divides a sample of data into five equal subsamples when arranged from the lowest to highest. Households who fall within the first quintile (0-20%) are the poorest in terms of asset quintile and the fifth quintile (80-100%) ranked as the highest in terms of asset holding. The results show that ownership of assets play a major role in the utilization of GAMPs as farmers who fell within the fourth quintile group utilize more of the GAMPs than those who fell within the lowest asset quintile. This shows the importance of assets in households' decision to consider practices that can lead to the improvement of household welfare. Since household assets are also an indicator of wealth, the findings show that well-to-do farmers are better placed to utilize GAMPs as compared to farmers with fewer resource endowments, ceteris paribus. Owners who double as managers of their fish farms were the least to utilize GAMPs compared to owners who have employed people to manage their farms, *ceteris paribus*. This result is not surprising because if farm owners who doubled as their own farm managers have other activities that demand the investment of time, they might not be able to practice the recommended management practices since the utilization of GAMPs require the investment of time. Therefore, due to the time and cost dimensions in utilizing GAMPs it will be better if farmers employ farm managers as full-time employees to manage their farms effectively.

Holding all other things constant, the frequency of extension visits is significant and positively influence the utilization of GAMPs. This is because not only is extension advice important, but the frequency or number of times a framer receives advice on particularly good practice(s) within a season is an important factor that can influence farmers to use the recommended practice(s) under consideration. This result is not different from the findings of Amankwah and Quagrainie (2019) that extension contact significantly influences improved fish feed uptake, implying that the frequency of extension contact enhances the probability of adopting the technology. Furthermore, studies have shown that those who adopted improved farming practices often also maintained constant communication with agricultural extension officers, which inevitably increased their exposure to and knowledge of aquaculture production technologies (Blythe et al., 2017; Kazal et al., 2020).

Membership of a social group also significantly affects the uptake and utilization of GAMPs. Membership of farmer-based organizations (FBOs) or non-governmental organizations (NGOs) presents an avenue where farmers meet to learn from peers on improved methods of production which could include the application of GAMPs (Asante-Addo et al., 2017). Though the finding turns to disagree with the work of Prodhan and Khan (2018), who found an inverse relationship between belonging to a social group and adoption of improved management practices, they indicated that they could not precisely tell if the societal organizations were related to aquaculture or not. Thus, one stands to reason that if the social relations were not related to aquaculture, these farmers had time commitments outside of their jobs as aquaculture producers, which may have prevented them from adopting improved practices. However, the outcome of this study is in line with other studies that found a positive relationship between group membership and the uptake of improved aquaculture management practices (Abebaw and Haile, 2013; TOROITICH, 2021).

The regional dummies tell that there is a geographic heterogeneity in the uptake and utilization of GAMPs. Across the regions, evidence shows that farmers in the Volta and Eastern regions utilized good management practices more than those in the Ashanti Region. But, the reverse is true for those fish farmers from the Brong-Ahafo region since their rate of utilization is far lesser than farmers from the Ashanti region. This finding conforms to the work of Amankwah and Quagrainie

(2019), who found that adoption probabilities were higher for households located in the Ashanti, as compared to those from the Brong Ahafo region.

In terms of pond size, the results show that the greater the area under cultivation in square meters, the better the utilization of GAMPs in both the Poisson and the multiple linear regression models. Since the area of land owned is an indication of wealth, it could mean that farmers with larger land areas have the financial capability to practice good and improved management practices as compared to their counterparts with smaller holdings. Though the effect of farm size on agricultural technology utilization has, however, been mixed in the literature, Croppenstedt et al. (2003) and Ren et al. (2019) found that farm size decreased the intensive use of improved agricultural technologies. Other researchers like Ricker-Gilbert et al. (2011) and Lunduka et al. (2013) also provide evidence that households who work on larger farms are more likely to adopt improved technologies.

Also, marital status is found to influence the utilization of GAMPs, ceteris paribus. One can imagine that married couples may enjoy support from their spouses in terms of labor supply for the management of their farms. Besides, couples can come together to raise funds for financing the activities of their aquaculture enterprise compared to singles. However, the results also point out that widows/widowers applied more GAMPs compared to singles.

Having access to agricultural information through radio has a positive effect on the application of GAMPs. Of course, farmers who often listen to radio programs concerning aquaculture production are privy to information on good practices that can lead to efficient production. Also, the relatively easy access to radio and the wide coverage of radio waves and infrastructure contribute to its importance in enhancing the utilization of GAMPs. A research carried out by Agwu et al. (2008) to determine the adoption of improved agricultural technologies by farmers through information disseminated by radio farmer program in Nigeria, observed that out of nineteen technologies, adoption of six of the technologies by the farmers were enhanced through the radio farmer program that was organized on periodic basis. Similarly, Mtega and Msungu (2013) found, through a study in Tanzania, that radio was the highest-ranked communication media used by the farmers in the study area. This finding is similar to the result in this study.

4.4 The effect of aquaculture management practices on the survival rate of fingerlings

In table 5, the empirical results obtained from the estimation of the fractional regression model (FRM) is presented. Considering the empirical adequacy of both models consisting of the three indices generated from the good aquaculture management practices, it is undoubted that the models fit the data relatively well in all cases. Though the values found for the pseudo R-squared is comparatively low, such statistics are usual in cross-sectional studies (JS Ramalho and da Silva, 2009). The Wald chi-square and the likelihood ratio test in all the models indicate that the models fit the data well. Out of the explanatory variables used, eight, including one of the indices generated on GAMPs, influenced the survival rate of fingerlings.

Specifically, the application of GAMPs influences the survival rate of fingerlings and is statistically significant at 10% level of significance. This means that farmers who applied good management practices on their fish farms experienced a higher survival rate of fingerlings as compared to their fellows who paid little attention to good aquaculture management practices. The management practices employed by farmers included water quality management, waste management, sanitation management, good feeding methods, and record-keeping, among others. Similar to the results reported in this study, previous research by Kazal et al. (2020) found that farmers who adopted good practices obtained higher productivity than non-adopters. Meanwhile, one can argue that higher productivity in itself is a function of a higher survival rate. Likewise, other studies have indicated that the factors behind the positive association between adoption, survival rate, and productivity in aquaculture production include the maintenance of proper stock density and feeding rates (Karim et al., 2014; Sakib and Afrad, 2014).

Table 5: fractional regression estimates of the effect of GAMPs on the survival rate of fingerlings

	Model 1	**Model 2**	**Model 3**
VARIABLES	Coefficient	Coefficient	Coefficient
GAMPs by scaling	0.0205*		
	(0.0115)		
GAMPs by FA		0.0173	
		(0.0409)	
GAMPs by PCA			0.00630
			(0.0184)
Brong-Ahafo	0.844***	0.886***	0.883***
	(0.0958)	(0.0920)	(0.0925)
Volta /Eastern	0.285**	0.268**	0.266**
	(0.112)	(0.118)	(0.118)
Male owner	-0.293*	-0.309	-0.309

	(0.165)	(0.192)	(0.191)
Frequency of visits	-0.00826	-0.00881	-0.00870
	(0.00807)	(0.00840)	(0.00837)
Cost of chemical	0.947*	0.837	0.840
	(0.555)	(0.607)	(0.608)
Second quintile	-0.192*	-0.0791	-0.0781
	(0.112)	(0.105)	(0.105)
Third quintile	-0.185	-0.0752	-0.0736
	(0.130)	(0.128)	(0.128)
Fourth quintile	-0.222**	-0.274**	-0.272**
	(0.110)	(0.123)	(0.123)
Fifth quintile	-0.188	-0.199	-0.197
	(0.140)	(0.146)	(0.146)
Feed	0.0101	0.00832	0.00841
	(0.00807)	(0.00762)	(0.00767)
Male farm manager	0.168	0.237	0.237
	(0.177)	(0.204)	(0.203)
Divorced	0.0215	0.0995	0.0985
	(0.171)	(0.191)	(0.191)
Married	0.135	0.197	0.197
	(0.118)	(0.132)	(0.132)
widowed/widower	0.332	0.467*	0.466*
	(0.265)	(0.280)	(0.278)

Cost of transport	-0.160	-0.256	-0.256
	(0.164)	(0.164)	(0.164)
Constant	0.676***	0.776***	0.777***
	(0.183)	(0.174)	(0.174)
Wald chi- square	117.16***	154.61***	153.79***
Log likelihood	-146.900	-120.649	-120.645
Pseudo R2	0.07	0.07	0.07
LR test (α = 0)	0.000***	0.000***	0.000***
Observations	407	355	355

*** p<0.01, ** p<0.05, * p<0.1, denote significance at 1%, 5% and 10%

The results of the regional dummies indicate that households in the Eastern-Volta regions and those from the Brong-Ahafo Region experienced a higher fingerlings survival rate compared to those from the Ashanti Region. Though there is variation in the survival rate of fingerlings among the regions, these four regions have contributed significantly to the development of the aquaculture sector in Ghana, as the contribute about 86% of Ghana's aquaculture production annually (Asiedu et al., 2017).However, Amevenku et al. (2019) concluded that although fishing is a risky and laborious venture, it remains the major occupation preferred by households in the Volta Basin of Ghana.

Also, the results suggest that male ownership has a negative implication on the survival rate of fingerlings at 10% level of significance. This is not surprising because of the eminent role that women play in the aquaculture industry. The Food and Agriculture Organization of the United

Nations indicated that in countries where an aquaculture sector has been established, women have rapidly become involved in aquaculture at every level. Quite apart from the expansion of their traditional fisheries roles in marketing, credit, and processing, women have also become very active in aquaculture production itself (Agbebi et al., 2016). This finding is also important since the Tiseed project based on which this data was collected, has a particular focus of making aquaculture inclusive of the poor, young women and men (Kruijssen et al., 2020).

Holding all other variables constant, the use of chemicals also influences the survival rate of fingerlings at a 10% level of significance. Several chemicals are used in aquaculture production for the health management of fish. Some of the common ones used in fish production include sodium chloride, formalin, potassium permanganate, methyl blue, hydrogen peroxide as well as copper compounds among others (Shamsuzzaman and Biswas, 2012). Research has also supported the fact that as aquaculture production is expanding, there is an increasing desire to using more chemicals in aqua-health management to increase productivity (Chowdhury et al., 2015). Though the use of chemicals is good in expanding production as it helps in enhancing the survival rate of fingerlings, the continuous influence of chemical sellers and pharmaceutical companies on farmers to buy their products is problematic, since a majority of the farmers do not know the appropriate dosages or method of application that could have adverse implication on human health and the environment (Mohamed et al., 2000; Okocha et al., 2018). Therefore, this calls for the need for farmers to be given adequate training on fish health management using chemicals.

Ownership of assets also had a significant negative effect on the survival rate of fingerlings. Though research has indicated the value of assets in household aquaculture investment decisions (Kumar and Quisumbing, 2011), one will have equally thought that farmers who have more assets should be able to take all relevant measures and have a higher survival rate of fingerlings due to their ability to invest adequately in the aquaculture business. However, it is also important to note that assets are means but not ends in themselves if the farmer lacks the technical know-how in aquaculture production. The results specifically indicate that farmers in the second (20-40%) and fourth (60-80%) asset quintiles experience lower survival rate of fingerlings at a significance level of 10% and 5% levels respectively compared to those in the lower asset quintile (0-20%).

Also, another variable that influences the survival rate of fingerlings is marital status. Holding all other factors constant, farmers who reported widowhood experience a higher survival rate of fingerlings than those who were singles. This outcome might be because the widows/widowers might have managed their fish farms effectively than the singles which led to the higher survival rate of the fingerlings as compare.

4.5 Effect of GAMPs on the technical efficiency of farmers in Ghana

4.5.1 Test on the specification of the model

The likelihood ratio test was used to test the null hypothesis of no inefficiency factor in the production function. The outcome indicated in table 6, do not agree with the null hypothesis of no technical inefficiency effect as indicated in the models, since they are significant at a 1% significance level. This supports the hypothesis that there is an inefficiency effect in the production function. The estimated sigma squared (σ^2) in the three models as indicated in table 5 were significant at a 1% significance level, indicating that the models fit the data well (Manjunatha et al., 2013; Rahman, 2003).The estimates for the factors influencing technical inefficiency in aquaculture production are presented in the table 6.

Out of the ten (10) explanatory variables used in the production function model, five (5) of them are significant in influencing the level of output. Among the five (5) significant variables, only the amount of feed and lime have positive influence on the quantity of fish harvested by the farmers, while the cost of transport, disinfectants, and chemicals had a negative influence, thus reducing the output of the fish farmers.

The amount of feed used for instance is significant in all the three models at 1% level of significance. Thus, the quantity of fish produced increases in the amount of feed used. This result is expected and shows the importance of feed as a major ingredient that should be given attention to ensure efficient and profitable aquaculture production. Evidence has it that quite apart from stocking density, another major factor that influences fish yield is the feeding rate (Iliyasu et al., 2016; Mohan Dey et al., 2005). Due to the important recognition given to feeds in aquaculture production, feed management was given a key recommendation in a research on aquaculture production conducted in Egypt as the amount of feed used was found to have a great effect on output (El-Sayed, 2013). There is also a need for effective attention during feeding to reduce feed waste and that high-quality feeds should be considered rather than the cheapest (Dickson et al., 2016). Besides, the importance of feed in aquaculture led El-Sayed et al. (2015) to conclude that fish farmers should be allowed to use a wide range of different feeds from different sources including farm-made mixes, and conventionally pelleted feeds.

The cost of transport incurred during the farming operation is also significant at 1% in all three models, holding all other factors constant. The results signify that when the cost of transport increases by one Ghana cedi, the quantity of fish produced reduces. These findings agree with *a priori* expectation because when there is an increase in transportation cost, the amount of money that would have been used to purchase other inputs to increase output or productivity might be redirected to cater for transportation. It is also possible that increasing transport costs lead farmers to reduce the size of production, which invariable affects output negatively. The negative effect of transport cost on aquaculture production is further elaborated by previous finding that in pursuing a "single" fertilizer strategy for fish farm development in Ghana, the cost of transport influences the choice of fertilizer/manure to be used (Asmah, 2008). This is particularly important in tilapia production where different quantities of fertilizers are needed to produce a given quantity of fish (Asamoah et al., 2012; Wijkstrom and Vincke, 1991).

The cost of disinfectants also negatively influences the amount of fish produced at 1% level of significance in all models. Disinfectants are very important in aquaculture because they are used to control most disease-causing organisms that may have a negative influence on fish health. The categories of disinfectants used in aquaculture are considered nonpublic health products. These disinfectants are used to control algae growth, odor-causing bacteria as well as bacteria that cause spoilage, deterioration, and microorganisms that infect only animals (Wanja et al., 2020). Considering the critical role played by disinfectants in promoting fish health, it is evident that the higher cost of it can cause a reduction in productivity.

Also, chemical cost has a negative effect on the productivity of fish at 1% significance level. This means that when the cost of chemicals increases by a Ghana cedi, there is a corresponding reduction in the amount of fish produced by 2.36kg. This outcome may also be a result of the importance of chemicals in promoting the efficient growth of fish. Therefore, if farmers cannot afford chemicals due to their high cost, fish health will be compromised, which will inevitably affect productivity.

The results also indicate that the higher the cost of lime, the higher the output, as the results from all three models indicate. Thus, farmers who could afford to buy more lime to aid their fish production had higher output compared to their counterparts who could not afford more lime. This outcome is not surprising because the pond management system promoted by the Fisheries

Commission involves the use of lime and fertilizers in addition to pelleted feeds, since lime helps in improving the fertility of the pond for efficient fish growth (Gordon and Pulis, 2010).

Table 6: Maximum-Likelihood Estimates of the Stochastic Production Function

	SFA (Model 1)	**SFA (Model 2)**	**SFA (Model 3)**
Variable	Coefficient	Coefficient	Coefficient
Main model			
Cost of electricity	-0.0394	-0.0236	-0.0262
	(0.140)	(0.139)	(0.138)
Hired labor cost	0.0123	0.0136	0.0135
	(0.0134)	(0.0132)	(0.0132)
Amount of feed	0.244***	0.246***	0.246***
	(0.00519)	(0.00516)	(0.00515)
Cost of fuel	-0.0936	-0.129	-0.130
	(0.139)	(0.137)	(0.137)
Cost of dugs	-0.105	-0.415	-0.413
	(2.257)	(2.246)	(2.243)
Transportation cost	-0.862***	-0.863***	-0.863***
	(0.224)	(0.231)	(0.231)
Disinfectant cost	-0.00191**	-0.003***	-0.003***
	(0.00084)	(0.000864)	(0.000863)
Cost of chemical	-2.360***	-1.689**	-1.702**

	(0.860)	(0.861)	(0.861)
Cost of lime	0.00575***	0.00904***	0.00905***
	(0.00103)	(0.00129)	(0.00129)
Maintenance cost	-0.0440	-0.0759	-0.0771
	(0.0908)	(0.114)	(0.114)
Constant	0.785***	0.817***	0.818***
	(0.0675)	(0.0739)	(0.0739)
Technical inefficiency model			
GAMPs by scaling	-0.132*		
	(0.0792)		
GAMPs by FA		-0.130	
		(0.279)	
GAMPs by PCA			-0.0888
			(0.131)
Membership of a group	0.877*	0.956*	0.970*
	(0.531)	(0.573)	(0.572)
Credit	-0.265	-0.157	-0.150
	(0.669)	(0.678)	(0.676)
Male manager	0.424	0.329	0.342
	(2.013)	(2.119)	(2.102)
Area	-3.038**	-3.827**	-3.806**
	(1.246)	(1.746)	(1.719)

Radio	1.268**	1.263**	1.291**
	(0.534)	(0.560)	(0.562)
Technical advice	-1.039*	-1.313**	-1.293**
	(0.559)	(0.580)	(0.579)
Brong_Ahafo	-0.241	-0.125	-0.130
	(0.558)	(0.590)	(0.585)
Ashanti	-1.689*	-1.502	-1.485
	(0.966)	(1.264)	(1.242)
Male owner	-0.455	-0.378	-0.380
	(1.905)	(1.981)	(1.966)
Age of owner	-0.00723	-0.00179	-0.00212
	(0.0182)	(0.0190)	(0.0190)
Model diagnostics			
Sigma squared	-0.222***	-0.283***	-0.284***
	(0.0716)	(0.0779)	(0.0779)
Mean technical eff	0.804	0.803	0.803
Wald chi-squared	2528.65***	2598.18***	2600.79***
No. of observations	415	355	355

*** p<0.01, ** p<0.05, * p<0.1, denote significance at 1%, 5% and 10%

The technical inefficiency models have generally produced expected results. Surprisingly, not many of the variables included in the models explain the variation in terms of the levels of technical efficiency among the farmers as expected.

Firstly, good aquaculture management practices negatively affect technical inefficiency at 10%

significance level. This means that farmers who applied GAMPs have less technical inefficiency or were technically efficient compared to their fellow farmers who did not apply the management practices. This finding agrees with previous studies that found that adopters of improved aquaculture practices were technically more efficient than non-adopters (Karim et al., 2020; Rahman et al., 2020a). Although the outcome of this research indicates that those who applied more GAMPs are technically more efficient than their counterparts who apply less, there exists enough room for increasing the level of technical efficiency. The mean technical efficiency in all three models was calculated at about 80%, which means that aquaculture farmers could increase the production of fish by 20% by only improving their technical efficiencies.

Farmers who are members of a social group are less technically efficient than farmers without social group membership. This finding is not in line with *a priori* expectation as one would have thought that membership of a social group should make farmers more technically efficient. It is believed that group meetings help farmers to learn from their peers on new technologies and methods of farming. However, this finding can be justified by the fact group meetings must not necessarily influence technical efficiency if the content of the discussion is not geared toward making farmers more technically efficient.

The area used by a farmer in meters square, reduces technical inefficiency of farmers at 5% level of significance. Though previous studies have reported mixed results on farm size and technical efficiency of farmers (Boubacar et al., 2016; Zhang et al., 2016), is the results in this study shows a negative relationship between pond size and technical efficiency, which tells that the smaller farms were technically more efficient than the larger ones. This is also in line with the work of Rahman et al. (2020a) who had a negative correlation between farm size and technical efficiency among shrimp farmers in Bangladesh. Also, in line with an empirical investigation by Manjunatha et al. (2013), small farms were found to be more technically efficient than large farms. This is because smallholder farmers usually dedicate enough time for farm maintenance since farming is their major occupation and primary source of income for them. Hence, they work hard to ensure that they get the best out of their investment.

Access to information through the radio is significant at 5% with an inverse relationship with the technical efficiency of farmers. This finding again does not agree with *a priori* expectation as one would have expected that farmers who get access to information on aquaculture production through radio do better and are more technically efficient. An alternative consideration of this outcome could be that farmers can have access to information through radio but may not practice content of the information received. Also, farmers may have access to information but the frequency of the information received may also be a matter of importance in determining whether it will influence their technical efficiency or not (Phiri et al., 2019).

Furthermore, the results show that farmers who had technical advice from the Fisheries Commission or other extension agents are technically efficient in all three models. The role of training in improving the knowledge and technical ability of farmers holds validity in this circumstance. This is because training increases the ability of farmers to perceive and as well respond to new events. It also enhances the skills of farmers which includes the efficient use of farm inputs. Similarly, past studies have also found a positive and significant coefficient of extension training on the efficiency of farmers (Mengui et al., 2019; Rahman et al., 2020a; Yengoh et al., 2010).

The results of the regional dummies show that farmers in the Ashanti Region are relatively more efficient than their colleagues from the Volta-Eastern regions. This is not surprising as Crentsil (2018) concluded in their research that the Ashanti Region was among the best fish-producing regions in the country. Meanwhile, Crentsil and Essilfie (2014), held a contrary view that farmers from other fish-producing regions of Ghana apart from the Brong-Ahafo Region were more efficient than their counterparts from the Ashanti Region. However, Onumah and Acquah (2010) found an insignificant impact of regional differences in the variation of the technical efficiencies among smallholder fish producers in Ghana. Though the impact of location cannot be ignored as a determining factor of technical efficiency among farmers in this study, however, the conclusion is that the right combination of production inputs bears much more effect on output and for that matter efficiency than just the location of the farm.

4.6 Effect of GAMPs on the profit efficiency of farmers

The null hypothesis that there is no profit inefficiency is assessed by using the likelihood ratio test. However, the statistics shown in the table below reject the null hypothesis of no profit inefficiency in the model in favor of the alternate hypothesis of potential inefficiency effects in the profit function. Values of the estimated sigma squared in all the models were significant at 1% significance level, signifying that the respective models fit the data well. The estimates for the determinants of profit inefficiency are reported in Table 7 below.

The study identified the main factors that influence the profit obtained from aquaculture enterprises as well as the efficiency of farmers engaged in the enterprises. The maximum likelihood estimates are presented in the table 7 below. The sign and direction of the majority of the prices of inputs meet *a priori* expectation, supporting the fact that the profit function of fish farmers in Ghana is convex with regard to prices of inputs (Ansah et al., 2014a).

The elasticities of profit for all the variables are statistically significant in all three models except the cost of electricity, cost of chemical and maintenance cost. Among the significant variables, the cost of labor, cost of fingerlings, and disinfectants had negative signs with an inverse relationship with profit. This means that when the price of each of those inputs increases, the profit level of a fish farmer decreases. This is in line with the work of Ansah et al. (2014a), who found that the average profit of farmers decreases as the cost of inputs increases among smallholder farmers in Ghana. Also, a study conducted by Setsoafia et al. (2017) on the profit efficiency of artisanal fish producers acknowledged that input prices had a negative relationship with the profit levels of the farmers. As indicated in the methodology, this study employed the alternative profit function where the value of output is used instead of its price in the main model. Therefore, it can be seen from the results that the amount of fish harvest had a positive influence on the profit of farms. This means that all other things held constant, the quantity of fish harvested has a positive implication on the profit of farmers. This finding is also in line with the findings of Ansah et al. (2014a), who reported a positive relationship between the amount of maize and cowpea produced and the profit levels of farmers.

Also, the cost of lime has a positive effect on profit at 5% level of significance, *ceteris paribus*. Though the outcome seems not to agree with prior expectation, this might be as a result of the important role lime plays in aquaculture production, since it helps in pond fertilization for efficient production (Gordon and Pulis, 2010).

Table 7: Maximum-Likelihood estimates of stochastic profit frontier

	SFA (Model 1)	**SFA (Model 2)**	**SFA (Model 3)**
Variable	Coefficient	Coefficient	Coefficient
Profit function			
lnharvest	20.94***	21.41***	21.42***

	(2.028)	(2.231)	(2.231)
Electricity cost	-0.757	-0.616	-0.670
	(4.498)	(4.662)	(4.660)
Hired labor cost	-1.475***	-1.452***	-1.451***
	(0.492)	(0.509)	(0.509)
Disinfectant cost	-0.0297**	-0.0476**	-0.0473**
	(0.0145)	(0.0200)	(0.0200)
Chemical cost	-45.99	-36.98	-37.27
	(31.87)	(33.74)	(33.72)
Fingerling cost	-4.699***	-5.292***	-5.296***
	(1.607)	(1.771)	(1.771)
Lime cost	0.0771**	0.128**	0.127**
	(0.0387)	(0.0549)	(0.0548)
Maintenance cost	-2.962	-3.384	-3.401
	(4.129)	(4.294)	(4.294)
Constant	27.26***	28.68***	28.71***
	(2.945)	(3.288)	(3.287)
Inefficiency model			
GAMPs by scaling	-0.200***		
	(0.0751)		
GAMPs by FA		-0.747**	
		(0.345)	
GAMPs by PCA			-0.350**

			(0.155)
Total family size	-0.863**	-0.621***	-0.614***
	(0.356)	(0.235)	(0.227)
Advice from fishery commission	0.337	0.451	0.443
	(0.707)	(0.772)	(0.748)
In-house training	0.420	1.377**	1.396**
	(0.748)	(0.672)	(0.651)
Brong_Ahafo	-2.331**	-2.043**	-2.128**
	(1.074)	(0.844)	(0.855)
Ashanti	-1.942*	-1.254	-1.336*
	(1.029)	(0.765)	(0.756)
Area	0.864***	0.762***	0.726***
	(0.317)	(0.274)	(0.264)
Model diagnostics			
Sigma squared	7.367***	4.538***	4.619***
	(1.148)	(0.915)	(0.927)
Mean profit efficiency	0.531	0.43	0.427
Wald chi-squared	132.18***	113.84***	113.87***
No. of observations	325	299	299

*** p<0.01, ** p<0.05, * p<0.1, denote significance at 1%, 5% and 10%

Though the variables in the inefficiency models produced the expected results especially the indicators of aquaculture management practices. However, not all of the other indicators agree with the prior expectation of reducing the levels of profit inefficiency among the farmers. However, it is pertinent to know that a positive coefficient in the inefficient model shows an increase in profit inefficiency while a negative coefficient representing a reduction in profit inefficiency.

First and foremost, all the indicators of GAMPs in all the models contribute to reducing the profit inefficiency levels of fish farmers in Ghana. This means that good water quality management, sanitation, and biosecurity management, feed management, record keeping, among others, are important management practices that when utilized, can reduce the profit inefficiency levels of aquaculture farmers in Ghana. This outcome confirms a research conducted by Dickson et al. (2016), who found that best aquaculture management had a positive impact on the profit levels of fish farms in Egypt. The researchers further elaborated that through best management practices, fish farmers were able to cut down feed costs to achieve better food conversion ratios than their counterparts who least practiced the best aquaculture management strategies.

In developing economies like Ghana, increasing family size has a direct connection with the amount of labor for agriculture activities including aquaculture. This means that the households with a higher amount of family labor are more diversified in their activities than those with very little labor (Asravor, 2018). Evidence exists that in fishing communities, diversification in fishery and farming strategies are common to larger family sizes since it provides these families with alternative sources of income (Amevenku et al., 2019). This means that there can be reinvestment of income in the alternative enterprises making them more efficient. Meanwhile, Itam et al. (2014) and Kareem et al. (2016) found a reverse relationship between family size and the inefficiency levels of small-scale fish farmers as larger family sizes reduce the level of efficiency.

One would have thought that farmers who conduct in-house training for their employees will be more profit efficient, but that has not been the case in this study. The results rather suggest that farmers who conduct in-house training for their employees are less profit efficient or more profit inefficient. Though the results do not agree with prior expectation, it could happen that the training given to the employees are geared towards improving production to the neglect of practices that can help in reducing inefficiency.

The results of the regional dummies in all the models show that fish farmers from the Ashanti and Brong-Ahafo regions are profit efficient than their counterparts in the Volta and Eastern regions. Though Asamoah et al. (2012) found an insignificant impact of regional differences in terms of technical efficiency among smallholder fish farmers, Onumah and Essilfie (2020) offered an alternative view by concluding that the Ashanti region was among the best fish producing regions in the country. Therefore, it is not surprising that farmers from the Brong-Ahafo and Ashanti regions are more profit efficient, *ceteris paribus*.

The land area under cultivation is positive and significant at 1%. This means that farmers who produce in larger areas are less profit efficient than their colleagues working on smaller land areas. As this outcome can be linked to the inability of smallholder fish producers to acquire enough inputs due to larger farm holdings, Yuan et al. (2020) also found a strong positive relationship between farm size and efficiency among tilapia producers in China. This calls for the need to educate farmers on intensification strategies in their aquaculture businesses rather than extensification to help reduce the levels of inefficiencies.

CHAPTER FIVE

5.0 Summary, conclusion and recommendation

5.1 Summary of key findings

1. With determinants of GAMPs, the results indicate that credit access has a positive effect on the utilization or application of GAMPs.
2. Farmers who had technical advice either from the Fishery Commission (FC) or other extension agents made use of the GAMPs.
3. Also, in-house training influences the application of GAMPs, meaning that farmers who give their employees on-the-job training adopted good management practices more.
4. The results also show that ownership of assets played an important role in farmers' level of utilization as farmers in the higher asset quintile group applied more management practices than those in the lower quintile group.
5. As group membership serves as avenues that farmers meet their peers to learn about good farming practices, it is not surprising that it has a positive influence on the utilization of GAMPs.
6. However, the findings indicate that the higher the age of the manager, the lower the utilization of the GAMPs.
7. Owners who also manage their farms were the least to utilize the management practices.
8. The regional dummies show that whiles farmers in the Volta and Eastern regions utilized more of the GAMPs than farmers from the Ashanti Region, the reverse is true for farmers from the Brong-Ahafo region as they utilized less of the management practices than those from the Ashanti region.

9. With the effect of GAMPs on the survival rate of fingerlings, the results revealed that the higher the cost of chemicals used, the higher the survival rate of fingerlings.
10. Also, male owners, as well as asset ownership, have an inverse influence on the survival rate of fingerlings.
11. Farmers from both Volta and Eastern regions together with those from the Brong-Ahafo Region enjoyed a higher survival rate of fingerlings than those from the Ashanti Region.
12. With respect to the technical efficiency of farmers, the results show that GAMPs help to reduce the technical inefficiency of farmers as expected.
13. Farmers who received technical advice are also more efficient than their colleagues who had no such advice since the advice received helped in their uptake and utilization of the GAMPs, thus making them more technically efficient.
14. The area used for fish farming is another variable that reduces technical inefficiency. The amount of feed used also increases the number of fishes produced.
15. Also, GAMPs is a major variable that has a positive influence on the profit efficiency of farmers.
16. Family size is another important variable that helps to reduce the levels of profit inefficiencies among the farmers, emphasizing the importance of family labor in aquaculture production.
17. The regional dummies also indicate that farmers from the Brong-Ahafo region and Ashanti region are more profit efficient than those from the Volta and Eastern regions.

5.2 Conclusions

From the key findings, access to credit has a positive effect on the utilization or application of GAMPs. Apart from access to credit, farmers who had technical advice either from the Fishery

Commission (FC) or other extension agents made use of the GAMPs. Also, in-house training influences the application of GAMPs, meaning that farmers who give their employees on-the-job training utilized more of the management practices.

The results also show that ownership of assets played an important role in farmers' level of utilization as farmers in the higher asset quintile group applied more management practices than those in the lower quintile group. As group membership serves as avenues that farmers meet their peers to learn about good farming practices, it is not surprising that it has a positive influence on the utilization of GAMPs. Quite from that, owners who also manage their farms were the least to utilize the management practices. The regional dummies show that whiles farmers in the Volta and Eastern regions utilized more of the GAMPs than farmers from the Ashanti Region, farmers from the Brong-Ahafo region utilized less of the management practices compared to those from the Ashanti region. With the effect of GAMPs on the survival rate of fingerlings, the results revealed that the higher the cost of chemicals used, the higher the survival rate of fingerlings. Also, the results show that GAMPs help to reduce the technical inefficiency of farmers. Farmers who received technical advice are also more efficient than their colleagues who had no such advice since.

The area used for fish farming reduces the level of technical inefficiency. The amount of feed used also increases the number of fishes produced. Again, farmers from the Ashanti Region are technically more efficient than those from the Volta and Eastern regions. GAMPs is a major variable that has a positive influence on the profit efficiency of farmers. Farmers who could utilize the various management practices were more profit efficient. Finally, family size is another important variable that helps to reduce the levels of profit inefficiencies among the farmers, emphasizing the importance of family labor in aquaculture production.

5.3 Policy recommendations

A policy intervention to enhance the utilization of GAMPs would be to encourage the participation of women in aquaculture production because of their readiness to use new technologies. Though the current participation of women in aquaculture production is low, the results show that women turn to be more efficient with a higher survival rate than their male counterparts.

Equally pertinent in fostering the utilization of GAMPs is making credit easily accessible to aquaculture producers at reasonably low-interest rates and collateral requirements, especially given the high cost involved in the uptake and utilization of GAMPs. Credit access will help encourage and sustain the uptake and utilization of the GAMPs for higher yields and efficiency among the farmers. Also, feed availability and accessibility to fish farmers are recommended to enhance efficient aquaculture production in Ghana. It will also be necessary that government and other development partners make sure resources are allocated to district fisheries officers to facilitate their regular interaction with the fish farmers. Farmers should also be encouraged to form or join associations. This is because the formation of farmer-based groups helps farmers to learn from their peers through group meetings as compared to when they do everything on their own. So, farmers who are not part of farmer groups should be encouraged to participate.

Finally, there is the need to promote the GAMPs, because of their ability to increase the survival rate of fingerlings and also in the reduction of technical and profit inefficiencies of farmers.

5.4 **Limitations of the study and suggestions for future research**

The first limitation of this study is that the challenges Ghanaian farmers face in the utilization of the aquaculture management practices was not considered in this study. Therefore, there is a need for future research on the challenges faced in the utilization of the good aquaculture management practices in Ghana. Also, this study placed a major emphasis on tilapia farmers to the neglect of other fish species, so, future studies should consider farmers who cultivate other fish species to find out their management practices and their efficiency levels.

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