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**DRIVERS OF ADOPTION OF MULTIPLE SUSTAINABLE AQUACULTURE
TECHNOLOGIES AMONG SMALLHOLDER FISH FARMERS IN THE LAKE
VICTORIA BASIN REGION, KENYA**

ACHOM BARBARA EMODOI

MDF/147849/2021



**A Dissertation Submitted in Partial fulfillment of the requirements of the
degree of Master of Science in Development Finance of Strathmore
University Business School**

FEBRUARY 2024

DECLARATION

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the dissertation contains no material previously published or written by another person except where due reference is made in the dissertation itself.

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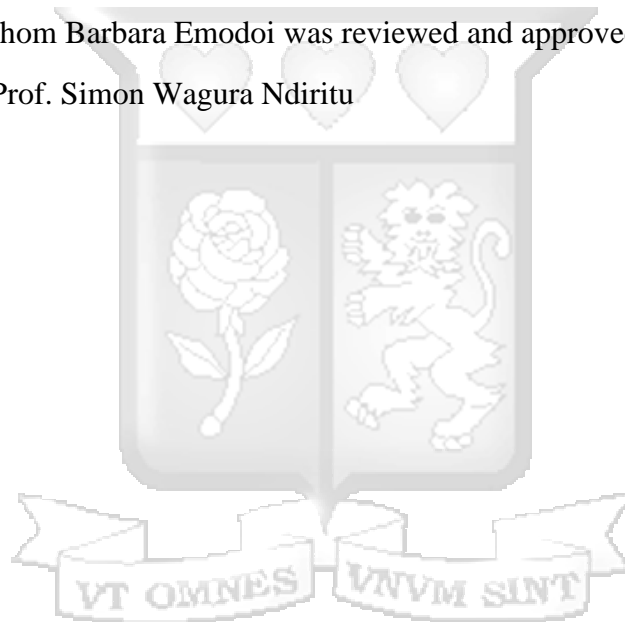
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ABSTRACT

The study was undertaken in the Lake Victoria basin region (Busia, Homabay, Kisumu, and Siaya counties), Kenya, to determine the drivers of adoption of multiple sustainable aquaculture technologies. The global aquaculture sector grew in the recent past to become one of the most vital sectors to aid food security in the world but with constraints in factor inputs, new and better technologies must be developed to cope with the emerging demand for fish. Therefore, the study investigated the influence of socioeconomic factors, fish production, fish marketing and Aquaculture Business Development Programme (ABDP), in determining adoption decisions of fish farmers with regards to hormonal sex reversal, selective breeding and feed regime. The focus population comprised 5332 smallholder fish farmers as outlined in the ABDP report issued in 2022. Through multistage sampling (clustering and random sampling), primary data gathered from 724 fish farmers was analyzed using Multivariate Probit model. The findings revealed that the multiple sustainable aquaculture technologies were jointly adopted by fish farmers as complements. From the results still, the increase in household income, income from other activities, fish income, number of ponds, fish species being tilapia, high initial capital, amount of crops sold in kilograms, membership in fish association group, membership in fish marketing groups, high perishability and farmer being a beneficiary of ABDP were the critical drivers of adoption of multiple sustainable aquaculture technologies. Generally, the MVP model was fit for the test given the rejection of hypothesis that the three technologies were independent. The study concluded that the aquaculture technologies under study were widely practiced by farmers who were keen to see their incomes improve from all aspects as fish production thrives in tandem. From a policy and practice perspective, the study provided recommendations on the interventions of focus to build a business case of the trade to ensure farmers' income increased. This could be achieved through continual farmer training and engagement with fisheries personnel in the counties; expansion of fish farming facility to at least 3 ponds of 300 square meters and establishment of suitable storage facilities such as temperature-controlled warehousing and logistics, all of which are imperative to the development of aquaculture sector.

Key words: *Sustainable aquaculture technologies, Multivariate Probit model, socioeconomic factors, fish production, fish marketing, Aquaculture Business Development Programme.*

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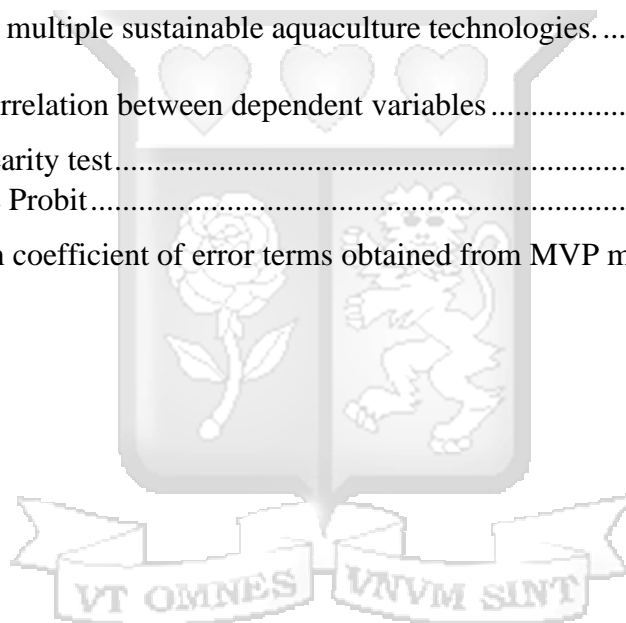
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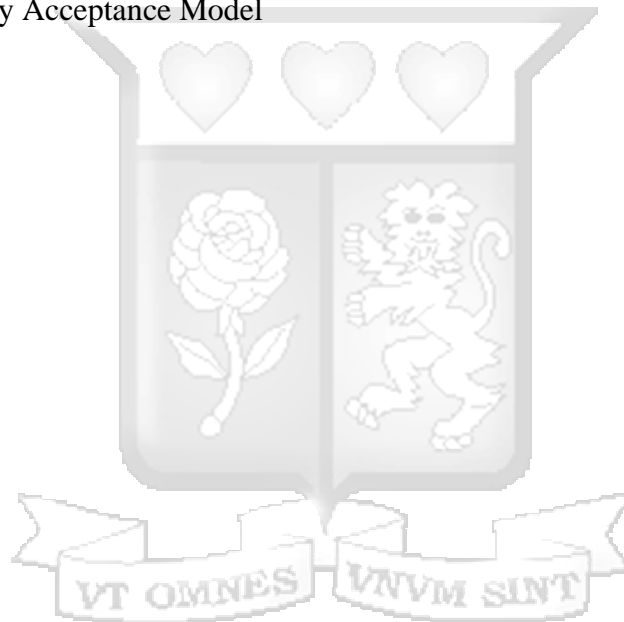
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ABBREVIATIONS AND ACRONYMS

ABDP	Aquaculture Business Development Programme
ATs	Sustainable Aquaculture Technologies
DOI	Diffusion of Innovation theory
ESP	Economic Stimulus Program
FAO	Food and Agriculture Organization of the United Nations
FFEPP	Fish Farming Enterprise Productivity Program
GIANT	Genetically Improved Abbassa Nile Tilapia
KNBS	Kenya National Bureau of Statistics
MVP	Multivariate Probit Model
TAM	Technology Acceptance Model



DEFINITION OF TERMS

Aquaculture Technologies	Intensification of technical capabilities in areas of aquaculture such as feeds, genetics, disease control, biosecurity, among other concerns (FAO, 2020).
Aquapark	Aggregation of several ponds or cages in one land mass (landscape aquapark) or sea (seascape aquapark) (Odende, et al., 2022).
Pond	Artificial body of water constructed for the purpose of rearing fish (Boateng, et al., 2022).
Cage	A system of rigid floating frames that confines fish in a mesh enclosure (Njiru, Aura, & Okechi, 2018).
Hormonal sex reversal	It is a technique where production of fish is based on monosex populations because mixed sex breeding diverts the goal from growth to reproduction thereby increasing the number of small fish being produced which ideally fetches low value in the market (Sarker et al., 2022).
Feed regime	Availing dietary supplies to fish either through artificial formulated feed or natural food organisms in the water that the fish are bred (Munguti, et al., 2021).
Selective breeding	Is an agriculture and animal husbandry method employed to enhance efficiency, quality, and long-term viability of a species by harnessing the genetic diversity found within a population's desirable traits (Abwao et al., 2023).
Smallholder fish farmers	Fish farmers with production capacity of less than 50 tons per year (FAO, 2020).



CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Aquaculture contributed 56% to the global production of aquatic animals (Food and Agriculture Organization of the United Nations (FAO), 2022). Additionally, aquaculture's share of the overall fish stock in Kenya amounts to 12.8% as reported by Kenya National Bureau of Statistics (KNBS) 2020. The consumption rate of aquatic animals surged to 3.0% between 1961 and 2019, significantly surpassing the global population growth rate of 1.6%. Regarding fish consumption, the global per capita consumption rose by 1.6%, escalating from 9 kg per capita in 1961 to 20.5 kg per capita in 2019. However, it experienced a decrease to 20.2 kg per capita in 2020 and further to 19.9 kg per capita in 2021. In terms of nutrition, aquatic animals account for 17% of the total animal proteins consumed, with 200 million people in Africa regularly consuming fish. Africa's contribution to the global fisheries and aquaculture production stands at only 7%, in contrast to Asian countries, which lead with 70%, followed by the Americas with 12%, Europe with 10%, and Oceania with 15%.

In Kenya, aquaculture has emerged from a minor role to being integrated into the national food system. As of 2020, the sub-sector contributed 0.7% to Kenya's GDP, according to KNBS (2022). This integration underscores its potential in enhancing food security by increasing fish consumption and generating income, particularly for groups such as women and youth. While various initiatives have been introduced to facilitate technological transfer across the aquaculture value chain, semi-intensive production reigns supreme. However, there is a growing interest in aquaculture development within the country, as evidenced by recent policies and initiatives within the blue economy sector (Obwanga et al., 2020; Munguti et al., 2021).

1.1.1 Adoption of aquaculture technologies

According to FAO (2020) sustainable Aquaculture Technologies (ATs) is defined as the intensification of technical capabilities in areas of aquaculture such as feeds, genetics, disease control, biosecurity, among other concerns while smallholder fish farmers refer to farmers operating in between 1-10-hectare piece of land or fish farmers with production capacity of less than 50 tons per year. This study focused on fish feed regime, hormonal sex reversal and selective breeding because as per the Kenya aquaculture sector report provided by Munguti et

al. (2021), hormonal sex reversal and selective breeding to improve the desirable traits in Nile tilapia and Catfish were the most common fish production technologies used in Kenya.

Abwao et al. (2023) define selective breeding as an agriculture and animal husbandry method employed to enhance efficiency, quality, and long-term viability of a species by harnessing the genetic diversity found within a population's desirable traits. The benefits of this method include increased growth rate, disease control, enhancement of growth and fish appearance, boosting heritability of desired traits and multiple trait balancing. The method has proven to be effective as compared to other genetic improvement methods like cross breeding, manipulation of chromosomes and hybridization.

Hormonal sex reversal is a technique where production of fish is based on monosex populations because mixed sex breeding diverts the goal from growth to reproduction thereby increasing the number of small fish being produced which ideally fetches low value in the market. This is usually done through administration of hormone via the diet that sexually undifferentiated fingerlings consume (Sarker et al., 2022). The choice of hormone depends on the desired direction of sex reversal and it is meant to control fish population, however its effectiveness varies across species. The method can be administered through immersion, feeding or random application.

As for feed regime, Ragasa et al. (2022) state that fish feed constitutes 60%-80% of the total cost of production and so a thorough analysis of the input would be value adding to the aquaculture community. Aquaculture feeding refers to the availing of dietary supplies to fish either through artificial formulated feed or natural food organisms in the water that the fish are bred. The need for fish feed intensified on the onset of Economic Stimulus Program (ESP) in Kenya where demand shot to an average of 100,000 metric tons of formulated feed per year and eventually dropped to 34000 metric tonnes as of 2021 (Munguti et al., 2021). The types of sustainable feeds include backyard formulated feeds, commercial feeds as well as imported feeds which can be compounded or pelleted.

Obiero et al. (2019) highlight the types of technologies available in Kenya which include but not limited to- hormonal sex reversal, supplementary feed, value addition techniques, commercial pelleted feeds, complete starter feeds, liner ponds, integrated aquaculture systems, on farm feed formulation, Recirculating Aquaculture Systems, bio floc, periphyton and aquaponics. Others include hapa nets, use of ovulation hormones, water monitoring using pH cards and turbidity discs. Aung et al. (2021) put forward that Integrated Aquaculture and

Agriculture together with Modified Pond Management Practices are the main ATs implemented among small- scale aquaculture farmers in Myanmar but worthy ATs for the stated group have not been established yet.

1.1.2 Drivers of adoption of aquaculture technologies

Socioeconomic factors have been identified as the drivers of the adoption of ATs in many studies. Obiero et al. (2019) identify the hurdles that limit participation in aquaculture to be lack of capital, lack of technical skill and practical knowledge, markets, and land ownership and since the latter is perennial, the only way out is investing in new ways of production to ensure social sustainability. In Myanmar as noted by Karim, Leemans, Akester, and Phillips (2020), aquaculture is conceived to be non-agricultural land use and by extension, construction of ponds at the expense of real agricultural practices is often frowned upon. Summarily, factor endowment is a challenge when it comes to adopting new technologies due to the huge investments required.

Onuche, Oladipo, Enize, and Daikwo (2020) established that the likelihood of perceiving aquaculture innovations positively was bolstered by education, extension contact, experience, gender and information source and on the other hand, distance to urban centre, primary education and age negatively influenced perceptions of aquafarmers. Overall, the drivers of adoption were identified to be gender, education and other income while negative adoption was associated with access to credit, age, information source and pond size. Boateng, Mtethiwa, and Agyakwah (2022) conjectured that age, gender, extension service membership to farmer based groups, knowledge of pond aquaculture and availability of suitable land were the positive influencers of adoption of pond aquaculture.

Government support, education achieved by farmers and insurance policy were identified by N'Souvi, Sun and Che (2021) as the major drivers of improved technologies while Mantey, Mburu and Chumo (2020) measured access to policy information, age, years of schooling, access to credit, price of harvested tilapia, extension service, distance from water source, membership to farmer groups, land size, cost of fingerlings and distance to fingerlings source. Duy, Trung, Lan, Berg and Da (2021) looked at social capital in terms of fisheries association, access to a wholesale agent, access to credit and household savings while Hu, Zhang, Reardon and Hernandez (2017) used annual income from non-farm activities, operated pond area, pond ownership, average year of ponds and land size under crop production. Farmer based groups was hypothesized by Joffre, Vries, Laurens and Poortvliet (2020) to influence the uptake of ATs in Vietnam and the study concluded that adoption of at least three technologies was

spurred by virtue of a farmer belonging to a farmer group, an inference supported by Boateng, Mtethiwa, and Agyakwah (2022).

In the same vein, Aung, Khor, Tran, Akester and Zeller (2021) inferred that the adoption of ATs in Myanmar is determined by the age of household head, existence of off-farm income, access to information from individual extension agents, access to point of sale, participation in farmer organizations and location. Fish production characteristics like the number of ponds, pond area and quantity of feed formulated were used to measure the effectiveness of government intervention on farmers' practices and income by Ragasa, Mensah and Amewu (2022). Total pond area as a proxy for pond size was hypothesized by Boateng et al. (2022) to influence the number of innovations that farmers take up while Awour et al. (2020) tested the influence of extension services on the likelihood of adoption of innovations. Mitra, Khan and Nielsen (2019) studied culture type (monoculture or polyculture) while Brugere, Padmakumar, Leschen and Tocher (2020) measured perception about aquafeed.

According to Obwanga et al. (2020), Kenya has seen several interventions in the recent past including but not limited to Kenya Market-Led Aquaculture Programme, Kenya Climate Smart Agriculture Project, Aquaculture Business Development Programme (ABDP) and currently the National Agricultural Value Chain Development Project which features the blue economy. ABDP is still ongoing, due for completion in 2026. The study measures ABDP as one of the independent variables to see how farmers are behaving in the wake of an intervention whose mandate is to provide subsidized inputs like feeds, hapa nets, predator nets pond liners and certified fingerlings, training on technologies and management practices, introduction of new production technologies like the aquapark concept and building market linkages. Interventions have been used as an explanatory variable in studies conducted by Amankwah, Quagraine and Preckel (2018); Ibrahim, Nasr-Allah and Karisa (2019) and Ragasa et al. (2022).

Summarily, against the backdrop provided, this study measured the influence of socioeconomic characteristics in terms of years of schooling of household head, age of household head, gender of household head, household size, distance from household to the main fish farm, household income and other household income. Fish production factors included fish income, need for credit, fish species, number of ponds, costly inputs, high initial cost and fingerling suppliers while membership to fish association group/cooperative, membership to fish marketing group, amount of crops sold in kilograms and high perishability made up the fish marketing measures. Lastly the study considered beneficiaries of ABDP under the ABDP predictor variable.

1.1.3 Aquaculture sector

WorldFish (2020) estimates the number of people depending on smallholder fish farming and fisheries to be 800 million globally. According to Karim et al. (2020), tremendous growth has been recorded in the aquaculture sector globally since fish is a cheap source of proteins for impoverished populations and a concerted effort to elevate this sector will enable countries achieve the Sustainable Development Goal of zero hunger by the year 2030. According to FAO, (2020), the multiplicity of production systems within aquaculture has fueled its growth given that it can be practiced under diverse environmental conditions.

Ulhaq, Pham, Le, Pham and Le (2022) note that shrimp production in Vietnam is a key exports earner having raked in \$3.35 Billion as of 2018. The share of shrimp farming to the total exports of Vietnamese seafood is estimated at 40%. This is a huge figure to warrant deliberate effort to improve production techniques and for that reason, there has been a transition to high tech bottom lined and canvas ponds from the traditional earthen ponds which according to reports, have 90% success rate and reduces the need to use chemical and microbiological drugs that could jeopardize their exports intents as far as content requirement in international trade is concerned.

Notable African governments encouraged aquaculture through interventions whereby; Egypt had large scale integrated aquaculture projects such as Commercial Tilapia Model which involved both the government and private sector players. Together with the Genetically Improved Abbassa Nile tilapia (GIANT) and Genetically Improved Farmed Tilapia (GIFT), initiatives, Egypt rose to become Africa's leading farmed fish producer with aquaculture accounting for 78.2% of the total fish stock (Hinrichsen et al., 2022). Nigeria implemented the National Accelerated Fish Production Programme adopted with a commercial catfish model which was market- led in which the federal government provided a 50% fishing input subsidy to bolster capture production, to name a few (Ragasa, Karisa, Rurangwa, Tran & Shikuku, 2022).

Similarly, Boateng et al. (2022) intimated that ponds account for only a small portion, specifically 7%, of the overall aquaculture production in Ghana, a phenomenon pervasively attributed to the low adoption given the total area utilized for fish farming. Nigeria has however recorded an improvement where pond farming contributes 18% to the total aquaculture production in a span of 50 years which still reflects a dismal trajectory given the huge capacity and potential the country has. This gap in performance can only be filled through extensive

investment in technologies and techniques pushed by official planners like the state government, local government, and autonomous entities like individuals but there must be a harmonization of macro-meso- micro agricultural framework to spur adoption of agricultural technologies (Kaleem & Sabi, 2021).

The Government of Kenya embarked on an intensive fish farming campaign under the ESP between 2009 and 2012 with an injection of approximately KES 5.7 billion and several programs have followed thereafter. These programs have created demand for aquaculture technologies to boost small-scale aquaculture productivity. The practice was piloted in 38 counties inclusive of the traditional non-fish-eating zones with a total of 69194 ponds constructed nationwide. Fast forward to current times, the number has risen to 146008 ponds and 33492 cages (KNBS, 2019). However, aquaculture production systems continue to be highly fragmented, and farmers end up establishing ponds in very small sizes of land which now makes technology an important factor of production in aquaculture (Munguti et al., 2021). It is for this reason that interventions have been implemented to boost smallholder production.

1.3 Statement of the problem

On average 20% of Africa faces hunger. According to Integrated Food Security Phase Classification (IPC) (2023) 5.4 million people in Kenya face acute food insecurity as of June 2023. Given the perennial structural deficit in the country's aquaculture production, per capita fish consumption has been oscillating. 6.0 kg per capita was the consumption rate in 2000 but dropped to 3.4 kg per capita in 2010. It rose to 5.0 kg per capita in 2015 and dipped again to 4.3 kg per capita in 2018 against the global average of 20.5kgs according to FAO (2018). This shows that demand is steadily increasing due to increased awareness of the benefits of fish and food security concerns in developing countries (Tran et al., 2019). This has exacerbated the need for imports with Kenya's fish imports standing at 21386 metric tons as of 2021 (Ministry of Agriculture, 2022).

Imports from EAC region and China have flooded the market and there is a likelihood that the supply deficit will increase into the future if significant volumes will not be realized by 2030, with the import increase projected to be 15.5% (FAO, 2020). This can be achieved through intensification of production systems from seed to feeds and management practices alike (Ragasa et al., 2022). van Duijn, van der Heijden, Bolman and Rurangwa (2018) report that semi-intensive fish production is practiced by close to 92% of farmers in Western and Central Kenya. Likewise, Obiero et al. (2019) presents that much as 80% of fish farmers agreed that

adoption of aquaculture technologies (commercial fish feeds, breeding and genetic techniques, value addition and post-harvest loss reduction techniques) have positive influence on income, consumption and wealth creation, only 30% of the farmers had fully adopted sustainable technologies.

Obiero et al. (2019) still notes that there has been low uptake of these technologies besides the fact that one could be attracting more users than the others. The study attributes low uptake to perceived gaps in best management practices and technical skills which this study sought to substantiate. Many studies have looked at the drivers of adoption of innovations in the aquaculture sector for instance, Boateng et al. (2022) and Orinda, Okuto and Abwao (2021) have studied adoption using variables like gender, age, extension service, household size and membership to farmer groups. However, little research has been done on mainstream technologies used such as hormonal sex reversal, selective breeding and feed regime. Therefore the study addressed the knowledge gap by assessing the nature of the uptake of the selected technologies by smallholder fish farmers in Lake Victoria basin region.

1.4 Research Objectives

1.4.1 General Objective

The main objective of the study was to establish the drivers of adoption of multiple sustainable aquaculture technologies among smallholder fish farmers in the Lake Victoria basin region in Kenya.

1.4.2 Specific Objectives

To address the general objective, the study attempted to answer the following specific objectives:

- i. To investigate the effect of socioeconomic factors on adoption of multiple sustainable aquaculture technologies.
- ii. To assess the influence of fish production on adoption of multiple sustainable aquaculture technologies.
- iii. To analyse the effect of fish marketing on adoption of multiple sustainable aquaculture technologies.
- iv. To examine the role of Aquaculture Business Development Programme on adoption of multiple sustainable aquaculture technologies.

1.5 Research Questions

The study answered the following questions:

- i. What is the effect of socioeconomic factors on adoption of multiple sustainable aquaculture technologies?
- ii. What is the influence of fish production on adoption of multiple sustainable aquaculture technologies?
- iii. What is the effect of fish marketing on adoption of multiple sustainable aquaculture technologies?
- iv. What is the role of Aquaculture Business Development Programme on adoption of multiple sustainable aquaculture technologies?

1.6 Scope of the study

The aim of this research was to establish the drivers of adoption of multiple sustainable aquaculture technologies among smallholder fish farmers in Busia, Homabay, Kisumu and Siaya counties of the Lake Victoria basin region. The conceptual scope of the research examined the influence of social economic factors, fish production, fish marketing and ABDP on adoption of ATs. The theoretical scope focused on the diffusion of innovation theory and technology acceptance model. The unit of analysis of this study was 725 smallholder fish farmers drawn from the sub counties of the respective counties, as the geographical scope, as determined in the sample distribution table 3.1. Time scope was limited to 6 months from September to February 2024.

1.7 Significance of the study

The empirical evidence of this study benefits the following stakeholders.

1.7.1 Fish farmers

This study provides the necessary information required to inform decision making among potential aquaculture farmers keen to eke a living from the practice.

1.7.2 Policy makers

The county fisheries department as the pioneers of these pro-poor innovations, will use this study to gauge the effectiveness and efficiency of various interventions meant to improve farmers' livelihood. This study also contributes to the debate on the best sustainable practices in aquaculture.

1.7.3 Academicians and researchers

This study adds to the knowledge of aquaculture technologies by providing critical findings as well as revealing potential areas of research in sustainable aquaculture.

1.8 Chapter summary

This chapter starts with the background on sustainable Aquaculture Technologies. In the first part, the chapter presents an overview of aquaculture. It also discusses its importance and challenges, the types of ATs, why they are adopted, and the variables used in the study. Next, the chapter outlines the research objectives and questions to emphasize the core business of the study and lastly it states the scope and the significance of the study.



CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the theories and empirical studies relevant to ATs. This study considers Diffusion of Innovation theory (DOI) and Technology Acceptance Model (TAM) as the ideal theories to use in the context of adoption of ATs. Empirical review highlights what was done before and what knowledge should be pursued while a conceptual framework has been incorporated to demonstrate the interconnection between variables which are operationalized at the end of the chapter.

2.2 Theoretical review

This study's theoretical structure is anchored upon Diffusion of Innovation theory and Technology Acceptance Model. DOI holds that the feature of an innovation conditions the responsiveness of end users to its eventual adoption, albeit the adoption rate is subsequently affected by characteristics of social systems, channels of communication, the role of communicators and awareness activities. Concisely, the longevity of an innovation is pegged upon collaboration in the social domain rather than its design, superiority, or technical features (Sartipi, 2020). TAM is of the premise that the use of technology is based on an individual's attitude and internal beliefs (Turner, Kitchenham, Breerton, Charters & Budgen, 2010).

2.2.1 Technology Acceptance Model

The model was developed by Fred Davis in 1989 who established that the most important determinants of technology acceptance are perceived usefulness and perceived ease of use, in that, there is a significant correlation with current, future usage, self-predicted future usage and the usage behavior. The main reason why people accept or reject an innovation can be explained by the perceived usefulness and perceived ease of use and contextually, people will adopt or fail to adopt sustainable aquaculture technologies because they believe it will improve their production outcomes since players in the agribusiness space are out to make profit and basically if there is a positive adoption- revenue correlation then the adopters will perceive the model to be useful. On the other hand, a farmer will adopt ATs if he supposes that less effort will be required to use it (Davis, 1989).

Several studies have delved into the diverse points of view with regards to TAM in various fields such as mobile learning, mobile banking, mobile instant messaging systems, among

others. This study investigates TAM regarding adoption of ATs with the pain point being, perceived satisfaction and perceived efficiency that determine adoption. Findings and conclusions of numerous studies such as Granić and Marangunić (2019) point to the fact that perceived usefulness overrides perceived ease of use as the significant determinant of technology acceptance in the education domain. A study by Ulhaq et al. (2022) employed TAM in the methodology and it established that perceived usefulness is important in determining adoption of Information and Communications Technology among farmers.

In the same vein, Sagnier, Escande, Lourdeaux, Thouvenin and Valléry (2020) linked TAM with the acceptance of virtual reality where an interactive three-dimensional environment is simulated that users can be engaged and interact. The study found out that perceived usefulness overrides the willingness to use virtual reality as opposed to cyber sickness as hypothesized by some authors whilst the correlation with perceived ease of use was significantly low. TAM model has been criticized by Turner et al. (2010) who set out to evaluate if TAM predicts actual use. The study found out that only behavioral intention to use had a higher likelihood of correlation as far as actual usage is concerned while perceived usefulness and perceived ease of use had a low likelihood of correlation with actual usage and for that reason, the study raises a caveat on the use of the model in a field within which it has not been verified. Practically, the assumption is that fish farmers will adopt technologies if conditions are favorable to them. For instance, if they perceive the cost to be affordable, perceive that the technologies are useful hence important in aquaculture and that the technologies are easy to use.

2.2.2 Diffusion of Innovation theory

The theory was familiarized by Everett Rogers in 1965. Diffusion is described as the spread of information about an innovation among people. This phenomenon follows a social process and goes on for some time until technology proliferates far and wide. The theory goes further to identify the features of an innovation which are precursors to its adoption, even so, contrary to the social nature of the theory, do not consider the input of social factors in the diffusion chain. These features include compatibility, complexity, relative advantage, observability and trialability. Furthermore, the theory categorizes adopters into innovators, early adopters, early majority, late majority, and laggards (Min, So & Jeong, 2019; Sartipi, 2020).

With reference to ATs, according to the theory, the initiator of innovation needs to understand the social issues its potential customers grapple with together with their personalities. Sartipi (2020) mention that in England, agricultural knowledge and technologies were trickled down to farmers through extension officers who organized farmers' meetings because the reason

behind lack of adoption was that farmers were just uninformed and therefore according to the theory, knowledge levels influence decision making in technology adoption. So, this study measured the level of education proxied by the years of schooling and the existence of an intervention where farmers are trained, to test the assumption that knowledge levels affect the adoption of ATs. The shortcomings of the theory as pointed out by Rogers himself include pro innovation bias which explains that although it is an advantage for end users to take up innovation, it should be in tandem with the context.

Secondly, individual blame bias is placed on the farmers and by extension, the providers of extension services for poor knowledge transfer. Thirdly, the equality issue has been highlighted where the innovation is adopted in a particular region while leaving others in the dark. Additionally, some adopters may not hark back to when they familiarized themselves with an innovation and this affects the comprehension of the diffusion curve since the timelines are not known. George Moore censured the theory by stating that the adoption curve is perpetual for technologies that fizzle fast after a short appearance in the market (Cook, Satizábal & Curnow, 2021; Min et al., 2019; Sartipi, 2020). In connection with the theory, the study shedded light on how farmers get to learn these technologies, the number of times and the nature of those information channels, both infomal and formal.

2.3 Empirical Review

The empirical review of this study mirrored various studies conducted on ATs, relevant variables used, and methodologies applied. In addition, conclusions and recommendations in the studies provided direction for this research.

2.3.1 Socioeconomic factors and adoption of aquaculture technologies.

Hu et al. (2017) used gender of household head, household size, education level, hours to nearest big city to measure aquaculture innovation uptake using Ordinary Least Squares method and the study showed that the household head being male had significant positive influence on adoption of modern input without feed. Additionally, hours to nearest big city had significant negative influence on adoption of modern inputs with or without feeds and adoption of commercial feeds while education level did not pose significant influence. In most social settings, men own and control factors of production and most crictically capital which is required to take up modern technologies. N'souvi et al. (2021) applied the logit model to measure the influence of education, household size, age and experience and the findings revealed that education significantly affected adoption of ATs. This study included education proxied by the years of schooling as one of the variables to check these findings.

Boateng et al. (2022) used two stage Heckman regression model to evaluate adoption and disadoption of pond aquaculture. The farmer being male significantly affected the decision to adopt or disadopt pond farming in that the likelihood was high if the farmer is male. Also, the older the farmer, the higher the chances of adopting pond aquaculture, explained by the fact that high capital is required to start and run the enterprise. Education had a significant positive influence on disadoption meaning that the more the farmer was educated, the less likelihood of abandoning the trade. Education is believed to increase farmers' risk tolerance, access to resources and involvement in policy advocacy. Aung et al. (2021) found the age of the farmer to negatively influence the decision to adopt ATs, significantly implying that the older the farmer, the more likely it is that he will maintain status quo in production. Younger people are believed to have higher affinity for technology to drive efficiency and would take up anything that makes life easier.

Boateng et al. (2022) fronted a contradictory finding on age whereby the older the farmer the more the likelihood of adoption. This could be explained by the level of experience, financial muscle and knowledge level which accelerates with time. Also the household size showed a positive correlation as well as frequency of extension visits, membership of farmer groups, availability of land, water supply, knowledge of pond aquaculture and the farmer being male. Onuche et al. (2020) concluded that off farm income has a positive influence on adoption ;an opposing view from what Aung et al. (2021) posted whereby access to off farm income had a significant negative influence on adoption of ATs, as well as fish productivity.

Amankwah et al. (2018) shared the same sentiments by establishing a negative influence of off farm income on adoption decisions with low influence though. The study hypothesised that household income, off farm income as well as fish income influenced adoption of ATs with the assumption that when farmers have extra source of income, they are motivated to channel a portion of it towards fish production as argued by Ngoc et al. (2021). Against this backdrop, this research focused on the age of farmer, household size, gender, education level, household income other household income to build a consensus on the conflicting findings.

2.3.2 Fish production and adoption of aquaculture technologies.

Mitra et al. (2019) conducted a study on the effect of credit constraints on aquaculture productivity using endogenous switching regression model and the study established that factors of production such as fingerlings, water cleaning measures and modern inputs like feeds, positively influenced productivity. The study further explained that feed had the highest output elasticity and the effect is higher among farmers who had access to credit. Duy et al.

(2021) concurred with these findings by posting that financial capital is important among shrimp farmers in Vietnam's Mekong Delta. Using logistic regression model, the study revealed that household capital had 1% positive statistical significance on boosting the profits of farmers. Also, access to loan had a positive influence on profit.

Mantey et al. (2020) also posted similar findings by affirming that access to credit showed positive correlation with adoption of cage aquaculture, same as N'souvi et al. (2021) who measured the influence of insurance policy and found that it significantly affects the decision to adopt ATs positively, in that, an insurance policy increased the probability of a farmer adopting ATs by 34.5%. However Onuche et al. (2020) brought a different view from Nigeria, using Heckman Probit sample selection model. The study established that access to credit reduced the chances of adopting aquaculture technologies. The argument that credit can be diverted to other spheres of life like paying school fees, consumption, funding other business ventures and other miscellaneous undertakings was shaky in some context for instance in Vietnam; Duy et al. (2021) presented a positive influence of credit access on shrimp productivity. This showed that there is no consensus out there yet and this study sought to find out more on that.

Mantey et al. (2020) looked at the cost of fingerlings and distance to fingerling source which represents fingerling supply and the study disclosed that distance to fingerlings significantly increased the likelihood of adoption and reduced the likelihood of disadoption. The cost of fingerlings negatively correlated with cage disadoption indicating that the higher the cost, the more the farmer was likely to disadopt. In support of this, Mitra et al. (2019) posted that fingerlings significantly influenced productivity of both credit constrained and credit unconstrained farmers. Fingerlings, a crucial input, incur higher costs upon purchase. The cost also involves the trade-off between monosex and mixed sex fingerlings, potentially leading farmers to inadvertently invest in the wrong technology. This underscores the significance of fingerling suppliers as key contributors to the ecosystem. However, existing studies lack thorough exploration of their reliability and trustworthiness.

Obiero et al. (2019) gave an approach from a descriptive point of view by pointing out that the most common species reared were tilapia followed by a meagre percentage breeding catfish. Githukia et al. (2020) also intimated that 96% of the farmers reared tilapia fish while only 38% reared African catfish. Moreover, Agbekpomu, Yeboah, Oyih and Agyakwah (2019) exhibited the same approach by presenting that 64.9% of the farmers practiced monoculture of tilapia

while only 20.5% practiced polyculture of tilapia and African catfish. Clearly these studies took a deep dive into the culture system but did not establish the influence of cultured species on adoption decisions, statistically. A study by Aung et al. (2021) established that polyculture system had a positive significant influence on technical efficiency of small scale farmers. Overall, few studies used fish species variable to measure its influence on adoption of ATs, a goal that this research aimed to accomplish.

Githukia et al. (2020) reported annual income from fish farming but did not measure its influence on gender roles while Obiero et al. (2019) noted that although technologies are good, only few translate to increased profit margins. Among the profit enhancers were hormonal sex reversal, value addition techniques and complete manufactured feeds. In a similar script, N'Souvi et al. (2021) submitted that polyculture of prawn-crabs was a profitable venture which increased farmers' income significantly in Indonesia. That being said, the studies reviewed spoke from an impact angle but did not tell us what informed farmers' decision to adopt polyculture or all the other technologies mentioned before.

Obiero et al. (2019) measured the influence of farm size on adoption of ATs and observed a significant positive effect on adoption. Further, Joffre et al. (2020) studied the adoption of ATs among clustered shrimp farmers in Vitenam using hierarchical regression analyses and the study established that the number of ponds had significant positive effect on adoption of water quality management and practices, feed input practices and disease control practices. However, farm size was negatively correlated with adoption of the three practices. This study delved deeper into specific variables, namely; fish income, the demand for credit, fish species, the number of ponds, costly inputs, high initial capital, and fingerlings suppliers. The aim was to address and bridge existing knowledge gaps in these areas.

2.3.3 Fish marketing and adoption of aquaculture technologies.

Boateng et al. (2022) measured the influence of farmer group and results indicated a positive correlation with adoption of pond aquaculture. Further, from a marginal analysis perspective, one extra farmer joining a farmer group increased the likelihood of adoption by 13%. Likewise, Aung et al. (2021) recorded a positive significant influence of membership to farmer organizations on the use of ATs. Nevertheless, N'souvi et al. (2021) report that farmer membership to cooperatives reduced ATs adoption and profitability of prawn-crab farming. On the other hand, Duy et al. (2021) provided an alternative viewpoint by examining social capital through the lens of fisheries associations, unions and informal networks such as

wholesale agents. Results revealed that wholesale agents and fisheries association had a significant influence on shrimp production, with unions also showing a positive influence.

Ankrah et al. (2021) shed light on the influence of cooperative membership on farmer income and the results showed that there was a 28.54% and 34.75% increase in household and farm income respectively which was still a marginal analysis of the same variable. Joffre et al. (2020) deviates from the examined studies in its treatment of the clusters concept where farmers established groups to regulate interactions with various value chain actors, including input suppliers. The research revealed that shrimp farmers affiliated with cluster groups were more inclined to adopt new technologies. This finding aligned with the perspective of Kumar, Engle and Tucker (2018) who posited that the dissemination of knowledge was more effective in smaller groups of individuals sharing similar socioeconomic characteristics.

Onuche et al. (2020) checked the influence of distance to urban centre on perception and uptake of ATs and the study found a negative relationship meaning as distance increased, access to markets was difficult and perishable goods become bad in the process. In the same vein, Hu et al. (2017) measured hours to the nearest big city using Ordinary Least Squares estimations and reported a significant negative correlation between hours and adoption of modern intensification practices showing that farmers closer to big cities were highly likely to adopt ATs and finally, Boateng et al. (2022) found that the likelihood of disadopting pond aquaculture increased with a one kilometre increase in distance. Very few farmers own cold chain facilities apart from those who are close to government-owned fish landing sites and so when farmers travel long distances to get better prices for their produce, quality and sellability depreciates as time goes. On the whole, these studies looked at the cause rather than the problem of perishability as a barrier to technology adoption for improved fish productivity.

The price per kilogram of harvested tilapia reduced the likelihood of abandoning cage aquaculture according to Mantey et al. (2020) posing a significance level of 5% , however, the literature did not look at other activities that could affect the business. Hu et al. (2017) submitted that total area under crops in acres positively influenced the uptake of modern inputs with feeds, commercial feeds and modern inputs without feeds. These findings were also supported by Ngoc et al. (2021) who put forward that crop production has a positive significant influence on adoption of improved shrimp aquaculture practices. In contrast, Amankwah et al. (2018) reported that cattle had a negative influence on adoption of improved feed and farmland on the other hand had positive influence on adoption, though not significant. Changing the

pivot to volume sold rather than the acreage under production or the activity itself was the focus of this study, which assumably determined if farmers would still use the technologies even when the amount of crops sold in the market would increase. Therefore this study measured the influence of cooperative membership, marketing group membership, high perishability constraint and amount of crops sold to analyze the marketing situation and its influence on adoption decisions.

2.3.4 Aquaculture Business Development Programme and adoption of aquaculture technologies

Amankwah et al. (2018) studied the impact of aquaculture feed technology on fish income in Kenya using Propensity Score Matching techniques. Government subsidized feed was one of the variables studied given that the government was implementing the Fish Farming Enterprise Productivity Program (FFEPP) under the ESP, and the study established a significant (1%) positive influence of subsidized feed on adoption of improved feed technology. Ragasa et al. (2022) posted similar findings from the farmers surveyed under the Ghana Aquaculture for Food and Jobs program where the model of delivery was through training, subsidized feeds among others. The study looked at the effect of feed formulation training on farmers' feed use and fish income using Analysis of Variance and Difference in Difference models and results reported improved levels of knowledge on feed formulation, feeding and management practices as well as income.

Comparably, Ibrahim et al. (2019) reviewed the impact of Genetically Improved Abbassa Nile tilapia (GIANT), a selective breeding program introduced in Egypt's Abbassa area by WorldFish, and the study observed that the use of GIANT strain recorded lower feed conversation rate and higher yields and generally, farmers who adopted the new strain reported more sales and higher profits than their counterparts who farmed commercial strains. Albeit the results were not uniform for all the governorates in the area, which clearly shows the skewness in effectiveness of donor projects where some regions derive more benefits than others or better yet, some farmers pick up too well than other farmers in the same neighborhood. Likewise, Mantey et al. (2020) reported that when farmers access policy information in aquaculture, the probability of adopting cage tilapia increased by 38.7% with a 1% positive significance.

N'Souvi et al. (2021) using the Logit model, also noted that the probability of prawn crab farmers to adopt ATs increased by 28% in the wake of government support, which exhibited a positive significant influence. However, the two studies did not narrow down to the specific

interventions that the government may have put in place to avoid generalization risk in instances where some government or donor-led programs do not bear much fruit as evidenced in the study conducted by Parrao et al. (2021). The study undertook a meta-analysis of 21 studies looking at the effect of 13 aquaculture interventions on nutrition, income, women empowerment and productivity in low- and middle-income countries. Using standard methodologies, the study established that the interventions led to only a marginal increase in income, productivity, and consumption. It also reported that 12 of the impact studies were highly biased. This study therefore considered measuring ABDP as a variable, keen to examine its influence on the household's technical capability regarding fish production.

2.4 Summary of literature and research gaps

Many studies on adoption of ATs have been conducted, however, the focus on multiple technologies was limited. The reviewed research showed the importance of intensification of aquaculture production systems and where policy makers need to focus when implementing new innovations in society. A few gaps were identified. Aung et al. (2021) reported a contradictory finding on age of farmer, Onuche et al. (2020) and Ragasa et al. (2022) posted conflicting finding from a different geographical context, Amankwah et al. (2018), Agbekpornu et al. (2019) and N'souvi et al. (2021) applied different techniques to measure variables and lastly, Boateng et al. (2020), Mitra et al. (2019) and Duy et al. (2021) narrowed down to the specific concepts that this study analyzed in totality. The gaps were summarized in Table 2.1.



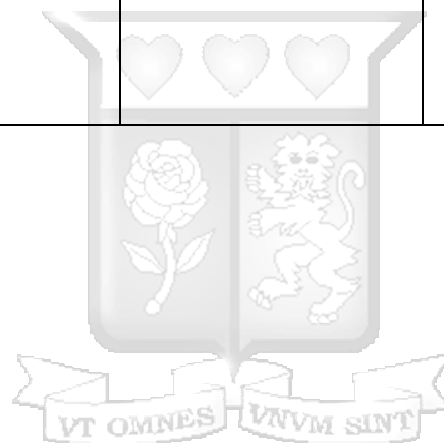
Table 2.1 Summary of Literature and Research Gap(s)

Authors	Study objective	Methodology used	Findings	Research gap	Type of gap	How the study has filled the gap
Aung, Khor, Tran, Akester and Zeller (2021)	The impact of sustainable aquaculture technologies on the welfare of small-scale fish farming households in Myanmar	Endogenous Switching Regression	Age of household head negatively influenced adoption	The study contradicted other studies that measured the same variable	Conceptual	This study checked the findings.
Onuche, Oladipo, Enize and Daikwo (2020)	Perception and uptake of aquaculture technologies in Kogi state, central Nigeria	Heckman Probit model.	The likelihood of farmers adopting aquaculture innovation increased by 0.017% when farmers had other income	The study was done in a different geographical setting and found conflicting results from those done in Kenya	Contextual	This study was based in Kenya
Amankwah, Quagraine and Preckel (2018)	Impact of aquaculture feed technology on fish income and poverty in Kenya	Propensity Score Matching technique: Probit and logit	Off farm income negatively influenced adoption of improved feed	The study gave a contradictory finding on the said variable	Methodological	This study used different technique to test the variable.
Mitra, Khan and Nielsen (2019)	Credit constraints and aquaculture productivity	Endogenous Switching Regression model	Feed had the highest output elasticity and the effect was higher among farmers who had access to credit	The study focused on the productivity of credit unconstrained farmers	Conceptual	This study measured the influence of credit access on adoption of ATs on all farmers.
Duy, Trung, Lan, Berg and Da (2021)	Assessment of the impacts of social capital on the profit	Logistic regression model	Financial capital and access to loan had a	The study did not consider farmers' views regarding	Conceptual	This research looked at the barriers of high initial cost and costly inputs and

	of shrimp farming production in the Mekong Delta, Vietnam		positive influence on profit	financial implications of fish production.		their influence on adoption of ATs
Agbekpomu, Yeboah, Oyih and Agyakwa (2019)	Characteristics and structure of freshwater fish farmers in Ghana: A socio-economic analysis	Descriptive, Student t-test	64.9% of the farmers practiced monoculture of tilapia while only 20.5% practiced polyculture of tilapia and African catfish	The study presented descriptive statistics only, did not measure the influence of culture species on adoption decisions	Methodological	This study measured the influence of culture species on adoption of ATs using Multivariate Probit model
N'souvi, Sun and Che (2021)	Aquaculture technology adoption and profitability of the polyculture system practiced by prawn and crab farmers: A case study of Anhui province in China	Logit model	Farmer membership to cooperatives reduced ATs adoption and profitability of prawn and crab farming	The study posted a contradictory finding from other studies.	Methodological	This study used Multivariate Probit model.
Boateng, Mtethiwa and Agyakwa (2022)	Drivers of pond aquaculture adoption and disadoption; the case of Ghana	Heckprobit model	The likelihood of disadoption of pond aquaculture increased with a one kilometre increase in distance	The study measured the cause rather than the problem which was perishability as a barrier to fish production	Conceptual	This study measured the effect of high perishability of fish on adoption of ATs.
Ragasa, Mensah and Amewu (2022)	Impact of fish feed formulation training on feed use and farmers' income: Evidence from Ghana	Difference-In-Difference estimation Analysis of Variance	Government support in form of training, increased farmers' knowledge level on feed use, management	The study was based in Ghana	Contextual	This study looked at the effectiveness of ABDP intervention in Kenya.

			practices as well as income			
Parrao et al. (2021)	Aquaculture for improving productivity, income, nutrition and women's empowerment in low- and middle-income countries: A systematic review and meta-analysis	Standard methodological procedures	Government interventions led to a small increase in production, income, and consumption.	This study generalized findings of both low-income and middle-income countries.	Contextual	The study looked at the effectiveness ABDP intervention in Kenya

Source: Author (2024)



2.5 Conceptual framework

Adom, Hussein and Agyem (2018) described conceptual framework as a researcher's own understanding of the progression of a situation being studied, represented in a diagram. Basically, it is a plan of how the research problem will be solved by linking the main concepts of the study. The dependent variables were sustainable aquaculture technologies which were analyzed from socioeconomic factors, fish production, fish marketing factors and intervention points of view (Figure 2.1).

Independent variables

Socioeconomic factors

- Years of schooling of household head
- Age of household head
- Gender of household head
- Household size
- Distance from household to the main fish farm
- Household income
- Other household income

Fish Production

- Fish income
- Need for credit.
- Fish species
- Number of ponds
- Costly inputs
- High initial cost
- Fingerling suppliers

Fish Marketing

- Fish association group/cooperative
- Fish marketing group
- Amount of crops sold in kilograms.
- High perishability

Aquaculture Business Development Programme

- Beneficiary of ABDP

Dependent variables

Sustainable aquaculture technologies

- Hormonal sex reversal
- Selective breeding
- Feed regime

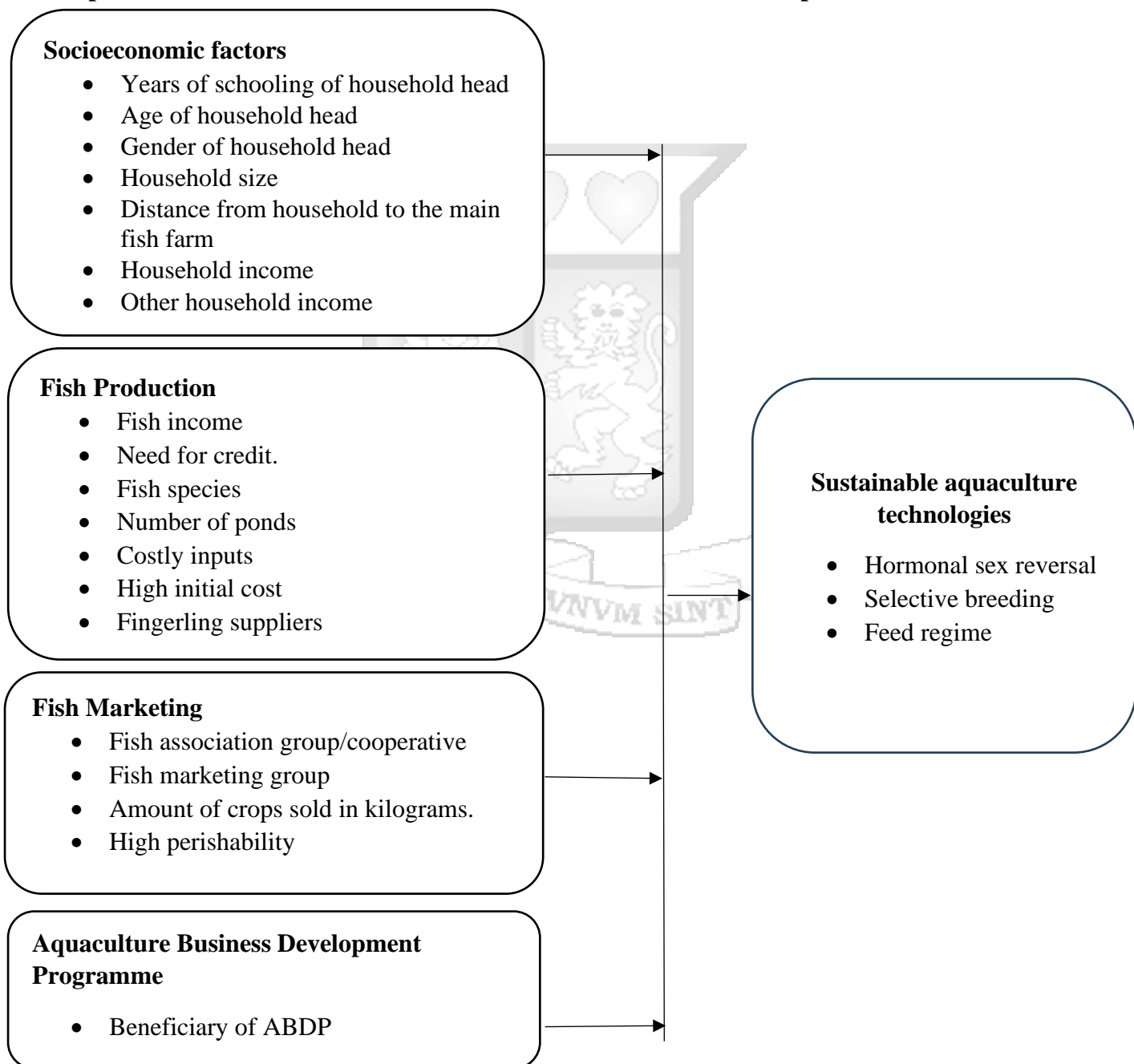


Figure 2.1: Conceptual framework depicting linkages between dependent and independent variables. Source: Author (2024)

2.5.1 Operationalization of the Variables

The measurement of the variables is depicted in table 2.2.

Table 2.2 Operationalization of the Variables

Variable	Specific variable name	Type of variable	Measurement	Literature source	Data source	Theory supported
Dependent variable						
Sustainable aquaculture technologies	Hormonal sex reversal	Binary	1=Yes 0=Otherwise	Sarker et al. (2022)	Information from farmers	Diffusion of Innovation Theory
	Selective breeding	Binary	1=Yes 0=Otherwise	Abwao et al. (2023)	Information from farmers	Diffusion of Innovation Theory
	Feed regime	Binary	1=Yes 0=Otherwise	Ragasa, Mensah and Amewu (2022)	Information from farmers	Diffusion of Innovation Theory
Independent (test) variables						
Socio economic factors	Years of schooling of household head	Continuous	Number of years	Boateng et al. (2022)	Information from farmers	Technology Acceptance Model
	Age of household head	Continuous	Number of years	Boateng et al. (2022)	Information from farmers	Technology Acceptance Model
	Gender of household head	Binary	1= Male 0= Female	Githukia et al. (2020)	Information from farmers	Technology Acceptance Model
	Household size	Continuous	Number of people in the household	Onuche et al. (2020)	Information from farmers	Technology Acceptance Model
	Distance from the household to the main fish farm	Continuous	Distance in kilometres	Aung et al. (2021)	Information from farmers	Technology Acceptance Model
	Household income	Continuous	Income in KES	Agbekpomu, et al. (2019)	Information from farmers	Technology Acceptance Model

Variable	Specific variable name	Type of variable	Measurement	Literature source	Data source	Theory supported
	Other household income	Continuous	Income in KES	Onuche et al. (2020)	Information from farmers	Technology Acceptance Model
Fish production	Fish income	Continuous	Income in KES	Githukia et al. (2020)	Information from farmers	Technology Acceptance Model
	Need for credit	Binary	1=Yes 1=Otherwise	Mitra et al. (2019)	Information from farmers	Diffusion of innovation Theory
	Fish species	Binary	1=Tilapia 0=Otherwise	Ssekyanzi et al. (2022)	Information from farmers	Diffusion of Innovation Theory
	Number of ponds	Continuous	Number of ponds	Ssekyanzi et al. (2022)	Information from farmers	Technology Acceptance Model
	Costly inputs	Binary	1= If inputs are costly 1=Otherwise	Agbekporu, et al. (2019)	Information from farmers	Technology Acceptance Model
	High initial cost	Binary	1= If initial capital is high 1=Otherwise	Ssekyanzi et al. (2022)	Information from farmers	Technology Acceptance Model
	Fingerling suppliers	Binary	1 =If farmers know reliable fingerling suppliers 0= Otherwise	Duy et al. (2021)	Information from farmers	Diffusion of Innovation Theory
Fish marketing	Fish association group/cooperative	Binary	1=If farmer belongs to a fish association group/cooperative 0=Otherwise	Boateng et al. (2022)	Information from farmers	Diffusion of Innovation Theory

Variable	Specific variable name	Type of variable	Measurement	Literature source	Data source	Theory supported
	Fish marketing group	Binary	1=If farmer belongs to a fish marketing group 0=Otherwise	Boateng et al. (2022)	Information from farmers	Diffusion of Innovation Theory
	Amount of crops sold in kgs	Continuous	Amount in kilograms	Aung et al. (2021)	Information from farmers	Technology Acceptance Model
	High perishability	Binary	1=If product is highly perishable 0=Otherwise	Aung et al. (2021)	Information from farmers	Technology Acceptance Model
ABDP	Beneficiary of ABDP	Binary	1=If farmer is a beneficiary of ABDP 0=Otherwise	Amankwah et al. (2018)	Information from farmers	Technology Acceptance Model

Source: Author (2024)

2.6 Chapter Summary

Chapter two provided context to the research by reviewing literature and establishing relevant connections with the Diffusion of Innovation theory and the Technology Acceptance Model. Various authors' findings on the adoption of aquaculture technologies have been examined, and gaps in the existing research identified.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter starts by explaining the research philosophy, design, population, sampling, data collection and analysis along with discussions on research quality, validity, and reliability. Lastly, the chapter highlights the ethical considerations.

3.2 Research Philosophy

According to Saunders, Lewis and Thornhill (2009) research philosophy refers to system of assumptions about knowledge development which shapes researcher's understanding of research questions strategy, data collection and interpretation techniques. This study was anchored on the positivism philosophy which is a philosophical objective stand of a typical scientist and incorporates working with observable social reality to produce law-like generalizations. The researcher's role is to produce causal explanations and prediction. The research progressed through developed, tested questions that contribute to development of theory through a deductive approach. The study was based on broad based data collection and quantification of data gathered from smallholder fish farmers.

3.3 Research Design

The research employed analytical cross-sectional research design, involving the collection of data at a single point in time. According to Saunders et al. (2009), cross-sectional design aims to investigate a specific phenomenon at a particular moment, typically chosen when the study is constrained by time, as is often the case in academic research.

3.4 Population and Sampling

3.4.1 Target Population

Saunders et al. (2009) describe population as the full set of cases from which a sample is taken. The study targeted smallholder aquaculture farmers in counties where the Aquaculture Business Development Programme is being implemented, that is, Migori, Kakamega, Homa Bay, Nyeri, Meru, Kirinyaga, Tharaka Nithi, Kisii, Kisumu, Siaya, Busia, Embu, Kiambu, Machakos and Kajiado. The smallholder aquaculture development component targeted 35000 beneficiaries. The research concentrated on Busia, Homabay, Kisumu, and Siaya due to their status as traditional aquaculture-practicing counties and their adjacency to Lake Victoria. As per ABDP (2022), these four counties collectively host around 5,332 fish farmers.

3.4.2 Sampling procedure

The research utilized multistage sampling due to the extensive geographical coverage and diverse sampling frames. In the large population of 5,332 farmers engaged in fish farming, the sample was stratified into counties. Following this, random sampling was employed, ensuring that each individual had an equal probability of being selected. This probability is calculated using the formula.

$$P (\text{Selecting sample}) = n/N \text{ where } n \text{ is the sample size and } N \text{ is the total population}$$

$$\text{Consequently, } P (\text{Selecting sample}) = 725/5332 = 0.099 \text{ or } 9.9\%$$

Respondents in each sub county were randomly selected. Saunders et al. (2009) advance that stratified random sampling enables the researcher to group the population into homogenous subgroups that show similar characteristics and every individual stands a chance of being selected.

3.4.3 Sample size determination

The respondents of the survey were smallholder fish farmers in Busia, Homabay, Kisumu and Siaya counties. The sample size was derived using Andrew Fisher’s formular, assuming a 95% confidence level, Z-score=1.96

$$n = \frac{Z^2 * p (1-p)}{e^2}$$

Where n is the sample size, p is the population proportion which is 725/5332=14% (0.14) and e is the margin of error set at 2.525%. Mohr, Wilson and Freund (2021) explain that with a bigger sample size and a constant confidence coefficient, the maximum error of estimation decreases meaning that with a bigger sample size, the level of precision increases without losing confidence. N’Souvi et al. (2021) used an error limit of 10%. Therefore, the sample size is:

$$n = 1.96^2 * 0.14(1 - 0.14) / (0.02525)^2 = 725 \text{ smallholder fish farmers}$$

The sample size was distributed as follows.

Table 3.1: Sample size and data collection breakdown

Value	Frequency	Percentage
Siaya	182	25.1
Busia	182	25.1
Kisumu	180	24.83
Homabay	180	24.83
Total	724	99.86

Source: Study data (2024)

3.5 Data collection Methods

The study collected primary data by use of structured questionnaires designed based on the conceptual framework. Kothari (2004) argues that questionnaires are a dominant instrument for data collection in social sciences because they are easy to administer. Questionnaires were administered through Kobo Collect, by enumerators who were trained in data collection methodology.

The questionnaire collected data on respondent identification and household characteristics, fish production and marketing, pond production and output, crop production, knowledge, attitude/perceptions, sustainable aquaculture technologies, fish production and marketing constraints and social capital and networking. The researcher approached the County Directorate of Fisheries in the respective counties to request permission to conduct the study.

3.6 Data Analysis

Multivariate Probit model (MVP) was used to fulfil the research aims. The model acknowledges interconnections among error terms in the adoption equations and simultaneously estimate a trio of binary probit models making it more effective compared to the univariate model which examines each aquaculture technology separately (Ndiritu, 2021).

For cases involving choices among multiple alternatives, the MVP model is presented through two equations. The first one encompasses a system of equations where latent dependent variables are described by a linear combination of observable attributes associated with households (h) and ponds (p). Also, (ε_{hp}) a multivariate normally distributed stochastic component is accounted for.

$$T_{hpk} = X_h \beta_k + \varepsilon_{hp} \quad (k= S, H, F)$$

Where

T_{hpk} - adoption of k th ATs by the h th household on pond p

S denotes Selective Breeding

H -Hormonal sex reversal

F - Feed regime

The second set of equations follow that the household choice of ATs is dichotomous in nature and is given as

$$T_{hpk} = \begin{cases} 1 & \text{if } T_{hpk} > 0 \\ 0 & \text{otherwise} \end{cases}$$

T =denotes the dependent variables represented by the level of probable utility derived from adoption of aquaculture technologies

Multivariate Probit model allows for correlations between choices for the three sustainable technologies. It explains the relationship between independent variables and binary dependent variables (Ndiritu et al., 2014).

The organization and coding of data was done using Kobo Toolbox. Stata/SE 15.0 software was used for analysis of both descriptive and inferential statistics. MVP analysed interdependence of variables as well as the relationship between independent and dependent variables.

3.7 Research Quality

Saunders et al. (2009) describe research quality as the degree to which data collection and analysis methods will yield the same results in other occasions. Research quality was measured in terms of validity and reliability of the research instrument.

3.7.1 Validity of the Research Instrument

According to Saunders et al. (2009) validity examines if the relationship between two variables is causal with regards to inferences being based on actual results. The study checked for content validity which is the extent to which the survey tool provides adequate coverage of the questions. Content validity was achieved by a pretest of the questionnaire on fish farmers in selected wards across the counties and the feedback endured relevance of the questions. Internal validity looks at the measuring power of the instrument with regards to what the researcher plans to study. Internal validity was achieved by including all the questions that could measure the intended variables of the study.

3.7.2 Reliability of the Research Instrument

Research reliability is the degree to which research instrument produces consistent results time and again (Saunders et al., 2009). Reliability was measured using Cronbach's alpha coefficient which is a reliability coefficient that gives unbiased estimate of data generalizability. Internal consistency and reliability are deemed high when the alpha coefficient is close to 0.70 implying that the data would be generalized to mirror all responses within the target population and therefore the questionnaire was deployed after obtaining an alpha coefficient of 0.8411.

Table 3.2 Cronbach's alpha coefficient

Average interitem covariance:	0.155282
Scale reliability coefficient:	0.8411

Source: Study data (2024)

3.7.3 Pilot Test

A pilot test was conducted before the assumption of the survey. A pilot test is a trial run prepared for the main study, meant to make the questionnaire user friendly to attain the intended purpose (Kothari, 2004). The pretest took place in multiple wards across Nambale, Nyakach, Nyando and Alego Usonga Sub Counties, involving 26 households in the survey. Feedback discussions regarding the tool's functionality occurred post the pretest. The wards used for the pretest were excluded from the main survey.

3.8 Ethical Issues in Research

The researcher sought approval from both the Strathmore University Institutional Scientific and Ethics Review Committee and the National Commission for Science Technology and Innovation. The researcher adhered to ethical standards during the research period by seeking consent from respondents whose participation was volitional. The researcher upheld confidentiality by using code on data instruments hence the names of respondents were not written. Information gathered was used for academic purposes only.

3.9 Chapter Summary

Chapter three discusses how the research was conducted and the rationale for the various approaches chosen all the way from research philosophy, research design, population and sampling, data collection, data analysis, tests for research quality and finally the permission to carry out the study.



CHAPTER FOUR

PRESENTATION OF RESEARCH FINDINGS

4.1 Introduction

This chapter presents the findings from the study. In the first part, descriptive statistics on socioeconomic characteristics, fish production, fish marketing and ABDP and information on technology uptake are presented. Correlation tests have also been submitted and lastly, the results of Multivariate Probit on the drivers of adoption are presented alongside the likelihood test ratio.

4.2 Response rate

The aim of the study was to collect responses from 725 smallholder aquaculture farmers in Busia, Siaya, Kisumu and Homabay Counties. The responses were collected from all the sub counties and the research garnered 99.86% response rate which was sufficient for utilization in a quantitative study according to Kothari (2004) who presents that a response rate of 70% and above is allowed for data analysis, necessarily representing the whole population.

Table 4.1 Response rate

Value	Frequency	Percentage
Yes	724	99.86
No	1	0.14

Source: Study data (2024)

4.3 Socioeconomic characteristics

The results on socioeconomic characteristics are presented in Table 4.2. The findings indicated that 88.96% of the household heads were male while females made up the remaining 11.03%. This means that fish farming is male dominated for the most part with the reasons behind it being ownership of factor inputs such as land. Also, aquaculture is said to be labor intensive in terms of pond preparation, feed formulation, fish harvesting, water exchanges and so forth. The mean age for an aquaculture farmer was 51 years (SD= 13.71). This hints that the practice attracts individuals who are middle aged and advanced in age because of the capital and technical requirements. Farmers noted that the activity is highly capital intensive, a factor of production that most young individuals would find difficult to access.

The average years of schooling of the household head was 11 years (SD=3.91), suggesting that most farmers have basic education as a conservative estimate, which is essential in knowledge acquisition, technology awareness and decision making. The average household size was 6

persons (SD=2.80) (Table 4.2). A bigger household with higher number of adults have access to labour for agricultural activities like fish farming, crop production and livestock keeping. The average household income per annum was KES. 79812.80 (SD=175813) whilst other activities brought in KES. 156572 (SD=221440) per year. Other activities registered the highest income amount.

Most farmers noted that the main motivation for fish farming was income generation and very few targeted consumption. The main income activities that bring farmers money were crop farming, followed by fish production, business and trade, salaried employment and the others include casual labor, livestock farming, petty trade, pension and remittances. This confirms that fish production cannot be done in isolation as is right now. The average distance from the household to the main fish farm was 1.05 kilometers (SD=2.60) implying that most farmers have ponds near their homesteads and for the case of cage farmers, the culture facility could be a bit farther from the homestead but around the vicinity (Table 4.2).

Table 4.2 Socioeconomic variables that influence adoption of multiple sustainable aquaculture technologies.

Variable	Description	Observations	Mean	Standard Deviation
Years of schooling of household head	Number of years spent in school	721	11.33	3.91
Age of household head	Age of household head in years	724	51.32	13.72
Household size	Number of people in the household	724	6.09	2.8
Household income in KES. per annum	Household income per annum	717	79812.8	175813
Distance from household to the main fish farm	Distance from household to the main fish farm in Kilometers	724	1.06	2.61
Gender of the household head	1 if the household head is male, 0 Otherwise	724	0.89	0.31
Income from other activities per year in KES.	Amount of income from other activities in KES	714	156572	221440

Source: Study data (2024)

4.4 Descriptive statistics on fish production

Results on fish production are presented in Table 4.3. Fish production earned households an average income of KES.115367.08 (SD=412416) per year, with most farmers appreciating that fish income contributes a decent amount to total household income. The contribution of fish income to the overall household income is reflected in the following statistics: 43.31% of farmers ranked it on a scale as significant, 22.76% considered the contribution to be small, while 9.38% and 5.93% ranked it as almost all and none, respectively. About 47% of farmers needed credit for fish production, pointing to the fact that only half were intending to scale or commercialize their operations. Tilapia was the most farmed fish followed by African catfish and a little bit of mudfish (Table 4.3). However, some farmers introduced catfish to control population of fish in an instance where hormonal sex reversal had failed resulting in mass reproduction in a pond. Tilapia is the favorite species because most consumers prefer it hence huge demand for it. Also, it has a shorter production cycle of 8 months compared to catfish and mudfish that take 9 months or more.

On average, farmers knew at least 3 fingerlings suppliers from whom they could buy at any time. In addition, 58.34% of farmers purchased fingerlings, 26.48% got donations from the development programme, 26.2% got through government subsidy programme, while only 7% produced their own and a small number got donations from their social circle. The average number of ponds was 2.64 (SD=3.86) meaning that farmers own less than three ponds which is the optimal number for commercialization. This also confirms the smallholder nature of aquaculture practices where it can be done in a small area majorly for income generation as farmers explained.

93% of the farmers perceived costly inputs, especially feeds, as a big hinderance to fish production which often leads to abandonment of ponds (Table 4.3). 19.03% of farmers had abandoned their ponds due to human theft and predators like monitor lizards and pelicans who hunt for fish, extreme water issues which could either be floods that sweep away stocked ponds or severe shortage of water that cause the ponds to dry up hence fish cannot survive and lastly because they were under maintenance and yet to be restocked.

Table 4.3 Fish production variables that influence adoption of multiple sustainable aquaculture technologies.

Variable	Description	Observations	Mean	Standard Deviation
Fish income in KES per annum	Total income from fish production per year	724	115367	412416
Need for credit	1 if farmer needed credit, 0 otherwise	724	0.47	0.5
Fish species: Tilapia	1 if fish species farmed is tilapia, 0 otherwise	340	0.94	0.24
Number of ponds	Total number of ponds per household	673	2.64	3.86
Fingerling suppliers	Number of fingerling suppliers that could serve farmer any time	724	3.35	37.1
High Initial capital	1 if farmer perceive initial cost as high, 0 otherwise	721	0.96	0.19
Costly inputs	1 if farmer perceives inputs to be costly, 0 otherwise	715	0.93	0.26

Source: Study data (2024)

4.5 Descriptive statistics on fish marketing

Results on fish marketing are presented in Table 4.4. Farmers have aligned themselves to various social factions. Fish marketing group had only 10% of the farmers, 60% were members of fish association group, emphasizing the importance of farmer cluster concept in agriculture. Farmers count on these groups for support and information diffusion. In the survey, some farmers disclosed that they started fish farming because they saw their neighbours, or family members doing it. Farmers sold 2833.38 kgs (SD=19167.5) of crops in the last one year while 73% of the farmers perceived high perishability to be a barrier in the fish business.

Table 4.4 Fish marketing variables that influence adoption of multiple sustainable aquaculture technologies.

Variable	Description	Observations	Mean	Standard Deviation
Fish association group/cooperative	1 if farmer belongs to fish association group, 0 otherwise	724	0.6	0.49
Fish marketing group	1 if farmer belongs to fish marketing group, 0 otherwise	724	0.11	0.31
High perishability	1 if farmer perceives fish to be highly perishable, 0 otherwise	706	0.74	0.44
Amount of crops sold in kgs	Amount of crops sold in kilograms in the last production cycle	360	2833.38	19167.5

Source: Study data (2024)

4.6 Descriptive statistics on Aquaculture Business Development Programme

Results on ABDP variable are presented in Table 4.5. Beneficiaries of ABDP made up 70% of the sample revealing that a good number of farmers were covered under the program. With respect to previous interventions, only 38.9% of the farmers had benefitted from programs initiated by county government, non-governmental organizations, national government, private companies, universities and other institutions.

Table 4.5 ABDP variable that influence adoption of multiple sustainable aquaculture technologies.

Variable	Description	Observations	Mean	Standard Deviation
Beneficiary of ABDP	1 if farmer benefited from ABDP, 0 otherwise	724	0.7	0.46

Source: Study data (2024)

4.7 Adoption of sustainable aquaculture technologies

Results on adoption of multiple sustainable aquaculture technologies are presented in Table 4.6. 97.24% of fish farmers received training on selective breeding, 99.86% were trained on hormonal sex reversal and 99.86% of farmers also got training on feed regime. 57.38%, 67.86% and 94.48% of farmers applied hormonal sex reversal, selective breeding and feed regime technologies respectively. On the presupposition that these technologies could be used as either complements or substitutes, hormonal sex reversal and selective breeding was practiced by 47.86% of the farmers, hormonal sex reversal and feed regime used by 55.59% while selective breeding and feed regime was used by 63.17% of the farmers.

Additionally, other technologies applied include value addition techniques (52.14%), Integrated Aquaculture Systems(45.79%), Recirculating Aquaculture Systems(28.14%), bio floc (32.69%), periphyton (32.83%), aquaponics (26.34%), Integrated Aquaculture Agriculture (40.55%), hapa nets(65.52%) ovulation hormones (25.79%) and water monitoring using pH and turbidity discs (31.59%) (Table 4.6). These figures show the semi intensification of systems and that uptake of technologies is gaining momentum but not at a good pace enough to revolutionize the aquaculture industry in Kenya.

Table 4.6 Adoption of multiple sustainable aquaculture technologies.

Technology training and usage	Frequency	Percentage
Number of farmers trained on hormonal sex reversal	724	99.86
Number of farmers trained on selective breeding	705	97.24
Number of farmers trained on feed regime	724	99.86
Hormonal sex reversal	416	57.38
Selective breeding	492	67.86
Feed regime	685	94.48
Hormonal sex reversal and selective breeding	347	47.86
Hormonal sex reversal and feed regime	403	55.59
Selective breeding and feed regime	458	63.17
Value addition techniques	378	52.14
Integrated Aquaculture systems	332	45.79
Recirculating Aquaculture Systems	204	28.14
Bio floc	237	32.69
Periphyton	238	32.83
Aquaponics	191	26.34
Integrated Aquaculture Agriculture	294	40.55
Hapa nets	475	65.52
Ovulation hormones	187	25.79
Water monitoring using pH cards and turbidity discs	229	31.59

Source: Study data (2024)

4.8 Correlation Analysis

A Pearson correlation analysis was conducted to assess the relationship between hormonal sex reversal and selective breeding, hormonal sex reversal and feed regime and selective breeding and feed regime. The correlation between selective breeding and feed regime and hormonal sex reversal and selective breeding was positive and moderate $r(724) = 0.630$ while the correlation between selective breeding and feed regime and hormonal sex reversal and feed regime was positive and low $r(724) = 0.468$ implying that they can be run independently in the model (Table 4.7). The correlation between independent variables is presented in appendix 3.

Table 4.7 Pearson's correlation between dependent variables

	Hormonal sex reversal and selective breeding	Hormonal sex reversal and feed regime	Selective breeding and feed regime
Hormonal sex reversal and selective breeding	1		
Hormonal sex reversal and feed regime	0.811	1	
Selective breeding and feed regime	0.630	0.468	1

Source: Study data (2024)

4.9 Multicollinearity

Multicollinearity was checked through the Variance Inflation Factor (VIF) test. The VIF checks for correlation of independent variables and particularly the variance rises when there's correlation. The absence of correlation between independent variables is indicated by the result of $VIF = 1$. When $1 < VIF < 5$, the value of VIF indicates that there exists a moderate correlation between the variables while $VIF \geq 5$ to 10 indicates that the variables are highly correlated (Shrestha, 2020). For the study, $VIF = 1.43$, which is less than 10, thus the study concludes that the data does not suffer multicollinearity in the results as shown in Table 4.8.

Table 4.8 Multicollinearity test

Variable	VIF	1/VIF
Household income	2.15	0.465
Fish income	1.85	0.539
Other household income	1.77	0.565
Number of ponds	1.67	0.601
Beneficiary of ABDP	1.59	0.629
Selective breeding and feed regime	1.52	0.659
Hormonal sex reversal and feed regime	1.47	0.681
Years of schooling	1.46	0.686
Amount sold in kgs	1.42	0.703
Fish association group/cooperative	1.37	0.729
Fingerling suppliers	1.35	0.739
Age of household head	1.31	0.764
Distance from household to the main fish farm	1.26	0.795
Costly inputs	1.25	0.797
Number of people in the household	1.25	0.797
High initial capital	1.25	0.802
Need for credit	1.22	0.822
Fish species	1.21	0.824
High perishability	1.19	0.841
Fish marketing group	1.19	0.841
Gender of household head	1.18	0.848
Mean VIF	1.43	

Source: Study data (2024)

4.10 Drivers of adoption of multiple sustainable aquaculture technologies.

Table 4.9 Multivariate Probit

	(1) Hormonal sex reversal and selective breeding		(2) Hormonal sex reversal and feed regime		(3) Selective breeding and feed regime	
	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.
Years of schooling of household head	0.037	0.036	0.015	0.034	0.008	0.034
Age of household head	-0.013	0.01	-0.006	0.009	-0.003	0.01
Number of people in the household	-0.008	0.052	0.018	0.045	0.093	0.058
Household income p/a in KES	0.01	0.011	0.265**	0.001	0.993	0.007
Distance from household to the main fish farm in kilometers	-0.008	0.08	0.006	0.071	0.067	0.085
Fish income per annum in KES	-0.163	0.197	-0.022	0.158	0.267*	0.171
Amount of crops sold in Kgs	-0.015*	0.009	-0.010**	0	-0.006	0
Farmer needs credit	-0.014	0.259	-0.067	0.251	0.232	0.255
Fish species; Tilapia	-0.274	0.573	1.072**	0.449	-0.442	0.605
Membership in fish association group	-0.578**	0.262	-0.16	0.246	-0.694**	0.264
Gender of the household head: Male	-0.166	0.393	0.064	0.33	0.013	0.373
Number of ponds	0.004	0.04	0.056	0.04	0.079*	0.04
Beneficiary of ABDP	0.724**	0.352	0.710**	0.312	0.675*	0.347
Membership in fish marketing group	-0.592	0.442	-0.598	0.415	-0.152***	0.363
Other household income p/a in KES	0.001*	0	0.135*	0.717	-0.524	0.736
Number of fingerling suppliers	0.024	0.077	-0.06	0.079	0.072	0.074
High initial capital	1.68**	0.801	0.099	0.463	1.238	1.071
High perishability	-0.208	0.264	-0.077	0.25	-0.511**	0.258
Costly inputs	0.136	0.389	0.049	0.369	0.164	0.387
Constant	-1.086	1.236	0.312	1.124	-2.401	1.238
Number of observations	724					
Wald chi2(90)	81.63					
Prob > chi2	0.001					

Legend: * p<.05; ** p<.01; *** p<.001 Source: Study data (2024)

4.10.1 Effect of socioeconomic factors on adoption of multiple sustainable aquaculture technologies

For starters, the coefficient of household income was positive and significant in the uptake of hormonal sex reversal and selective breeding at 10% level as shown in Table 4.9. An increase in household income increases the need to get better technologies in production which in turn boosts income, hence the likelihood of adopting these technologies increases. Other household income was found to be positively significant in the adoption of hormonal sex reversal and selective breeding at 5% and hormonal sex reversal and feed regime at 5% significance level too (Table 4.9). These findings suggest that as other household income increases, there is a growing necessity for farmers to diversify their investment portfolio, with fish farming being one of the potential avenues.

4.10.2 Effect of fish production on adoption of multiple sustainable aquaculture technologies

Fish income had positive significance on adoption of selective breeding and feed regime at 5 percent level (Table 4.9). Naturally when a particular trade pays off, one would want to continue doing it. Farmed species being tilapia had a positive significance on the uptake of hormonal sex reversal and feed regime combination at 10% percent level (Table 4.9). Tilapia was the most farmed fish and a species that has attracted development of various strains compared to other species and so farmers would eventually end up applying these technologies because they are developed around tilapia.

The number of ponds positively and significantly influenced the likelihood of uptake of the combination with selective breeding and feed regime at 5 percent significance level (Table 4.9). This can be explained by the fact that when ponds increase, the number of fish farmed increases and the feed uptake goes up. Also, a farmer can experiment with different strains when he owns several ponds. The study also noted that most farmers farm exotic/cross tilapia while some breed the lake catch together with the exotic strain to achieve a combination of both. The coefficient of high initial capital as a barrier to fish production was positive and statistically significant in the adoption of hormonal sex reversal and selective breeding at 10 percent significance level, meaning that the more farmers perceive it as a barrier the more they would adopt this combination and so much effort is put into sourcing for capital (Table 4.9).

4.10.3 Effect of fish marketing on adoption of multiple sustainable aquaculture technologies

The amount of crops sold in kilograms was found to influence the likelihood of choosing hormonal sex reversal and selective breeding and hormonal sex reversal and feed regime

combinations negatively and significantly at 5 percent and 10 percent significance level, respectively (Table 4.9). This suggests that with an increase in the quantity of crops sold, there is a decrease in the adoption of technologies, resulting in a corresponding decline in output. Crop production being one of the main income earners for the household, farmers easily choose it, this can be done at the expense of fish farming. Farmer membership in fish association group/cooperative had a significant negative influence on adoption of hormonal sex reversal and selective breeding and selective breeding and feed regime combinations at 10% significance level each (Table 4.9).

Farmer membership in fish marketing group had a negative significant influence on adoption of selective breeding and feed regime combination at 1% significance level (Table 4.9). This shows that farmers who belong to farmer associations and fish marketing groups are less likely to adopt the said combinations. In addition to key marketing variables, high perishability barrier had a negative significant influence on adoption of selective breeding and feed regime at 10% significance level, alluding that the chances of adopting selective breeding and feed regime plummets when a farmer pervasively perceive fish to be highly perishable and a barrier to fish production and marketing (Table 4.9).

4.10.4 Effect of ABDP on adoption of multiple sustainable aquaculture technologies

Lastly, a farmer being an ABDP beneficiary had a positive significant influence on adoption of all three combinations that is, hormonal sex reversal and selective breeding, hormonal sex reversal and feed regime and selective breeding and feed regime at 10%, 10% and 5% significance levels respectively as depicted in Table 4.9. The effect of this intervention insinuates that when a farmer is included in a program it is highly probable that they will derive some benefits whether through training, donations or technical support and adopt the technologies in the long run.

Multivariate probit model was estimated jointly for three binary dependent variables, hormonal sex reversal, selective breeding and feed regime. The Wald chi2 test (90) = 81.63, prob = 0.001 was significant at 1 percent level indicating that the subsets of the coefficients of the model were jointly significant (Table 4.9). Furthermore, the Wald Chi square test indicated that the explanatory power of the variables included in the model were satisfactory and so the MVP model fits the data. Based on the results of MVP, some variables are significant in one combination, a few significant in two combinations of technologies and only one variable is significant across all combinations. Results indicated that beneficiary of ABDP was significant in all ATs combinations (Table 4.9).

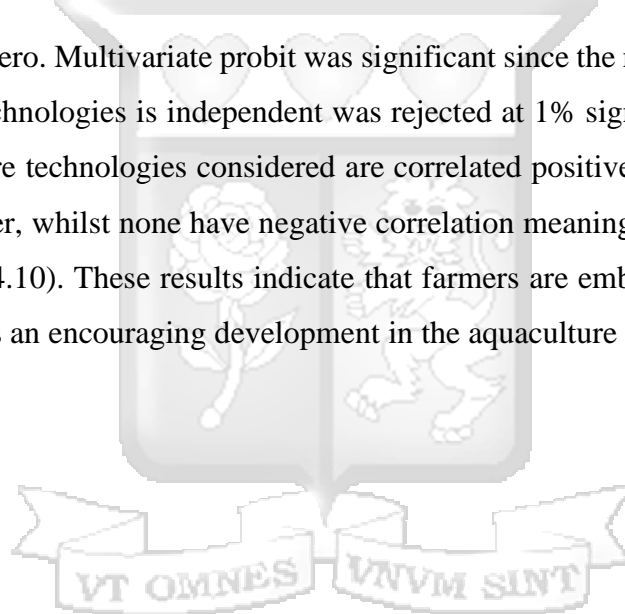
4.11 Substitutability and complementarity among aquaculture technologies

Table 4.10 Correlation coefficient of error terms obtained from MVP model estimation.

Binary correlation	Correlation coefficient	Robust standard errors	P-value
rho21	1.376	0.219	0
rho31	1.743	0.386	0
rho32	1.176	0.225	0
rho21	0.88	0.049	0
rho31	0.941	0.045	0
rho32	0.826	0.071	0

Likelihood ratio test of overall error terms correlation $\rho_{21} = \rho_{31} = \rho_{32} = \rho_{21} = \rho_{31} = \rho_{32} = 0$: $\chi^2(10) = 139.359$ Prob > $\chi^2 = 0$. Source: Study data (2024)

The numbers in rho refer to 1=Hormonal sex reversal; 2=Selective breeding; 3=Feed regime ρ are jointly equal to zero. Multivariate probit was significant since the null hypothesis that the choice of the three technologies is independent was rejected at 1% significance level. All the sustainable aquaculture technologies considered are correlated positively indicating that they complement each other, whilst none have negative correlation meaning that they are not used as substitutes (Table 4.10). These results indicate that farmers are embracing modern ATs at their disposal which is an encouraging development in the aquaculture value chain.



CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This is the last chapter of the study, discussed in accordance with the specific objectives. The chapter collates the findings into one summary for purposes of discussion. Conclusions drawn from the findings have informed the recommendations for policy and practice thereafter, whilst limitations have provided direction for future research.

5.2 Summary of findings

This study set out to establish the drivers of adoption of multiple sustainable aquaculture technologies among smallholder fish farmers in the Lake Victoria basin region of Kenya. Specifically, the study sought to establish the influence of socioeconomic factors, the influence of fish production, effect of fish marketing as well as the effect of ABDP intervention on adoption of hormonal sex reversal, selective breeding, and feed regime. The research utilized Multivariate probit model to analyze adoption of ATs. The results indicated that the average age of an aquaculture farmer was 51 years with a household size averaging 6 persons and an average year of schooling of 11 years. The main household income was KES 79,812.80 per annum. Additionally, the average other household income was KES 156,572 per annum. About 88.96% of household heads were male and the average distance from the household to the main fish farm was 1.05 kilometers.

On fish production, most farmers derived income from fish farming registering average fish income of KES 115367 per annum. 47% of the farmers needed credit to finance their operations and tilapia was the most farmed fish at 94%. The average number of ponds was 2. About 93% and 96% of fish farmers perceived that costly inputs and high initial capital were major constraints to fish production respectively. On average, farmers knew around 3 fingerling suppliers they could source from. The market side saw the average amount of crops sold to be 2833.38 kilograms per production cycle, 60% of farmers belonged to a fish association group/cooperative while only 11% subscribed to a fish marketing group. Around 74% of fish farmers registered that high perishability of fish was a barrier to fish production and marketing and lastly, 70% of the farmers had benefitted from ABDP intervention.

The first objective sought to evaluate the effect of socio-economic factors on adoption of multiple sustainable aquaculture technologies and the results revealed that household income and other household income had positive significant influence on adoption of hormonal sex

reversal and feed regime. Other household income also showed a positive significant influence on adoption of hormonal sex reversal and selective breeding.

The second objective was to assess the influence of fish production on adoption of multiple sustainable aquaculture technologies and the findings showed a positive significant influence posed by fish income on adoption of selective breeding and feed regime. The fish species being tilapia had a positive significant influence on adoption of hormonal sex reversal and feed regime besides exhibiting a negative influence on the uptake of hormonal sex reversal and selective breeding and selective breeding and feed regime. The number of ponds posed a significant positive influence on adoption of selective breeding and feed regime whilst high initial capital as a barrier to fish production posed a positive significant influence on the uptake of hormonal sex reversal and selective breeding.

The third objective was to establish the effect of fish marketing on adoption of multiple sustainable aquaculture technologies and the study discovered that the amount of crops sold in kilograms had a significant negative influence on adoption of hormonal sex reversal and selective breeding and hormonal sex reversal and feed regime. Farmer membership in fish marketing groups posted a significant negative influence on adoption of selective breeding and feed regime besides the negative influence transcending all the other combinations. Moreover, membership to fish association group/ cooperative had a negative significant influence on adoption of both hormonal sex reversal and selective breeding and selective breeding and feed regime mix. Lastly, the barrier of high perishability had a negative influence on all the technologies while posing a significant negative influence on adoption of selective breeding and feed regime.

The fourth objective was to examine role of ABDP intervention on adoption of multiple sustainable aquaculture technologies and the findings depicted a positive significant influence of the intervention on adoption of hormonal sex reversal and selective breeding, hormonal sex reversal and feed regime and selective breeding and feed regime. Overall, farmers engaged in fish farming for three main reasons namely; income generation, food security and investment diversification.

5.3 Discussion of Findings

5.3.1 Socioeconomic factors and adoption of aquaculture technologies

Household income had a positive significant influence on adoption of hormonal sex reversal and selective breeding implying that these technologies are capital intensive. These speaks to

the fact that monosex and mixed sex fish are sold differently at the point of sale and the former costs higher because all the farmer needs to do is put fish in a culture facility and start feeding, everything else has been done (Sarker et al., 2022). For selective breeding the survey indicated that most farmers breed exotic/cross tilapia which in as much as they carry desirable traits like fast growth and higher weight, the cost is higher. These results were supported by the research of Duy et al. (2021) which found that household income had a significant positive effect on shrimp production profit at 1% level of significance. This deduction aligned with the findings of Boateng et al. (2022) indicating that the adoption of various innovations in management practices was significantly and positively influenced by income. The rationale behind this is that higher income encourages farmers to invest in fish production, a phenomenon that contributed to Ghana's recognition as one of the top 10 aquaculture producers in Africa (Hinrichsen et al., 2022).

Ngoc et al. (2021) noted a significant positive influence of monthly household income on the willingness to adopt innovations in shrimp production, as well. Existence of other household income showed a significant positive influence on adoption of hormonal sex reversal and selective breeding and hormonal sex reversal and feed regime implying that farmers channel extra income to boost their fish production enterprises, as in, a cage farmer could be a mechanic in the nearby urban center, with a shop on the side but still farms fish. This came in handy especially during the incident in Lake Victoria where there was mass death of fish due to upwelling of the lake. From the interviews, cage farmers who had income from other activities quickly restocked their cages after environmental assessment by fisheries authorities.

The study supported the findings of Onuche et al. (2020) which established that when other income increased by USD 1.19, the probability of adopting aquaculture innovations increased by 0.017%. However, the study's findings disagreed with the submissions of Aung et al. (2021) which established a significant negative influence of access to off farm income on adoption of ATs as well as fish productivity, arguing that households that rely more on main income than on other income from farm activities focused less on investing in modern technologies. Amankwah et al. (2018) posted the same results by showing a negative correlation between off farm income and adoption of improved feed.

5.3.2 Fish production and adoption of aquaculture technologies

Results revealed that high initial capital barrier increased adoption of hormonal sex reversal and selective breeding given that farmers must buy hormones and other input for administering

or pay a higher cost at the hatchery for monosex fingerlings or hire a monosex expert to do it on the farm. For selectively bred fish, farmers get strains that have desirable traits like fast growth rate and lower feed conversion rate which cuts the cost of production given that fish feed accounts for 60% of the cost, as compared to local strains (Ragasa et al., 2022; Munguti et al., 2021). The implication of this finding is that the more farmers perceive high initial capital to be costly, the more they become well prepared to meet all the costs and eventually use better technologies.

The study showed that farmed fish species being tilapia posed a significant positive influence on the adoption of hormonal sex reversal and feed regime, showing that the technologies are mostly used by farmers who practice monoculture of tilapia and apply proper feeding for commercial purposes. The study was consistent with the results of Mitra et al. (2019) which established that monoculture of tilapia increased the need for credit significantly which can be used to source for monosex fish technology and buy feeds which form the bulk of the cost of production. The study did not agree with Aung et al. (2021) who found out that polyculture had a significant positive influence on technical efficiency.

The number of ponds had a significant positive influence on the uptake of selective breeding and feed regime indicating that an increase in the number of ponds increases the likelihood of applying this combination of ATs. This is because a farmer would want to keep exotic and local strains in separate ponds due to varying behaviors like feeding, growth rate and reproduction. Also, the more the number of ponds, the more farmers need to administer a higher amount of feed (Munguti et al., 2021). These results also agree with the findings of Joffre et al. (2020) which reported that the number of ponds significantly influenced the adoption of feed input and water quality management practices, however, when the farm size increases and the number of ponds remain constant then the likelihood of disadopting feed input practice is high.

Income from fish farming also had a significant positive influence on adoption of selective breeding and feed regime. When farmers register good income from their harvest they are encouraged to continue with the business and the basic business of fish rearing is having the right breed that will fetch good money and feeding the fish too (Obwanga et al., 2020). These findings resonate with the deductions of N'Souvi et al. (2021) that polyculture of prawn crabs increases profit which ideally farmers would plough a portion of it back to the business and continue using the ATs or adopt new ones to boost their profits. Likewise, Obiero et al. (2019)

supports the study by posting that hormonal sex reversal and commercial feeds are among the main technologies that augment profits in the fish business.

5.3.3 Fish marketing and adoption of aquaculture technologies

Fish association group/ cooperative posed a significant negative influence on the adoption of hormonal sex reversal and selective breeding and the adoption of selective breeding and feed regime. This shows that associations prevent adoption of these technologies and respondents also intimated that some farmers in the program did not benefit from inputs disbursed as officials would pilfer what is meant to go to the beneficiaries. Also, some group of farmers under the aquapark model complained that the promise to give them pond liners was not fulfilled, almost two years since the operationalization of aquaparks. Also, the model of operation where fish are only fed at the behest of county official in charge of the park seemed not to sit well with farmers (Odende et al., 2022). The results reject the hypothesis of Kumar et al. (2018) that diffusion of new knowledge and technology is more effective in small homogenous groups.

N'Souvi et al. (2020) posted similar findings by deducing that farmers cooperatives reduced the uptake of aquaculture technologies as well as profitability. Nonetheless, the study posts a contradictory finding to the one conducted by Boateng et al. (2022) who presented that farmers who belong to farmer groups have higher chances of adopting pond aquaculture. Likewise, Aung et al. (2021) submitted a positive significant influence of farmer groups on the uptake of aquaculture technologies. Additionally, Ankrah et al. (2021) submitted that belonging to cooperatives increased farmer income significantly. Fish marketing groups also had significant negative influence on adoption of selective breeding and feed regime combination at 1% significance level. The study disputed the findings of Duy et al. (2021) who presented that fisheries association, wholesale agents and fisheries unions depicted a significant positive influence on the productivity of shrimp farmers.

The coefficient of amount of crops sold in kilograms was negative and statistically significant on adoption of hormonal sex reversal and selective breeding and hormonal sex reversal and feed regime. The results dispute the findings of Ngoc et al. (2021) who established that crop production increased the chances of adopting new innovation in shrimp production. High perishability had a significant negative influence on adoption of selective breeding and feed regime just as Odhiambo (2022) who posted similar findings by stating that most farmers did not have access to cold storage facilities and those who had access could get market linkages

with wholesalers while those without the preservation capacity only sold to retailers and consumers. Ready market is crucial in aquaculture since it takes care of supply and income and capital for the producer who will most likely continue to adopt these technologies (Pomeroy, Navy, Ferrer & Purnomo, 2017).

5.3.4 Aquaculture Business Development Programme and adoption of aquaculture technologies

Farmer having benefitted from ABDP intervention had a significant positive effect on the decision to adopt hormonal sex reversal and selective breeding, hormonal sex reversal and feed regime, and selective breeding and feeding regime combinations at 10%, 10% and 5% significance levels respectively. Categorically, results showed that households that practice fish farming under the ABDP intervention umbrella exhibited impressive knowledge levels on why they should practice hormonal sex reversal giving such reasons as; to control the sex ratio of fish and producing single sex fish. Moreover, the efficacy of the method in terms of administration through feeding, immersion or random method, the right timing for reversal and the fact that hormone is chosen based on the direction of reversal was well understood (Sarker, et al., 2022). Assessment of the correctness of responses was based on discussions of Abwao et al. (2023) on breeding.

About selective breeding fish farmers were well versed with features like trait enhancement, heritability of desired traits, growth rate acceleration, weight control, disease control, balancing multiple traits, mitigating against environmental fluctuations and prevention of genetic diversity loss (Abwao et al., 2023; Ibrahim et al., 2019). The feed regime exhibited the highest knowledge level with farmers demonstrating good knowledge on feed storage, modes of feeding fish, and complete and supplemental fish diets. The empirical results supported the hypothesis of Ragasa et al. (2022) about government intervention of training farmers on feed formulation, feed use and management practices, as in, farmers knowledge level improved after training and more farmers formulated their own feeds. The results also corroborate the findings of Amankwah. et al (2018) that subsidized fish feeds had a positive influence on adoption of improved feed technologies.

Besides, the results are also in line with the findings reported by Mantey et al. (2020) that the probability of farmers adopting cage tilapia farming increased by 38% when a farmer gained access to policy information. Government intervention to spur production, mostly done through production subsidies is crucial for sector growth but its effectiveness should be checked to

avoid imbalance in benefits accrued to the recipients, for instance some farmers in a particular locality not receiving fish feeds as planned. Ibrahim et al. (2019) noted that some unscrupulous hatcheries mixed different strains which led to some farmers recording varying performance from those who bred the GIANT strain. Observations from the study also noted that some farmers were doing well in the program while others had nothing to write home about, thereby confirming the reservations of Parrao et al. (2021).

5.4 Conclusion

The study set out to establish the drivers of adoption of multiple sustainable aquaculture technologies among smallholder fish farmers in the Lake Victoria basin region. The position of the study is that the variables under investigation have significant influence on adoption of ATs. With regards to socioeconomic factors, household income and other household income had a positive significant influence on adoption of multiple ATs. The second objective measured the effect of fish production on adoption and four variables namely, fish species being tilapia, number of ponds, fish income and high initial capital had positive significant influence on adoption of ATs depicting that any factor that boosts production drives the uptake of multiple ATs.

All the variables under fish marketing had significant negative influence on adoption of different combinations of ATs while ABDP intervention had positive significant influence on adoption of all combinations of ATs, reiterating the importance of sector stimulus programs. Farmers are embracing these technologies if they can afford them and so disposable income is important in leveraging uptake of innovations, which brings to fore the relevance of technology acceptance model in the study.

5.5 Recommendation

In line with the findings, recommendations are made thereof for policy and practice.

5.5.1 Recommendations for policy

The study recommends sector interventions packaged to drive small scale farmers towards commercial focus. As evidenced by the performance of ABDP and previously FFEPP where aquaculture production went up and tanked immediately after the program ended. The module of delivery should be based on collaboration with county directorate of fisheries and players in the private sector to build appropriate structures for sustained farmer engagement, post intervention.

Measures to reduce post-harvest losses should be implemented. The study recommends designating a section for cold storage facilities in the upcoming County Aggregation and

Industrial Parks in the counties where farmers and aggregators can preserve fish to sell at their own expected price since the study reported that membership to fish marketing group does a disservice to their decision to adopt important production technologies. In addition, construction and operationalization of fish landing sites, to be manned by market players would also come in handy especially for cage farmers who also double up as fishermen.

Thirdly there must be concerted efforts towards continual farmer training for sector transformation, ultimately. Some counties had too few fisheries personnel on call to help farmers. The study therefore recommends aquaculture business schools run by farmers but coordinated by fisheries officers where farmers can attend on a fortnight or monthly basis to learn new technologies, share ideas and discuss pertinent issues. Equally, these efforts should be geared towards finding a solution for fish feeds which is the main impediment cited by farmers. In the spirit of subsidization of production instead of consumption, the fish feed sub sector should also be considered to nail a lasting solution for the troubled industry.

5.5.2 Recommendation for practice

Research data has shown that most farmers operate landscape ponds with a few farming fish in cages, for those who can access the lake. Commercialization of the trade is essential to boost household income and according to a technical study conducted by IDH (2023), farming fish in less than 3 ponds of 300 square meters each is economically unviable. Therefore, there is need for sensitization of farmers, even through grassroot projects, that the focus has be more on the business case, that will then translate to resilience.

5.6 Study limitations and Suggestion for further research

The study was limited in scope. Among the fifteen counties where ABDP Programme is being implemented, only four counties were surveyed but 15 counties would have given a broader perspective from different agroecological zones. This study explored what drives farmers to adopt multiple sustainable technologies in the Lake Victoria basin region of Kenya that is known for fishing and fish farming activities. Nevertheless, according to Opiyo et al. (2018) a good chunk of the country is suitable for fish farming. There are some regions that practice aquaculture like sections of Eastern as well as Southern Kenya, Rift Valley, Central Kenya, and the Coast regions. This study recommends a deep dive into the drivers of adoption of pond, Recirculating Aquaculture Systems and breeding technologies in the non-traditional aquaculture-practicing areas.

Moreover, the study did not assess the impact of sustainable aquaculture technologies on productivity of smallholder fish farmers in the country and future research can narrow in on that. Since the study reveals a strong social network system among respondents, a closer look into the effect of these social factions on adoption of modern aquaculture technologies. The study also reveals that 94% of farmers practice monoculture of tilapia in their grow-out ponds but does not give much emphasis on polyculture. It would be interesting to see a clustering of monoculture versus polyculture farmers and the nuances in the adoption decisions. Lastly, the study was limited theoretically; only the Diffusion of Innovation theory and the Technology Acceptance Model were applied. The study should have considered decision making theories, personality theories and organizational structure theories.



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APPENDICES

APPENDIX 1 Introduction Letter

Dear respondent, I am Master of Science at Strathmore University Business School conducting a survey for academic research purposes to contribute to the available literature on the use of technology to improve the productivity of fish farming in Kenya. The study intends to answer questions related to farm and farmer characteristics, production status of farms, knowledge, practices, fish marketing and the challenges farmers face with regards to adoption of technologies. The study aims at understanding the drivers of the adoption of three selected sustainable aquaculture technologies.

All information obtained from the respondents will be handled with a very high degree of confidentiality and participation in the survey is voluntary, so feel free to inform the enumerator in case you don't feel free to participate in this survey.



APPENDIX 2 Research Questionnaire

SECTION 0; INTERVIEW BACKGROUND

1. Interviewed by (enumerator's name):	
2. County	
1. Kisumu 2. Siaya 3. Busia 4. Homabay	
3. Sub- County	
5. Mobile phone No	
6. GPS readings of village	



SECTION A: RESPONDENT IDENTIFICATION AND HOUSEHOLD CHARACTERISTICS

A01. Are you the head of this household?	<i>1 = Yes</i> <i>0 = No</i>							
A02. What is your relationship to the household head?	<i>1 = spouse</i> <i>2 = son</i> <i>3 = Daughter</i> <i>4</i> <i>= Other,</i>							
A03. What is the gender of household head?	<i>0 = Female</i> <i>1 = Male</i>							
A04. What is the highest level of education of the household head (years of schooling)?	<i>Enter Number in years</i>							
A05. What is the marital status of household head?	<i>1 = Married living with spouse</i> <i>2 = Married but spouse away</i> <i>3 = Divorced/separated</i> <i>4 = Widow/widower</i> <i>5 = Never married</i> <i>6 = Other, specify</i>							
A06. How old is the household head?	<i>Enter number in years</i>							
A07. How many people are in your household?	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;"></td> <td style="width: 50%;"></td> <td style="width: 50%;"></td> </tr> <tr> <td style="text-align: center;">Male</td> <td style="text-align: center;">Female</td> <td style="text-align: center;"><i>Enter number</i></td> </tr> </table>					Male	Female	<i>Enter number</i>
Male	Female	<i>Enter number</i>						
A08. How many adults (junior elders) are living in this household?	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;"></td> <td style="width: 50%;"></td> <td style="width: 50%;"></td> </tr> <tr> <td style="text-align: center;">Male</td> <td style="text-align: center;">Female</td> <td style="text-align: center;"><i>Enter number</i></td> </tr> </table>					Male	Female	<i>Enter number</i>
Male	Female	<i>Enter number</i>						
A10. Is fish production in this household's main activity?	<i>1 = Yes 0 = No</i>							

A11. If not, what is the first one?

1 = Crop and livestock production

2 = Salaried employment

3 = Casual labour

4 = Business and trade

5 = Petty trade

6 = Remittance

7 = Pension

0 = Do not know



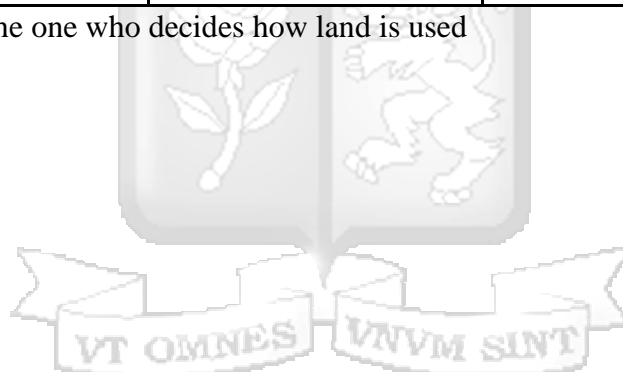
SECTION B: FARM CHARACTERISTICS

B1	What is the distance from the Household to the fish farm	Enter number in Kilometers
B2	Name of your fish farm	1= landscape fish pond 2= Sea scape ponds (lake cages)
B3	Who owns the fish farm/land?	1=Individual farm 2=Farmer group 3=Research Institute 4.=Community 5=Development organization 6=Government
B4	How does the farm operate?	1=Member of aquapark 2=Free to use 3=Private individual 4=Group controlled
B5	What features does your farm have (Choose all that apply?)	1=Hatchery 2=Nursery ponds 3=Grow-out ponds. 4=Brooder ponds 5=Recycling water Treatment ponds
B6	How many of each do you currently own	1.Hatchery Number 2.Nursery ponds Number 3.Grow-out ponds Number 4.Brooder ponds Number
B7	Are you a beneficiary of Aquaculture business Development Programme	1=Yes 0=No

SECTION C: LAND OWNERSHIP AND USE

Plot ID	Plot Description / Name	Size of this plot (acres)	Tenure system (code)	If plot is <i>owned</i> , ** who owns (code)	If rented, rent value (KES/year)
1					
2					
3					
4					
Plot description code		Tenure system		Plot owner	
0. = Homestead 1.= Fish Farm 2.= Cash crop 3.= Food crop 4.= Fodder crop 5.= Grazing land 6.=Other		1.= Owned with title 2.=Owned without title 3.= Communal/public 4.= Rented in 5.= Rented out		1.= HH head 2.= Spouse 3.= Joint (HH head & spouse) 4.= Other male 5. = Other female 6= Others (specify) _____	

**Ownership means the one who decides how land is used



SECTION D: FISH PRODUCTION AND MARKETING

1D Fish owned.

Pond Type (codes)	Number of ponds	Fish type (codes)	Breed (0 = local; 1 = exotic/cross)	Number owned by male	Number owned by female	Number owned jointly	Total number owned by household
Pond type code		Fish type code					
1. Brooder		1. Tilapia (Oreochromis niloticus)		3. Carp (Cyprinus carpio)		5. Nile perch (Lates nilotica)	
2. Nursery		2. African Catfish (Clarias gariepinus)		4. Mud/Lung fish (Protopterus spp)		6. Ornamental fish	
3. Grow out						7. Trout (Rainbow, Brown)	
4. Hatchery							

**** Ownership means the one who decides on purchase and sale of respective ponds and the use of proceeds from that pond**

2D Fish sales: Has the household sold any fish in the last six (6) months? (0=No, 1=Yes)
If yes, enter details for each fish type sold in the last six (6) months - enter details for each species separately.

Fish species (code)	Breed (0 = local; 1 = exotic/cross)	Price of Species (KES)	Who decided on how the money was used?
Fish type codes		Who receives and decides how money is used	
1. Tilapia (Oreochromis niloticus)		1. HH male	
2. African Catfish (Clarias gariepinus)		2. HH female	
3. Carp (Cyprinus carpio)		3. Joint HH (male & female)	
4. Mud/Lung fish (Protopterus spp)		4. non-household member	
5. Nile perch (Lates nilotica)		5. Other (specify)_____	
6. Ornamental fish			
7. Trout (Rainbow, Brown)			

E5 What kind of support do you get?.....

E6 What is the survival rate of fish attributable to the three technologies. Please enter percentage out of 100%

Selective breeding	
Hormonal sex reversal	
Feed regime	

E7

Approximately how much of your household income is from selling fish?	1=Almost all 2=Most of it 3=Some of it 4= A small amount 5= None
-----------------------------------------------------------------------	------------------------------------------------------------------------------



SECTION F: CROP PRODUCTION

Are you engaged in crop production 1 =yes,0=No If no proceed to section G

Crop type	Area of land under Crop production				Crop Productivity			Proportion Sold (%)	Sale value (KES)
	Area owned	Area rented	Rent (KES)/period	Rent period (months)	Crop use (code)	Yield	Yield unit		
Crop type					Crop use			Measurement unit	
1. = Vegetables 2. = Legumes – Beans, Groundnuts 3. = Cereals – Millet, Sorghum 4. = Cereals – Maize, Barley, Wheat, Oats 5. = Cereals - Rice 6. = Other (specify) _____					1. = Own consumption 2. = Sale 3. = Both			1. Kg 2. Tones 3. Crates 4. Buches 5. Standard 90kg sack Other (specify) _____	

SECTION G: HOUSEHOLD CREDIT NEED AND SOURCES

Reason for Loan	Needed Credit	Did your household receive credit?	If No, why did your household not receive credit	Who applied for the credit? If yes	If yes			
					What was the source of the credit?	What was the amount of credit received?	Did you receive the amount you requested?	Who makes the decision about what to do with the money/ item borrowed?
	0=No 1=Yes	0=No 1=yes	CODE 1	CODE 2	CODE 3	KES	0=No 1=Yes	Code 2
1	Buying aquaculture input and services for farm							
2	Buying other agricultural inputs/materials							
3	Other purposes							

CODE 1			CODE 2		CODE 3	
1=Borrowing is risky 2=Interest rate is high 3=Too much paperwork/ procedures	5=I have no asset for collateral 6=No money lenders in this area for this purpose	8=No credit association 9=Not available on time 10=Other, specify.....	1=Self 2=Spouse 3=Self and spouse jointly	4= Other household member 5=Self and other household ember(s)	1=Money lender 2=Farmer group/coop 3=Merry go round 4=Microfinance	5=Bank 6=Relative 7= Other, specify.....

4=Expected to be rejected, did not try	7=Lenders don't provide the amount needed			6=Spouse and other household member(s)		
----------------------------------------	-------------------------------------------	--	--	----------------------------------------	--	--



SECTION H: KNOWLEDGE ON AQUACULTURE TECHNOLOGIES AND SOURCES OF INFORMATION

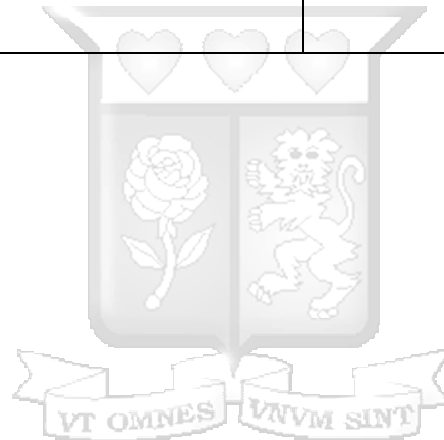
Knowledge (The responses to this section will be used to assess the knowledge of farmers about selective breeding, hormonal sex reversal and feed regime)

Issue		Do you know about the technologies in fish production [ISSUE]?	If yes in I1 No do need training/advice on [issue]? Code 1	If yes in I1 where did your household receive extension training/advice on about [ISSUE]?(CODE1	Were you satisfied are you with advice from Code 1	Number of times trainings/advice received
		0=No>> I2; 1=Yes>>I3			0=very dissatisfied 1=dissatisfied 2=not sure 3=Satisfied 4= very satisfied	
		G1	G2	G3	G4	G5
1 Selective breeding						
1a	Trait enhancement					
1b	Heritability of desired traits					
1c	Weight control					
1d	Growth rate					
1e	Disease control					
1f	Aesthetics					
1g	Loss of genetic diversity					
1h	Mitigate against the effects of environmental fluctuations					
1i	Balancing multiple traits					
2 Hormonal sex reversal						
2a	Controls sex ratio of fish population					
2b	Timing is important for successful hormonal reversal					

2c	Choose hormone base on the desired direction of sex reversal e.g., female to male					
2d	Use immersion and feeding method					
2e	Apply hormones randomly					
2f	Monosex fish propagation & mixed sex fish propagation					
2g	producing single sex fish					
2h	effectiveness varies among different fish species					
2i	Improves genetic diversity					
3 Feed regime						
3a	Aflatoxin for starter feed, grower feed, finisher feed and brood stock feed					
3b	Complete diets					
3c	Supplemental diet					
3d	Using a scale					
3e	Determining feeding rate					
3f	Dividing into portions					
3g	Measuring feed by volume					
3h	Feeds must be stored off the walls and preferably on racks					
3i	Feed should be stored under cool and dry conditions					

CODE 1

1=Government extension service	8=Seed traders/Agro-dealers	12=Research center	17=Farmer Field School
2=Spouse	9=NGOs	13=Farmer business school	18=Farmer training center
3=Other household members	10=Other private trader	14=Radio/TV	19=Other, specify.....
4=Farmer Coop or groups	11=Private Company	15=Newspaper	
5=Neighbor 6= Model/lead farmers		16=Mobile phone	
7=Other farmers			



SECTION I: ATTITUDES/ PERCEPTIONS TOWRADS SUSTAINABLE AQUACULTURE TECHNOLOGIES

The responses to this section will be used to assess the attitude of farmers towards selective breeding, hormonal sex reversal and feed regime) Kindly indicate your answer with a tick(✓)

	1=Strongly agree, 2=Agree, 3=Undecided, 4=Disagree, 5=Strongly disagree	Code
	Selective breeding	
i	Produces permanent genetic gains that are cumulative	
ii	The average genetic response is higher than the local strains	
iii	Ecological risks affect the success this method	
iv	The method involves heavy capital and heavy human resource investment	
v	Economic value of the enterprise has increased since adopting this method	
vi	The method mitigates the challenges of cohort weight and size	
vii	Fish productivity has increased	
viii	Technology is easy to use	
ix	Technology is useful	
x	It is popular among local farmers	
xi	It is environmentally friendly	
	Hormonal sex reversal	
i	optimizing sex-reversal to produce very high sex conversion rate	
ii	Survival rates is high	
iii	Productivity is higher than mixed sex culture	
iv	Survival rates is not influenced by the feed regime	
v	The method involves heavy capital and heavy human resource investment	
vi	Economic value of the enterprise has increased since adopting this method	
vii	Fish productivity has increased	
viii	Technology is easy to use	
ix	Technology is useful	
x	It is popular among local farmers	
xi	It is environmentally friendly	
	Feed regime	
i	Feeding is intensive	
ii	Feed conversion rate is high	
iii	Selectively bred and hormonally sex reversed fish record varying feed uptake	
iv	Quality of feeds sourced is high	
v	Feeding fish influences the quality of water	
vi	The method involves heavy capital and heavy human resource investment	
vii	Fish productivity has increased	
viii	Technology is easy to use	
ix	Technology is useful	
x	It is popular among local farmers	
xi	It is environmentally friendly	

SECTION J: SUSTAINABLE AQUACULTURE TECHNOLOGIES

Responses in this subsection will be used to assess the level of practice of sustainable aquaculture technologies.

Practice	Code
Hormonal sex reversal	1=Yes 0= No
Selective breeding	1=Yes 0= No
Feed regime	1=Yes 0= No
Hormonal sex reversal and selective breeding	1=Yes 0= No
Hormonal sex reversal and feed regime	1=Yes 0= No
Selective breeding and feed regime	1=Yes 0= No
Value addition techniques	1=Yes 0= No
Integrated Aquaculture systems	1=Yes 0= No
Recirculating systems	1=Yes 0= No
Bio floc	1=Yes 0= No
Periphyton	1=Yes 0= No
Aquaponics	1=Yes 0= No
Integrated Aquaculture Agriculture	1=Yes 0= No
Hapa nets	1=Yes 0= No
Ovulation hormones	1=Yes 0= No
Water monitoring using pH cards and turbidity discs	1=Yes 0= No



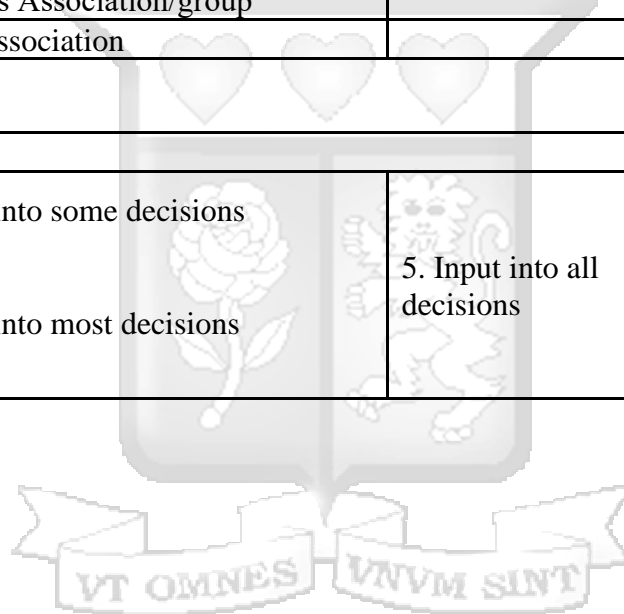
SECTION K: FISH PRODUCTION AND MARKETING CONSTRAINTS

	Constraints	Is [CONSTRAINT] an issue in fish production? (1=Yes>>column 3; 0=No>>next [constraint])	Indicate its level of importance in (only those with Yes in column 2) (1= not important at all, 2=Somewhat unimportant 3=Neutral, 4=Somewhat important, 5=Extremely important)
1L	High initial capital		
2L	Gaps in technical skills		
3L	Small scale focus		
4L	Preference for traditional methods		
5L	Complexity of technologies		
6L	Lack of information		
7L	Cost benefit analysis		
8L	Technologies are difficult to use		
9L	Labor intensive		
10L	Lack of market		
11L	Lack of government support		
12L	Lack of credit		
13L	Primary occupation of the farmer		
14L	Distance to urban center		
15L	Low profitability		
16L	High perishability		
17L	Costly inputs		

SECTION L: SOCIAL CAPITAL, NETWORKING (PARTICIPATION IN COMMUNITY INSTITUTIONS)

Variable Code	Institution Type	Are you currently a member of any of the following group? 0=No; M1	Number of years M2	How much input do you have in making decisions in this [GROUP]? CODE 1 M3
1.1	Savings and credit association			
1.2	Merry-go-round			
1.3	Fish association group/ cooperative			
1.4	Fish marketing group			
1.5	Church association			
1.7	Women's Association/group			
1.8	Youth Association			

CODE 1	
1. No input	3. Input into some decisions
2. Input into very few decisions	4. Input into most decisions
	5. Input into all decisions



QUESTION		CODE	RESPONSE
M1	How many buyers do you know WITHIN this location who could buy your fish any time?	Number of fish customers	
M2	How many fingerling suppliers do you know who could sell you any time?	Number of fingerlings	
M3	Generally speaking, fish buyers can be trusted	1=Strongly disagree 2=Disagree 3=Slightly disagree 4=Neither agree or disagree 5=Slightly agree 6=Agree 7=Strongly agree	
M4	Which types of buyers do you trust more (rank 3)?	1=contract Farms 2=Wholesalers 3=Retailers 4=Assemblers 5=Brokers 6=others (specify).....	
M5	Main reason for trusting buyers in N4 (follow order above)	1=Relatives 2=Regular customer 3=Give always better price 4= Has reliable scale 5=Provide credit 6= Other (specify).....	
6	You are confident of government extension officials including to do their job	1=Strongly disagree 2=Disagree 3=Slightly disagree 4=Neither agree or disagree 5=Slightly agree 6=Agree 7=Strongly agree	

Thank you very much for your time and participation!

APPENDIX 3 Correlation analysis

Variable	Years of schooling of household head	Age of household head	Number of people in the household	Household income	Distance from household to the main fish farm	Fish income	Amount sold in kgs
Years of schooling of household head	1						
Age of household head	-0.147	1					
Number of people in the household	-0.142	0.1981	1				
Household income	0.2158	-0.146	-0.0483	1			
Distance from household to the main fish farm	0.0877	-0.065	-0.0094	0.1731	1		
Fish income	-0.098	0.1945	-0.0113	-0.4401	-0.0657	1	
Amount sold in kgs	-0.08	-0.127	-0.0003	0.0222	-0.0403	-0.0337	1
Need for credit	-0.034	0.0037	0.0247	0.071	-0.0551	-0.1409	-0.0056
Tilapia	-0.01	0.0386	0.0889	0.1128	0.0216	-0.1417	-0.1966
Fish association group/cooperative	-0.03	0.0667	0.0699	0.0366	-0.0331	-0.1001	-0.1224
Gender of the household head	0.0731	0.0152	0.085	0.0253	0.0491	0.0252	0.0413
Number of ponds	0.2036	-0.046	-0.062	0.3759	0.129	-0.2838	-0.0434
Beneficiary of ABDP	-0.11	0.1358	0.1473	-0.2976	-0.0966	0.166	0.0143
Fish marketing group	0.0597	-0.087	0.0633	0.0216	0.0177	-0.0648	0.1077
Other household income	0.3066	-0.063	0.0153	0.1303	0.16	0.0869	0.1734
Fingerling suppliers	0.0765	0.0059	0.0263	0.0103	0.0074	0.026	-0.0026
High Initial capital	-0.038	-0.02	0.0037	-0.0431	0.0198	-0.049	0.0302
High perishability	-0.024	0.0492	0.0704	0.041	-0.0395	-0.0356	0.0735

Costly inputs	-0.035	-0.002	0.0076	0.0477	0.0156	-0.0023	0.0402
	Need for credit	Tilapia	Fish association group/cooperative	Gender of the household head	Number of ponds	Beneficiary of ABDP	Fish marketing group
Need for credit	1						
Tilapia	0.0739	1					
Fish association group/cooperative	0.1385	0.1086	1				
Gender of the household head	0.0046	-0.012	-0.008	1			
Number of ponds	0.0704	0.0906	-0.0087	0.0269	1		
Beneficiary of ABDP	-0.014	-0.033	0.1761	-0.0112	-0.1378	1	
Fish marketing group	0.0173	0.0591	0.1401	-0.0181	0.0938	0.0276	0.1401
Other household income	-0.138	-0.025	0.0188	0.0549	0.0983	-0.1234	0.0188
Fingerling suppliers	0.0382	-0.025	0.0335	0.0152	-0.0099	0.018	0.0335
High Initial capital	0.0975	0.0737	-0.0491	-0.0458	0.0183	0.0292	0.0491
High perishability	-0.039	0.0113	-0.0394	-0.0318	0.0517	0.0386	-0.0394
Costly inputs	-0.021	0.0273	-0.0369	-0.0457	0.0445	-0.0522	-0.0369
	Fish marketing group	Other household income	Fingerling suppliers	High Initial capital	High perishability	Costly inputs	
Fish marketing group	1						
Other household income	0.0591	1					
Fingerling suppliers	-0.009	0.1322	1				
High Initial capital	0.0224	-0.049	0.01	1			
High perishability	-0.045	-0.047	0.0253	0.1507	1		
Costly inputs	0.0612	0.0153	0.011	0.1159	0.2729	1	

Source: Study data, (2023)

APPENDIX 4 Institutional Ethical Review Letter



8th September 2023

Ms Achom Barbara Emodoi
barbara.achom@strathmore.edu

Dear Ms Achom,

RE: Drivers of the Adoption of Multiple Sustainable Aquaculture Technologies in Kenya

This is to inform you that SU-ISERC has reviewed and **approved** your above **SU-masters** research proposal. Your application reference number is **SU-ISERC1848/23**. The approval period is from **8th September 2023 to 7th September 2024**.

This approval is subject to compliance with the following requirements:

- i. Only approved documents including (informed consents, study instruments, MTA) will be used.
- ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by SU-ISERC.
- iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to SU-ISERC within 72 hours of notification.
- iv. Any changes anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to SU-ISERC within 72 hours.
- v. Clearance for the export of biological specimens must be obtained from relevant institutions.
- vi. Submission of a request for renewal of approval at least 60 days prior to the expiry of the approval period. Attach a comprehensive progress report to support the renewal.
- vii. Submission of an executive summary report within 90 days of completion of the study to SU-ISERC.

Before commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology, and Innovation (NACOSTI) <https://research-portal.nacosti.go.ke/> and obtain other clearances needed.


Yours sincerely,

**Mr Ambrose Rachier,
Chairperson; SU-ISERC**




Ole Sangale Rd, Madaraka Estate. PO Box 59857-00200, Nairobi, Kenya. Tel +254 (0)703 034000
Email admissions@strathmore.edu www.strathmore.edu

APPENDIX 5 NACOSTI Research Permit



REPUBLIC OF KENYA


Ref No: 208760



**NATIONAL COMMISSION FOR
SCIENCE, TECHNOLOGY & INNOVATION.**

Date of Issue: 21/September/2023

RESEARCH LICENSE



This is to Certify that Miss. BARBARA ACHOM EMODOI of Strathmore University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Busia, Homabay, Kisumu, Siaya on the topic: Drivers of the Adoption of Multiple Sustainable Aquaculture Technologies in Kenya for the period ending : 21/September/2024.


Applicant Identification Number

208760


License No: NACOSTI/P/23/29584

Director General

**NATIONAL COMMISSION FOR
SCIENCE, TECHNOLOGY & INNOVATION**



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See overleaf for conditions

APPENDIX 6 Letter of Collaboration with County Directorate of Fisheries

26th September 2023

Timothy Odende
County Director Fisheries
Busia County

Dear Mr Odende,

REF: FISH PRODUCERS SURVEY

Warm greetings.

My name is Achom Barbara Emodoi, a Master of Science student at Strathmore University Business School. I am working on a research project aiming to generate research findings on the adoption of sustainable aquaculture technologies that will help inform investments and policies in the fisheries sector.

The fish producers project has two key objectives:

- i. To identify the drivers of adoption of multiple sustainable aquaculture technologies among smallholder fish farmers.
- ii. To provide recommendations on how specific market interventions can be identified, prioritized and executed as well as provide key conditions required to sustain those interventions

It is in this regard that I request to have a list of all fish farmers in Busia County to facilitate a comprehensive data collection exercise.

I would be glad to share my research findings with you after the research and I trust that you will find it of great interest and of practical value to the county.

I look forward to hearing from you soon. If you have any questions, please do not hesitate to contact the undersigned at barbaraachom5@gmail.com or 0740233877.

I appreciate your support and will be willing to provide additional information if you need it.

Yours Sincerely,



Achom Barbara Emodoi

26th September 2023

George Okoth
County Director Fisheries
Homabay County

Dear Mr Okoth,

REF: FISH PRODUCERS SURVEY

Warm greetings.

My name is Achom Barbara Emodoi, a Master of Science student at Strathmore University Business School. I am working on a research project aiming to generate research findings on the adoption of sustainable aquaculture technologies that will help inform investments and policies in the fisheries sector.

The fish producers project has two key objectives:

- i. To identify the drivers of adoption of multiple sustainable aquaculture technologies among smallholder fish farmers.
- ii. To provide recommendations on how specific market interventions can be identified, prioritized and executed as well as provide key conditions required to sustain those interventions

It is in this regard that I request to have a list of all fish farmers in Homabay County to facilitate a comprehensive data collection exercise.

I would be glad to share my research findings with you after the research and I trust that you will find it of great interest and of practical value to the county.

I look forward to hearing from you soon. If you have any questions, please do not hesitate to contact the undersigned at barbaraachom5@gmail.com or 0740233877.

I appreciate your support and will be willing to provide additional information if you need it.

Yours Sincerely,



Achom Barbara Emodoi

26th September 2023

Susan Adhiambo
County Director Fisheries
Kisumu County

Dear Ms Susan,

REF: FISH PRODUCERS SURVEY

Warm greetings.

My name is Achom Barbara Emodoi, a Master of Science student at Strathmore University Business School. I am working on a research project aiming to generate research findings on the adoption of sustainable aquaculture technologies that will help inform investments and policies in the fisheries sector.

The fish producers project has two key objectives:

- i. To identify the drivers of adoption of multiple sustainable aquaculture technologies among smallholder fish farmers.
- ii. To provide recommendations on how specific market interventions can be identified, prioritized and executed as well as provide key conditions required to sustain those interventions

It is in this regard that I request to have a list of all fish farmers in Kisumu County to facilitate a comprehensive data collection exercise.

I would be glad to share my research findings with you after the research and I trust that you will find it of great interest and of practical value to the county.

I look forward to hearing from you soon. If you have any questions, please do not hesitate to contact the undersigned at barbaraachom5@gmail.com or 0740233877.

I appreciate your support and will be willing to provide additional information if you need it.

Yours Sincerely,



Achom Barbara Emodoi

26th September 2023

Emman Otieno
County Director Fisheries
Siaya County

Dear Mr Otieno,

REF: FISH PRODUCERS SURVEY

Warm greetings.

My name is Achom Barbara Emodoi, a Master of Science student at Strathmore University Business School. I am working on a research project aiming to generate research findings on the adoption of sustainable aquaculture technologies that will help inform investments and policies in the fisheries sector.

The fish producers project has two key objectives:

- i. To identify the drivers of adoption of multiple sustainable aquaculture technologies among smallholder fish farmers.
- ii. To provide recommendations on how specific market interventions can be identified, prioritized and executed as well as provide key conditions required to sustain those interventions

It is in this regard that I request to have a list of all fish farmers in Siaya County to facilitate a comprehensive data collection exercise.

I would be glad to share my research findings with you after the research and I trust that you will find it of great interest and of practical value to the county.

I look forward to hearing from you soon. If you have any questions, please do not hesitate to contact the undersigned at barbaraachom5@gmail.com or 0740233877.

I appreciate your support and will be willing to provide additional information if you need it.

Yours Sincerely,



Achom Barbara Emodoi

