EFFECT OF INFORMATION LINKS AND FLOW THROUGH SOCIAL NETWORKS IN EXPOSING SMALLHOLDER FARMERS TO CAGE FISH FARMING TECHNOLOGIES IN UGANDA

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented in this university or any other forthe award of a degree

Signature: .... Date: 04/09/2024..........

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Recommendation

This thesis has been submitted with our approval as university supervisors

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DEDICATION

This thesis is dedicated to my entire family and friends in academia. More profoundly, this work is dedicated to my late mother, Joyce Nakamya for your unswerving support, protection and encouragement that gave me a sense of resilience and perseverance from a tender age.

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ABSTRACT

Globally, cage fish farming technologies are intensive production systems highly promoted under the blue economy and seen as sustainable sources of income and employment, especially for smallholder farmers in fish-dependent communities. Despite their potential, adoption of such technologies by smallholder farmers in Uganda is still low. In addition, limited extension services in the country further challenge the sector in terms of accessing agricultural information, particularly for smallholder fish farmers. As a result, many smallholder farmers rely on social network platforms to access information about cage fish production and market. However, these platforms face challenges in adopting new technologies and accessing information on best agricultural practices and research findings from institutions. Therefore, this study was conducted to contribute empirically to the existing knowledge and to enhance adoption of cage fish farming technologies among smallholder fish farmers practicing along the shores of Lake Victoria in Uganda, ultimately aiming to improve their livelihoods. The results showed that out of the 384 sampled smallholder farmers, 98% were rearing Nile Tilapia fish species in cage technologies, while only 2% were rearing catfish. Moreover, the majority of respondents (82.8%) used metallic cage units to rear fish, while 11.5% used wooden and only 5.7% used HDE plastics. The Multinomial Logit (MNL) results indicated that age, gender, farming experience, education level, wooden cage type, extension visits, social capital, television access, and distance to the nearest market were statistically significant and associated with knowledge, attitude, and perception outcomes. The relative risk ratio values were 1.0, 12.6, 1.99, 1.0, 0.17, 0.28, 1.89, 7.32, and 1.06, respectively. Furthermore, the Double Hurdle (DH) results revealed that an increase in the experience and group membership of a cage fish farmer by one-unit change increased the probability of using social networks by 0.43 and 0.70 units, respectively. Additionally, a unit increase in extension visits and credit access decreased the probability of using social networks by 0.59 and 1.06 units, respectively. The results from Propensity Score matching (PSM) estimated an average treatment effect (ATT) of 4539.21 kilograms of fish annually over the control group and was statistically significant at t=2.32; p=0.006. The treated group harvested an average of 24627.71 kilograms of fish annually, compared to 20088.5 kilograms for the untreated group. Therefore, integrating social networks into existing policy interventions can empower smallholder farmers and facilitate sustainable agricultural development in Uganda's agricultural sector.

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BMU	Beach Management Unit
CFF	Cage fish farming
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
Information Network	Refers to channels through which information is shared.
GoU	Government of Uganda
KMRI	Kenya Marine Research Institute
LVFO	Lake Victoria Fisheries Organisation
MAAIF	Ministry of Agriculture Animal Industry and Fisheries
MoFPED	Ministry of Finance Planning and Economic Development
NaFiRRI	National Fisheries Resource Research Institute
USD	United States Dollar
WB	World Bank

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Globally, fish has become a popular product for consumers. Its increased demand has been attributed to the fast-growing population and increased preference for white meat (FAO, 2020). Globally fish production is estimated to rise to about 50% to meet the world's skyrocketing consumption demand, shifting from 5.2 kg per annum in 1961 to 19.4 kg in the year 2020 (The State of World Fisheries and Aquaculture, 2020). The projected increase in the consumption rate for fish products is attributed to the expected growth rate of the world’s population. Therefore, this calls for a change in production, entailing a shift in thinking from capture fishing to efficient fish farming technologies. Smallholders, who majorly form the rural dwellers in fishery-dependent communities worldwide, would play a significant role in relation to this (Atukunda, 2021; FAO, 2018). Through smallholder aquaculture production enhancement, they would potentially increase the availability of fishery resources and their incomes. In addition, cage fish farming is envisaged to alleviate poverty in fishery-dependent rural areas, mainly in economically developing nations, who greatly depends on captured fishing as the primary source of income.

Africa's aquaculture sector has greatly developed, becoming the primary source of fishery resources, outmatching the total production from capture fishery (Adeleke *et al*., 2021). According to FAO (2020) and FishStat (2021), the aquaculture sector has contributed significantly to an average of 48% of total produced fish in the region for decades. This significant growth has greatly increased to an annual rate of 6%. According to Musinguzi *et al*. (2019), private investments play a crucial role in aquaculture sector expansion across the Sub-Saharan's inland water bodies. Lake Victoria Fisheries Organization (LVFO) (2021) highlighted an exponential rise in private investments from 9 cages in 2006 to more than 500,000 by 2019. By mid-2023, over 91% of the cage fishery resources came from lakes Victoria (Kenya, Tanzania, Uganda); Kariba (Zambia, Zimbabwe); Kivu (Rwanda, Democratic Republic of the Congo), Muhazi (Rwanda) and Volta (Ghana) while 9% was from dams and rivers (Chan *et al*., 2021).

Additionally, the fishery production is estimated to 10.4 million tonnes, and about 49% of the total production comes from the aquaculture sector (FAO, 2018; FishStat, 2020; Searchinger *et al*., 2018). Regarding economic contribution, about U$24 billion is earned from the traded fish in the region, accounting for over 4% of the traded goods (World Bank, 2020). Recent studies that have been done indicate that investments in new agricultural technologies, management practices, and new products substantially benefit producers and consumers (Kumar & Engle, 2016; Kumar *et al.,* 2018). However, there still needs to be a more coherent in understanding the impact of technological change in fish farming development in Africa. Like the rest of Sub-Saharan Africa, aquaculture sector in East Africa is limited to lack of good quality breed and feed, low technical capacity, poor market, limited value addition practices, limited extension services, and increased competition for raw fish products and cheaper imported fish products (Kaminski *et al*., 2017; Rothuis *et al*., 2014).

In Uganda, the fisheries sector is the second foreign income earner after coffee. In 2020, it accounted for only 2.5% of the national budget and 12.5% of agricultural gross domestic product (GDP). This sector has developed significantly, employing about 1.2 million people, hence generating over 100 million dollars in exports, and providing over 50% of the country's dietary proteins to Ugandans (Catherine, 2021). Although the sector growth is still significantly low in Uganda's economy, this is attributed to its performance, which has significantly worsened due to the continuous overfishing in the natural water bodies (FAO, 2016; FAO, 2020).

Cage fish farming has the potential to make a significant contribution to food security and income generation in the East Africa region. The advent of cage fish farming in Uganda has been linked to the increasing demand for fish products within and outside the country LVFO, 2021). The cage fish farming sub-sector is among the highly developing sectors in the country, contributing, on average, 2.3% to Uganda's GDP annually. According to FOA and FishStat (2022), cage fish production is exponentially growing at an increasing rate of 4.6% per year, increasing in the export markets and attracting approximately US$ 690 million in revenue from exporting fish.

It is with evidence that Cage fish farming technology has greatly contributed to increased production presenting a promising solution to food insecurity and unemployment. This practice is imminent, especially for rural and underserved communities where traditional agricultural practices may be limited. According to FAO (2021) and FishStat (2021), this sub-sector, with its capacity to produce high yields of fish in controlled environments, offers a sustainable source of protein and livelihood for populations that are often marginalized. However, to fully gain understanding concerning the impact of cage fish farming, identifying and understanding the key players within the industry is imminent, particularly the smallholder farmers who dominate the sector. These small-scale farmers are crucial, as they are the primary contributors to production, driving both local food supply and economic activity. GoU/MAAIF (2022) indicates a steady annual increase of smallholder farmers participating in cage fish farming. The report also shows that approximately 419,249 metric tonnes of fish were produced from the cage farming sub-sector.

Additionally, cage fish farming technologies have demonstrated tangible results among fish-dependent communities. Cage fish farming is a source of income (Nnodim & Raji,2020) and food security, especially in rural areas (Owani *et al*., 2022), and boosts marine biodiversity (Dalsgaard *et al.,* 2012). Although the benefits of cage fish farming technologies are numerous and scientifically proven (Mbowa *et al.,* 2017; NaFiRRI, 2016a), little is empirically known about the performance of smallholder cage fish farmers. Reviewed literature on the cage fish farming sub-sector showed that many factors influence farmers' performance. For instance, Egge (2005), Shiferaw *et al*. (2009), Diiro (2013), Teklewold (2013), Shiferaw *et al.* (2014), and Ogada *et al.* (2014) identified some of the factors and grouped them broadly into three categories.

The first category was related to the characteristics of producers: education level, experience farming, age, gender, level of wealth, farm size, land size and characteristics, labor availability, and resource endowment. The second category included the attributes of the technologies, such as the perceived usefulness and complexity in assembling. The third category included institutional factors, which included access to agricultural information, credit, markets for products and inputs factors, and access to extension support. In this case, factors such as enabling policies, market access, credit access, and accessibility influenced the smallholder farmers to adopt new technologies.

The current demand-driven extension approaches promoted by many development partners globally have yielded several debates among academicians and policymakers. Davis and Heemskerk (2018) reveal that in many rural settings, access to and dissemination of agricultural information are crucial factors in determining farmers' performance. FAO (2021a), around 81% of representing a significant number of farmers in Uganda had no extension and advisory services access. Many smallholder farmers in rural areas struggle to access agricultural information (Ssebaggala & Matovu, 2020). GoU/BMAUA (2019) indicates that only 15% of generated technologies, better agriculture practices, and research findings from research institutions in Uganda are accessed by the farming communities through established formal extension systems. Consequently, this has led to weak connectivity between smallholder farmers to potential markets and input suppliers. As an alternative, most smallholder farmers solely depend on informal sources of information (UNCDF, 2021).

In addition, social networks greatly influence the diffusion of agricultural information among farmers. Social networks are informal platforms that facilitate nonlinear information sharing on the diversity of subjects and actors (Tatlonghari *et al.*, 2019). The social interactions among the farmers enable them to share pertinent information, which is critical in decision-making. For instance, Bandiera and Rasul (2006) highlighted the significant impact of social networks in sharing information about improved sunflower seeds among smallholder farmers. Conley and Udry (2010) also revealed that information about pineapple farming circulated faster through social network platforms than established formal institutions. Muange *et al*. (2014) used social networks to understand technical efficiency among cereal farmers.

In general, the studies highlighted supports the findings that social networks as well as social learning helps in creating awareness and dissemination of information. However, scanty literature was available on how information flows through the social links among actors and their effects in the context of the technologies they use. Additionally, Ramirez (2013) highlighted the importance of social networks in disseminating information about innovations. Therefore, the purpose of the was to explore the role of information links (dyads) and information flow through social networks in sensitizing smallholder farmers to new technologies.

1.2 Statement of the problem

Although smallholder farmers are pivotal in the food supply chain, the majority of them need more access to essential resources, which are pertinent to enhance their production and productivity. In light of the limited extension services in the study area and increased focus on the demand-driven agricultural extension approaches, smallholder farmers are excluded from accessing critical agricultural information. Hence, smallholder farmers resort to the use of social network platforms, which are observed as viable options for sharing and spreading agrarian information. The philosophy underlying social network platforms posits that they facilitate continuous capacity development and enable individuals to collaborate and change situations in a profound, strategic, and meaningful manner. Despite the envisaged potential, the cage fish farming sub-sector still needs to produce more to meet the ever-increasing fish demand. The problem of limited extension services in the country further challenges the sub-sector and limits the diffusion of information. In response, many smallholder farmers rely heavily on social network platforms to access information about cage fish production and markets. As a result, many fish farms owned by smallholder farmers have yet to live up to their expectations. It is upon this premise that this study sought to provide an in-depth nexus on the contribution of information sharing and interactions among smallholder cage fish farmers in Uganda.

1.3 Objectives of the Study

1.3.1 General objective

To contribute towards improved livelihoods of fishery-dependent communities through enhanced adoption of cage fish farming technologies among smallholder fish farmers along the shores of Lake Victoria in Uganda.

1.3.2 Specific objectives

i. To determine factors influencing smallholder farmers' knowledge, attitudes, and perceptions towards cage fish farming technologies along the shores of Lake Victoria in Uganda.
ii. To assess the effect of information flow through social networks among smallholder farmers on the adoption of cage fish farming technologies along the shores of Lake Victoria in Uganda.
iii. To examine the role of social networks in exposing smallholder farmers to cage fish farming technologies along the shores of Lake Victoria in Uganda.
iv. To determine the impact of social networks on fish harvest among smallholder farmers along the shores of Lake Victoria in Uganda.

1.4 Research Questions

The study attempted to provide answers to the following specific research questions:

i. What are the factors influencing knowledge, attitudes, and perceptions among smallholder farmers towards cage fish farming technologies along the shores of Lake Victoria in Uganda?
ii. What effect does information flow through social networks have on the adoption of cage fish farming technologies among smallholder farmers along the Shores of Lake Victoria in Uganda?
iii. What role do social networks play in exposing smallholder farmers to cage fish farming technologies along the shores of Lake Victoria in Uganda?

iv. What impact do social networks have on fish harvested by smallholder cage fish farmers along the shores of Lake Victoria in Uganda?

1.5 Justification of the Study

After the depletion of the captured fish resources in natural water bodies, promoting cage fish farming technologies became a top priority in Uganda's strategic plan Vision 2040, launched in 2010. In Uganda, there is a growing momentum to harness and utilize the potential of natural water bodies for the socio-economic well-being of Ugandan citizens. Having the geographic advantage of Africa's largest freshwater lake, the potential of a sustainable blue economy is massive.

Cage fish farming technologies were viewed as viable production systems to address the existing shortages in fish supply, increased food insecurity, and poverty among the fish-dependent rural communities in Uganda. Cage fish farming technologies enabled farmers to increase their returns per unit area without endangering marine biodiversity. Therefore, enabling smallholder farmers in Uganda's fish-dependent communities to adopt cage fish farming technologies could be crucial in improving their livelihoods and realizing national and international development goals. Such as ending hunger, promoting gender equity and environmental resource conservation, and reducing poverty among the rural poor.

More information is needed regarding the effect of social networks among the smallholder cage fish farmers in the country, and fish farming has hindered the development of robust policies to address fish demand in the country. Furthermore, the scanty literature on cage fish farming technologies in Uganda needs to be clarified as to why smallholder farmers still have not adopted such viable agricultural interventions in Uganda's fish-dependent communities. As highlighted by Seline *et al*. (2014), adopting an innovation involves decision-making and the level of exposure. Other reviewed literature on the adoption of new technologies indicated that access to farm inputs (Melesse, 2018), features of innovation (Pier Paoli *et al*., 2013), and social capital (Muange & Schwarzer, 2014) were significant determinants.

Mbowa *et al.* (2017) highlighted the need for more studies on smallholder farmers living in fishing communities that undertake similar activities to allow for a greater understanding of the factors driving cage fish technologies in Uganda. Based on the rural farmers' settings and social networks, there is a need to understand what it takes to use such technologies. While empirical literature has documented that the wild catch in Lake Victoria cannot withstand the test of time, cage fish farming is the ultimate solution. With the declining number of fish stock in the lake juxtaposed by an increase in demand for fish, there is a need to understand the drivers and challenges facing cage fish farming to inform on policy directions.

Therefore, this study is the fundamental source of information to validate the existing aquaculture policies and ensure the sustainability of the blue economy. Empirically, the study elucidated new theoretical thinking about social networks and the type of information shared related to cage fish production. Different stakeholders can harness the findings to unlock the full potential of the cage fish farming sector in Uganda and replicate it in other areas.

1.6 Scope, Limitation, and Assumption of the Study

The focus of the study took place in fourteen districts covering Lake Victoria islands in Uganda. The study targeted only smallholder cage fish farmers with stocking densities of less than fifty thousand fish stock. The study adopted a cross-sectional survey where both interviews and focus group discussions were administered. The data collected and used in this study was based on the respondent's willingness to participate in the study voluntarily and after consenting. The sampling techniques employed in this study assumed that the respondents were more knowledgeable in their fish farming activities and, hence, could give responses that would allow robust data analysis. However, the findings from this study were thought to be helpful but were limited in the sense that respondents involved in the study hardly kept records. Consequently, most of the answers to questions were based on the farmer's memory. However, thorough, in-depth probing was undertaken, and we were able to ensure that respondents gave accurate data.

1.7 Operational Definitions of Terms

A person's social network: This study described it as a dyadic structure where two actors are linked to one another and can interact and share information related to cage fish farming.

Alter: Referred to what the ego can identify as individual network contact that excludes non-human entities.

Aquaculture: Considered farming fish under confinements such as earth ponds and floating cages submerged in natural water bodies such as lakes or seas.

Attitude: As used in this study, referred to how the respondent feels about cage fish farming technologies.

Ego: An individual (our respondent) in the centre of a social network.

Fish cages: Innovations used to rear fish under enclosures submerged in lake or sea waters.

Fish harvest: As used in this study, fish harvest refers to the total value of fish an individual can harvest using cage fish farming technology or wild fishing gear.

Household: Referred to a household head and the dependents who have lived in the same house and share meals for not less than six months

Information flow: Refers to the way information is passed on from one individual to another.

Information links: In this study, information links are considered as channels through which information is shared.

Knowledge: In this study, knowledge refers to what the respondent knows about cage fish farming technologies.

Perception: Referred to how the respondent assesses cage fish farming technologies.

Smallholder farmer: A farmer whose stocking density is not more than fifty thousand fish, regardless of the number of cage units

Social Networks: This study refers to social networks as individuals who perform similar enterprises and are connected.

CHAPTER TWO

LITERATURE REVIEW

2.1 An Overview of the fisheries sector in Uganda

Aquaculture has become a significant practice that sustains the living standards of the people and the global economy. Additionally, it involves the cultivation of fish in controlled environments, including ponds, cages, or enclosures in natural water bodies. With the people's involvement as a source of their provision, this practice contributes significantly to meeting the growing global demand for fish, providing a reliable source of protein that is essential for food security (FAO, 2018). Further, this sector has proved to be one of the first growing sectors that not only supports the economic growth of Uganda by creating jobs and income opportunities but also provides sustainability globally (Adeleke *et al.,*2021). Fish farming, being considered a practice for smallholder farmers, has developed and improved the living standards of the people, especially in areas where traditional agriculture might not be as productive.

Uganda is one of the countries in Africa that is endowed with 20%of natural freshwater resources, covering the total land area, contributing to fish farming as the main economic activity in the area (DFR, 2011; FAO, 2019). Evidently, fisheries contributed to 3% of the total Uganda GDP in 2019, (MoFPED, 2020). The main fish production in Uganda is majorly done in Lake Victoria, Kyoga, Albert, Edward, and George. Moreover, over 160 minor lakes, rivers, wetlands, water reservoirs, valley dams, and ponds as well contribute to the total fish production in Uganda. (MAAIF, 2019).

Total capture production peaked in 2014 at 461,200 tons but decreased by 14% in 2015 to reach 396,200 tons (UBOS Statistical Abstracts, 2019). Over the last few years, there has been a decline in the catches of the most valued species of the Nile Perch, in most water sources compared to the peak production achievement experienced in the year 2005 (175,000 tons) compared to 71,900 tons in 2015 (UBOS Statistical Abstracts, 2019). Uganda is ranked the second largest aquaculture producer in sub-Saharan Africa following Nigeria. In addition, the production of fish farming in Uganda has greatly grown from 800 tons in 2000 to 217,000 tons in 2018 significantly, with the major dominating species being Nile tilapia (51%) and Catfish (49%) (NAFIRRI, 2020).

The information indicates that approximately 72% of the total fish produced is consumed locally in Uganda, reflecting its significance in the people's diet, with the remaining 28% being exported. This sector is a significant source of livelihood, employing between 1 million and 1.5

million artisanal fishermen who rely on traditional fishing practices. Additionally, the information implies that over 5,000 of the population in Uganda is directly engaged in producing and marketing the fish value chain. This includes engaging in the processing, transportation, and sales, further highlighting the sector's broad economic impact. In 2015, the employment figures in the fisheries and aquaculture sectors were substantial, with 140,377 Ugandans directly involved. Of these, 116,213 were engaged in inland water fishing, a testament to the country's rich freshwater resources, while 24,434 were engaged in fish farming. This growing sub-sector is increasingly recognized for its potential to boost production and sustainability.

The significant engagement in these sectors underscores the critical role that fisheries and aquaculture play in Uganda's economy, providing essential employment opportunities and supporting millions of livelihoods across the country. In addition, approximately 450,000 tonnes of the total fish production, estimated to be around 60%, is exported. In contrast, traditional methods are used to process approximately 20% is the fish production, including smoking, salting, frying, and sun-drying. Substantial quantities of smoked and sun-dried fish from the lake are locally traded legally and illegally, as well as in western Uganda and the Democratic Republic of Congo.

In 2015, fish and fishery product exports were valued at USD 118.3 million in the European countries. The main species exported was the Nile perch, mainly in fillet form. In the same year, similarly, those that were imported had a value of USD 2.5 million (FAO, 2015). Fish is Uganda's most affordable animal protein source, with an average annual per capita consumption of about 8 kg, constituting over 50% of an average Ugandan's animal protein intake. The yearly per capita consumption was estimated at 12.5 kg in 2013, higher than the estimated average of 10.1 kg in Africa. Although fresh fish is generally preferred, smoking, sun-drying, and salting done by artisanal processors, the largest percentage presented by women, are major for shelf-life expedition. The most popular fish commodity is dried lake sardine, known as "mukene." However, annual fish production trends significantly threaten foreign exchange earnings, household income, and food and nutrition security (EPRC, 2017).

However, Uganda's fisheries sector is facing various challenges, such as market pressure and unsustainable fishing methods (NEMA, 2018). Currently, total fish production indicates that only 460,000 MT of fish is captured in fisheries, while the other is about 220,000 MT from aquaculture. The low fish performance in captured fish is characterized by the limited knowledge, and perception of the people in fish farming; as well as inadequate existing policies governing the sector. Additionally, aquaculture experiences insufficient extension services, low investment in fish farming, high costs, and limited access to high-quality fish seed and feed. Both capture and aquaculture systems also experience high post-harvest losses, as well as a lack of human, technological, and infrastructural capacity at all stages of the value chain, resulting in overall low production and productivity (NaFiRRI, 2017).

On the contrary, it is believed that Aquaculture development in Uganda has the potential to enhance fishing communities with the expertise to supplement their capture fisheries. However, there are limitations in the development due to the low adoption of appropriate technologies, insufficient investment in research, and inadequate aquaculture extension services (SPCR, 2017). The target in the National Development Plan 2015-2020 is 300,000 metric tons for aquaculture alone (NDP II, ASSP 2015-2020). Similarly, the regulatory framework guiding aquaculture in the country has been primarily influenced by export standards for Nile perch from the European Union (EU). In contrast, aquaculture is attributed to a weak regulatory framework, hence affecting the overall production of fish.

For this reason, the Capture Fisheries Trends recorded from 2010 to 2020 indicate that although capture fish production has been increasing since 1980, reaching a peak in 2014 at 461,196 metric tons, it then declined to 389,244 metric tons in 2016. Furthermore, in 2019, the sector registered a significant production drop to 139,354 metric tons. Catch assessment surveys conducted revealed that in Lake Victoria, the catches of Nile perch increased from 85,000 metric tons in 2010 to 91,000 metric tons in 2014, and tilapia increased from 17,000 metric tons to 42,000 metric tons during the same period. Overall, fish catch increased by 16.6% over the five years from 2010-2014, indicating a recovery of fish stocks. The most substantial increase in fish catch was reported in Lake Victoria (50.4%), while three lakes recorded declines in fish catch.

2.2 Cage Fish Technologies

Cage fish farming technology is defined as a method of aquaculture where fish are reared in large, enclosed cages or net pens that are submerged in natural water bodies, such as lakes, rivers, or coastal waters. These cages allow the fish to live in a more natural environment while still being contained, making it easier for farmers to manage and monitor their growth, health, and feeding. Therefore, it suggested that one of the sustainable fish production strategies highly advocated by the World Bank as essential in aiding poverty alleviation among rural communities in developing is the development as well as adoption of proven technologies (World Bank, 2012). Additionally, cage fish farming has proven to offer farmers a wide range of benefits to their livelihoods in terms of improving household incomes and food security (Isyagi, 2001; Mbowa *et al*., 2017) as well as improving their abilities to deal with the effects caused by the depletion of wild fish stocks (Ssebisubi, 2011). In addition, cage fish farming technologies have minimal impact on marine biodiversity and ecosystems (Halwart *et al*., 2007; Nair *et al*., 2009). The available literature shows that several fish cage designs and models have been used for fish farming in Uganda.

There are four types of fish cages (fixed, floating, submersible, and submerged) commonly used by fish farmers in Uganda but with different holding capacities (NaFiRRI, 2017). The fixed cages are inexpensive, have small holding capacities, and are widely used by smallholder farmers, whereas the floating and submersible cages are comparatively expensive and have larger holding capacities. Floating and submersible cages are commonly used by commercial fish farms (Mbowa *et al.,* 2017; Ouma *et al*., 2016). According to NaFiRRI (2017), the smallest floating cage unit is (2 by 2) meters squared and can give an average yield of about 400 kilograms of live fish in eight months. Cage fish technologies enable producers to rear their fish while targeting specific markets and seasons of the year (Mugamire *et al.,* 2013).

In Uganda, cage fish farming practices are mainly carried out in Lake Victoria waters in locations identified by the National Fisheries Resource Research Institute (NaFiRRI). Farmers interested in cage fish farming apply for marine permits from the line ministry and fisheries and operational certificates from NEMA-Uganda. Practicing farmers receive free extension services and periodical training organized jointly by the Fisheries Department and Fisheries Research Institute (GoU, 2014).

2.3 Concept of Smallholder Cage Fish Farmers

The concept of caged fish by smallholder farmers arises as a classification based on the stocking density of fish size, the focus of production, and the income inflow of the farmer. Machete *et al.* (2004) argued that low purchase of inputs, application of use essential technologies, and subsistence production are the significant attributes of smallholder producers. Moreover, smallholder cage fish farmers operating under different conditions, vary across geographic regions and concentrate more in rural areas. Even though there are no defined attributes of smallholder cage fish farmers in Uganda, features such as resource scarcity, information asymmetry, little use of input, and purpose of production, whether business or own consumption, form that category. According to Dixon *et al.* (2003), smallholder fish farmers form the economic backbone of many developing countries. Further, noted that a significant number of the population in fishery-dependent communities are considered smallholder producers and reside in rural areas. According to Delgado (1998), smallholder production is essential in terms of employment, human welfare, and political stability.

2.4 Concept of Social Network

Sociologists describe a social network as a set of relationships where individuals (actors) are linked to one another. Social networks are also viewed as instruments that facilitate the exchange of information between actors (Muange *et al*., 2014). According to Thuo *et al.* (2013) and Rogers (2003), the social structures in many farming communities are differentiated based on relationships and ties among network members, their connection contacts, and the functioning network that influences the actions of community members. Their relationship could be made of a formal structure, containing a patterned form of social relationships, or it could be informal, consisting of interpersonal relationships among members of a network with similar characteristics (Rogers, 2003). Thuo *et al.* (2013) stated that research–extension–farmer linkage is an example of a formal social structure, while a friendship relationship reflects an informal structure. Social network structural patterns can differ based on the attributes of individuals associated with distinct social groups (Coulon, 2005) and their economic behavior (Jackson, 2010). This gives a reflection on how individuals interact with others and what motivates them to for such interactions.

2.4.1 Information links through social networks (SNs)

Through social networks, individuals are linked to one another through structures known as dyads. A dyad refers to a pair of actors in an interactional situation (Shelley *et al.,* 1990). Information linkages enable actors to get connected to their peers or institutions and provide them with opportunities to learn new things. Specific information, such as agricultural information, is learned quickly when linkages between the targeted end users and the inventors or promoters are established. In addition to facilitating information and innovation dissemination, information links also facilitate communication coordination within the network and build trust among actors (Tatlonghari *et al.,* 2012).

Information linkages enable farmers to access crucial information. Information linkages do manifest themselves spontaneously within individuals who share common areas of interest

(Fafchamps & Gubert, 2017). For example, farmer-to-farmer (peer) information links are informal but crucial to spreading new knowledge and practical applications. The information link for the farmer to the extension agent is considered formal. In the context of the study, information links through social networks were observed as critical platforms where actors get connected and information is shared (Tripp, 2016).

2.4.2 Information flow through social networks (SNs)

To begin with, it is clear that most of the agricultural information in a social network is dictated by the "embeddedness" or social ties between members (Sorenson *et al.,* 2006). Similarly, such structural patterns significantly enhance individual interaction to derive social benefits from any social network setup. Furthermore, Thuo *et al.* (2013), indicated that social network partners typically share closely comparable interests. The strength of ties among social network members defines the quality of a social relationship they have, hence enhancing the flow of information (Granovetter, 2005).

Furthermore, the flow of information is more effective and efficient in a network setup characterized by both strong and weak ties (Bandiera & Rasul, 2006; Monge *et al.,* 2008). This implies that strong relationships are defined by regular interactions that require time, resources, and emotional involvement, as well as a reciprocating exchange of favors (Hampton, 2011; Ruef, 2002). In contrast, weak relationships are differentiated by rare interactions and little or no emotional engagement among the key players (Granovetter, 2005; Hampton, 2011). Conversely, weak networks connect people to a limited variety of social contacts, providing new information, encouraging innovation, and connecting social groupings to the larger society (Burt, 1992; Granovetter, 2005; Ruef, 2002).

In the state of a farming community, social relationships are imminent for it helps to integrate new information into the social network structure. However, the presence of strong linkages enhances the technology diffusion processes among the people by assisting farmers in developing a common knowledge and skills of technology characteristics (Meagher, 2010). Similarly, the ability to achieve connections and interaction among the actors and institutions that support farming communities is critical for integrating new technology into a social system (Bandiera & Rasul, 2005; Clark, 2002; Tiwana, 2008). Therefore, strengthening the alliance of both strong and weak relationships in farmers' social networks could help to implement agricultural projects and adoption of modern technologies. Evidently, in a farming community, social relationships enhance the transitioning of information into the social structure. However, the presence of strong linkages further helps technology diffusion processes by assisting farmers to build and implement new systems, hence forming platforms through which individuals share information that complements the inputs they use in production (Kasarjyan *et al.,* 2007).

In situations where formal institutions are limited, such as poor farming communities, social networks, and social ties form platforms through which individuals share information that complements the inputs they use in production (Kasarjyan *et al.,* 2007). Therefore, it is essential to examine the attributes of farmers' social networks, the characters of s ocial links within the networks, and the various functions that actors in social relationships play to help them obtain knowledge about new technologies.

A farmer's exposure to new technologies is a result of social interaction. Access to information increases an individual's exposure to new technologies and abilities in decision-making (Ayu, 2017). An individual with limited access to agricultural information and new technologies from formal sources often relies on informal social networks (Newman, 2005). Interpersonal interactions, whether formal or informal, play a crucial role during the learning phase as both individuals actively build knowledge through sharing. Useful information builds knowledge and enables farmers to make informed decisions (Conley & Udry, 2010). In a social network, information flows through structures known as linkages that connect individuals who share the same characteristics.

Additionally, social networks evolve, and the ties change because of the circumstances individuals experience in their social lives (Hanneman & Riddle, 2005)). The changes in the individual social network, known as a *dyad* (Easley & Kleinberg,2010), affect the exposure of an individual to improved technologies. Understanding the information links and flow in a smallholder's social network is crucial in enhancing exposure. Many studies have concentrated on the characteristics of social networks and their influences on the diffusion of technologies, adoption, and technical efficiencies (Muange *et al*., 2014; Vishnu, 2018). Based on the reviewed literature, no empirical study has been conducted on the role of information links through social networks in exposing smallholder farmers. Also, the scanty literature indicates that no comparative study has ever been carried out on how information links and information flow among smallholder farmers and, more so, between wild fishermen and farmers practicing cage farming. Hence, under this study, it was envisaged that information links play an insignificant role in exposing smallholder farmers to new technologies.

2.4.3 Social network structures

Conversely, a dyad (single pair of actors) is the most straightforward social network with the *ego*(respondent) and the *alter* (whom the respondent refers to) (Smith & Christakis (2008). Social network analysts argue that within a society, patterns of social arrangements emerge spontaneously. Social structures directly influence the behavior and actions of individuals. According to Prell (2012), social structures serve as platforms through which actors to share information and knowledge. Actors within the same social structure are likely to share the same information about a subject in the shortest time because of their closeness and interactions.

The information flow through social networks depends on the structural layout of the networks and the embeddedness of the actors (Vishnu *et al.,* 2018). The social network structures determine the type of information one can receive through a social tie at a particular time (Hanneman & Riddle, 2005). The interactions and relations among actors in the same social network provide both opportunities for information flow and exposure (Conley & Udry, 2010). Hence, a guiding question for the study is whether the structure of social networks matters for information exchange among smallholder farmers, especially when it comes to information related to cage fish farming technologies. Therefore, understanding information links and information flow among smallholder farmers among the cage fish farmers can inform policy-makers and researchers on areas that need to be strengthened to improve cage fish farming practices.

2.5 Empirical literature review

A study conducted in Kenya's Busia, Nyamira, and Machakos counties found that the majority of farmers who used traditional farming methods had good knowledge and a positive attitude towards indigenous vegetables. Furthermore, the study determined the importance of ensuring access to technologies and information to change the current trend of indigenous vegetable production methods (Ntawuruhunga, 2017). Most socio-demographic variables and farmer characteristics, such as gender, education, profession, and years of farming experience, land tenure, farm size, and total land owned by farmers, had a significant positive effect on farmers' KAP in all three study areas covered. As a result, the study's findings should only be extrapolated to other areas with further investigation.

Further, a study focused on the level and extent of adoption of fifteen selected field crops, horticulture, livestock, and forestry technologies (Floyd *et al*., 1999). The results showed that the level of awareness of new technologies was more than 80 percent among households involved in the study. The dominant reasons for not trying a technology among the 20 percent of households were related to constraints internal to the farming system, such as lack of labor, lack of information/inputs needed to try the technology, and technology-related technical problems or incompatibility with the prevailing farming system. Hence, implies that the extension input, social structures, and household food self-sufficiency significantly influenced the level and distribution of adoption. The influences of agroecological zone, access, and gender on adoption were much smaller and more variable among the different technologies. Hence, such a scenario prompted the researcher to carry out further investigations on the adoption of new technologies, this time in the developing country Uganda in particular.

Furthermore, the bivariate logistic model was selected to examine the variables that influence Ugandan fish smallholder farmers' investing behavior and involvement in microcredit programs (Kiiza & Pederson, 2001). Further, the findings indicated that the main determinants of rural households' involvement in loan programs were proximity to the institution, having two or more sources of income, and stable income. According to the estimated model, farmers were less likely to participate, most likely as a result of the unpredictable nature of agricultural income, and the chance of involvement increased with the borrower's educational attainment. The authors noted that while using the logit model, it is unable to fully reflect the underlying causes of information restrictions. Nonetheless, they pointed out that it accomplished the useful goal of identifying crucial elements.

Further, the study conducted by Mohamed (2003), indicated that smallholder farmers and artisanal fishers in Zanzibar's access to official information sources on c redit schemes. Using a T-test, he contrasted borrowers and non-borrowers to analyze the variables that influence each farmer's capacity to apply for and utilize financial loans in their development. Moreover, the model utilized was logistics regression. Apart from the socio-economic variables comprised of, age, gender, education, income, and awareness of credit availability, there was a noteworthy correlation found between income level and the productivity assets values owned by both users and non-users. The current study will be conducted in fishery-dependent communities where most capture fishermen live. Thus, the factors affecting information access in remote areas of landlocked countries like Uganda are likely to be different from those of a country with a coastline such as Zanzibar.

This study employed a variety of techniques, such as logistic regression modeling, binary Probit models, multinomial Probit models, and the Heckman two-step model, based on the empirical literature review. It is noted that the nature of the dependent variables and the study objectives play a major role in selecting the appropriate model. A multinomial regression was applied for some of the study's objectives that have more than two dependent variables and are ordered. Another objective is binary in nature, with a value of one if the responder accepted the technology and zero otherwise. Either Logit or Probit models are used to estimate such models. Both the Logit and Probit models estimate parameters using the maximum likelihood method. Probit assumes a typically distributed error term, whereas the Logit model assumes a logistic distribution of the error term. The Logit model is often preferred due to the consistency of parameter estimation associated with the assumption that the error term in the equation has a logistic distribution (Baker, 2000; Ravallion, 2001). Therefore, more details on econometric models to be used in this study are given in the next chapter.

Furthermore, several variables that are generally classified as socio-economic, institutional, and environmental factors were used in the previous investigations. In particular, the approach of this study is not all that different from that of previous investigations. Each study did, however, have some limitations when it came to the analysis of the variables that affected their dependent variables. As a result, the various empirical investigations from various nations that are discussed in this section have determined the most likely reasons for the variables impacting adoption and information sources and have suggested potential solutions to address these issues. The outcomes of those various empirical investigations might not be relevant to the field of research at hand. For these reasons, certain variables were chosen while excluding others based on how they seemed from the Ugandan point of view. Thus, in this research in the context of Uganda aquaculture, the study will contribute to the empirical literature on the degree to which information links through social networks have enhanced the well-being of smallholder fish farmers who have implemented cage fish farming technology.

2.5.1 Knowledge and Technology Adoption

Previous studies have shown that KAP plays a significant role in the adoption of technologies in various contexts. Tokede *et al*. (2020) investigated how farmers' knowledge and attitudes influenced agroforestry adoption in Nigeria. The study found that the majority of respondents who did not practice agroforestry had little understanding of agroforestry practices and had negative attitudes toward practicing agroforestry. Their findings, therefore, suggested that knowledge and attitude played a significant role in influencing the adoption of agroforestry. Similarly, Sun *et al*. (2022) analysed the impact of agricultural production knowledge on farmers' willingness to adopt Integrated Pest Management (IPM) technologies. Their results indicated that integrated agricultural production knowledge significantly increased farmers' willingness to adopt IPM technology.

Similarly, in Tama *et al*. (2021), knowledge was found to have the most significant total impact in a study of the factors influencing farmers' intentions to continue conservation agriculture in Northern Bangladesh, while attitude had the most critical direct impact. The study's findings emphasized the importance of increasing knowledge as a way of improving farmers' intentions toward technology adoption. Some studies have shown the moderating effect of knowledge. Chen *et al.* (2021) applied the theory of planned behavior to investigate the moderating effect of knowledge sharing on information technology adoption among apple farmers. Their findings revealed that both implicit and explicit knowledge sharing had a positive moderating effect on transitioning the intention to choose information technology into actual behaviour, with the degree of knowledge sharing having a more substantial moderating effect.

Previous studies that have also shown that even when there is plenty of knowledge about a technology, farmers may still not adopt a technology. Dzvene *et al.* (2021) studied farmers' knowledge, attitudes, and perceptions about the use of in-field rainwater harvesting (IRWH) techniques by farmers. They revealed that while there was a significant amount of knowledge about the IRWH technique among the elders, it did not influence on farmers sustained and continued adoption. Also, in Salina *et al*. (2021), livestock farmers' and traders' ability to track the movement of animals and their associated products as a means of controlling animal diseases in Malaysia was investigated. Their findings revealed that there were respondents who had adequate knowledge and attitudes toward cattle movement and traceability, yet only a small proportion followed the recommended practices. This study showed that knowledge and attitude might not be the only factors that can influence adoption.

The type and sources of information are essential aspects of knowledge that can influence the adoption of technology. Obiero *et al*. (2019) found that among fish farmers, the simplicity of knowledge about technology in terms of ease of use promoted wider technology adoption and increased yield and income. Also, Ayoub (2023) studied the relationship between knowledge sources and innovation in sustainable farming practices for various crop categories. The study revealed that various knowledge sources were ranked differently by different who had adopted different practices. Additionally, Larochelle *et al*. (2019) used a randomised control trial in Northern Ecuador to investigate the use of text messages to induce behavioural changes in farmers. Farmers who received text messages demonstrated significantly greater knowledge and were more likely to implement the majority of integrated pest management (IPM) practices.

The link between social networks and knowledge systems has also been studied. Sutherland *et al.* (2017) investigated agricultural knowledge systems with a focus on new knowledge networks established by new entrants into small-scale farming. The authors sought to identify the types of knowledge that small-scale farmers access when embarking on new activities, as well as whether the network types were characterized to suit different kinds of knowledge. Their findings demonstrated that new knowledge networks were characterized by various types of expertise and were dominated by formal agricultural advisors who provided managerial knowledge through centralised networks. Also, in Italy, Gava *et al*. (2017), a social network analysis was used to examine the impact of knowledge exchanged within a system, with a focus on cohesion, knowledge co-creation, and brokerage among biogas adopters' business decisions and contribution to knowledge upgrading.

The authors found that the most influential node was significant in disseminating knowledge across adopters regardless of their background. Their findings also revealed that the networks were centered on self-education tools, with the upstream industry acting as brokers (Gava *et al*., 2017). Also, Filippini *et al*. (2020) investigated how farmers' adoption of smartphones for professional use was influenced by the networks to which they belonged. Their research discovered that centrality measures of the production network were necessary for driving smartphone adoption among farmers in rural Italy. Ramirez (2013) studied the effects of professional collaboration within social networks on farmer decision-making behaviour in the adoption of irrigation technology. According to the study, it was shown that the best way to increase the adoption of irrigation technology was to provide more opportunities for renters, particularly cash renters, to be exposed to new information.

2.5.2 Attitude and Technology Adoption

Attitude is also an essential factor that influences technology adoption, as shown in various studies. In a study of Litchi farmers in China, it was found that farmers with a generally positive attitude towards technology adopted top grafting techniques better (Li *et al*., 2019). Dokuboba *et al*. (2019) studied the influence of entrepreneurship skills on the performance of cage fish farming. They found that attitude towards work played a significant role in determining its success in Ghana. In Kenya, Ouko *et al*. (2022) studied the adoption of Black Soldier Fly Larvae as feed among cage and pond fish farmers using the Technology Acceptance Model (TAM). They found that attitude was a significant determinant of intention to adopt.

In studies that have examined the factors that can influence attitude, (Orinda *et al*., 2021) studied cage fish culture in Kenya and found that influencing the attitude and perception of farmers through training could play a significant role in promoting the adoption of cage farming technology. Additionally, knowledge about technology has also been shown to have a significant positive effect on attitudes, perceptions, and intentions to adopt genetically modified crops (Safi Sas *et al*., 2021). Sharifzadeh *et al.* (2021) studied pesticide adoption among farmers and found that education played a significant role in influencing KAP. These studies have shown the need to strengthen education strategies among farmers to promote adoption. In a study on the adoption of water resource management among smallholder irrigators, Oremo *et al*. (2019) found that KAP was dependent on culture. In contrast, educational attainment, level of income, access to extension, and membership in local networks all had a significant impact on adoption.

2.5.3 Perceptions and Technology Adoption

Perceptions about the benefits of a technology are critical in promoting adoption. Kumari and Sharma (2022) in their study they focused on investigating the behavior of the people both before and after India adopted cage fish farming. They discovered that cage fish farming has a favorable effect on the flow of capital for livelihood and finances. Also, by applying TAM, Ulhaq *et al.* (2022) studied the adoption of monitoring technologies, such as on water quality among intensive shrimp farmers. They found that farmers who perceived ICT as being useful had higher chances of adopting the technology. Although the level of awareness positively influences farmer's perception, this revealed that channels used to rely on agricultural information are perceived differently (Businge *et al*., 2024). In the same study, it was revealed that positive perception increases the chances of technology adoption among farmers.

2.5.4 Social network and technology adoption

Social networks form the basis on which knowledge can be transferred from one person to another. The characteristics of the social ties among livestock farmers that are linked to information about calcium supplements were investigated (Vishnu *et al.*,2019). In their research, they created a map of the social network structures related to the dissemination of information on the use of calcium supplements in India. According to their findings, small-scale peer groups of livestock farmers were the most common source of formal communication in the research areas when it came to crucial information assistance for the use of technology. In China, Wang *et al*. (2020) studied farmers' adoption of water-saving irrigation technology and discovered that social networks and extension services can significantly improve agricultural technology adoption efficiency.

Shikuku (2019) investigated whether farmers affiliated with agriculture development organizations were positioned differently in agriculture-related information networks than non-affiliated farmers and whether farmer attributes differentiated their informal information networks. The authors discovered that farmer network size, density, and composition varied significantly; development project-affiliated farmers were embedded in larger networks, while the non-affiliated farmers within their networks engaged in more diverse agricultural production and reported more frequently adopting and adapting agroecological practices.

In addition, a noteworthy study on social networks looked into how Spanish farmers used social networks to make decisions to better understand how they shared information, resources, and expertise (Albizua *et al.,* 2020). In their findings they indicated that the region's network was centered around large-scale farmers who practiced intensive land management; they assessed the flow of information and resources about farm management, policy, technology, and finance. The results showed that the reputation of these large-scale farmers and their pivotal position in the social network were important factors in the intensive farming methods proliferation throughout the research area.

Using social network analysis, Zhang *et al*. (2020) revealed a number of insights which included the relationships and kinships among producers sharing social networks improving in their farming practices and use of resources. Additionally, their study also showed that although the pattern of the linkages was significant, the number of links farmers had in the community had no bearing on their adoption decisions. Further, the authors found that farmers who were seen as powerful did not always follow advised practices, but farmers with fewer connections and positions of intermediary on key information routes between various groups demonstrated more progressive practices. Their findings draw attention to the drawbacks of agricultural programs that place an undue emphasis on farmers who are thought to be prominent as well as the part that network brokers play in encouraging the adoption of cutting-edge farming techniques.

According to the findings, a network of adopters who were closer to one another had a greater influence on the adoption of hybrid rice than did a network of adopters who were farther away. Additionally, a network with a large number of adopters may not have much of an impact if they were far away (Ward *et al.,* 2015). Their research also revealed that network effects in hybrid cultivation were far more critical than interactions with agricultural extension officers. Also, Varshney *et al*. (2022) investigated farmers' adoption decisions of hybrid mustard seeds about the adoption choices of their social networks in India. The study's findings show that lower-caste farmers' adoption choices were more pronounced than their counterparts', and that social network effects were significant in intra-caste but not in inter-caste.

Further, in their study on the dissemination of innovation in heterogeneous groups, Krishnan and Patnam (2013) focus on three types of dissemination models through social networks. The first model is based on imitation effects and assumes that adoption takes place as soon as people get exposed to the new technology. In the second model, the social impact model, people are said to adopt technology when a sufficient number of people in the group adopt it. Finally, in the third model of social learning, people only adopt it if there is sufficient evidence to convince them that it is worth embracing innovation. Hence, it such literature informs that producers are rational. Implying that they only value and embrace a social network that yields tangible benefits to them.

An equally significant token used SNA to assess the performance of agricultural advisory systems in three East African countries: Kenya, Tanzania, and Rwanda (Bourne *et al.,* 2017). The authors based their approach on measuring knowledge flow and capacity for collective action, considering that the improvement of these two elements is the basis of a modern advisory system. For this purpose, they applied ego network analyses in eleven sites in East Africa. When SNA is used to analyze agricultural technology communication, it identifies frequently used agricultural advice sources and, on the other hand, those who are not well-connected to existing networks (Abizaid *et al*., 2016). Additionally, a study on different methods of advising services clarified that farmers frequently want access to sources (Babu *et al*., 2012). Thus, it eventually damages their poor and income. The authors conclude that creating an advice system that comprehends how farmers behave and communicate on social media is crucial. The study conducted by Murendo *et al.* (2015) regarding the adoption of mobile money in Uganda serves as an illustration of the significance of informal social networks. According to the study, learning inside the network accelerated the adoption of mobile money by helping to spread information about it more quickly. The author suggests using social networks for programs that encourage the usage of this technology.

Ward and Pede (2014) claim that the neighborhood impact is a crucial factor in determining the adoption of hybrid rice in their study on capturing the social network effects of hybrid rice that is popular in Bangladesh. They demonstrate that, in comparison to dealing with extension officers, the network effect is substantially stronger and that networks possessing adjacent hybrid rice adapters have greater influence than those with distant adapters. The authors propose that networks based on geography, friendship, kinship, and religion aid in educating farmers about the technology. Based on research on social networks and technology adoption in Mozambique, Chuang and Schechter (2015) found that the decision to hire a farmer's sunflower correlates with the decisions of relatives and friends, not the decisions of people of various religions.

In rural areas in Kenya and Ethiopia, institutional and informal farmer groups utilized the social network analysis study to disseminate information about innovation (Darr & Pretzsch, 2006). They looked at group dynamics that influence how innovations spread in a group environment. SNA was used by Jafari *et al.* (2020) to quantify how organizational systems affect social communication structures. They concluded that it can be applied to comprehend organizational communication and information flow patterns.

Further, the kind of study found a strong neighborhood effect on the introduction of new technologies in agriculture (Krishnan & Patnam, 2014). They believe that neighbors have an impact on farmers' decisions to use new technology. The authors caution against overestimating the influence of household factors on adoption decisions if they ignore the interactions between these farmers. In a related study, Conley and Udry (2010) discovered that Ghanaian pineapple growers modify their inputs based on advice from their neighbor who has previously achieved success. The author highlights how crucial network connectedness and information-flowing social learning are to farmers' agricultural decisions. Nevertheless, past studies on social networks need to pay more attention to the interactive aspects among the actors.

In addition, social networks have a rich connotation, while research has focused majorly on the dimensions of their effects, leading to even contradictory conclusions. Therefore, the social network approach conceptualized in this study does not focus on cage fish farmers as the basic unit of analysis but rather on the information links (ties) that exist within these farmers and other stakeholders in the fishery sector. The existing literature on social networks in Uganda's agricultural sector has focused mainly on whether networks among farmers exist or not (Ajayi *et al.,*2017). However, very few studies have gone further to look at the role of information links through social networks in exposing smallholder farmers to farming technologies, especially in the fishery sector in Uganda.

2.6 Knowledge, Attitude, and Perceptions (KAP) and social networks

Several researchers have also studied the relationship between farmers' KAP, social networks, and the adoption of technologies. Utaranakorn and Yasunobu (2016) investigated the relationship between managerial ability, the formation of social networks, and information sharing within their network connections. Their findings revealed that farmers with strong managerial abilities, particularly group leaders and managers, had a better chance of expanding their networks by becoming consultants and transferring knowledge/technology. As a result, their social networks became more active and more robust, both within and outside of their villages.

The results revealed that knowledge and attitude influenced farmers' behaviour directly. At the same time, social networks had an exogenous influence on conservation behaviour in a study seeking to understand the conservation behaviour of farmers in China (Aregay *et al.,* 2018). Also, using a social network analysis approach, Kendall *et al.* (2022) investigated the relationship between farmer networks and practices in the adoption of precision agriculture technologies in China. The study found that the structure of farmer's social networks, such as the degree of centrality, closeness, and betweenness, significantly influenced their adoption decisions. Moreover, the study revealed that farmer's KAP played a critical role in mediating the relationship between social networks and adoption decisions.

Other studies have also found that social networks can influence farmer's KAP and their adoption of new technologies. For example, using a survey method, Hlaing (2020) examined the impact of social networks on farmer's KAP and their adoption of sustainable rice farming practices in South Korea. The study found that farmers who were more connected in the social network had higher levels of knowledge and positive attitudes towards sustainable rice farming practices. Additionally, farmers who were more connected in the social network were more likely to adopt sustainable rice farming practices. Similarly, a study by Chaudhuri *et al.* (2019) investigated the role of social networks in promoting the adoption of improved rice cultivation practices in India. The study found that farmers who had higher levels of participation in social networks and had access to information and knowledge about the new technology were more likely to adopt improved rice cultivation practices. The study revealed that the social network's role in information dissemination was critical in promoting the adoption of new technologies.

As a result, another study supports the relationship between farmer's KAP and social networks and their decision to adopt new agricultural technologies (Chete, 2021). The study investigated the role of social networks in the adoption of improved maize varieties among smallholder farmers in Nigeria. The findings revealed that farmers' knowledge and attitude towards the new maize varieties positively influenced their adoption decisions. Moreover, the study found that social networks played a crucial role in promoting the adoption of the new maize varieties through knowledge sharing and peer learning. A similar study by Ambali *et al.* (2020) explored the influence of social networks on farmer's adoption of improved rice varieties in Nigeria. The study found that farmers who had social networks with other adopters of improved rice varieties were more likely to adopt the new technology. Additionally, the study highlighted the importance of trust and communication in social networks in promoting the adoption of new technologies.

Furthermore, investigating the role of social networks in the adoption of improved cassava varieties among smallholder farmers in Nigeria Sunday (2021), found that social networks had a significant favorable influence on the adoption of improved cassava varieties. Moreover, the study highlighted the importance of trust and communication within social networks in promoting the adoption of new agricultural technologies. Additionally, a study by Chichongue *et al.* (2020) examined the factors influencing the adoption of conservation agriculture practices among smallholder farmers in Mozambique. The study found that farmers' knowledge, attitudes, and practices were significant predictors of their adoption decisions. The study found that social networks played a crucial role in promoting the adoption of conservation agriculture practices through information sharing and peer learning.

Additionally, focusing on the factors influencing the adoption of improved agricultural technologies among smallholder farmers in Malawi by Vuntade and Mzuza (2022), the results indicated that farmers' KAP significantly influenced their adoption decisions. The study highlighted the importance of social networks in facilitating access to information about new agricultural technologies, building trust, and promoting the adoption of new technologies. Adams *et al.* (2021) conducted a study that investigated the factors that impact the adoption of enhanced maize varieties in Ghana. The research revealed that although farmers' adoption decisions were heavily impacted by their knowledge, attitudes, and practices, social networks were crucial in spreading awareness about the advantages of enhanced maize varieties and swaying farmers' choices.

For this reason, Negera *et al.* (2021) looked into how social networks among farmers affected Ethiopia's adoption of climate-smart farming practices. According to the study, farmers were more likely to implement climate-smart farming techniques if they belonged to farmer organizations and participated in more social activities. The study also emphasized how crucial it is for farmers to share knowledge via social networks to encourage the uptake of new technologies. Similarly, Milkias (2020) investigated the factors influencing Ethiopian farmers' adoption of improved cereal varieties through the use of a survey method. According to the study, farmers' decisions to adopt enhanced grain varieties were greatly influenced by their understanding of and perception of their benefits. According to the study, farmers' decisions to adopt enhanced grain varieties were greatly influenced by their understanding of and perception of their benefits. According to the study, farmers were more likely to adopt new technology if they were in social networks with other farmers who had adopted improved cereal types.

Additionally, a study was carried out to examine how social media can encourage smallholder farmers in Kenya to adopt improved potato varieties (Waaswa *et al.,* 2022). According to the study, farmers were more willing to implement the new technology if they were in social networks with other growers of improved potato types. The study also emphasized the role that social networks' trust and communication play in encouraging the uptake of innovative agricultural technologies. Maina *et al*. (2021) conducted a study that examined the factors that impact smallholder farmers in Kenya's adoption of improved dairy management methods. According to the study, farmers' decisions to accept the new methods were greatly influenced by their attitude and level of understanding about them.

Additionally, the study highlighted the importance of social networks in promoting the adoption of new agricultural technologies through information sharing, peer learning, and collective action. Similarly, a study by Kamau *et al*. (2017) investigated the role of social networks in promoting the adoption of climate-smart agricultural practices among smallholder farmers in Kenya. The study found that farmers who had strong social networks were more likely to adopt climate-smart agricultural practices.

Ri and Agaba (2022) examined the factors influencing smallholder farmers' adoption of bio-fortified crops in Uganda. The study found that the adoption of bio-fortified crops was significantly influenced by farmer's knowledge, attitude, and practices toward nutrition and health. Moreover, social networks played a crucial role in disseminating information about the nutritional benefits of bio-fortified crops and influencing farmer's adoption decisions. Similarly, a study by Lukuyu *et al.* (2020) examined the factors influencing the adoption of climate-smart agricultural practices among smallholder farmers in Uganda. The study found that farmers' KAP was a significant predictor of their adoption decisions.

Additionally, the study highlighted the importance of social networks in promoting the adoption of new agricultural technologies through knowledge sharing, trust building, and collective action. Moreover, Freeman and Qin (2020) investigated the role of social networks in the adoption of sustainable land management practices in Uganda. They found that farmers who were members of community groups were more likely to adopt sustainable land management practices.

Overall, the literature suggests that social networks are an essential factor in shaping farmer's knowledge of agricultural practices. Social networks can influence farmer's access to information, attitudes toward new practices, and adoption decisions. However, the relationship between these factors is complex and context-specific, and further research is needed to explore the underlying mechanisms that influence farmer's adoption decisions in different contexts, especially in cage fish farming.

2. 7 Institutional, Socioeconomic factors and technology adoption

Institutional factors refer to the characteristics of organizations and interactions that control farmers' access to and use of resources and services. These factors include access to extension services, subsidies, credit facilities, and membership in farmer groups (Jin *et al*., 2017; Kinyili *et al*., 2021).

Extension services play a crucial role in educating farmers about upcoming technologies that can help them address challenges in the entire cassava value chain. Extension providers empower farmers by helping them identify and analyse agricultural problems and take advantage of available opportunities to maximize their profits. They are directly involved in creating awareness, providing training on new skills needed for technology utilization, and helping farmers understand improved cassava processing technologies and their relevance (Matata *et al*., 2010).

Access to credit facilities is a significant challenge for smallholder farmers in the processing industry due to the high cost of machinery and equipment. The availability of credit facilities can increase adoption by making these technologies more affordable. However, commercial credit facilities are limited for the agricultural sector, and rural banks have stringent collateral and coverage requirements, making it difficult for smallholder farmers to access loans (Quartey, 2015).

Membership in farmer groups also influences adoption decisions, as collective decisions made within these groups can lead to the adoption of particular agricultural practices and technologies. Farmer organizations facilitate the efficient delivery of extension services to their members and also enable collective marketing decisions, which help farmers increase their financial capacity to invest in technology (Tey, 2013).

Numerous studies have examined the significance of social and economic factors among smallholder farmers (Matata *et al*., 2010; Zerihun *et al*., 2014). The traits that characterize an individual, household, or population are known as socioeconomic factors. These characteristics have a direct bearing on raising welfare by increasing investment, output, and management. These comprise the following: age, gender, size of the household, education, experience of the farmers, income level, and area of land (Murendo *et al.,* 2016; Kassie, 2015, & Tey, 2013).

The study conducted by Tey (2013) defines socioeconomic elements as the attributes that characterize a farmer, household, or population. These factors are closely linked to improving welfare through increased capacity for production, investment, management, and marketing. The most important socioeconomic variables that are linked to the adoption of agricultural technology are the experience, size, and income of farmers, as well as demographic parameters like age, gender, household size, and level of education.

Age, for example, affects the decision to embrace agricultural technologies, as some older farmers are less inclined to do so because of their short-term goals, motivation, and energy loss

(Murendo *et al.,* 2016). According to Kinyili (2021), elderly farmers tend to think that the adoption of any innovation is less likely or may take a long time to bring about significant benefits and prefer to value their prior knowledge of agricultural operations more than contemporary alternatives. On the other hand, Kassie and colleagues (2015) contended that contingent on the situation, there exists a positive or negative correlation between age and adoption. Even while risk-averse behavior and short-term planning prevent older farmers from adopting technology, certain elderly farmers are more likely to have many years of farming experience.

Similarly, a farmer's experience increases the information and knowledge available to them to evaluate and decide on a specific agricultural technology or practice with confidence (Kassie *et al.*, 2016). Consequently, farmers are more likely to use agricultural technology that offers a large variety of advantageous features. Implying that sharing information about an agricultural technology among farmers is critical.

The reviewed research on gender (Kalumendo *et al.,* 2023; Kassie *et al.,* 2016) indicates that, in comparison to male farmers, the majority of female farmers typically have less access to and control over production resources. The socio-culturally built roles, advantages, and statuses that people, particularly in the poor world, are subjected to are blamed for this gender inequity. Women are therefore unable to significantly influence the adoption of technologies (Chisenga, 2015). Females are restricted to reproductive, communal, and specific producing responsibilities due to the distinct division of labor, which hinders their ability to contribute to development. Furthermore, female farmers' restricted mobility reduces their access to other production resources and extension services (Kassie *et al.,* 2015). In the domain of technology, there haven't been any conscious attempts to take into account farming households headed by men and women equally (Chisenga, 2015).

Regarding education level farmers who have had formal education are better able to seek out and evaluate pertinent information about a technology, which increases their likelihood of understanding the innovation and making deft decisions about it. Consequently, compared to people without any formal education, they are more likely to easily adopt new processing technologies (Martey *et al*., 2019). Better cassava technologies require land, which can be rented or owned by the family.

The land is significant since more labor will be needed on larger plots of land (Tey, 2013). Farmers with greater land holdings are more inclined to utilize agricultural technologies because they save labor and mostly rely on natural processes. It follows that the adoption of agricultural technologies is thought to be positively correlated with the size of the land. Therefore, when they own a sizable amount of land that is dedicated to agriculture, these farmers are more inclined to adopt advanced agricultural methods.

Another factor influencing farmers' decisions to embrace agricultural production technologies is their income. Due to their greater flexibility in allocating cash for the acquisition of technical equipment, smallholder farmers with larger income holdings are more likely to embrace agricultural production technologies (Murendo *et al*., 2016).

Therefore, there is a growing acknowledgment of the impact of both socioeconomic and institutional factors that influence resource use and practices, as well as the adoption of agricultural technologies among rural populations (Binam *et al*., 2017). However, there needs to be more focus on how the combination of socioeconomic and institutional factors influences the adoption of agricultural technologies (Matata *et al*., 2010; Mercer, 2004; Mwase *et al*., 2015). This gap is particularly evident in Sub-Saharan Africa, where there are various constraints to the adoption of agricultural technologies. Therefore, it is essential to grasp the contribution of both socioeconomic and institutional factors in the adoption of agricultural technologies within the local context to comprehend better the barriers to the adoption of cage fish farming technologies. Therefore, the purpose of this study was to model many institutional and socioeconomic factors that influence smallholder farmers in Lake Victoria in Uganda to adopt cage fish farming technology.

In addition, the discussion below elaborates on the farmers' knowledge, attitudes, and perceptions (KAP). Further, informal social networks directly influence the adoption of cage fish farming technology. Farmers with higher levels of knowledge, more positive attitudes, and positive perceptions towards new technologies are more likely to adopt them (Businge *et al*., 2024).

Accordingly, it is acknowledged that farmers' (KAP) participation in unofficial social networks and their adoption of cage fish farming technology are important factors (Bourne *et al.,* 2017). Because they are more aware of the technology's potential to increase productivity and income, farmers who possess greater information about the advantages and practical features of cage fish farming are more inclined to implement it (Bourne *et al.,* 2017; Businge *et al.,* 2024).

On the other hand, a positive attitude towards innovation and change also plays a crucial role; farmers who are open to adopting new methods and technologies are more open to integrating cage fish farming into their practices (Businge *et al*., 2024). Additionally, positive perceptions of the technology, such as attributing it as profitable, sustainable, and low-risk, further encourage adoption. Similarly, informal social networks, including relationships with fellow farmers, community leaders, and local extension agents, greatly influence adoption decisions (Carrington 2014; Chen *et al*., 2014). Hence, such networks create a platform that facilitates the exchange of information, experiences, and support, reinforcing positive attitudes and perceptions and making farmers more confident and willing to invest in cage fish farming technology.

Similarly, Chuang and Schechter (2015) revealed that farmers who are members of farmer groups or cooperatives and have access to formal social networks are efficiently linked to information and technical support, enhancing their likelihood of adopting the technology. Such associations and organizations provide a platform for sharing knowledge, experiences, and resources, making it easier for farmers to learn about and implement new technologies. There are also mediating variables that can influence the relationship between a farmer's Knowledge, Attitude, and Perception (KAP) on the adoption of cage fish farming. For instance, Sun *et al*. (2022) indicated that farmers who receive extension education and training are significantly enhanced in their ability to comprehend and apply new technologies effectively. Additionally, access to credit and financial resources is a critical factor that is enhanced among farmers through groups and associations (Kakisina & Puttileihalat, 2024). Hence, provides the necessary capital for purchasing inputs and setting up the infrastructure required for cage fish farming. Moreover, government policies and programs play a crucial role in creating a supportive environment for adoption by providing subsidies, extension services, and regulatory frameworks that encourage and facilitate the uptake of this technology. Together, these factors create a conducive environment that supports farmers in adopting and successfully implementing cage fish farming, thereby improving their productivity standards of life.

Farmers' characteristics are another crucial element that influences farmers KAP in adopting cage fish farming technology. These characteristics influence how farmers react to new technologies in terms of their willingness to embrace them and their ability to implement the technology successfully (Chuang & Schechter, 2015). In this case, the age of the farmer is a crucial factor in determining the knowledge, attitude, and perception (KAP) they have towards the technology. For instance, Tokede *et al*. (2020) revealed that older farmers are more prone to traditional views and practices, which may hinder them from adopting new technologies. With their experience, they may prefer tried-and-true methods and hence decline to invest in cage fish farming. On the other hand, younger farmers are often more open to innovation and ready to embrace new technologies (Todua, 2017).

Conversely, gender plays a crucial role in influencing the adoption rate of caged fish farming technology (Wairimu, 2022 & Wang, 2020). Therefore, men and women can access resources, training, and decision-making power differently. For instance, men are always dominant in farming decisions and resource allocation, affecting how technologies like cage fish farming are adopted and scaled. On the contrary, women face barriers in accessing capital and information, which influence their ability to adopt and benefit from such technologies.

Farming experience, on the same note, is another imminent factor that significantly affects a farmer's Knowledge, Attitude, and Perception (Tama, 2021; Suvedi, 2017). Hence, attributed to the fact that smallholder fish farmers who are more exposed to extensive experience in traditional aquaculture are always skeptical of new technologies due to their rooted, strong attachment to established practices. Correspondingly, (Simtowe, 2016) revealed that experienced farmers have a deeper understanding of the risks and benefits of new methods, which in return effectively influences their Attitude towards adoption. On the contrary, farmers with less experience are always willing and more open to experimentation and learning new techniques. Their attitudes effectively encourage them to view cage fish farming as an opportunity to enhance productivity.

Smallholder fish farmers have different abilities when it comes to owning cage fish technologies. Undoubtedly, smallholder fish farmers who have access to or can afford multiple or advanced cage units are likely to have more experience and resources to invest in new technologies (Shoko, 2017). They are always willing to adopt cage fish farming if they see it as an elevation to increase efficiency and profitability. Their willingness is also attributed to factors such as the type of cage units, which include floating vs. fixed cages, hence impacting how they perceive technology and adoption (Shoko, 2017). Different designs of cage fish farming technology have varying levels of complexity and cost associated with them.

The level of education of the smallholder fish farmers is also a significant determinant of the KAP. Further, higher education levels are characterized by advanced knowledge of what is trending and new technologies, and they are better equipped to understand and apply complex concepts in their farming practices. On the other hand, Salina *et al*. (2021) found that education fosters a positive perception and Attitude toward innovation and improves the ability to evaluate and adopt new methods critically. In the same way, lower education levels limit a farmer's ability to grasp new technologies and reduce their confidence in trying out new methods. Hence, makes them miss out on new trends because they are not curious about what is new; they prefer following their traditional ways of farming. Another attribute influencing farmers' knowledge, Attitude, and perception of cage fish farming technology is the location of cage units in water bodies (Seline, 2014).

Therefore, it dramatically influences the adoption rate, attributed to accessibility to resources and support services. Smallholder fish farmers whom the location of their cage units is situated in areas with well-developed infrastructure, such as proximity to roads, markets, and service centers, are at an advantage (World Bank, 2003). Hence, farmers benefit from more accessible access to essential resources like quality feeds, fingerlings, and technical support. Further, it implies that they can reduce operational challenges, making it more feasible for farmers to implement new technologies, as they can access extension advice, training, and troubleshooting assistance from experts. Additionally, farmers whose cage fish locations are in remote or less accessible areas experience extreme challenges in adopting new technologies.

Conversely, Ulhaq (2022) stated that physical distance from support services is attributed to deployments; hence, receiving crucial information and technical guidance becomes a challenge for farmers, making it harder for them to stay updated on best practices and innovations. The lack of infrastructure in remote areas, on the other hand, increases the cost and difficulty of transporting necessary inputs, discouraging adoption. Hence, those in more accessible areas are at an advantage to adopt and benefit from advancements in cage fish farming.

Fish farming is a practice that requires labour intensity; therefore, in this case, labour used in cage fish farming significantly influences a farmer's ability to adopt new technologies (Owani *et al*., 2022). The reason smallholder fish farmers rely on family labour to benefit from greater flexibility and lower operational costs is that they do not need to pay wages or deal with the complex situations of managing external workers (Mbowa *et al.,* 2017; NaFiRRI, 2022). Moreover, family members are always more willing to invest in the success of the farm, making them more willing to learn and adapt to new practices. In contrast, Rola-Rubzen, (2020) revealed that farmers who depend on hired labour face higher costs and are always reluctant to try new technologies; this is because they try to avoid paying wages, time, and resources needed to train workers in new techniques. The additional expense and management challenges may make them more cautious about investing in cage fish farming technologies, especially if they are still determining the return on investment.

Religion, on the other hand, indirectly influences the knowledge, attitude, and perception of smallholder fish farmers regarding the adoption of cage fish farming technology (Oyawole, 2021). Hence, characterized in terms of shaping farmers' values, practices, and perceptions about aquaculture. For instance, some religions promote principles of environmental stewardship, leading farmers to adopt sustainable aquaculture practices, including modern technologies that enhance efficiency and reduce environmental impact. However, Abdollahzadeh and Baiyegunhi (2016) revealed that certain religious or cultural beliefs might discourage the adoption of fish farming due to perceptions about the sanctity of natural water bodies or because of dietary restrictions that limit the consumption of certain fish species. Meanwhile, religious communities' positions serve as influential social networks where shared beliefs and practices can either encourage or discourage the adoption of new technologies. For instance, if a religious group collectively views cage fish farming positively, members are more likely to adopt it, whereas negative perceptions within the community could discourage adoption. Hence, religion plays a crucial role in influencing farmers' decisions about embracing new technologies in aquaculture.

Conversely, Mbowa *et al*. (2017) indicated that stocking densities in cage fish farming indicated the level at which a smallholder farmer is intensively utilizing the technology and their readiness to adopt advanced practices. Therefore, it implies that higher stocking densities indicate farmers' willingness to employ a more advanced and productive approach, focused on maximizing the use of space and aiming for higher yields (NaFiRRI, 2017). Thus, portrays a greater willingness to embrace new technologies and innovations that can enhance efficiency and profitability. Moreover, managing high stocking densities is attributed to disparities, including maintaining water quality and ensuring fish health. High densities are influenced by rapid waste accumulation, reduced oxygen levels, and increased risk of disease outbreaks, hence requiring consistent monitoring. Therefore, smallholder fish farmers must have access to the proper knowledge, resources, and tools. According to Mbowa *et al*. (2017), access to water quality testing kits, aeration systems, and proper feeds for effective management of these risks

The number of training sessions received by smallholder farmers is another attribute influencing the adoption rate of cage fish farming technology (LVFO, 2015). Significantly, training acts as fuel to equip farmers with the necessary knowledge and practical skills for the effective implementation and management of the technology. Conversely, Li *et al*. (2019) revealed that smallholder fish farmers who participate in more training opportunities are better equipped to understand the complexities of cage fish farming and are more likely to adopt best practices that enhance productivity and sustainability.

Further, frequent training builds farmers' confidence in using new technologies as they become more familiar with the processes and handle complex issues independently. Exposing them to more training increases their confidence while encouraging them to adopt cage fish farming. This practice motivates them to innovate and improve their practices over time, changing their Attitude and perception of cage fish farming technologies. Additionally, Emma (2013) revealed that continuous training keeps farmers abreast of the latest advancements and trends in aquaculture, ensuring they remain competitive and adapt to changing conditions in the industry.

Additionally, capital investment significantly influences the adoption of cage fish farming technology (Emma, 2013). Thus, it resonates with the fact that adequate financial resources are essential in acquiring the necessary equipment, such as cages, nets, and aeration systems, and the infrastructure needed to support a successful operation, including boats, feeding systems, and water quality monitoring tools (Emma, 2013). Farmers with access to sufficient capital are better positioned to invest in these resources, which allows them to implement cage fish farming technology effectively and at scale. Moreover, this allows them to adopt more advanced technologies, such as automated feeding systems or advanced water filtration, hence enhancing productivity and profitability.

However, Davis and Heemskerk (2012) showed that smallholder fish farmers who experience limited financial resources are always unwilling to adopt. Costs of cage fish farming are always high, hence prohibiting them from practicing farming using advanced technologies. Therefore, such disparities render the management of cage fish farming more accessible so that they can sustain the practice with ongoing financial support. However, this can be made easier for them if they can access credit and financial services, such as loans or grants. Additionally, the necessary capital to invest in cage fish farming. Without such support, the lack of capital remains a significant barrier to adoption, limiting their potential to benefit from this technology.

With regard to institutional characteristics, it is evident that this influences smallholder fish farmers' adoption of cage technology because it plays a crucial role in enhancing farmers' knowledge, Attitude, and perception (KAP) towards cage fish technology (Davis & Heemskerk, 2012). This is characterized by access to extension services, credit and financial resources, fish markets, and farm inputs. Together, these factors significantly influence how farmers passively engage with new technologies and the possibility of adoption.

Smallholder fish farmers' access to extension services significantly enhances farmers' knowledge and technical skills in cage fish farming technology (Davis & Heemskerk, 2012). Access to extension services enables smallholder farmers to receive essential training, information, and support for farmers, helping them understand the complexities of cage fish farming. Through regular interactions with extension agents, farmers get exposed to best practices, disease management, water quality maintenance, and optimal stocking densities (Chete, 2021). This knowledge empowers them to make informed decisions and reduces the uncertainties associated with adopting new technologies. Additionally, Businge *et al*. (2021) revealed that extension services bridge the gap between research institutions and farmers, ensuring that they can access information on the latest advancements in cage fish farming. As a result, this influences their positive Attitude towards adopting new technologies, as they feel supported and confident in their ability to succeed.

Access to Credit and Financial Resources is another institutional characteristic influencing smallholder fish farmer's Knowledge, Attitude, and Perception (KAP) of cage fish farming systems (AUDA, 2022). Access to credit and financial resources influences the smallholder fish farmers' adoption of cage fish farming (LVO, 2021). Financial resources are necessary to cover the establishment of cage units, purchasing high-quality feeds, and investing in necessary infrastructure and equipment. Therefore, smallholder farmers with access to credit are more willing to adopt this technology without depleting their savings or compromising other aspects of their livelihoods. Additionally, Eyster (2014) revealed that the availability of credit helps them scale up their operations, experiment with innovations, and manage risks more effectively. However, smallholder fish farmers who need access to financial resources are always reluctant to cage fish farming because of the costs involved and the perceived financial risks. This financial constraint makes them pre-judge, hence influencing their perception of the technology, as these farmers may view it as unattainable or too risky to pursue.

Market access by smallholder fish farmers is another critical institutional characteristic that significantly influences farmers' knowledge, attitudes, and perceptions of cage fish farming (Eyster, 2014). Additionally, smallholder fish farmers' reliability and accessibility to market for their produce ensures that farmers sell their fish at fair prices, providing a steady profit that, in the long run, convinces them to invest in cage fish farming. When farmers have access to vibrant markets, they change their negative perception of cage fish farming, describing it as a profitable and sustainable venture. Therefore, in return, it encourages them to adopt and expand their operations, knowing that they have a secure outlet for their produce. In contrast, if market access is limited or prices are volatile, farmers' perception towards cage fish farming changes due to concerns about marketability and profitability. There, poor market access negatively influences adoption, as the perceived risks and uncertainties outweigh the potential benefits smallholder farmers receive.

Cage fish farming ideally requires accessories to perform it. Therefore, access to high-quality farm inputs, such as feeds, cage accessories, and other necessary supplies, is essential for the successful implementation of cage fish farming technology (Mbowa *et al*., 2017). In contrast, the constant availability and affordability of these inputs directly influence a farmer's ability to maintain healthy fish stocks and achieve optimal production levels. Attributing to this fact, farmers' ability to easily access high-quality feeds and cage accessories significantly influences the adoption rate of new technologies, as they have the necessary tools to ensure the success of their operations. Further, consistent access to inputs helps build confidence in the technology, promising stable production and avoiding disruptions caused by input shortages (Mbowa *et al*., 2017). Limited access to inputs, on the other hand, negatively hinders cage adoption; this is attributed to the fact that smallholder farmers struggle to maintain their operations to achieve desirable outcomes.

Concerning the above discussion, external factors are another major challenge influencing smallholder holder fish farmers' knowledge, Attitude, and perception of fish farming technology adoption (Dzvene *et al*., 2021). One of the external factors is policy, which plays a pivotal role in influencing farmers' KAP with cage fish farming technology. Effective policies play a crucial role in providing farmers with a conducive environment for the growth of fish farming, providing them with clear guidelines, incentives, and regulations that govern them. Policies that are focused on offering subsidies for inputs like fish feed, providing tax breaks for aquaculture investments, significantly lower the financial barriers to adoption, making cage fish farming more accessible and attractive to farmers. Moreover, policies that support research and development in aquaculture influence innovativeness and the dissemination of new technologies, further encouraging adoption.

Additionally, FAO (2015) stated that regulatory policies that ensure sustainable practices, such as water quality standards, environmental protection regulations, and guidelines on stocking densities, improve farmers' perceptions of cage fish farming. However, a lack of supportive policies or regulations will influence farmers reluctant to adopt cage fish farming technology. On the other hand, policies that promote access to extension services, credit facilities, and markets greatly influence farmers' KAP on caged fish farming. Therefore, Government investment in building effective extension services and improving access to financial resources and markets contribute to the adoption rates of cage fish farming technology.

Macroeconomic factors are another element that influences smallholder fish farmers' KAP in cage fish farming technologies (Fisher *et al*., 2019). This factor determines how smallholder fish farmers perceive cage farming; this includes national economic policies, inflation rates, and currency stability, which significantly influence farmers' KAP on the adoption of cage fish farming technology. Conversely, a stable macroeconomic environment implies a low rate of inflation and favorable exchange rates, which immensely creates a sense of security for farmers, encouraging investment in new technologies like cage fish farming. Thus, implies that when the economy is stable, accessibility to funds is enhanced, exposing farmers to affordable credit, competitive prices for inputs, and reliable markets for their produce, all of which foster a positive perception of the technology's viability. However, an unstable macroeconomic environment implies high inflation, eroding purchasing power, making it difficult for farmers to afford the necessary inputs and equipment. The negative attitude towards investing in cage fish farming is due to farmers perceiving greater financial risk and uncertainty.

On the other hand, microeconomic factors such as local market dynamics, supply and demand, and individual access to credit influence farmers' decisions to adopt cage fish farming technology." For instance, Freeman and Qin (2020) revealed that in regions where local markets are strong and demand for fish is high, farmers perceive cage fish farming as a profitable venture, resulting in higher adoption rates. Therefore, with enhanced access to microfinance and local credit facilities, farmers who can secure loans or financial assistance at favorable terms will be willing to invest in the technology. However, if local market conditions are weak, farmers will perceive cage fish farming as costly and unprofitable, leading to hesitation or resistance to adopting the technology.

Infrastructure is a fundamental aspect when establishing and ensuring the growth of agricultural sectors (Suleiman *et al*., 2022). This external factor greatly influences farmers' knowledge, attitude, and perception of adopting cage fish farming technology. Well-established infrastructure facilitates more accessible access to markets, farm inputs, and technical support. For instance, well-maintained roads and reliable transport services simplify farmers' movement from their fish farm to market quickly and efficiently, ensuring better prices and reducing losses due to spoilage. Access to electricity can enable the use of advanced technologies, such as aeration systems and automated feeders, which enhance productivity and efficiency. Efficiency and effective infrastructure enhance farmers' perceptions towards adopting cages and accessing the resources and support needed to operate successfully. Conversely, poor infrastructure acts as a barrier, creating logistical challenges, increasing costs, and fostering a negative perception for farmers to consider adopting cage fish farming, especially in remote or underdeveloped areas.

Other fundamental factors for fish farming are environmental and marine, comprising water quality, climate conditions, and the health of aquatic ecosystems, which are critical in shaping farmers' attitudes toward cage fish farming. Farmers must ensure the environmental suitability of their locations for cage fish farming, as poor water quality or unfavorable climate conditions expose fish to high mortality rates, disease outbreaks, and low productivity. However, the available literature do not clearly bring out such envisioned effects (Suleiman *et al*., 2022).

Consequently, Mbowa *et al.* (2017) indicated that areas prone to water pollution or fluctuations in water temperature are less suitable for cage fish farming, leading farmers to perceive the practice as risky or unsustainable. Favorable environmental conditions enhance the success of cage fish farming, encouraging more farmers to adopt the technology. For instance, farmers' awareness of environmental regulations and the need for sustainable practices influence their attitudes and perceptions. Those who understand the importance of environmental stewardship may be willing to adopt technologies that minimize environmental impact and ensure long-term viability. Environmental and marine factors, therefore, play a crucial role in determining the perceived risks and benefits of adopting cage fish farming technology.

2.8 Analytical Framework Reviews

The study used inferential statistical techniques such as means, percentages, frequencies, standard deviation, and Pearson chi-squared and selected econometric models.

2.8.1 Multinomial Logit model

A multinomial Logit (MNL) model was used to analyze factors influencing farmers' knowledge, attitudes, and perceptions (KAP) as the test for independence of errors terms are rejected against the use of the multi-Probit model (Sosina *et al*., 2009). Given a collection of independent variables, the MNL model is used to forecast the probabilities of the various possible outcomes of a categorically distributed dependent variable (Green, 2012). The MNL is applicable in situations where the dependent variables are more than two (Ben-Akiva & Lerman, 1985). Its modeling approach falls under the Random utility theory (RUT), where the choice between alternatives is explained by personal characteristics and the utility derived from each alternative. In this study, the dependent variable has three outcomes that are identically and independently distributed, hence the appropriateness of the model. Accordingly, Washington *et al*. (2003) and Hosmer *et al*. (2013) revealed that MNL models explain the correlation between the dependent variable and the independent variable in conditions when their values are obtained with rating scales.

From the reviewed literature, MNL and multinomial Probit (MNP) are commonly used in analyzing adoption decision studies that involve multiple choices. Therefore, both the MNL and MNP are essential for analyzing farmers' decisions as these are usually made jointly (Hausman & Wise, 1978; Wu & Babcock, 1998). The MNP was, however, applied when the dependent variables are correlated and cannot be identically and independently distributed. For example, Nxumalo *et al*. (2019) used an MNL to examine the determinants of market channel choices that respondents utilized. The findings emanated from the MNL regression analysis revealed that factors such as age, marital status, gender, credit access, education, and farming experience significantly influenced the choice of the market channel among maize and sunflower farmers in the study area.

Multinomial Logit has an advantage because it is applied in determining choice probabilities that may be expressed analytically, Multinomial Logit has an advantage (Tse, 1987). (Tse, 1987). MNL provides a convenient closed form for underlying choice probabilities, with no need for multivariate integration, making it simple to compute choice situations characterized by many alternatives. In addition, Hausman and McFadden (1984) argue that the MNL simplifies the computational burden because of its likelihood function, which is globally concave.

2.8.2 Double Hurdle Model (DH)

This study adopted a Double Hurdle (DH) approach to quantify the intensity of the adoption of cage fish farming technologies. The approach emphasizes two tiers that farmers encounter during the adoption process. The adoption decision is believed to be simulated by several factors that form the first tier. In contrast, the intensity of the technology adoption is considered in the second tier (Cragg, 1971). According to Berhanu and Swinton (2003), the two tiers of the model (decision and intensity) have a connection. According to Wooldridge (2002), the model assumes joint decisions on use and intensity of adoption. Based on the available literature, a Double Hurdle (DH) was employed for this study because of its ability to give realistic estimates involved in the two levels of decision-making processes. Secondly, it loosens the assumptions of correlating the error terms of the two outcomes and models the two choices independently.

2.8.3 Social Network Analysis Techniques

The study considered a "whole network" approach to capture the node sizes and the relationships existing among the cage fish farmers in the study area. The aim was to understand the role and structural layout of information links that empirically facilitate the exchange of information in the social networks of smallholder farmers, which is crucial. Further, the study assumed that the respondent was paired with other actors by the information linkages. According to Conley and Udry (2010), a complete social network exists when there is an ego and alter. Further, the study focused on the information linkages between the ego and alter matches, and individual farmer's networks were analyzed using UCINET and visualized NetDraws.

2.8.4 Treatment Effect Estimation Methods

From the available literature, several methods were used to estimate the treatment effect while dealing with the treated and untreated groups. To date, several estimation approaches have been conducted, such as graphic method (Balakrishnan & Kateri, 2008; Chen *et al*., 2016;), moment estimation (Markovic *et al*., 2009), maximum likelihood estimation (MLE) (Balakrishnan & Kateri, 2008; Chen *et al*., 2016), kernel density estimation (Kang *et al*., 2018; Markovic *et al*., 2009), least squares estimation with particle swarm optimization (Carneiro *et al*., 2016), to mention but a few. For this study, Maximum likelihood estimation (MLE) was used because it provides a means of estimating the sum value by using the parameters that "maximize" the agreement between the selected model and the observed data.

In other words, MLE is an effective technique for estimating parameters, as described by (Yang *et al.,* 2019). However, Orkcu *et al*. (2015) proposed an approach based on the differential evolution algorithm to search for the maximum value of the likelihood function. Usta *et al*. (2016) combined the probability-weighted moments and the power density method to estimate the Weibull parameters. In Orkcu (2015), the particle swarm optimization (PSO) was adopted to provide accurate estimations of the Weibull parameters. Petkovic *et al*. (2015) proposed an adaptive neuro-fuzzy inference system to predict the parameters of the Weibull distribution. Mazen *et al*. (2018) discussed various approaches, including maximum likelihood method, percentile-based method, least squares method, weighted least squares method, and maximum product of spacing estimators by numerical simulations. However, all these methods depend heavily on the sample data. Therefore, in the case of this study, it was assumed that levels measured in the number of exposures through social networks influence the individual's knowledge, attitude, and perception, similar to those with whom s/he interacts.

2.8.5 Propensity score matching method

On account of the propensity score, the matching method, Rosenbaum and Rubin (1983) developed a concept of propensity scores (PS) to conduct non-randomized studies. The propensity score technique became popular, especially in epidemiologic studies (Austin, 2007). PS is a measure of the likelihood that a subject would have been treated using only his covariate scores. Rosenbaum and Rubin (1983) showed that the PS is a balancing score and can be used in observational studies to control for confounding bias. Propensity scores can be calculated using more than one method, most frequently using logistic regression, where the co-variables used to predict the exposure are included in one model without the outcome of interest (Austin, 2011). The unique properties of PS and its ability to create a "quasi-randomized" experiment (Kurth *et al*., 2006). Hence, in cases where logistic regression is lacking, such as when analyzing rare events (outcomes).

Propensity Score matching has many approaches (Austin, 2008; Sturmer *et al*., 2006). However, the most common is one-to-one matching, where the nearest neighbor pair is used without replacement within specified s calipers of the propensity score. The pairing of an exposed subject with a non-exposed subject occurs when their PS values fall within a certain pre-specified distance known as a caliper (Austin, 2011). Once a paired matched sample is formed, the treatment effect could be calculated by directly measuring the outcomes among treated and untreated individuals. For continuous outcomes, the treatment effect could be estimated as the difference between the mean outcomes for treated and untreated subjects. For dichotomous outcomes, treatment effect can be calculated as the difference between the proportions of subjects with the event.

For this study, PS matching is considered suitable because it can control the unaccounted factors that bias the respondent (Heckman *et al*., 1998). Secondly, it will match individuals in the treatment group with those in the control group with similar characteristics and further compare the behavioral change between the two groups. It will also allow the researcher to evaluate behavioral change while considering other factors that can predispose some individuals in the control group to treatment.

2.9 Theoretical framework

This study was anchored on two theories: The Innovation Diffusion Theory advanced by Rogers (1995) and the Random Utility Theory as stated (Mc Fadden & Fadden 1977).

2.9.1 Innovation Diffusion Theory

Diffusion is defined as the process through which an innovation is embraced and accepted by members of a particular community is known as diffusion. This approach has been applied by experts in a variety of fields, including marketing and agriculture, to boost the uptake of novel goods and procedures. The spread of an innovation is influenced by many interrelated elements. The innovation itself, how it is disseminated, the passage of time, and the characteristics of the social structure into which it is being incorporated are the four main variables (Rogers, 1995). An improved comprehension of the myriad aspects influencing innovation adoption will enable instructional technologists to more effectively explain, anticipate, and account for the factors impeding or promoting the spread of their solutions.

According to this research, diffusion happens gradually and may be divided into five main phases: knowledge, persuasion, decision-making, implementation, and confirmation. This theory states that prospective adopters of innovation must become knowledgeable about it, be convinced of its benefits, make the decision to adopt it, put it into practice, and then confirm (reaffirm or reject) that decision. The adoption of technologies by smallholder farmers in Kakamega North Sub-County is influenced by several factors, including capital and credit facilities, the availability of marketing, demographic factors, and the agricultural officers' failure to provide information on agricultural production technologies, including the availability of agricultural extension services

2.9.2 Random Utility Theory

One of the underlying motivations for the cage fish farmers' choices of alternative cage technologies is to maximize utility from the expected earnings from the various technologies. Thus, cage fish farmers' choice of which technology to engage in can be analyzed within the random utility framework. The random utility theory was adopted in this study following McFadden's (1974) random utility model. The random utility model is a sub-category of probabilistic choice models that are used to econometrically represent individuals' maximizing behavior (Manski, 1977). Therefore, the adoption of new technology is a complex process and involves decision-making based on several factors surrounding the intended user, such as getting enough exposure and a certain level of awareness.

In this study, it is hypothesized that adoption is an outcome of exposure that influences the decision-making process. When farmers are exposed to new agricultural technologies, such as cage fish farming, adoption becomes easy. The adoption of technology enables individuals to maximize utility, which results in improved income, output, and welfare. It is believed that adoption takes place when individuals get total exposure to the technology and its attributes.

As described by Green (2003), individuals randomly maximize utility based on the available alternatives. Therefore, this study assumes that individual farmers rationally make decisions to adopt cage fish farming or not to adopt it based on the expected value or utility relative to the available alternatives. Thus, it implies that every choice yields an outcome (utility) to the chooser, which in turn can be ranked. Hence, random utility theory explains how individuals appropriately apportion their limited resources and derive the maximum benefits from them. Thus, an individual (), would decide to adopt cage fish farming (), if the perceived utility and not to adopt cage fish farming if the perceived utility. It implies the probability that the farmer selects cage fish farming technology (), is conditional to the available set of alternatives () In this case, conventional wild fishing. And expressed as:

....(1)

Hence, , represents the unknown factors that influence the utility of famer to adopt cage fish farming technology (Therefore, the utility derived from the adoption of cage fish farming will depend on several factors. , (socioeconomic, institutional, environmental, and attributes of the technology) which influence decision-making.

....(2)

where; .

That implies that in this study, an , farmer can choose an alternative , conditional to . Then, the probability outcome for farmer to adopt cage fish farming technologies (, can be expressed as:

....(3)

Where, , Represents the probability outcome for farmer practicing cage fish farming; then, , represents the random disturbance term in the equation. , represents the cumulative (random residuals) for , Which are expected to be randomly distributed, as suggested by Green (2003).

Secondly, this study was also drawn from the social network paradigm, which is a classical pillar in the new institutional economics (Emma, 2013). Social networks are considered resource links that emerge from individual interactions (Newman & Dale, 2007). According to Boyd and Ellison (2007), individuals usually do not aim at meeting new people but are more interested in managing relationships through maintaining contacts. Hence, social networks are an alternative tool for disseminating crucial information and can support existing formal platforms. Social networks can foster strong bonds of trust and relationships between people because they are empirically formed through the linkages that bind actors, interactions, and information flows. (Muange & Schwarzer, 2014).

A dyad, or pair of linked actors, is the simplest type of social network. In this type of network, one actor whose network is under study is referred to as the ego, and the other as the alter (Smith & Christakis, 2008). As a result, the investigation is based on two key questions. First, what elements go into adding cage fish farmers to the mutual information-sharing network? What function do the size and composition of each unique network among cage fish growers serve, secondly? As a result, it was hypothesized that study participants with a greater network degree do have positions that make them more susceptible to opportunities in cage fish farming technologies; as a result, these people were more likely to have a higher intensity of exposure than those with a lower network degree.

Regarding social contact, which is viewed as an external resource (RTIMP, 2017; Senteramo, 2019; Scheinkman, 2008), social scientists have differing views. According to these views, the follower's preferences are influenced by the reference person's activities. Naturally, many economists classify social interactions as non-market transactions because they are not governed by monetary terms. Rogers (2003) introduced the concept of adopting technology more quickly, which the study utilized to recognize the importance of social connection. According to social interaction models in practice, people react to social cues when they believe the action they are taking will boost their marginal utility (Scheinkman, 2008). Stated otherwise, the inference implies the existence of a bi-directional change impact, which is either direct or indirect.

Building on the comprehensive literature review conducted by Musa and Basir (2021), Moreno *et al.* (2014), Owusu (2012), and Rogers (2003), this study elucidates that technological adoption is a diffusion process. The dissemination of technology occurs over time through specific communication channels within social networks, with the implications of this diffusion being cumulative among members who share the same social platform. The need for a system to help users obtain information about the technology is further highlighted (Roger, 2003). Diffusion of innovation theory, states that adoption of technology is impacted by five primary features, which are, relative advantage, compatibility, trialability, observability, and complexity.

The theory of Reasoned Action (TRA), created by Ajzen and Fishbein (1975), was also used in the study. The goal of Reasoned Action theory is to explain human behavior by highlighting the elements that influence the intention behind behavior. People's attitudes and views of the agricultural technology being promoted are the two aspects. Theoretically, TRA states that an individual's attitude toward a specific behavior is a result of their beliefs' strength and their assessments of the associated consequences.

The literature study indicates that in situations when access to formal extension organizations is restricted, social networks play a significant role in disseminating agricultural information (Abid, 2015). Particularly, in developing nations, access to extension services is restricted for smallholder farmers and is skewed toward influential farmers (Abid, 2015; Ngaruiya & Scheffran, 2016). Information about Uganda's adoption of cage fish farming, however, is still not well recorded among smallholder farmers. Studies on the present exchange of knowledge and interactions among smallholder cage fish farmers, as well as their part in the adoption of new technology, are therefore necessary.

In consideration of the current knowledge gap, this is the first study of its sort to investigate the importance of social networks and the possibility of information transfer among smallholder cage fish farmers in Uganda, taking into account the existing knowledge gap. In particular, three research questions serve as the study's compass: (1) How do smallholder cage fish farmers share information pertaining rearing fish under cage units through their social platforms? (2) What social network structures are majorly used by smallholder farmers in the study area? (3) What institutional structures are available to support the existing farmers' social networks? (4) In what ways may Uganda improve the use of technologies for cage fish farming? What policy implications are appropriate?

2.10 Conceptual framework

Factors that were assumed to influence the adoption of cage fish farming technology among smallholder fish farmers were Social Networks (SN), Farmers' characteristics, Institutional Characteristics, and External Factors. According to Easley and Kleinberg (2010), these factors are broadly categorized into institutional, socio-economic, environmental, and external factors (Figure 2.1). It was assumed that farmers' characteristics influence institutional characteristics and external factors, which, together with external factors, influence the knowledge, attitude, and perception of smallholder fish farmers in the adoption of cage fish farming technologies. A summary of conceptualized characteristics used in the discussion above is presented in Figure 2.1.

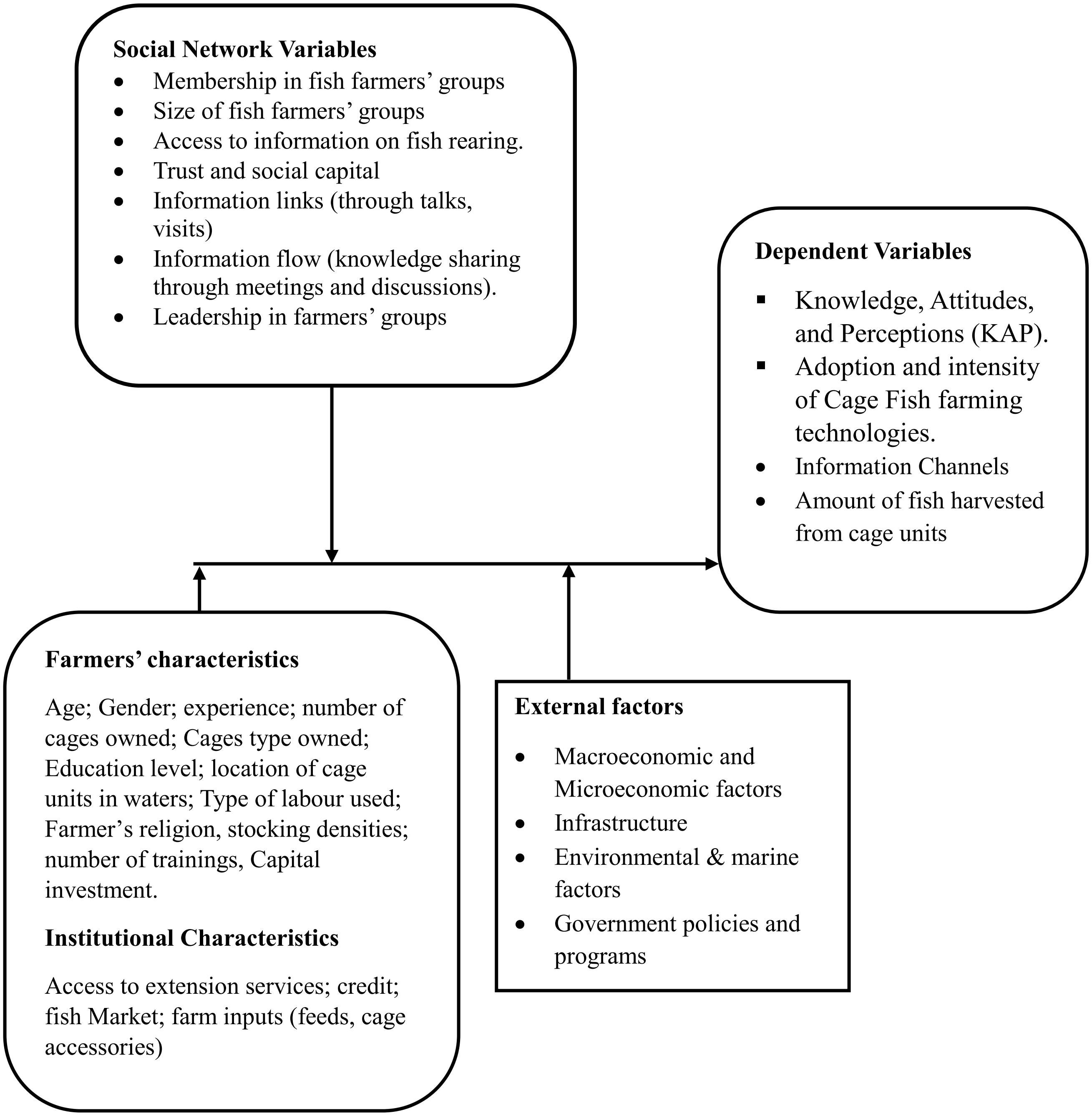

Figure 2.1: Conceptual Framework

CHAPTER THREE

FACTORS INFLUENCING KNOWLEDGE, ATTITUDE, AND PERCEPTION (KAP) OF SMALLHOLDER FISH FARMERS TOWARDS CAGE FISH FARMING TECHNOLOGIES ALONG LAKE VICTORIA IN UGANDA

Abstract

The decline in capture fishery resources has posed a threat to the economy and livelihoods of many Ugandans. As a result, rearing fish in cages has been identified as one of the blue economy's sustainable pathways towards aquaculture development. Despite the importance of cage fish farming regarding fish and food security and revenue generation, more rigorous empirical work needs to be done on the knowledge of this technology among smallholder farmers and communities around Lake Victoria in Uganda. This study on Knowledge Attitude and Perceptions (KAP) aims to understand the awareness level of cage fish farming technologies among smallholder farmers. A sample size of 384 randomly selected respondents was involved in the study, and data was collected using questionnaires. Specifically, the study considered the factors that influence knowledge, attitude, and perception among smallholder cage fish farmers. Since the KAP scores were categorical in nature with more than two discrete and unordered outcomes, multinomial logit was used. From the results, 78% of the sampled farmers had favorable KAP scores towards cage fish farming technologies. Male respondents were 1.86 times more likely to have positive attitudes than women. In addition, respondents who reared fish in metallic cages were 2.56 times more likely to have a positive perception than others after adjusting for the effect of other variables in the regression. The study's conclusions highlight how crucial it is to take into account the knowledge gaps that have been found and provide practical training to help smallholder farmers adopt more efficient cage fish farming techniques.

3.1 Introduction

Fish is one of Uganda's high-value commodities that greatly boosts economic expansion. Uganda has a huge potential for fisheries resources, including capture fisheries and aquaculture output, since water covers almost 40% of its surface. With approximately 40% of her surface area covered by water, Uganda has enormous fishery resource potential for capture fisheries and aquaculture production (Mbowa *et al.,* 2017). It is estimated that around 1.5 million Ugandans derive their livelihoods from the fisheries sector (UIA, 2021). However, despite its socioeconomic contributions, the industry has significantly declined from a supply of about 300,000 metric tonnes annually in the 1990s to only 172,000 metric tonnes in 2020 (FAO/FishStat, 2021). The poor performance is attributable to several challenges ranging from socioeconomic and environmental factors (Bolman *et al*., 2018; Mapfumo, 2019). In addition, technical issues, such as the existing regulatory frameworks, have yet to support control of fishing activities from freshwater bodies (Namulawa *et al.,*2020). Thus, poses significant risks to the country's second foreign exchange earner and source of livelihood among fishery-dependent communities around the natural water bodies.

In the same vein, the growing demand for fish in the country has climaxed into the need to accelerate the development of alternative fish production pathways suitable for the blue economy. Empirical studies have documented that cage fish farming offers a significant means of increasing fish production among smallholder farmers (Mbowa *et al.,* 2017). It is a low-investment activity and requires very little production area. Also, it makes it ideal for smallholder fish farmers to complement capture fishery from the lake. The design of the cage and its accessories can be tailor-made following the individual farmer's requirements based on differentials in their socioeconomic dynamics (Chu *et al.,*2020). The literature has made an effort to evaluate the factors that lead smallholder farmers in Uganda to practice cage fish farming. Specifically, studies have emphasized the socio-demographic factors of smallholder farmers as a significant driver towards cage fish farming (Kwikiriza *et al.,*2017). However, studies on socioeconomic and institutional factors affecting the KAP on cage fish farming technologies have yet to be empirically documented, especially on smallholder cage fish farmers in Uganda.

Knowledge refers to factual information and understanding of how the new technology works and what it can achieve (Abualoush *et al.,* 2018). This study conceptualized knowledge as the extent to which farmers are aware of cage fish farming as a whole package, from production to marketing. Attitude is determined by beliefs that are important to a person in decision-making. It is the product of a person's evaluation of how good or bad a given subject is, often after exposure to it (Shin, 2016). Attitude towards recent innovations is critical in explaining the level of willingness to adopt a given technology. Kumar *et al.* (2018) emphasized factors such as negative attitudes as the main drivers that lead to low technology adoption among small-scale farmers. The perception was conceptualized as the views farmers hold based on their experiences and general opinions on cage fish farming. According to Bilgihan *et al*. (2016), knowledge and perceptions about new technology then together determine the attitude toward it.

Exploring the primary stakeholders' knowledge, attitudes, and perceptions of cage farming is essential in understanding dynamic interactions and the level of technology awareness. Cage fish farming is an emerging technology in Uganda, and large-scale commercialization has yet to be realized in the country. No previous studies in the country have attempted to assess the KAP factors that inform cage fish farming in Uganda either at micro or macro levels. In this regard, this study aimed to determine the KAP levels of the significant stakeholders in cage fish farming in Lake Victoria, as well as the motivations and barriers to adopting the technology.

3.2 Knowledge, Attitudes, and Perception Theory

This study employed the KAP theory, as suggested by Nguyen *et al*. (2019), to examine smallholder farmers' levels of awareness of cage fish farming technologies. Knowledge, attitudes, and perceptions are critical components of behavioral change theory. While knowledge refers to the acquisition of factual information and understanding of how the new technology works (Kumar, 2018), perception relates to views smallholder farmers hold about it (Andrade et al., 2020). According to Aldosari *et al*. (2019), knowledge and perception towards new technology determine the farmer's attitude.

Previous studies have shown that KAP plays a significant role in the adoption of technologies in various contexts. In Tokede *et al*. (2020), it was investigated how farmers' knowledge and attitudes influenced agroforestry adoption in Nigeria. The study found that the majority of respondents who did not practice agroforestry had little knowledge of agroforestry practices and had negative attitudes toward practicing agroforestry. Their findings, therefore, suggested that knowledge and attitude played a significant role in influencing the adoption of agroforestry. Similarly, Sun *et al*. (2022) analysed the impact of agricultural production knowledge on farmers' willingness to adopt Integrated Pest Management (IPM) technologies. Their results indicated that integrated agricultural production knowledge significantly increased farmers' willingness to adopt IPM technology. Similarly, in Tama *et al*. (2021), knowledge was found to have the most significant total impact in a study of the factors influencing farmers' intentions to continue conservation agriculture in Northern Bangladesh, while attitude had the most significant direct impact. The study's findings emphasised the importance of increasing knowledge as a way of improving farmers' intentions toward technology adoption.

Reviewed studies have shown the moderating effect of knowledge. Chen *et al.* (2021) applied the theory of planned behaviour to investigate the moderating effect of knowledge sharing on information technology adoption among apple farmers. Their findings revealed that both tacit and explicit knowledge sharing had a positive moderating effect on transitioning the intention to choose information technology into actual behaviour, with the degree of knowledge sharing having a more substantial moderating effect.

Attitude is also an essential factor that influences technology adoption, as shown in various studies. In a study of Litchi farmers in China, it was found that farmers with a generally positive attitude towards technology adopted top grafting techniques better (Li *et al*., 2019). Dokuboba *et al*. (2019) studied the influence of entrepreneurship skills on the performance of cage fish farming. They found that attitude towards work played a significant role in determining its success in Ghana. In Kenya, Ouko *et al*. (2022) studied the adoption of Black Soldier Fly Larvae as feed among cage and pond fish farmers using the Technology Acceptance Model (TAM). They found that attitude was a significant determinant of intention to adopt.

Further, studies that have examined the factors that influence attitudes among aquaculture farmers in Kenya found that influencing the attitude and perception of farmers through training could play a significant role in promoting the adoption of cage farming technology (Orinda *et al*.,2014). Additionally, knowledge about technology has also been shown to have a significant positive effect on attitudes, perceptions, and intentions to adopt genetically modified crops (Sas *et al*., 2021). Sharifzadeh *et al.* (2021) studied pesticide adoption among farmers and found that education played a significant role in influencing KAP. These studies have shown the need to strengthen education strategies among farmers to promote adoption. In a study on the adoption of water resource management among smallholder irrigators, Oremo *et al*. (2019) found that KAP was dependent on culture. In contrast, educational attainment, level of income, access to extension, and membership in local networks all had a significant impact on adoption.

Perceptions are conceptualized as the benefits of technology that are very important in promoting adoption. Kumari and Sharma (2022) studied perceptions of livelihoods before and after the adoption of cage fish farming in India. They found that cage fish farming impacted positively on the flow of financial and livelihood capital. Also, by applying TAM, Ulhaq *et al.* (2022) studied the adoption of monitoring technologies, such as on water quality among intensive shrimp farmers. They found that farmers who perceived ICT as being useful had higher chances of adopting the technology. Ntshangase *et al*. (2018) explored the adoption of no-till agricultural practices among farmers. The study revealed a positive correlation between a farmer's perception of conservation practices and higher crop yields. The study also emphasized the positive role of extension in the promotion of conservation agricultural practices. In addition, Kazeem *et al*. (2017) discuss farmers' attitudes and perceptions. The study revealed that farmers' attitudes have an insignificant effect on technology adoption and negative perceptions.

Therefore, literature exploring the influence of farmers' knowledge, attitude, and perception on the use of cage fish farming technologies in Uganda is still limited. Hence, this highlights the importance of exploring knowledge, attitudes, and perceptions, as well as external factors.

3.3 Methodology and Analytical Framework

3.3.1 Description of the Study Area

A cross-sectional survey was conducted in fourteen districts sharing Lake Victoria waters in Uganda. The districts and their GPS coordinates were purposively selected because they are where cage fish farming is most practiced. They included; Busia (0.261189, 33.986978), Namayingo (0.198695, 33.904346), Bugiri (0.282896, 33.715206), Mayuge (0.483115, 33.400116), Buvuma (0.199646, 33.265001), Jinja (0.431399, 33.235855), Buikwe (0.761029, 33.040723), Kalangala (-0.261384, 32.380537), Wakiso (0.054163, 32.518079), Kampala (0.257534, 32.637307), Masaka (-0.305544, 32.037822), Kyotera (-0.913802, 31.763894), Mukono (0.183249, 32.868301), and Rakai (-0.704984, 31.754762), Figure 3.1.

In addition to catch fishing and cage fish farming, the Lake Victoria basin and its environs are home to a variety of other economic pursuits, including agriculture, water transportation, and ecotourism. The basin's districts are at a medium height and have year-round access to enough rainfall, which makes them perfect for producing crops including coffee, tea, sugar cane, and palm oil. Key players in the area are big international corporations including BIDCO, Jofald Rayel, Kakira Sugar Works, and Ice-Mark. In addition, farmers grow horticulture (vegetables and tomatoes) and other crops such as bananas, cassava, potatoes, maize, beans, and pineapples. The area also sees a lot of livestock production; the most common livestock species are chickens, goats, and dairy and meat cattle (Ministry of Finance Planning and Economic Development. MoFPED, 2020).

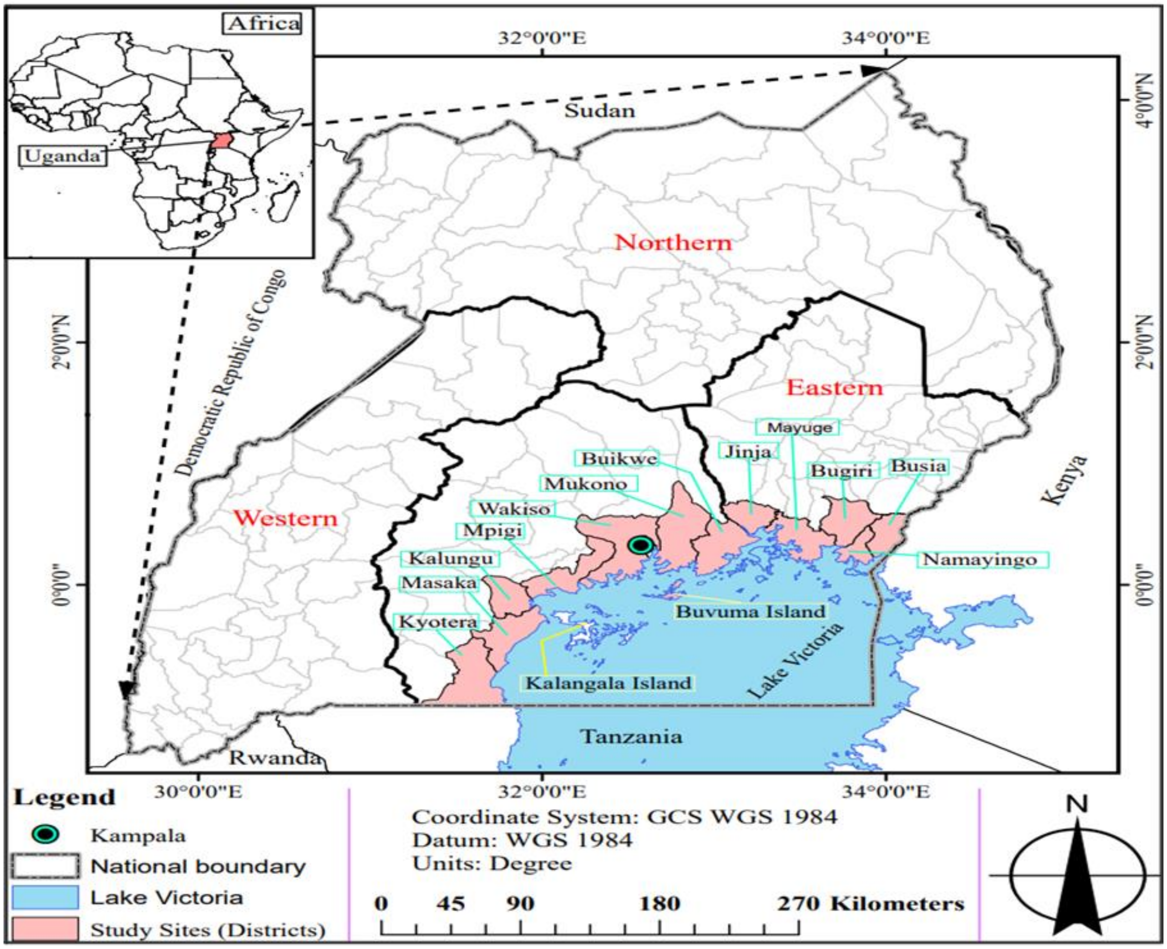

Figure 3.1: Map of the study area

Source: Geography department, Egerton University.

3.3.2 Sampling procedure

For the study, the targeted population of smallholder cage fish farmers was chosen from the lists that the corresponding fisheries officers in each of the fourteen districts had created. To choose the 384 respondents who owned cage fish farms, random sampling was used. The study took into account smallholder male and female fish farmers operating in the study area who raised fish in cages with a stocking density of no more than 50,000.

A simplified formula provided by Kothari (2004) was employed to determine the required sample size at a 95% confidence level, with a degree of variability = 0.5 and a level of precision = 5% (0.05).

(3.1)

Where n = the desired sample size; Z = Standard normal variable at the required level of confidence; p = the proportion in the target population estimated to have characteristics being measured; d = the level of tactical significance set; and $q = 1 - p$. The sample size distribution is presented in Table 3.1.

Table 3.1 Sample Size and Distribution

S/N	District	Number of farmers per District	Formal information users (Untreated group)		Informal information users (Treated group)		Total sample size
			Total	Sample	Total	Sample	
1	Bugiri	291	102	12	189	18	30
2	Buikwe	309	109	13	200	20	33
3	Busia	303	100	11	203	19	30
4	Buvuma	274	104	10	170	18	28
5	Jinja	298	108	12	190	18	30
6	Kalangala	276	106	10	170	16	26
7	Kampala	297	106	11	191	19	30
8	Kyotera	234	104	11	130	15	26
9	Masaka	239	106	12	133	13	25
10	Mayuge	296	104	12	192	10	28
11	Mukono	278	117	12	161	17	29
12	Namayingo	300	100	11	200	11	27
13	Rakai	110	50	6	60	7	13
14	Wakiso	305	111	11	194	18	29
	Total			**154**		**230**	**384**

Semi-structured questionnaires were used in the survey, and the enumerators were trained to administer them. Prior to data collection, the questionnaire underwent pre-testing, improvement, and validation. Following the National Research Ethical Committee's criteria, each respondent's consent was obtained before data on their Knowledge, Attitudes, and Perceptions (KAP), socioeconomic status, institutional features, and cage fish farm characteristics were gathered.

The selection of variables was guided by literature (Ankuyi *et al*., 2022; Muange *et al*., 2014; Muleme *et al*., 2017; Okonya *et al.,* 2019)

3.3.3 Data Collection and Analysis

The study collected primary data which were collected from the questionnaires and focus group discussions. The focus group discussion and questionnaire tools were pre-tested for accuracy (validity) and consistency (reliability), as recommended by Creswell and Plano Clark (2011). The questionnaires consisted of semi-structured questions and were administered to the respondents by trained enumerators. The data collected was transcribed, cleaned, and analyzed about the prescribed themes and then analyzed quantitatively. STATA (version 15) was used for the collected data.

3.3.4 Multinomial Logit Model Specification

There were twenty-one questions in the Knowledge, Attitude, and Perceptions (KAP) area about cage fish farming. We employed seven statements to gauge respondents' awareness of cage fish farming, with options to respond "true," "false," or "do not know." We also used seven sentences with four response alternatives, ranging from "strongly agree" to "strongly disagree," to gauge attitude. Finally, we used seven statements, each on a 4-point Likert scale with alternatives ranging from "very good" to "very bad," to gauge the farmers' opinions of cage fish farming systems.

For all seven assertions, a score of 1 was assigned to each correct response and a score of 0 to each incorrect response to create knowledge scores. Regarding the attitude scores, "strongly agree" and "agree" responses received a value of 1, while other responses received a score of 0. Regarding the perception scores, "very good" and "good" responses received a score of 1, while other responses received a score of 0. The overall score for each category, which ranged from 0 to 7, was then calculated by adding the scores for knowledge, attitude, and perception.

The scores obtained were translated into percentages, with 80% and higher being categorized as "high," 50% to 80% as "medium," and 50% to 50% as "low." A Multinomial Logistic model was employed following the classification of the dependent variable's scores as "high," "medium," or "low" and the selection of independent variables. For every KAP variable, the statistically significant predictors of the medium and high categories (to the base result from low category) were ascertained using the MNL. The relative risk ratio (RRR) with 95% confidence intervals was used to measure the degree of connection.

The study employed the Multinomial logit model because of its modeling approach, which falls under the Random utility theory (RUT), where the choice between alternatives is explained by personal characteristics and the utility derived from each alternative. In addition, this study's dependent variable had three outcomes and was independently distributed, hence the appropriateness of the model. Also, the model was selected for this study because of its ability to give realistic predictions compared to others in the same category.

The study assumed that each farmer faces a set of discrete, mutually exclusive outcomes of KAP, which are conditioned by a set of explanatory variables *x* (Table 3.2). The model to be estimated will enable the researcher to assess how changes in explanatory variables *x* affect the response variable (KAP) denoted as s p (*y= j/ x*), *j= 1, 2…J*. The question is how, *ceteris paribus*, changes in the elements of x affect the response probabilities. Let *x* be 1 x k vector with first element unity. The MNL model response probabilities are of the form:

$$P(y = j \mid X) = \frac{\exp(x\beta_{j)}}{1 + \sum_{k-1}^{j} \exp(x\beta_k),\ j = 1,\ldots\ldots J} \quad (3.2)$$

In order to allow interpretation of the effects of explanatory variables on the probabilities, we have to estimate marginal effects. Differentiating equation-1 partially concerning the explanatory variables provides marginal effects of the explanatory variables given in the form.

$$\frac{\partial P_j}{\partial X_j} = P_j(\beta_j - \sum_{j=1}^{j-1} P_j \beta_{jk}) \quad (3.3)$$

The marginal effects or marginal probabilities are functions of the probability itself that measure the expected change in probability of a particular KAP outcome reached concerning a unit change in a given independent variable from the mean. In this case, category one was treated as the reference category. Since in the computation it is considered as a base outcome and can be extended with a number of explanatory variables.

Table 3.2: Description of explanatory variables and their expected signs

Variable	Description	Unit of Measurement	Expected Sign
Age	Age of a farmer	Years	-
Gender	Sex of a farmer	Dummy: 1=male; 0=female	-/+
Education	Farmer's level of education	Years in school	-/+
Extension	No. of visits by ext. officer	Number of days in a month	-/+
Experience	Duration in cage fish farming	Years	-/+
Social capital	No. of social ties a farmer has	Number of social contacts	-/+
Smart Phone Access	Farmer owns Phone	Dummy: 1=Yes; 0=No	+
Tv Access	A farmer owns a TV set	Dummy: 1=Yes; 0=No	+
Farm Size	No. of cage units a farmer owns	No. of stocked cage units	-/+
Output	Amount Harvested fish per cycle	No. of Kilograms	-/+
Fish Market	Nearest fish market	Distance in Kilometers	+

3.4 Results and Discussions

3.4.1 Respondents' socioeconomic and institutional factors

In Table 3.3, the results of the selected farmers' socioeconomic and institutional characteristics are presented as means and percentages for both continuous and categorical variables. The socioeconomic and institutional characteristics of the chosen farmers are shown in Table 3.3 as means and percentages for both continuous and categorical variables. The respondents' mean age was roughly 45 years, with an 8-year standard deviation, and their mean educational attainment was 12 years, with a 3-year standard deviation. In the research area, there were, on average, four visits per year for extension services. The sampled respondents' average experience level in fish farming was 4.4, with a standard deviation of 1.9. With a standard deviation of 19 kilometers, the mean distance to the closest market where farmers sell their fish produce was 21 kilometers. On average, farmers owned around five cage units each and harvested an average of 5518 kilograms of fish, with the lowest producer harvesting around 1190 kilograms per cycle.

The results indicated that 71% of the farmers were male, while only 29% were female. One possible explanation for the gender disparity in cage farming is that women's participation in chores like fish feeding and harvesting, which are usually done in lakes, are restricted. Rola-Rubzen *et al*. (2020) assert that decision-making and the pace at which technology is adopted are significantly influenced by the gender of farmers. According to the study, the local fish farmers solely raise catfish and tilapia in cages. But just 2% of the farmers in the study raise catfish; the bulk (98%) raise tilapia. The fact that tilapia grows more quickly in captivity and has a higher feed conversion rate than other fish species may account for this preference (NaFiRRI, 2018). In Table 3.2, it was shown that 82.8% of the respondents used metallic cage units to rear fish, while 11.5% used wooden and only 5.7% used HDE plastics. Hence, that can be attributed to the durability and affordability of metallic cages compared to other types of cages.

The findings indicate that, in contrast to 93.7% of the cage fish producers surveyed, just 6.3% of them owned and utilized smartphones for making and receiving phone calls. Furthermore, only 28.7% of respondents had access to TVs, compared to 71.3% who did not. When it came to the placement of fish farms in bodies of water, 42.2% of them raised fish between 201 and 500 meters from the shoreline, 25.9% did so between 501 and 1000 meters, 11.7% did so inside 200 meters, and just 10.1% did so beyond 1000 meters. It's also important to note that the majority of farmers surveyed (54.9%) sell their seafood on the beaches where they live, 33.6% sell to neighboring communities, and only 9.1% and 2.4% sell their produce to fish processing companies and foreign markets, respectively.

Table 3.3: Socioeconomic characteristics of the respondents

Continuous Variable	Mean	Std. Dev.	Min.	Max.
Age (years)	46.5	8.9	26	68
Farmer's Education level (years in school)	11.5	3.1	7	18
Extension services (number of visits/year)	4	1.0	1	6
Farming experience (years)	4.4	1.9	2	12
Nearest market (km)	17.9	16.3	1	64
Cage units owned (numbers)	5.4	3.4	1	17
Categorical Variable	**Freq.**	**Percent**		**Cum.**
Gender				
Males (%)	273		71.1	71.1

Females (%)	111	28.9	100
Fish reared in cages			
Tilapia	376	98	98
Catfish	8	2	100
Types of cages used			
Metallic (%)	318	82.8	82.8
Wooden (%)	44	11.5	94.3
HDE Plastics (%)	22	5.7	100
Smart Phone Access			
Yes (%)	24	6.3	6.3
No (%)	360	93.7	100
Tv Access			
Yes (%)	110	28.7	28.7
No (%)	274	71.3	100
Location of cages in waters (distance from the shoreline)			
Within 200m (%)	45	11.7	11.7
201 to 500m (%)	162	42.2	53.9
501 to 1000m (%)	138	36.0	89.9
Beyond 1000m (%)	39	10.1	100
Target market			
In the community (%)	211	54.9	54.9
Outside community (%)	129	33.6	88.5
Fish processing companies (%)	35	9.1	97.6
Direct export (%)	9	2.4	100

In reference to the knowledge assessment, the findings, which are displayed in Table 3.3, indicate that (66.15 %) of the participants disputed that assembling fish cage units is difficult. Furthermore, 80% of respondents denied that fish raised in cages do not receive specially prepared meals, and 83.17% of respondents did not think that fish raised in cages matured more quickly. The majority of responders also concurred that the reproductive habitats for the captured fish were impacted by cage fish technology. These claims demonstrated that most of the farmers in the sample knew a fair amount about how the cage fish farming industry operated. Furthermore, the results showed little variation in the opinions of respondents regarding the labor expenditures associated with setting up cage units and other operational expenses. Therefore, findings suggest that costs are subjective and may vary depending on an individual's financial situation at a given time.

Table 3.4: Farmers' knowledge of cage fish farming technologies

Statements	I do not know %	False %	True %	Total (384) %
	Responses			
1 Fish cage units are difficult to assemble.	11.7	66.2	22.1	100
2 Fish reared in cages take more than a year to mature.	6.5	83.1	10.4	100
3 Fish reared in cages are **NOT** given formulated feeds.	4.1	80.7	15.1	100
4 Cage fish farming is **NOT** a profitable venture.	5.7	69.5	24.7	100
5 Fish cage units are too expensive.	8.3	49.7	41.9	100
6 Cage fish farming is a labour-intensive job.	8.1	43.8	48.2	100
7 Cage fish technologies affect breeding sites for capture fish.	6.8	36.7	56.5	100

Results in Table 3.4 indicate that the majority of the respondents had a positive attitude towards cage fish farming technologies. In statements 1, 2, and 4 (Table 3.4), respondents agreed that cage fish farming was a viable business (96.36%), innovative (89.59%), and better than wild capture fishing (94.8%).

Table 3.5: Farmers' attitudes towards cage fish farming technologies

Statements	Strongly Agree %	Agree %	Disagree %	Strongly Disagree %	Total (384) %
			Responses		
1 Cage fish farming is NOT a viable business	0.8	2.9	55.0	41.4	100
2 Cage fish farming is Not better than wild fishing	0.5	4.7	79.0	16.0	100

3 Cage fish farming does NOT address food insecurity	13.0	11.2	20.8	55.0	100
4 Cage fish farming technologies are excellent innovations	54.2	35.4	6.8	3.7	100
5 Cage fish farming technologies give tangible results	42.2	50.8	6.8	0.3	100
6 I consider cage fish farming a desirable career option	8.6	46.9	37.8	6.8	100
7 Cage fish farming is a time-consuming job	2.6	7.8	54.0	36.0	100

Table 3.5 shows that cage fish farmers had better perceptions of cage fish farming technologies. The majority agreed that it was easy to observe (91.41 %) and harvest (86.24%) the fish under cage technologies. However, 79.43% of the respondents perceived cage farming as an expensive venture.

Table 3.6: Farmers' Perceptions Towards Cage Fish Farming Technologies

	Responses				
Statements	Strongly Agree %	Agree %	Disagree %	Strongly Disagree %	Total (384) %
1 Fish cage units require comparatively low capital to start	2.6	18.0	53.4	26.0	100
2 It is very easy to harvest fish reared in cage units	20.6	66.7	11.7	1.0	100
3 Easy to observe and sample fish reared in cage units at any time	54.2	37.2	7.6	1.0	100
4 Rearing fish in cage units is NOT labor intensive	9.6	44.0	40.6	5.7	100
5 Using cage units to rear fish is NOT risky (drowning) by the users	6.0	55.7	35.4	2.9	100

6 Cage fish farming technologies are NOT affordable to smallholders	5.0	39.1	41.9	14.1	100
7 Rearing fish cage units do NOT grow faster	8.1	24.7	36.7	30.5	100

Table 3.7: Multinomial logit analysis on KAP outcomes

	Knowledge Scores			Attitude Scores			Perception Scores		
	RRR	Z	P>z	RRR	Z	P>z	RRR	Z	P>z
Low				***(base outcome)***					
Medium									
Experience (years)	1.99	1.90	**0.06***	1.01	0 .09	0.93	1.08	0.12	0.90
Gender	9.98	1.62	0.10	0.72	-1.15	0.25	9.12	1.09	0.27
Age (years)	1.00	-0.13	0.89	0.96	-2.69	**0.01*****	0.96	-0.37	0.71
Education (years)	1.00	-1.83	**0.07***	1.03	0.68	0.50	0.77	-1.22	0.2
HDE plastic cage type	578	0.01	0.99	0.43	-1.49	0.14	106	0.03	0.98
Wooden cage type	0.17	-1.89	**0.06***	3.68	2.93	**0.00*****	0.01	-2.23	**0.02****
Extension visits	0.28	-2.98	**0.00*****	1.09	0.83	0.41	0.06	-2.17	**0.03****
Social capital	1.89	1.91	**0.06***	0.81	-2.39	**0.02****	2.05	1.12	0.27
Smart Phone Access	1.32	0.34	0.73	1.22	0.89	0.37	0.44	-0.45	0.66
Tv access	7.32	2.43	**0.02****	1.47	1.65	**0.01***	28.0	2.28	**0.02****
Number of cage units	0.99	-0.07	0.94	0.87	-3.18	**0.00*****	0.92	-0.30	0.76
Location of cages (m)	0.92	-0.25	0.80	0.77	-2.48	**0.01****	0.88	-0.24	0.81
Market Distance (km)	1.06	1.69	**0.09***	1.00	-0.74	0.46	1.07	1.27	0.20
Target Market	0.88	-0.28	0.78	1.19	1.28	0.20	0.35	-1.18	0.24
High									
Experience (years)	1.78	1.50	0.14	0.90	-0.55	0.58	1.40	0.49	0.63
Gender	12.6	1.72	**0.09***	1.99	1.59	0.11	8.64	1.06	0.29
Age (years)	1.00	-0.03	0.97	1.02	0.62	0.54	0.98	-0.17	0.86
Education (years)	0.75	-2.08	**0.04****	0.99	-0.15	0.88	0.78	-1.16	0.25
HDE plastic cage type	350	0.01	0.99	0.29	-1.02	0.31	539	0.03	0.98
Wooden cage type	0.03	-2.50	**0.01****	10.9	4.25	**0.00*****	0.01	-1.96	**0.05****

Extension visits	0.33	-2.52	**0.01****	1.03	0.19	0.85	0.05	-2.26	**0.02****
Social capital	1.89	1.80	**0.07***	1.02	0.13	0.90	1.92	1.02	0.31
Smart Phone Access	1.03	0.04	0.97	1.77	1.37	0.17	0.42	-0.47	0.63
Tv access	2.51	1.05	0.29	1.16	0.37	0.71	32.2	2.38	**0.01****
Number of cage units	0.99	-0.10	0.92	1.02	0.39	0.70	0.90	-0.37	0.71
Location of cages (m)	1.15	0.42	0.67	0.93	-0.40	0.69	0.91	-0.19	0.85
Market Distance (km)	1.06	1.60	0.11	0.99	-0.86	0.39	1.05	0.92	0.36
Target Market	0.59	-1.02	0.31	1.08	0.32	0.75	0.44	-0.90	0.37

Asterisks**: ***p<0.01, **p<0.05, *p<0.1* ***Reference Category – Low KAP Scores.

Observations	384	384	384
LRchi^2 (26)	82.80	61.40	104.60
Prob>chi^2	0.00	0.00	0.00
Pseudo R^2	0.20	0.0860	0.16
Log-likelihood	-163.72	-326.60	-258.70

3.4.2 Analysis of Factors influencing Knowledge, Attitude, and Perceptions (KAP)

A multinomial logit model was employed, and the results are shown in Table 3.7. The outcome for knowledge was statistically significant with *p-value* < 0.00, LR chi**2** (26) = 82.8, and pseudo-R**2** value of 0.20. For attitude outcome, the model was statistically significant with *p-value*< 0.00, LR ch**2** (26) = 61.50, and pseudo-R**2** value of 0.12. Furthermore, the perception was also statistically significant with *p-value* < 0.00, LR ch**2** (26) = 104.7, and pseudo-R**2** value of 0.26.

In addition, the findings show that the following factors were statistically significant and related to knowledge outcomes in the medium category: prior experience raising fish in cages, education level, kind of wooden cage, number of extension visits, television availability, social capital, and distance to the closest market. The number of extension visits, gender, education level, kind of wooden cage, and social capital were all statistically significant factors that were linked to high-category knowledge outcomes.

Moreover, the number of cages possessed, the age of the farmer, the type of wooden cage, Social Capital, television access, and the placement of the cage units in the lake were all statistically significant and related to the medium category attitude outcome. Similarly, only the wooden kind was connected with attitude results in the high group and statistically significant. The kind of wooden cage, the number of extension visits, and television access were statistically significant and related to the perception outcome in both the medium and high categories.

The Relative Risk Ratio (RRR) for "experience" shows that the probability of falling into a high knowledge group is expected to change by a factor of 1.99 for every unit increase on this variable. According to the "experience" outcome, a farmer's chances of falling into a high category rise as their level of experience-based knowledge improves. The results are consistent with those showing that farmers' experience levels correlated with their level of awareness of new developments and technology in the agricultural sector (Schut *et al*., 2015).

A cage fish farmer's level of education was also positively significant and linked to their classification as medium or high knowledge. According to the data, there would be a factor of 1.00 rise in the relative risk for the medium knowledge category compared to the low knowledge category for every unit increase in schooling years. Similarly, if all other variables remain constant, a unit increase in schooling years would result in a 0.75 increase in the relative risk for the high knowledge group compared to the low. The results are consistent with those of other researchers (Aldosari *et al*., 2019; Jha *et al.,* 2018; Mittal & Mehar, 2016); this finding may suggest that more years of education have a beneficial impact on knowledge regarding cage fish farming. Therefore, it could be explained by the fact that highly educated farmers could be in a better position to carry out cage fish farming than those with little or no education.

Additionally, there was a favorable correlation (factors 0.17 and 0.03 respectively) between owning a wooden cage type and being in the medium and high knowledge groups compared to the low category, as compared to owning a steel cage. The results suggest that owners of wooden cage types for cage fish were more likely to be linked to a lack of understanding. Compared to HDE plastic and metallic cages, the production of hardwood cages does not require a greater level of technological expertise.

The medium and high knowledge categories of cage fish farming were favorably correlated with extension trips. According to the RRR, there is a 0.29 and 0.33 rise in relative risk for being in the medium and high categories for every unit increase of extension visits. As a result, compared to those in the low group, cage fish producers in the middle and high categories relied more on extension services. This result is consistent with other research (Altalb *et al*., 2015; Schut et al., 2015), which discovered a favorable correlation between awareness level and extension.

A farmer's social capital increased when they fell into the medium and high knowledge categories as opposed to the low knowledge category. The results indicate that the relative probability of falling into the medium and high categories increases by a factor of 1.89 and 1.90, respectively, for every unit increase in social capital. The results suggest that individuals who raised cage fish were more likely to be informed about the practice if they had a large number of social networks. Therefore, as demonstrated by Cofré-Bravo *et al*. (2019), Li *et al*. (2020), Magnan *et al*. (2015), and Muange *et al*. (2014), social capital is essential to raising farmers' knowledge.

The results also demonstrate that having access to television was positively correlated with having medium knowledge of cage fish farming as opposed to low knowledge. As a result, the relative likelihood of a farmer falling into the medium knowledge category rises by a ratio of 7.33 as compared to the low category for every unit increase in television access. The results suggest that a cage fish farmer with more access to agricultural programming as measured by the number of hours watched was also more educated. The findings suggest that farmers' knowledge can be increased using ICT (Kante *et al*., 2019; Ndimbo & Ndi Buma, 2023; Tambo *et al*., 2019).

The distance to the nearest fish market was positively associated with being in the medium category. The results indicate that a farmer's relative risk of falling into the medium-level category rises by a ratio of 1.06 with every extra mile to the market. The results might suggest that cage fish producers who are near the shore but far from the markets know more about the practice than those who are nearer the actual marketplaces. The discovery suggests that lake waters, which are far from fish markets, are used for the production of cage fish.

Gender was positively associated with a farmer falling in the high knowledge category. A farmer's gender was positively correlated with their classification as having high expertise. The likelihood of falling into the high knowledge category was 12.5 times higher for male cage fish farmers compared to those in the low category. The fact that men are the primary practitioners of cage fish farming may help to explain the findings. This result is consistent with the findings of Gebre *et al.* (2019), who demonstrated how culture affects gender roles and labor divides in the agriculture industry. The results, however, are at odds with those of Oyawole *et al.* (2021), who discovered no connection between the farmers' gender and technology savvy.

Additionally, age was positively correlated with a farmer's medium attitude group in terms of attitude. According to the research, there is a 0.96 rise in the relative risk for a cage fish farmer with an average attitude compared to one with a low attitude for every unit increase in age. The findings contradict those of Morris *et al.* (2017), who claimed that because younger individuals are less risk-averse and more open to new ideas than older people, they are more likely to be aware of developing technology. The results corroborate those of Husen *et al.* (2017), who discovered that farmers' risk-taking levels decline as they get older. They usually have a bias in favor of people who are familiar with farming technologies.

The type of cage a farmer uses in fish farming plays a crucial role in shaping their Knowledge, Attitude, and Perceptions (KAP) towards the practice. In particular, wooden cages have been found to influence farmers' placement within the medium KAP category positively. This positive association suggests that farmers who utilize wooden cages tend to exhibit a higher level of knowledge about fish farming techniques, a more favorable attitude towards the practice, and more informed perceptions about its benefits and challenges.

Focusing on perception, wooden cage type was also positively associated with a farmer being in either medium category. The findings indicate that a one-unit increase in the number of wooden cage units owned by a farmer is predicted by a factor of 0.17. Correspondingly, as farmers invest in and manage more wooden cages, their engagement and understanding of fish farming deepen. Unlike other types of cage fish technology, wooden cages are rated as more traditional technology and possibly cost-effective, hence encouraging more hands-on involvement and learning (Li *et al*., 2020). This involvement among smallholder fish farmers enhances their technical aspects of fish farming and their perception of the risks and rewards involved. As a result, ownership of wooden cages not only supports the operational aspects of fish farming but also fosters a more knowledgeable, positive, and perceptive approach among farmers. The result implies that farmers who own more wooden cage units tend to have a higher level of knowledge, a more positive attitude, and better perceptions about fish farming practices. The findings indicate that for every additional wooden cage unit owned, a farmer's likelihood of being in the medium KAP category increases by a factor of 0.17. This relationship highlights the importance of wooden cages as a contributing factor to the overall engagement and effectiveness of farmers in fish farming operations.

3.5. Conclusion

The study identified the factors influencing smallholder farmers' knowledge, attitude, and perceptions (KAP) towards cage fish farming technologies along the shoreline of Lake Victoria, Uganda. The study found that farmers' understanding of cage fish farming technologies is linked to their experience, level of education, social capital, access to extension services, gender, type of cage fish technology used, and access to aquaculture programs featured on television. The farmer's attitude was revealed to be influenced by age, cage fish technology used, social capital, access to aquaculture programs on television sets, number of cage units owned, and location of cages in the water. Additionally, the study also revealed that farmers' perception of cage fish farming technologies was influenced by the type of cage fish technology used, access to extension services, and access to aquaculture programs presented on television channels.

Therefore, from the study findings, the government of Uganda and its development partners can use multidimensional measures to improve the cage fish farmers' Knowledge, Attitudes, and Perceptions. For example, a " model farmer approach" can be used at the beach level. Secondly, subsidies should be given to imported HDE plastic cages and materials used for metallic cages. Thirdly, the public TV coverage in the country should be increased, and the frequency of aquaculture programs should be cast monthly. Also, the government should consider encouraging smallholder farmers to form farmers' groups and regular exhibitions focusing on cage fish farming technologies. For policy implication, this study proposes an appropriate policy framework to enhance cage fish production and productivity among smallholder farms. Therefore, the study recommends the development of appropriate policies and strategies to enhance farmers' knowledge, attitudes, and perceptions toward cage fish farming.

CHAPTER FOUR

EFFECT OF INFORMATION FLOW THROUGH SOCIAL NETWORKS ON THE ADOPTION OF CAGE FISH FARMING TECHNOLOGIES IN UGANDA

Abstract

The study aimed at analyzing how farmers' networks, and their spatial and temporal dynamics, affect the adoption of cage technologies. The objective of the research was to examine the impact of farmers' networks, along with their temporal and spatial dynamics, on the uptake of cage technologies. It made use of social network theory and network science to comprehend the role that cage fish farming plays in a sustainable blue economy. It specifically looked at how social network information flow affects Uganda's adoption of cage fish farming technologies. To investigate the relationships between the characteristics of the farmer network and the adoption of cage fish farming in Uganda, the study mapped the social networks of a sample of cage fish farmers in Lake Victoria and conducted semi-structured interviews. The degree of social networks utilized and the degree to which the pro-social networks differed in terms of the number of members were ascertained using a twofold hurdle model. The findings show that the majority of Ugandan cage fish producers obtain their firsthand information from other farmers. More crucially, the cage fish farmers' decision to use informal networks was influenced by factors such as the number of extension visits, loan availability, farming experience, kind of cage, membership in groups, and farm location. On the other hand, the number of cage units owned by fish farmers is influenced by variables such as target market, type of cage, farming expertise, and finance availability. The findings show a statistically significant difference in the number of cage units owned by farmers who use formal networks versus social networks. The report suggests that policymakers and extension personnel should modify the implementation of extension programs to hasten Uganda's adoption of cage fish technology.

4.1 Introduction

The goal of the Blue Economy (BE) idea is to advance sustainable and equitable development (FAO, 2020). Fish catches have decreased as a result of overexploitation of Lake Victoria's fish resources over time (Aura *et al.,* 2018). In this instance, adopting cage fish farming and changing one's perspective is necessary to realize the lake's full potential. Uganda must actively promote cage fish farming to augment the wild catch from its natural water basins. However, farmer-to-farmer relationships have been shown to supplement the extension services due to the limited number of agricultural extension officers for farmers in the nation. The literature study indicates that farmers' social connections with other farmers have an impact on how they adopt new technologies (Handschuch & Wollni, 2013).

Analysis of actor interactions and information exchange between individuals is essential in understanding how innovations are processed and adopted. Understanding how innovations are assimilated and digested requires an analysis of actor interactions and information sharing among individuals. The literature claims that an individual's personal network structure influences even the spread of information and the functionality of new technology. According to certain academics' analyses of the agricultural system, farmers' social networks have an impact on how quickly they adopt new agricultural technologies (Albizia *et al*., 2021). With the low number of extension agents per farmer, social network analysis has been used to investigate how technologies spread among small-scale farmers (Ward & Pede, 2015). In Uganda, where cage fish farming is still a relatively new technology, the social setting of early adopters and their consultative participation. Embedded in their interactions is the flow of knowledge, ideas, and information that inform the type and the number of cages these farmers embrace (Nakano *et al.,*2018).

In areas with limited access to formal extension institutions, social networks are a major source of agricultural knowledge dissemination (Abid, 2015). In particular, access to extension services is usually restricted for smallholder farmers in developing nations, favoring larger, more powerful farmers (Abid, 2015; Ngaruiya & Scheffran, 2016). The information flow among smallholder farmers and the adoption aspect remains to be investigated, given the paucity of literature and information on the adoption of cage fish farming in Uganda. Studies on the present exchange of knowledge and interactions among smallholder cage fish farmers, as well as their part in the adoption of new technology, are therefore necessary.

This is the first study of its sort to investigate the importance of social networks and the possibility of information transfer among smallholder cage fish farmers in Uganda, taking into account the existing knowledge gap. Research by Benard *et al.* (2020), Fisher *et al.* (2019), Cordelia *et al.* (2022), and Shikuku (2019) has focused on investigating how social networks influence farmers' adoption behavior in Uganda. Due to the low number of extension staff in the nation, Lamb *et al*. (2016) discovered that farmers rely on other farmers as their information contacts regarding technological developments. A similar study by Visilaky and Islam (2018) on women farmers in Uganda concluded that social networks are adequate mechanisms of information transmission in the absence of informed extension officers. Empirical evidence from these studies also indicates that social networks have facilitated farmers to cost-effectively transmit and share knowledge, especially on emerging farm technologies.

The literature that is currently accessible stresses how crucial it is to take into account interactions between farmers as well as those with extension agents when examining information flows in agriculture. Determining the degree of intensity in cage fish farming requires an understanding of the dynamics of information flow between cage fish farmers. The literature also emphasizes how social and communicative activities within network structures impact agricultural advances (Neumeier, 2017).

Analyzing the farmer-to-farmer social networks, Suvedi *et al.* (2017), showed through their analysis of farmer-to-farmer social networks that farmers who had more contacts with their peers also adopted technology at higher rates, which in turn resulted in higher income. Concurrently, farmers who are members of cooperative networks are more likely to embrace technology advancements. Beaman *et al*. (2021) state that while age, education, and landholding size are important adoption drivers, they do not fully explain the impact of knowledge flows on technology adoption. Therefore, social network analysis should be included in technology adoption analyses.

In addition, Vrain and Wilson (2021) argue that social networks are essential to the adoption of technology, as networks act as channels of information and a means of learning. Social networks are of great importance to smallholders and resource-poor farmers who rely on informal sources rather than formal sources and whose information needs often need to be met by formal dissemination services (Amlaku *et al.,* 2012).

Furthermore, the use of farmers' networks can be very cost-effective as well as very time-efficient. Social structures are already in place and do not need to be artificially constructed like other extension approaches Furthermore, social networks serve as a conduit for knowledge and a tool for learning, according to Vrain and Wilson (2021), who also contend that social networks are necessary for the adoption of technology.

Conversely, social structures impact economic results in ways that modify the quantity and quality of information, particularly when they take the shape of social networks. For smallholders and resource-poor farmers, who depend more on informal than official sources and frequently require formal dissemination services to meet their information demands, social networks are crucial (Amlaku *et al.,* 2012). Furthermore, it can be incredibly economical and time-efficient to use farmers' networks. Unlike other extension options, social structures already exist and do not require creation (Oriana et *al.,*2019).

A Cragg double hurdle was employed to examine the influence of market information networks on smallholder farmers' decisions to market native African vegetables (AIV) (Mwema & Crewett, 2019). To understand how sales decisions and volume are affected, the study examined the sources of market knowledge and social networks for information exchange. Their findings indicate that the second step of sales volume is determined.

The impact of market information networks on smallholder farmers' decisions to market native African vegetables (AIV) was investigated using a Cragg double hurdle (Mwema & Crewett, 2019). The study looked at social networks for information sharing and sources of market knowledge to comprehend how sales decisions and volume are impacted. According to their findings, the market intelligence network has proven beneficial for the second stage of determining sales volume. They concluded that knowledge from sources other than the farmer's hamlet filled the social capital gaps, raising the likelihood of AIV being sold the nation has benefited from the market information network. They concluded that information from sources outside of the farmer's hamlet bridged the social capital, increasing the possibility that AIV would be sold.

The study by Olwande *et al.* (2009), employed panel data to investigate the variables that impact fertilizer acceptance and application intensity. In their application, they employed the double hurdle model to establish a relationship between the farmers' age and educational attainment, proximity to the fertilizer market, availability of finance, presence of cash crops, and the likelihood of fertilizer adoption. The intensity of fertilizer use is determined by various factors such as the farmer's gender, financial stability, availability of cash crops, distance to extension services, and potential for agroecology.

Additionally, it was discovered that adoption is influenced by a study that increased farmers' exposure to and understanding of new agricultural technologies (Yigezu *et al.,* 2018). A sample of 820 small household farmers in Syria who grew wheat and barley were subjected to a double hurdle and duration analysis model. The results demonstrate adoption patterns, strength, and speed, with field days and demonstration trials contributing to a rise in no-till adoption and awareness. The amount of wheat planted and farmers' access to credit both have a favorable impact on adoption strength. The study's findings make it easier for farmers to get in touch with one another and streamline new agricultural technology, particularly those that need a substantial upfront investment to be adopted quickly and widely.

Cage fish farming is becoming more and more popular among Uganda's smallholder farmers, for whatever reason. Adoption is a sequential process rather than a single event, according to reviewed literature (Cook *et al*., 2021; Isaac *et al*., 2017; Lin *et al.,* 2021; Morse & MacNamara, 2020; Yigezu *et al*., 2018). The choice stage, which is succeeded by the intensity stage, defines the adoption process. There aren't many details about how widely this practice is being used by farmers, especially in Uganda.

To assess the level of cage adoption, we calculate the absolute difference in the number of cages among farmers who rely on unofficial social networks. The use of econometric models to show how much social network-using farmers have increased the intensity of their cage fish farming operations is what makes this research novel. This study examines how farmers who depend on other farmers have expanded the number of cages rather than the yield they produce, whereas previous research on social networks in Uganda has mostly concentrated on farmers' exposure to social networks

4.2 Methodology and Analytical Framework

4.2.1 Study Area and sampling procedure

The description of the study area and the sampling procedure were as described in section 3.2.1 (Chapter 3)

4.2.2 Measuring the nature of social interaction

The study's unit of analysis was the smallholder cage fish farmer who owned a fish stocking density of not more than 50,000 (NaFiRRI, 2021). Secondly, a smallholder farmer was either a female or a male rearing fish in cage units and accessing information about cage fish farming mainly from fellow farmers within Lake Victoria waters in Uganda. Additionally, the number of cage units a smallholder fish farmer owned was used to measure the intensity of adoption of the technologies in the study area.

The study assessed the interactions between fellow cage fish farmers within villages (intra-village links) and outside their respective villages (Inter-village links), then with change agents and other actors. The purpose of the study was to determine how the development of an intervening impact pathway affects an individual's decision-making (behavior) on the adoption of technology for cage fish farming (Inkoom et al., 2020; Kendall & Babington, 1939). The study assumed that social interaction promotes the dissemination of knowledge and information about technologies used in cage fish farming, which in turn influences a farmer's innate ability to make decisions, leading to the adoption and application of the technology.

This study evaluated the interactions between community leaders, change agents, and smallholder cage fish producers within the social network. Additionally, it investigated how information sharing within the network affects farmers' actions and the uptake of technologies for cage fish farming. The fundamental premise is that social interactions are essential for spreading knowledge about technology used in cage fish farming and, in turn, for influencing behavioral change.

The social interactions among smallholder cage fish farmers were evaluated by rating the information links on a scale of 1 to 4. The spectrum of social interactions was intended to be captured by this scale. These encounters were measured using the following variables: trust, usefulness, efficacy, and frequency. Based on these four elements, the measurement scale made it possible to approximate the social interaction index in the farmers' communication network. The rating scale proved to be a useful tool for farmers to evaluate their contacts with other actors about technological concerns related to cage fish farming, both in terms of quality and intensity.

Furthermore, another study employed an approach outlined to analyze data collected from farmers' social interactions (Inkoom *et al.,* 2020). The data was analyzed using the Kendall coefficient of concordance as a robustness check, alongside individual scoring structures employed by assessors. The choice of Kendall's W approach was made due to its ability to yield values within the range of zero to one (Kendall & Babington, 1939). A value of zero signifies a lack of concordance among assessors regarding the evaluated concept. In contrast, a value of one represents a complete degree of concordance or agreement among assessors regarding the concept under evaluation. Therefore, the mathematical model utilized for the computation of Kendall's W was as follows:

(4.1)

Where: *W*=Coefficient of Concordance, S=sum of squared deviates from the mean rank, M=number of respondents, and N=number of attributes being evaluated by the respondents

4.2.3 Estimating the Intensity of Adoption

The study assumed that smallholder farmers are rational in making decisions related to cage fish farming technologies. Hence, the adoption of cage fish farming was considered to have two distinct choice stages: first, the use of social networks, and second, the number of cage units a farmer owned. For this reason, Cragg's (1971) double-hurdle model was used for this study. The Double Hurdle model loosens the assumptions of correlating the error terms of the two outcomes and models the two choices independently. In this study, it is assumed that the establishment of each cage is determined by different sets of factors, which could be different from the factors that influence the use of social networks.

During analysis, we opted to use the double-hurdle model instead of Heckman's and Tobit's models because the former allows for more flexibility in modeling the two sequential decisions. In the double-hurdle model, a farmer first decides whether to use social networks and then decides whether to increase the total number of cage units owned. To identify the variables that influence the decision to use social networks, we used a Probit regression. For the decision on the number of cages, we used a multiple regression model. The first decision (use of social networks) is modeled using a Probit model to represent the probability of a limited observation.

= 1 if > 0 and 0 if 0

= α + (4.2)

Where = Latent variable describing whether or not adoption occurs *z* = a vector of explanatory variables hypothesized to influence the choice to participate, α= a vector of parameters, and ε =the standard error term.

The second hurdle involves an outcome equation, which uses a truncated model to determine the extent of adoption (intensity of cage fish farming). This second hurdle uses observations only from those respondents who indicated the use of informal social networks as their information contacts. Therefore, the truncated model is expressed as:

= if 0 and 0; = 0 otherwise

= β + (4.3)

Where: *y* = the observed response on the intensity of cage fish farming, x = a vector of explanatory variables hypothesized to influence the intensity of cage fish farming, *β* = a vector of parameters, μ = the standard error term. The description of variables is presented in Table 4.1.

Table 4.1: Description of Explanatory Variables used in Analysis

Variables	Description	Expected signs
Education level	Number of years of schooling in years	+/-
Age	Age of the respondent in years	+/-
Gender	Sex of the respondent (1=Male and 0=Female)	
FarmExpe	Farming experience in years	-
HHSize	Household size (number of people staying in a home)	-
ExtenCont.	Number of extension visits in a month	-
MktDist	Distance to nearest market (km)	
CreditAcc	Access to credit facilities (1=Yes 0=No)	-/+
Information flow	Number of information contacts before adoption	+/-
OffFarmInc	Off-farm occupation (1=Yes 0=No)	+
Inforsource	Primary information source used by cage fish farmers	-/+
Network Size	The number of cage fish farmers a respondent shares information with about cage fish farming.	+/-
SocioNet ties	Frequency of contact with an individual providing information about cage fish farming. Where 0= Daily, 1=At least once a week, 2=At least once a month, 3=Annually. (1=Weak ties (at least once per month	+/-

and annually): 2= Strong ties (at least once per week
and daily).

4.2.4 Testing Normality and Multicollinearity

In econometric analysis, normality tests are performed to determine whether explanatory variables to be used in the regression are normally distributed or not. In this study, t-tests and chi-square tests were performed on continuous and categorical variables, respectively. The assumption is that if the residuals are not normally distributed, then either the dependent variable or at least one explanatory may have the wrong functional form or important attribute missing. Also, testing for normality helped measure the goodness of fit. In addition, a diagnostic test for the existence of multicollinearity on categorical variables was conducted using the Variance Inflation Factor (VIF).

4.3 Results and Discussions

4.3.1 Socioeconomic characteristics of respondents

The results presented in Table 4.2 indicate that cage fish farmers in the study area, on average, interact with (6±1) fellow farmers and own around (5±3) cage units. The mean value for age was (45±8.2) years, with an average education level of (12 ± 3.1) years in school. The respondents also had a mean household size of (5±2.1) and a mean value of (5±1.2) years of cage fish farming. Additionally, the results indicate that the average number of extension visits received by farmers in the study area per year was (4±1.0), while the average size of farmer groups was, (22±7.6).

Regarding gender, male respondents constituted the majority (76.3%), while female respondents were only (23.7%). Most of the surveyed cage fish farmers (82.6%) used metallic cages, while (9.1%) and (8.3%) used HDE plastic cages and wooden cages, respectively. The study also explored the location of cage units in water away from the shoreline. The results revealed that (30.2%) of the sampled respondents practice cage fish farming within 200 metres from the shoreline. Then, (25.3%), were rearing fish at a distance between 201 and 500 metres away from the shoreline. The third category of the sampled farmers (22.4%) were rearing fish in the distance between 501 and 100 metres away from the shoreline.

The fourth category (22.1%) was rearing their fish at a distance beyond a kilometer away from the shoreline. The results indicated that (73.2%) of the sampled farmers sold their fish produce in local markets within their communities, (16.1%) to fish processing companies, and only (10.7%) exported their fish produce directly to foreign countries. Furthermore, the study examined the type of labour used by fish farmers. It was found that (69.3%) of the sampled fish farmers solely use family labour, and only (30.7%) use hired labour on their fish farms, as indicated in Table (4.2).

Table 4.2: Socio-economic characteristics of respondents

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
Dependent Variables				
Farmer social contacts	6	1.3	2	10
Cage units owned	5	3.1	1	16
Independent Variables				
Age of a respondent	45	8.2	32	63
Education level	12	3.1	7	18
Household size	5	2.1	1	11
Experience in fish farming	4	1.2	2	8
Number of extension visits	4	1.3	1	6
Size of farmer group	22	7.6	6	39
Gender (%)				
Male			23.7	23.7
Female			76.3	100.0
Type of Cages used (%)				
HDE plastic cage			9.1	9.1
Metallic cages			82.6	91.7
Wooden cages			8.3	100.0
Cage location in waters (%)				
200m away from shoreline			30.2	30.2
201 to 500m away from shoreline			25.3	55.5
501 to 1000m away from the shoreline			22.4	77.9
Beyond 1000m from shoreline			22.1	100.0
Target fish Market (%)				

Direct export	10.7	10.7
Fish Processing Company	16.1	26.8
Local Market	73.2	100.0
Type of labour used (%)		
Hired labour	30.7	30.7
Family labour	69.3	100.0

4.3.2 Analysis of farmers' information links through social networks

According to the data shown in Table 4.3, farmer contacts with input merchants received a mean score of 6.65, while farmer interactions with other farmers at the village level were regarded highly with a mean score of 6.82. Furthermore, with a mean score of 6.56, farmers' discussions about technology issues came in third. Conversely, farmers' social connections scored lowest for their interactions with extension and research agents, which received a mean score of 4.57, and for their access to media coverage of cage fish farming technology, which received a mean score of 5.35.

With a mean score of 6.16, the results on farmers' interactions with other farmers within their village were ranked highest. The interactions between farmers and input traders came in second, with a mean score of 5.96. The inter-village exchanges between farmers and their discussions with other farmers regarding technological matters received a mean score of 5.84 for each. Conversely, with a mean score of 4.20, the farmers' interactions with local officials were the least ranked item. Farmers' attendance at association meetings came next, with a mean score of 4.26. With a mean score of 4.55, it was also noted that the interaction between farmers and change agents was one of the lower-ranked topics.

Under the category of effectiveness of social interaction, the findings show that farmers' intra-village interactions had a mean value of 6.10, followed by farmers' interactions with the promoters of the cage technologies, which had a mean value of 5.97. On the other hand, the lowest mean score in this category was between farmers' interactions with the community leaders, 5.34.

Table 4.3: Analysis of information links among cage fish farmers' social networks

Farmers' information links in their social networks	Frequency				Effectiveness	
	Mean score	Mean rank	Mean score	Mean rank	Mean score	Mean rank
Farmer's interaction with fellow farmers at the intra-village level	6.82	5.54	6.16	5.19	6.10	5.30
Farmer's interaction with fellow farmers at the inter-village level	5.90	5.08	5.84	5.22	5.82	4.88
Farmer's interaction with the main promoter of cage technologies	5.62	4.46	5.54	4.82	5.97	4.84
Farmer's interaction with change agents (Extension officers /Researchers)	4.57	4.44	4.55	4.15	5.75	4.93
Farmer's interaction with input dealers	6.65	3.41	5.96	4.64	5.75	4.53
Farmer's interaction with other community leaders	5.54	4.16	4.20	4.46	5.34	4.32
Farmer's participation in association meetings	5.53	4.20	4.26	4.83	5.97	4.24
Access to cage fish farming technology-related information from the media	5.35	3.77	5.42	3.42	5.43	4.26
Farmer's conversation with fellow farmers on technological issues	6.56	4.53	5.84	3.39	5.81	4.21
Farmer's conversation with fellow farmers on market issues	6.17	3.72	5.82	3.67	5.46	3.28
Degree of trust in information obtained through social interaction				**Mean score**		**Mean rank**
Degree of farmer's confidence in externally provided technical information				6.12		1.15
Degree of farmer's confidence in externally provided market information				6.66		1.94
Test of the degree of agreement in farmers' ranking using Kendall's coefficient of concordance						
Social interaction measure						**Kendall's W**
Frequency of social interaction						0.55**
Usefulness of social interaction						0.46**
Effectiveness of social interaction						0.45**

Degree of trust in information obtained through social interaction	0.21**

4.3.3 Assessing the effect of information flow through social networks

Table 4.4 presents the VIF, which ranges from 1.02 to 1.98, with a mean of 1.33. These values indicate that there is no evidence of multicollinearity in the estimated model, as they are well below the critical VIF of 10.

Table 4.4: Estimation of Variance Inflation Factors (VIF)

Variable	VIF	1/VIF
Age of respondent	1.98	0.51
Targeted market	1.75	0.57
Gender of respondent	1.03	0.97
Extension visits	1.05	0.95
Type of cage unit used	1.42	0.70
Farming experience	1.11	0.90
Size of farmer group	1.32	0.76
Distance to market	1.47	0.68
Group membership	1.69	0.59
Credit access	1.44	0.69
Farm location	1.04	0.96
Type of labour used	1.03	0.97
Education level	1.02	0.98
Mean VIF	**1.33**	

Table 4.5 shows the results from a two-tier double hurdle model analysis. The maximum likelihood estimates indicated that the overall Chi-square = 25.27, p-*value* = 0.00, was significant at a 1% level showing that the model was fit to analyse the data for this study. The first tier of the model reflected outputs from a Probit model, whereas the second tier exhibited outputs from a Tobit model analysis. Further, the results in the first tier indicated that the age of the respondent, extension services, credit access, experience in cage fish farming, type of cage units used, group membership, size of farmer group, farmer's level of education, and location of cage units in waters were statistically significant and were associated with the use of social networks among cage fish farmers.

For the second tier, credit access, type of cage unit owned, farm location, farming experience, targeted fish market, and the respondent's age were statistically significant and associated with the number of cage units owned by the farmer.

Table 4.5: Double Hurdle Regression Analysis

	First Tier		**Second Tier**	
	Social networks		**Number of Cages**	
	Parameter	***P*-Value**	**Parameter**	***P*-Value**
Age of farmer	1.32	**0.02**	1.36	**0.00**
Gender	0.03	0.88	0.13	0.86
Extension services	0.59	**0.01**	0.65	0.13
Credit access	1.06	**0.00**	5.11	**0.00**
Experience in fish farming	0.43	**0.06**	1.26	**0.00**
Type of cage used	0.63	**0.09**	2.24	**0.00**
Target market	-0.49	0.22	-2.14	**0.01**
Group membership	0.70	**0.02**	1.96	0.12
Size of farmer group	1.43	**0.00**	1.52	**0.00**
Market distance	-0.00	0.58	-0.34	0.31
Farm location	-0.17	**0.06**	-0.09	0.42
Type of labour used	1.42	**0.04**	2.31	**0.03**
Education level	0.06	0.12	0.01	0.69
Number of observations = 384				
Wald Chi2 = 25.27				
Prob > Chi2 = 0.00				

The results in Table 4.5 indicate that the age of the farmer was statistically significant in both tiers of the model. That shows that age had a positive effect on the probability of cage fish farmers engaging in social networks and increasing the number of cage units used. Further, the finding implied that a one-unit increase in a farmer's age would increase the probability of using social networks and increase the number of cage units by 1.32 and 1.36 units, respectively. Therefore, the positive association is related to the fact that as the farmer advances in age, it becomes easier to build strong ties with others with whom they share the same kind of employment and also the likelihood of a farmer increasing in the number of cage units used. Similar results are also reported by Bruin *et al.* (2020).

As regards farmers' experience in cage fish farming, a unit increase in farming experience increased the probability of cage farmers using social networks and having more cage units by 0.43 and 1.26 units, respectively. Experience in cage fish farming has also been shown to have a positive association with both the use of social networks and the intensity of cage fish production. These results are supported by the findings of Danso-Abbeam *et al.* (2017), who revealed that as farmers gained experience, they were more likely to intensify production in a given farm enterprise. The finding can be attributed to the accumulation of skills and knowledge throughout the production process. More experience in this study is linked to more social networks. Therefore, that could imply that as a farmer ventures into cage fish production, social networks become integral in supporting the cage fish farming business through information and resource sharing.

As regards to extension services had a positive and significant effect on the probability of cage fish farmers engaging in social networks. The results implied that an increase in the cage fish farmer's access to extension services by one-unit change would increase the probability of using social networks by 0.59 units. The result means that access to extension services decreases the likelihood of farmers engaging in social networks. Hence, it was identified as a significant hurdle in the first tier. Indeed, the study shows that in the ideal situation, it is expected that farmers can access information about new technologies by contacting the extension agents. However, in situations where extension services are limited, as portrayed in this study, farmers would opt to use social networks as alternatives for information. The results are consistent with the findings by those who found that extension services are one of the most critical policy variables, which favourably influence the adoption of agricultural technologies among smallholder farmers (Kassa *et al.,* 2021).

In the first tier, credit access had a positive and significant effect on the probability of cage fish farmers engaging in social networks. The result implies that a unit increase in credit access increased the probability of using social networks by 1.06 units. The second tier, credit access, was positive and significant and associated with the number of cage units owned by the farmer. The results, therefore, showed that a unit increase in access to credit increases the likelihood of increasing the number of cage units by 5.11 units. Access to credit was also positively influenced by the decision to use social networks and the number of cage units owned. The result could imply that farmers who had more access to credit were more likely to use social networks and were also more likely to increase the number of cage units. This finding shows that farmers who were more credit-constrained utilized fewer social networks as a way to find alternative financial support from fellow farmers. Credit-constrained farmers were also less likely to decrease cage units owned due to the significant cost implication. Therefore, the result means that the use of social networks is key, especially among credit-constrained farmers.

The outcomes additionally demonstrated that a key determinant of cage unit intensity was the kind of cage unit. Therefore, the likelihood that a farmer will decide to raise the number of cage units by 0.63 units increases with each unit change in the type of cage used from metallic to either HDE plastics or wooden. The quantity of cage units utilized by fish farmers rises when the type of cage shifts from metallic to either HDE plastics or wooden. While no prior literature has handled this scenario, the authors attribute this to the fact that as farmers familiarize themselves with a given cage type, they tend to understand its pros and cons and, hence, tend to concentrate on it based on the axiom of specialization.

The number of cage units owned by fish farmers was unaffected by the farmers' group participation, but it did have a positive and statistically significant influence at 5% on social networks, a proxy for the farmers' information contacts. As a platform for information exchange, group membership has been crucial. By pooling transaction costs, such as transportation expenses, it has made it possible for farmers to connect with buyers at a cheaper cost, which lowers the fixed transaction costs associated with market participation. The study's findings are consistent with those of earlier research (Shikuku, 2019; Mulwa *et al.,* 2017). The results on the favorable impact of members' associations on intensity align with Ghimire and Huang's (2015) findings regarding the degree to which smallholder maize farmers adopt agricultural technology.

Farmers were less likely to use social media when their cage units were situated farther away from the coast. It was discovered that a farmer's location reduced the likelihood that they would use social networks. In contrast to farmers along the beach, the results suggest that most of these farmers work alone and do not collaborate. According to the findings, farmers along the coast may have been able to feed and gather fish as a community. No literature has looked into how cage unit placement affects social networks as of yet.

4.5 Conclusions and Policy Implications

The study aimed to investigate the aspects of information flow through social networks that influence smallholder farmers rearing fish in cage technologies along the shores of Lake Victoria in Uganda. The descriptive statistics indicated that the adoption rate was relatively low for wooden and HDE plastic technologies. However, the majority had embraced the use of at least one of the one category of technologies (metallic cages), notwithstanding the low adoption rate. Specifically, a Double Hurdle (DH) approach was deemed more suitable. The first tier of the model considered the adoption of cage fish farming technologies with respect to the farmer's source of information accessed, and a probit model estimate was used. In the second tier, the intensity was conceptualized in terms of the number of cage units a farmer owns, and a Tobit model was employed. The result suggests that farmers' decisions about the adoption and intensity of the technology use were made independently.

Consistent with the empirical evidence from the study findings on adoption, indicated that farmer's age, access to extension services, access to credit, experience, type of cage unit used, group membership, size of farmers group, location of cage units in the lake and type of labour used in cage fish farming were statistically significant in adoption decision-making processes. Conversely, the farmer's age, access to credit, experience, type of cage used, target market, size of farmers group, and type of labour used were significant drivers of intensity in cage fish farming technologies in the study area.

Several recommendations are made in light of the findings to enhance the acceptance and usage of cage fish farming technologies in the study area. First, social networks should be integrated into traditional government extension programmes. Also, agricultural stakeholders should actively encourage the formation of farmer associations at the grassroots level to strengthen social networks and enhance information sharing on cage fish farming technologies. Second, financial institutions should also provide more preferential interest rates on credit to enable smallholder farmers to purchase cage fish farming technologies and other related inputs such as nets, floaters, feeds, and solar accessories.

Finally, the results emphasize the need for practitioners and agricultural stakeholders to promote membership in farmer associations, design unique programmes and packages targeting the youths to join the aquaculture sector and credit access, create awareness of lucrative fish markets, and improve the quality of labour used to manage fish farm activities to enhance the adoption and intensity of the use of cage fish farming technologies. The strategy would be to improve the training materials and content that give farmers more access to knowledge. Therefore, more farmer training programs and innovative strategies that embrace social networks will thereby raise awareness, which will help boost the uptake and usage of cage fish farming technologies.

CHAPTER FIVE

ROLE OF SOCIAL NETWORKS IN EXPOSING SMALLHOLDER FARMERS TO CAGE FISH FARMING TECHNOLOGIES

Abstract

In Sub-Saharan Africa, the agricultural sector is greatly affected by access to and use of information. Governments and development partners use agricultural extension systems to provide farmers with the necessary information. Extension services are widely regarded as the panacea for agricultural and technological information diffusion among farmers. Even with their importance, Uganda's present extension system of 1 extension Agent to 1,800 farmers provides insufficient help, primarily to smallholder farmers due to limited access. As a result, farmer-to-farmer relationships are becoming increasingly vital in sharing agricultural information and skills transfer. This study focused on examining the role of information flow through social network analysis in expanding the caged fish adoption rate for improved fish farming in Uganda. Further on the application of social network systems, the appropriate data was generated from interviews who had adopted cages for fish production among farmers in Lake Victoria. The study revealed a positive association between information-seeking ties through social networks and cage technology awareness. The findings revealed that cage farmers majorly relied on their peers as their primary information sources. Furthermore, the study identified that the most central farmers in networks bridge the information flow between various farmers in different geographical regions. This study contributes to the body of knowledge of literature by empirically proving the role of information transfers via social network platforms in cage fish farming, an emerging technology. Notably, outcomes of the study inform the policy formulation by demonstrating whether formal extension services and informal interactions amongst farmers can be viewed as supportive or distinct entities in order to advance cage fish farming in Uganda.

5.1 Introduction

The decline in capture fishery resources in natural water bodies in the region has led many smallholder farmers to join the cage fish farming sub-sector (LVFO, 2020). Increasing aquaculture productivity in the Sub-Saharan region is critical for sustainable livelihood improvement, food security, employment, and promotion of the blue economy (Belton *et al*., 2018). Cage culture is one of the emerging subsectors in the Sub-Saharan region, with the most successful fish production trends (FAO, 2020). Cage fish farming techniques optimise space, increasing the fish productivity per unit area (Asche *et al*., 2018; Garlock *et al*., 2020; Mitra *et al*., 2020). Fish farming in the East African region has greatly increased, contributing to a high degree of technological evolution, increased productivity, and market dynamics (Belton *et al*., 2018; Garlock *et al*., 2020). The cage fish production techniques used by smallholder farmers need more guidance from formal extension agents due to their persistent shortage (ADA, 2022; Ssebaggala & Matovu, 2020). In order to improve productivity in the region, it is essential to note that current extension services do not position smallholder farmers to be leaders. As a result, many smallholder cage fish farmers rely on agricultural information obtained from their fellow farmers (Mbowa *et al.,* 2017; Oglend, 2020).

In addition, Uganda, like its counterparts in the Sub-Saharan region, has engaged in numerous reforms in the area of providing extension services, ranging from a commodity-focused extension system during the colonial period to a farmer-demand-driven extension system. Because of persistent challenges associated with the latter extension approach, the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) spearheaded the development of a more integrated, coordinated, and harmonized public extension system named the Single Spine extension service delivery system. However, smallholder cage fish farmers still face challenges in accessing adequate access to agricultural extension services and technology-related information.

Uganda ranks first in the East African region in cage fish farming (FAO, 2018; LVFO, 2020) and 3rdin Africa after Nigeria and Egypt (Adekele *et al*., 2021; Kaleem & Sabi, 2021) with 0.5 million MT per annum (Halwart, 2020; Mbowa *et al*., 2017). Uganda is at an advantage in cage fish production, this is attributed to the fact that it is surrounded with abundant water resources as well as the available cheap labour in the region (NaFiRRI, 2019). The Ugandan government has promoted cage fish farming to relieve pressure and support the livelihoods of several people who depend on fish-related activities for their income (Atukunda & Ahmed, 2019). The availability of extension agents is still very limited compared to the ration of farmers of 1:1800 presents a barrier to the adoption of innovative farming methods (Davis, 2020; Kaumbata *et al*., 2021; Kuehne *et al.,* 2017; Otchia, 2014). Consequently, especially in the absence of formal institutions such as extension services, cage fish farmers' social networks can be crucial in complementing the role of extension agents.

Social networks and extension services are the main channels that farmers can use to obtain technical information (MacGillivray, 2018; Skaalsveen *et al.,* 2020). Social networks emphasize that farmers use social connections to share technical information and interact with each other. This is because the more the adoption of technology rate by farmers the more the information and knowledge on caged fish farming process is increased (Schulz & Börner, 2023). Farmers obtain technical information through social interactions and determine implementation requirements and the expected performance of the technology.

Evidently, previous study outcomes in Sub-Saharan Africa suggests a positive relationship between farmers' informal interactions and information flow (Malit *et al*., 2021; Wang *et al*., 2020; Villegas *et al*., 2022). In particular, social network analysis is based on the idea that social interaction is primarily formed by relationships and the patterns formed by these relationships (Lin *et al*., 2016). A recent study that employed SNA in the context of agricultural technologies focused on social networks and extension services as a platform to enhance the efficiency adoption of modern technologies by farmers (Wang *et al.,* 2020). The study found that farmers who were more centrally located within the social network had a positive perception towards new agricultural technologies hence influencing their likelihood to adopt. Another recent finding by Mastenbroek *et al.* (2020) used SNA to investigate information factors as the barriers influencing the adoption rate of new agricultural technologies among farmers in Uganda. The results of the study indicated that social networks significantly influence the dissemination and advocating for new agricultural technologies information's, hence increasing the adoption of the technology.

In this study, *a social network was considered* a factor that enhances (individuals, agents, or groups) relationships between farmers, significantly influencing the flow of information (Crossley *et al.,* 2015; Marin & Wellman, 2011). Hence, the focus of this study is to contribute to the growing body of literature on social networks by empirically demonstrating the role of information links via social networks in the emerging technology of cage fish farming.

5.2 Methodology and Analytical framework

An *egocentric* approach was employed to map out individual actors sharing dyadic relations and the connections between them (Wellman, 1983). The actor in the centre is referred to as an '*ego,'* and the others s/he interacts with become the '*alters.'* Applying social network theory, we considered cage fish farmers and their information contacts as nodes and the talks (knowledge exchange) between the farmers and their primary information contacts as the connections between them. The *egonet* approach was used to determine the node sizes and clearly visualize how powerful or central an ego relates to several direct and indirect links. Different colours demonstrate ties linking actors, which were used to distinguish the various linkages. According to Dershem *et al*. (2011), the *egonet* approach uses an algorithm that makes the network maps appear more organized, informative, and easier to understand. The approach makes it easier to analyze the patterns of the connections among its members. In order to accomplish the study's objective, inferential statistics and sociograms were created using UCINET software. These sociograms allow for the visualization and analysis of social networks among actors (Xue et al., 2020).

Additionally, they help in locating the most important actors in a social network and their level of connectedness. In the context of this study, the focus was on the identification of critical actors in the social networks among smallholder farmers and how they got exposed to information on cage fish farming technologies. Alternative models that could have been used in this study include logistic regression, decision trees, and Bayesian networks. However, these models need to consider the relational nature of social networks and the interconnectedness of actors within the network. The application of SNA in this study is innovative as it applies the model to the context of cage technology adoption for fish farming in Uganda, contributing to the body of literature on the use of social network analysis in agricultural research.

Following an egocentric approach (Costa *et al*., 2018; Lee, 2019), the study was interested in the ego's attributes and his/her relational attribute data with the mentioned alters. By invoking elements of *social contagion* theories, which focus on dyadic relationships in the social system, the study hypothesized that there are characteristics of both cage fish farmer *A* and his/her information source/contact *B* (Burt, 1987). These shared characteristics position increases their closeness (social proximity) for *A* to socially learn from *B,* thereby also getting exposed to various cage fish farming technologies. To display cage fish farming (CFF) technology exposure through social networks, farmers responded to, among others, the following questions: *Who are your most important information sources on CFF*, and *how frequently do you discuss the CFF?* Responses from these questions were used to display each category of sociogram for the cage fish farmers.

Measures of centrality, namely degree, betweenness, closeness, and eigenvector, were used to show how actors control information, the power they possess, and the number of intermediary contacts between any two individuals. In addition, during the social network analysis, characteristics for both inter and intra-village levels were captured. Conceptually, each centrality measure represented a different process by which key players influence the flow of information through a network. Centrality measures indicated who occupied the critical positions in the network. The information needed to construct centrality was the identifier of the cage fish farmers who initiated the advice-seeking (egos) and the identifier of the individual who serves as the target of the advice-seeking (alters) from each of the sampled cage farmers.

5.2.1 Degree centrality

Degree centrality measures the importance of a node by the number of its connections, which was obtained from cage farmers' informal networks. A farmer with a higher degree of centrality maintains more contact with other farmers and is considered relatively influential in the farmers' network. Degree centrality is:

$$C(Di)=\sum k\neq inAi,j \tag{5.1}$$

Degree centrality uses adjacency matrix A for unweighted networks, which is defined as a $|V| \times |V|$ matrix with entries $Ai,j = 1$ if and only if farmer i and j connect, else zero.

5.2.2 Closeness centrality

Closeness is based on the length of the average shortest path between a node and all nodes in a sociogram and was obtained from the interactions between the cage fish farmers and their main information contacts. A farmer who is close to other farmers can quickly interact and communicate with them without going through many intermediaries. Closeness centrality is computed as the inverse of the sum of geodesic distances from a specific farmer i to the other $n -$ 1 farmers. The closeness centrality of farmer i is:

$$C(Ci)=[\sum k\neq inDi,j]-1 \tag{5.2}$$

Closeness centrality uses distance matrix D, which is defined as a $|V| \times |V|$ matrix with each entry of $D\ i,j$ equal to the length of the shortest path between farmers i and j in the farmers' network information data. A path is defined as a way to reach farmer j from farmer i using a combination of edges that do not connect through a particular farmer more than once. When i is not connected with any farmers, $D\ ij$ is defined as infinity, so the closeness centrality of farmer i is zero.

5.2.3 Betweenness centrality

Betweenness is formulated based on the number of times a particular node lies "between" the other nodes in the network and is obtained from cage farmers' first information contacts. It is the portion of the number of shortest paths that pass through the specific farmer divided by the number of shortest paths between any pair of farmers (Borgatti, 1995). The betweenness centrality of specific farmer k measures gatekeeping and control of information in a network and is constructed as follows:

$$C(Bk)=\sum i\neq j\neq k\neq inPij(k)/Pij \quad (5.3)$$

Betweenness centrality used path matrix *P*, which is defined as a |*V*| × |*V*| matrix with *P ij* entries being equal to the number of shortest paths between farmer *i* and *j*. If no paths exist between nodes *i* and *j*, *P ij* is set to zero, and *P ii* is set to one. *Pij* denotes the number of shortest paths from farmer *i* to *j*, and *P ij* (*k*) denotes the number of shortest paths from farmer *i* to *j* connecting via farmer *k*.

5.3 Results and Discussions

5.3.1 Descriptive Statistics

As presented in Table 5.1, indicate that most of the farmers (84.11%) had their first source of information on cage farming from fellow cage fish farmers, with the fishery officers (11.71%) being the minor source of information on cage fish farming. Therefore, the finding has policy implications for the extent of extension services to farmers. The discrepancy in the information source suggests that for effective awareness of cage fish farming in Uganda, empowering the outreach of cage fish farmers would provide an effective mechanism for disseminating information about this technology across the country.

Table 5.1: Farmers' sources of information on Cage fish farming

Sources of information (% of responses) (N=384)	Percentage (%)
Fellow cage fish farmer	84.11
Fisheries Officer	11.71
Village leaders	2.40
Media	1.78

5.3.2 Contact farmer and general farmer attributes

Among the 384 smallholder cage fish farmers who participated in the study, 126 were contact farmers, and 258 were general farmers (Table 5.2). The comparison of continuous and categorical variables between contact farmers and general farmers indicated slight differences and similarities in parameters.

Table 5.2: Socioeconomic characteristics of contact and general farmers

Dependent variable	Contact farmer	General farmer

egoship status (n=384)	126	258
Independent variables	Mean ± SE	Mean ± SE
Farmer's age (years)	47.3 ± 8.7	48.3 ± 5.6
Education level (years in formal education.)	15±3	11±2
Experience (years in cage fish farming)	5±1	4±2
Trainings attended (numbers in a year on fish farming)	8±4	3±1
Cage units owned (number)	8±3	4±1
Stocking density (per M^3)	320±160	240±110
Extension services (number of visits in a year)	2±1.6	2±1.3
Distance to the nearest fish market (Km)	17±3.3	15±2.1
Type of fish reared (%)		
0=Nile Tilapia fish	99.22	94.51
1=Catfish	0.78	5.49
Gender (%)		
0=female	4.72	3.21
1=male	95.28	96.79
Farmer settlement (%)		
0=village mate	74.66	82.11
1=no-village mate	25.34	17.89
Type of labour used (%)		
0=family labour	33.48	56.86
1=hired labour	66.52	43.14
Type of technology used (%)		
0=wooden cages	0.00	2.13
1=metallic cages	86.40	91.44
2=HDE plastic cages	13.60	6.43

In addition, the critical findings in Table 5.2 indicated that contact farmers' mean age was (47.3±8.7) years, compared to general farmers (48.3±5.6). While the contact farmers had an education mean value of (15±3), the general farmers had (11±2) years of formal schooling. In relation to mean values of access to extension services, the contact farmers had (5±1), as compared to general farmers (4±2), number of visits by fisheries extension agents per year. Further, the mean values for stocking densities per cage unit were (320±160) and (240±110) for contact farmers and general farmers, respectively.

For the type of fish reared using cage fish farming technologies, the majority are Nile Tilapia fish producers (Table 5.2). Further, the findings also indicated that cage fish farming is a male-dominated venture; they do it in their respective villages and use mainly family labour. In the same vein, the sampled farmers mainly use metallic cages to rear fish.

5.3.3 Econometric Analysis

The logistic regression was employed to understand the social ties among the smallholder farmers. The logistic model allows for predicting a binary outcome from a set of variables that may be continuous, categorical, binary, or a mix (Zhang *et al.*, 2020). Focusing on farmers' centrality as an antecedent to egoship emergence, we selected farmers' ties as the independent variables, which were expressed as (i) degree centrality (in-degree and out-degree) and ii) node between-ness centrality. Accordingly, egoship status (contact farmers or general farmers) was the dependent variable, represented as a binary response variable, with one assigned to contact farmers and 0 assigned to general farmers.

In this study, two models were developed based on the inclusion of the different degree centrality measures, one calculated from binary ties and the other from valued social relations. Further, dummy variables were added to the regression models to reduce the potential bias effects of categorical data on the egoship status. These variables were: respondent's gender (0 = female, 1 = male), age (0 = below mean age, 1 = above mean age), settlement (0 = village mate, 1=non-village mate), and education (0 = no formal education, 1 = have formal education).

Table 5.3 presents the results of the logistic regressions, and the findings revealed that farmers who received more advice-seeking ties were more likely to be in "contact farmer positions." The first model used binary tie relations, and the results indicated that all network variables were positively associated with *egoship* status. However, only in-degree centrality was significant at (p=0.02). The significance level of in-degree centrality in the first model was maintained when adding the dummy variables (p=0.03). In the second model that used valued tie relations, in-degree centrality from the contact frequency of receiving advice requests was also the only significant variable (p=0.04). However, when adding in the dummy variables, in-degree centrality was not significant (p=0.09).

Table 5.3 Logistic regression estimates of contact farmer network ties.

Network variables	Model 1 (binary tie relations) Coefficient ± SE	Model 1 with dummy Coefficient ± SE	Model 2 (valued tie relations) Coefficient ± SE	Model 2 with dummy Coefficient ± SE
Out-degree	0.31 ± 0.19	0.40 ± 0.26		
In-degree	0.29 ± 0.12	0.31 ± 0.14		
Out-degree frequency			0.00 ± 0.02	-0.04 ± 0.03
In-degree frequency			0.07± 0.03	0.06 ± 0.04.
Betweenness	0.00 ± 0.01	0.01 ± 0.007	0.04 ± 0.0	0.01 ± 0.06
Dummy variables				
Gender		3.133 ± 2.130		2.58 ± 1.64
Age		0.656 ± 1.086		0.47 ± 0.94
Settlement		1.922 ± 1.143		1.24 ± 1.02
Education		0.699 ± 1.465		0.82 ± 1.38
Log-likelihood	15.63	23.25	11.99	17.53
Log likelihood ratio test	0.00	0.00	0.01	0.01
Pseudo R2	0.43	0.58	0.34	0.47

Significance levels are denoted by ‘p<0.1, ‘p<0.05.

5.3.4 Contact Networks

Figure 5.1 represents a sociogram of the leading information contacts that were identified by the smallholder cage fish farmers as their source of farming information, with a degree of centrality depicted by the size of the nodes. From the sociogram, the bigger the node, the larger the in-degree centrality, and vice versa. In-degree, betweenness, closeness, centrality, and Eigenvector centrality measures were used to describe the structural and relational attributes of the cage fish farmers' networks.

The results revealed that respondents with a high degree of centrality had the largest number of connections. In this case, the role they play in the network is not of prime interest, but the number of *egos* that mention them as their primary sources of information. This measure of centrality captures the number of *alters that* an *ego* has. Within the context of this study, highly connected members have a high probability of exploiting resources and information presented by the net.

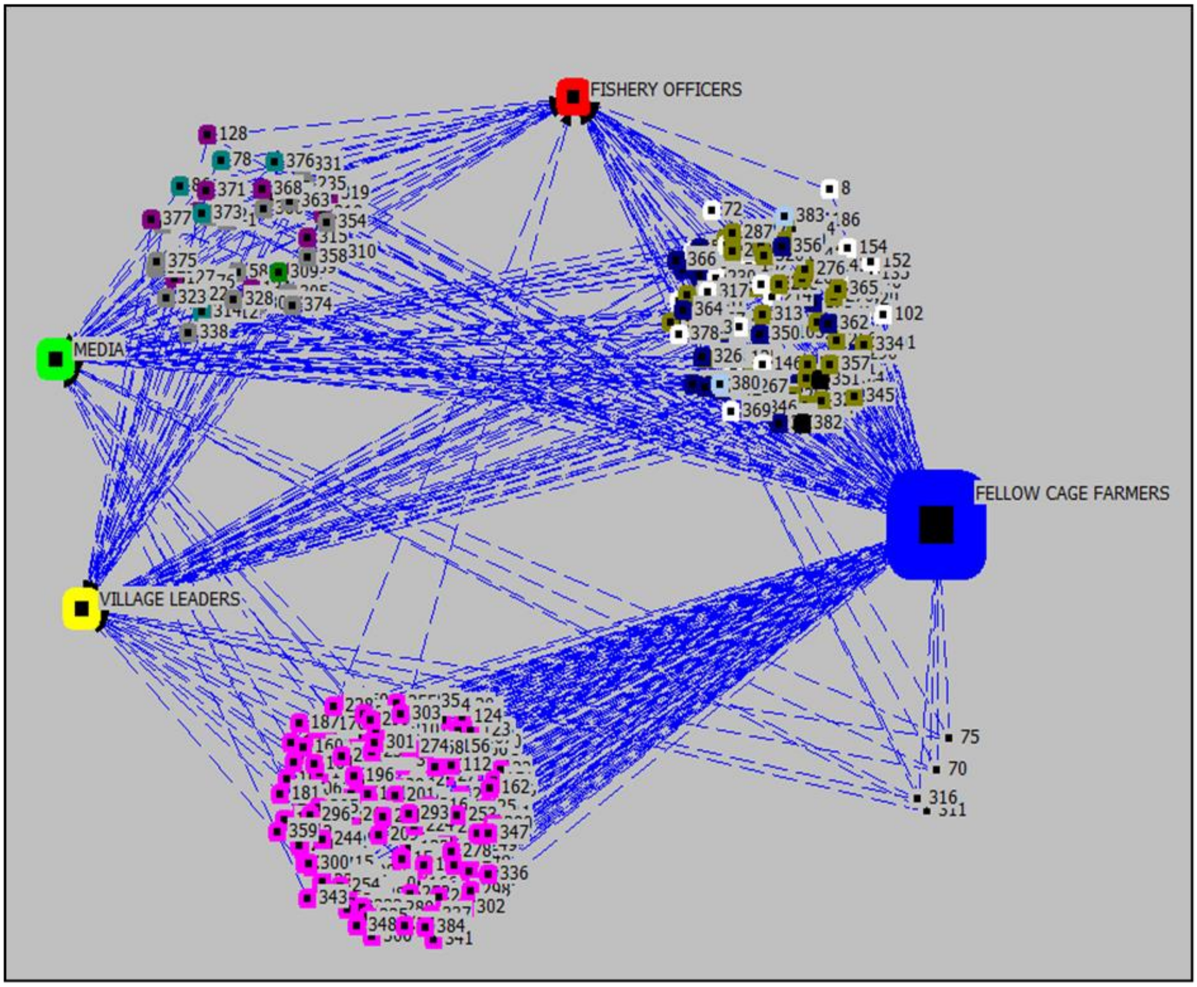

Figure 5.1: Sociogram for information contacts of actors

The results presented in Figure 5.1 display the three measures of centrality (degree, closeness, and betweenness), whereby fellow cage fish farmers (323 mentions) recorded the most significant degree of centrality. This indicates that fellow farmers, act as bridge to transmitting information within cage fish farmers' social networks. This finding implies that fellow farmers could influence the adoption of technologies. Therefore, the result agrees with Das *et al.* (2018) and Tasselli *et al*. (2015), implying that direct links among individuals in a network signify the actors' influence and power.

The findings, as presented in Table 5.4, show that village leaders recorded the second largest (86) in-degree while fishery officers recorded the lowest in-degree centrality (68) alters.

Based on the findings, it is evident that fishery officers have the least connections with farmers in the network. Nevertheless, they are expected to be the ideal information conduits for dissemination. The finding is attributed to the fact that, fishery officers are typically located far from the cage fish farmers, making them unreachable easily. Additionally, according to the average in-degree measure of centrality, that every cage fish farmers act as link for information flow since at least every farmer acts as a source of information to one farmer and receives information from one other farmer on average.

Table 5.4: Social metric measures of contact networks

Alters	In-Degree	Betweenness	Closeness	Harmonic Closeness	Eigenvector	2-Local Eigenvector
Fellow cage farmers	**323**	**56628**	**419**	334.5	0.08	517
Fishery officers	68	2339	929	164.5	0.02	162
Village leaders	86	6018	893	176.5	0.02	203
Media	78	5568	909	171.2	0.02	183

Furthermore, from Table 5.4, fellow farmers recorded an In-Degree centrality four times than the cumulative of the other alters. Betweenness measures the extent to which a particular node lies between different nodes in each network (Liu *et al.,* 2017). Betweenness measures how fellow cage farmers can function as a point of control in the communication process. Fellow cage farmers are considered to play an essential intermediary role and, therefore, could act as brokers in the fishing networks. Such actors influence the flow of information through a network by facilitating, hindering, or altering communication (Newman, 2005). The deletion of actors with high betweenness from a network can impact negatively or positively on the network depending on the role such information was serving; examples of such actors are visually illustrated in Figure 5.1.

In cage fish farmers' social network metrics, fellow cage fish farmers were identified as the epicentres of information dissemination. Closeness centrality is the only measure of centrality; the smaller the number, the better. Fellow cage farmers had the lowest average path link, which means that they are the closest link to other nodes on the net. Profoundly, if fellow cage fish farmers have specific information or unique production techniques, it takes only a few steps for this information to spread from one cage farmer to the rest in the network.

5.3.4 Kinship Networks

From the sociogram in Figure 5.2, smallholder cage farmers involved in this study reported a diversity of kinship ties, with absolute age differences playing a critical bonding role in the network. In this case diversity refers to group of people living together and hence enhancing the flow of information enabling the cage fish farmers with the right contacts of information for fish production and marketing. Similarly, the Cage fish farmers contacts vary ranging from age-mates, group members, same gender, friends, village-mates, and relatives, hence showing diversity. The findings agree with Kamau (2015), who demonstrated that high diversity is advantageous in mobilizing resources because it enables integration into several spheres of society or social circles/contexts.

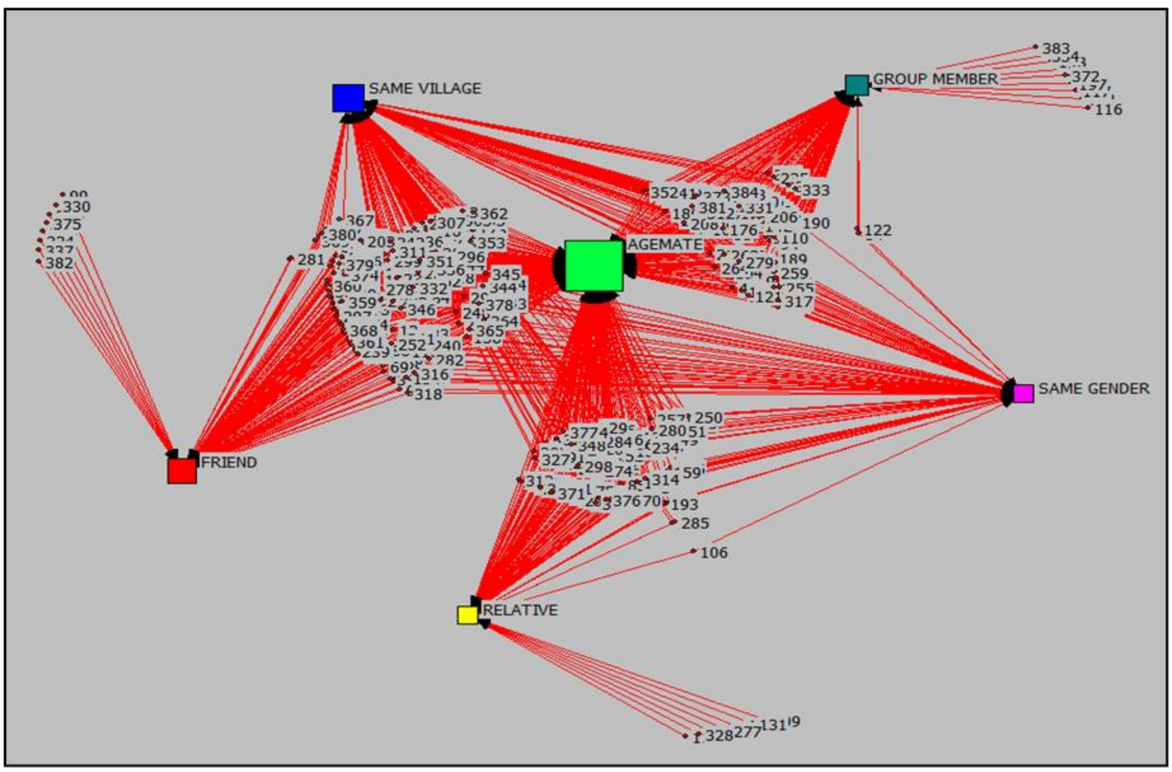

Figure 5.2: Sociogram showing kinship networks

5.3.5 Inter and Intra Village Social Links

Results presented in Figure 5.3 show that smallholder cage fish farmers in the study area have strong bonds (red ties) within the villages and weak linkages (blue ties) between the districts, as shown in the sociograms at both village and whole network levels. The high level of harmonic closeness depicted by the villages indicates a mix of *homophilic* and *heterophilic* groups where individuals have a high tendency to connect to other similar individuals within the village while being brought together by dissimilar (heterophilic) members who also connect them to different districts in the network. These farmers are at an advantageous level, supporting the flow of information on cage fish farming technology, as shown by the mix of solid bonds and weak ties (Figure 5.3).

Additionally, the results in Figure 5.3 show that some smallholder cage fish farmers had weak ties (blue lines). Therefore, the finding depicts farmers who had information contacts from fellow cage farmers in non-neighbourhood districts. The findings imply that farmers with weak ties served as links of information flow between neighbouring districts. The finding is in line with Marcours (2019), who found a strong and significant relationship between innovation promoters (weak ties) and adoption intensity. The researcher concluded that the denser the network between farmers and other agricultural agents involved in the technological innovation process, the higher the expected adoption intensity. In addition, they argued that once a technology is adopted within a network, peer relationships (strong ties) influence adoption decisions. In cage fish farming, farmers with weak ties are essential in facilitating the integration of new information into the farming network. However, as argued by Claasen and Lemke (2019), the presence of strong ties enhances a strong relationship between cage fish farmers helping in the development of a shared understanding of the features of these technologies. Therefore, advocating for cage fish farming technology among Ugandan smallholder farmers is imminent because it influences the interaction level among the farmers and other stakeholders in the fishery sector. Additionally, strengthening the collaboration of both strong and weak farmers using the social network approaches could be enhanced through creating awareness among smallholder farmers to cage fish farming technology.

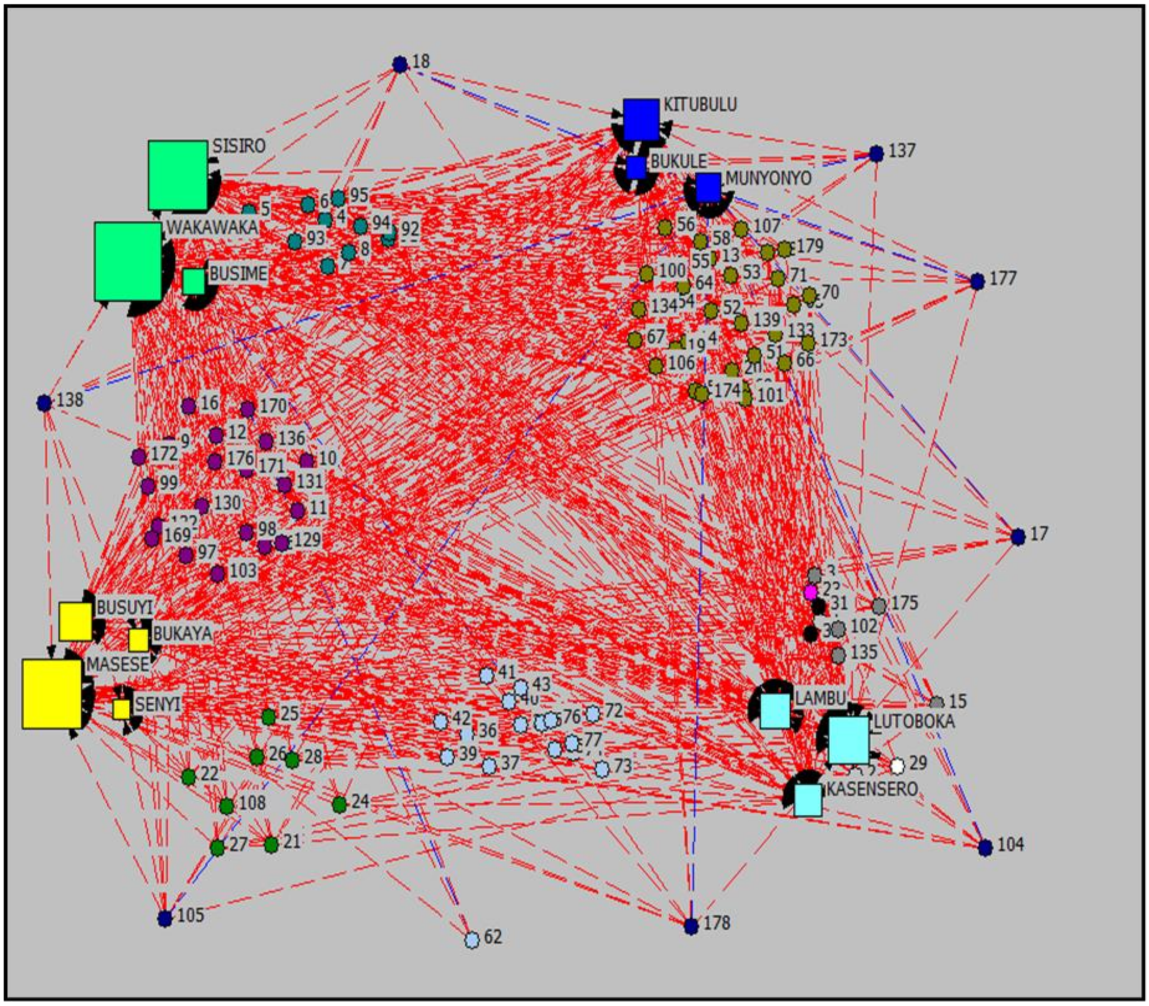

Figure 5.3: Sociogram for Inter and Intra Village Social Links

Results, as presented in Table 5.5, show that the extent to which cage fish farmers tend to pair up is relatively high, with the highest clustering coefficient being 0.78 while the lowest is 0.19. Additionally, the villages report relatively distributed eigenvector values, with Wakawaka and Sisiro villages (landing sites) reporting an eigenvector value of 0.124 and 0.121, respectively. The concept of eigenvector centrality measures the influence a node holds within a network, highlighting the significance of connections to influential individuals. In essence, connections to people with higher influence are particularly crucial (Newman, 2012). Villages with a high eigenvector value are connected to well-connected farmers and may exert direct or indirect influence on many others within the network.

Cage fish farmers as an equally aspect, who are more connected to high ranked and prominent farmers are more likely to be more influential due the relationship they have with the right people, since they can receive effective information from them trusted sources. Similarly, influence people are more likely to be efficient because the messages they deliver to each of their contacts would spread far, reaching a dynamic. According to Chaudhuri *et al.* (2020), actors who have more connected to other participants in various social networks are well positioned since they have other possible information to satisfy their needs. Alternatively, since they have many ties, they may be able access other possible alternatives as well as calling for more of the resources of the network as a whole.

Table 5.5**:** Social metric measures of village links

Villages (*landing sites*)	Clustering coefficient	In-Degree	Betweenness	Closeness	Harmonic Closeness	Eigenvector	2-Local Eigenvector
Busime	0.24	49	159	235	73	0.07	476
Sisiro	0.69	95	963	143	104	0.12	807
Wakawaka	0.78	100	1141	133	107	0.12	831
Busuyi	0.39	61	401	211	81	0.08	500
Masese	0.54	93	958	147	102	0.12	781
Bukaya	0.21	36	131	261	64	0.04	307
Senyi	0.19	27	44	279	58	0.03	255
Bukule	0.21	38	97	257	66	0.05	377
Munyonyo	0.36	54	210	225	76	0.08	537
Kitubulu	0.44	77	454	179	92	0.11	711
Lutoboka	0.49	83	566	167	96	0.11	759
Lambu	0.33	69	339	195	86	0.10	639
Kasensero	0.31	65	292	203	84	0.09	599

5.3.6 Inter Districts Social Links

As indicated by Figure 5.5, the Mayuge and Jinja districts represent the structural holes in the network. The structural hole between farmers in Masaka and those in Buikwe and Namayingo gives farmers in Mayuge a brokerage role similar to that of farmers in Jinja. Numerous structural holes in a social network create brokerage opportunities, and the actors who undertake these roles can control information flow between unconnected sides, according to Burt (1992). The social capital of structural holes in the network theory is fundamental in understanding the brokerage role of actors in the networks. Villages were drawn from fourteen districts where farmers practice cage fish farming. Structural holes theory shows the importance of a position in a network in terms of social capital. Cage fish farmers from Mayuge and Jinja are a centre of information by connecting farmers from Masaka and Kalangala to the rest of the cage fish farmers in the sampled districts.

Additionally, farmers in Jinja and Busia districts had more reciprocal ties. Namayingo depicts a similar relationship between Wakiso farmers and Kyotera vs. Buvuma cage fish farmers. Reciprocity implies the presence of mutual gain among the farmers. That is, districts with reciprocal ties have symmetrical information contacts. The farmers in the specified districts indicated that their information contacts were their counterparts and vice versa. Ideally, it is responding to a positive action with another positive action. Reciprocal links play a more critical role than non-reciprocal ones in the information diffusion process. In particular, reciprocal farmers affect not only the rate of information coverage but also the speed of technology diffusion, which is highly critical in creating awareness of cage fish farming techniques among farmers in Uganda.

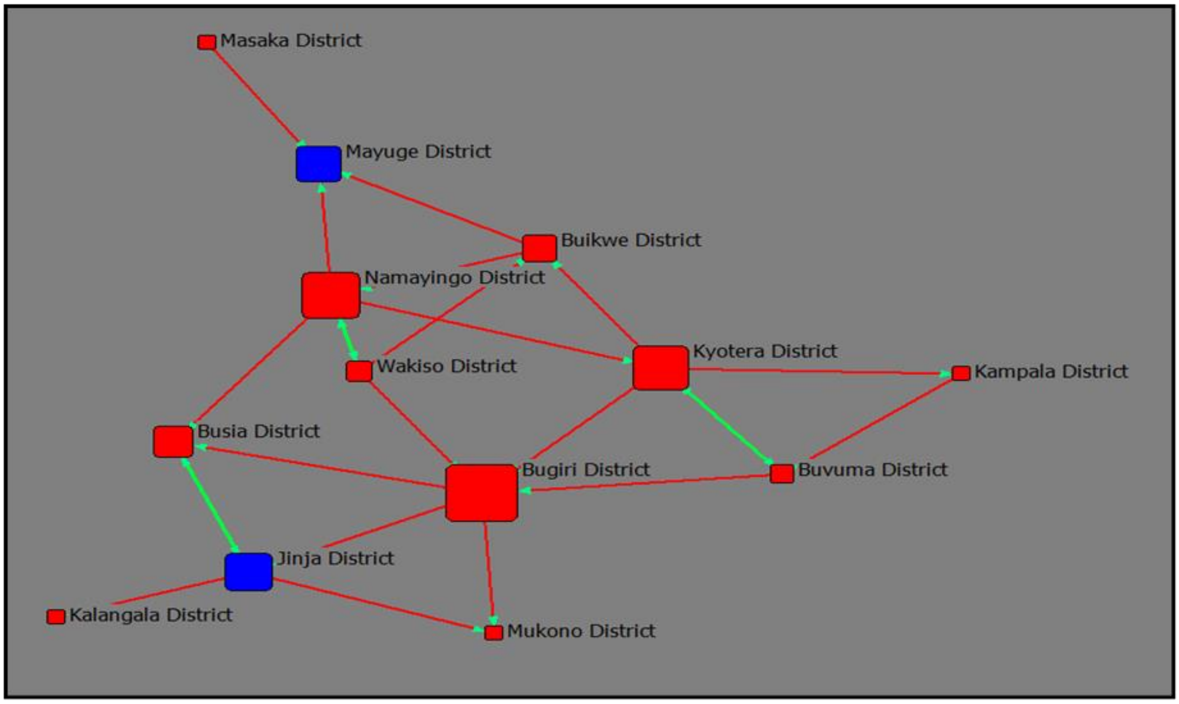

Figure 5.3 Sociogram for Inter Districts Social Links

5.4 Policy Implications and Conclusions

5.4.1 Policy Implications

Through the Ministry of Agriculture, Animal Industry and Fisheries (MAIAF) and the National Fisheries Resources Research Institute (NaFiRRI), the Government of Uganda is promoting the aquaculture sector to enhance sustainable fish production to meet the growing demand. Despite the above activities, the adoption of cage fish farming technology in the country remains slow. Therefore, integration of aquaculture sector with national reforms, will emphasizes on the farmer groups formation in order to act a bridge between the top-down and bottom-up approaches to increase aquaculture farming extension. Further, developing the social networks and farmer groups through policy support, exposes farmers to greater access to diverse knowledge sources in managing the exchange of aquaculture knowledge, awareness and adoption. Additionally, farmer groups enhance form external partnerships development, hence reducing the resource constraints to adopt and understand the best aquaculture practices.

The strong social cohesion among ego farmers identified in this study, as demonstrated by their significant presence at the core of the advice networks, signals their influence and ability to mobilise resources to achieve group goals. However, the alters in the network core also indicate the valuable brokerage roles of farmers outside their villages in information transfer to the larger population. The presence of these alters in the core may be critical to building group trust and ensuring accountability, especially at the early stages of awareness about cage fish farming.

The findings on ego status point to the importance of advice network analysis in assessing pathways to resource mobilization related to scaling up cage fish farming. Since farmer groups are perceived as hallmarks of democracy, local group composition can also be symbolic of the familiar voices and political concerns in a cage fish farming community. Therefore, fostering group formation skills among social minorities with an emphasis on capacity building rather than the diffusion of knowledge, as suggested by the available literature, may help to bridge the divide in opportunities between farmers. In this process, the opportunity costs of ego actors must also be acknowledged in developing interventions because many of them do not receive any external incentives. Internal capacity building can help ensure social minorities have equal opportunities to occupy ego positions and promote impartiality in conflict resolution.

Although the study is limited to a single case, the results could be applicable to similar farmer groups. The inordinate social influence of a few network actors is commonly found in rural settings where the costs of service delivery and knowledge transfer are high. These centralized advice networks are interwoven into existing power relations and hierarchies, likely reinforcing their roles in cage fish farming outcomes. However, organizational dynamics can be radically different from one group to another. For instance, community-based farmer groups adopting similar practices may have different priorities, attributed to individual members' perception, relationships, aspirations, resources, and environment. Similarly, the application of social network tools encourages this understanding as it moves from isolated successes of agricultural innovations to integrated social and environmental landscapes.

5.4.2 Conclusions

Sharing agricultural information among rural smallholder farmers is a complex phenomenon. The processes are entwined with a myriad of socio-economic, relational, and political factors that shape one's fish farming decisions. Farmers who emerge as egos in the farmers' social networks can significantly shape the adoption behaviour of alters by facilitating relations to share valuable information about cage fish farming practices. Therefore, the findings contribute to understanding these processes by:

i. Demonstrating a positive relationship between being sought for information ties and the propensity for members to be in ego positions.
ii. Affirming imbalances in agriculture information access and control through the clustering of ego actors at the core.
iii. Highlighting the value of social networks and farmer groups to encourage information sharing about new cage fish farming practices.

Through decentralized extension reforms, the findings from the study also show the critical role of farmer groups in disseminating information about cage fish farming technologies. The results align with other studies in the literature, which argue for the importance of peer advice ties in the diffusion of agricultural innovation. Serving as learning and resource platforms for cage fish farmers, farmer groups can help fill the gap in extension support in remote areas by being a bridge between farming households and government agencies. With effective and socially inclusive leadership, farmer groups can use agroforestry to meet the vision of knowledge-intensive, sustainable agriculture.

Therefore, to add up to the information this study, further studies can be done on network factors, majorly focusing on kinship and friendship ties. Additionally other studies can also examine the attribute and psycho-social factors, such as personality and perception, on ego-centric on farmers' decisions. A contrast explanation on this, is that various analyses focusing on other variables influencing farmers decisions would add greater depth in capturing ego selection and emergence. On the other hand, since expanding the network boundary beyond farmer groups can be non-actors and extension officers, shed light on the scalar effects of egos' prominence. Amid the decentralization of agricultural extension, these avenues for future research would be helpful to enhance the performance of social networks and farmer groups and secure broader societal goals such as sustainable cage fish farming activities and livelihood improvement interventions.

CHAPTER SIX

IMPACT OF INFORMAL NETWORKS ON FISH HARVEST AMONG CAGE FISH FARMERS

Abstract

Information platforms are the most critical elements influencing farmers' performance in developing nations. Smallholder farmers in Uganda have persistently experienced poor access to formal extension services. Data collection process employed a multistage sampling technique to conduct data collection on 384 cage fish smallholder fish farmers in Lake Victoria waters in Uganda. Further, Propensity score matching (PSM) was applied to examine the effect of informal networks used by smallholder cage fish farmers on the fish harvest. The analytical findings reveal that respondents who depend on informal sources of information were associated with a performance in terms of fish harvested and in a better position to share pertinent information about cage culture. In conclusion, the study provides insights into the importance of harnessing informal networks and the need to strengthen existing policies on cage fish farming practices.

6.1 Introduction

Uganda is among the landlocked Sub–Saharan Africa countries in, with colossal aquaculture potential, and it is ranked first in East Africa and third in Africa (FishStat, 2020). However, cage culture is insignificant (Halwart, 2020). The subsector is primarily dominated by smallholder farmers who depends on informal mode of communication as their information sources to enhance their fish production. Access to information is critical, since it enhance farmers' abilities to develop and sustain their production hence increasing farm productivity. In the absence of formal institutions, farmers use informal network sources to acquire agricultural information (Mesele *et al*., 2022; Pratiwi & Suzuki, 2017).

Informal network platforms (Boahene *et al.,* 1999; Lyon, 2000) contributes to the transmission of agricultural knowledge and information needed by farmers through social mode of contacts (Conley & Udry, 2010). In circumstances where formal institutions like government extension services are limited, informal networks play a crucial role. It is conceptualized that relations, technical ties, and forms of networks factors are greatly influence by the norms and the person's behavior that an individual possesses (Pratiwi & Suzuki, 2017; Yang & Tang, 2003).

Informal networks play a vital role in enabling the farmers to and other actors to effective create and build knowledge bases (Mesele *et al.*, 2022) through sharing ideas and experiences.

Although informal network platforms play a crucial role in information sharing, their structures and ties differ (Thuo *et al.,* 2013). In their article, they highlighted a need to characterize the ties among the actors sharing a social network and the extent of accessing information and other resources. Some studies have partly explored how social structures affect knowledge sharing based on village level and the technological adoption rate of enhance production among farmers (Aydin, 2018; Carrington, 2014; Conley & Udry, 2010; Emma, 2013; & Ramani & Aya, 2015). Nevertheless, these studies mainly focused on adoption and little on access to information through social networks.

By the same token, Hope and Reinelt (2010) conducted an impact study on leadership development using social network analysis. In their methodology, they used network structures and social graphic illustrations to explain the leadership styles in different sectors and organisations in the study area. In the same vein, Demir and Taktak (2011) used spatial data to conduct a study on both public and private institutions. Their findings reveal that the network density, centrality, proximity, and betweenness among the ego's network are calculated based on the number of alters. In a nutshell, these studies majorly focused on out-degree, in-degree, in-closeness, out-closeness, and betweenness measures. They also highlighted a need for more spatial studies on determinants of network centralities using hierarchical clustering techniques.

In addition to the above discussion, Gulpinar (2013) conducted a study to analyze the effect of social network analysis on staff positions in the telecommunication market. The study identified the important factors enhancing the social network, density, centrality, proximity, and betweenness based on the actors. In their conclusion, the characteristics of individuals are not significant without understanding the determinants of loss of customers. Amabile *et al*. (2014) built on the same study to understand the determinants of cooperation among workers in institutions. The findings reveal that successful cooperation increases attributed to the influence of the size of social networks as well as the structure of social networks, leading to job satisfaction.

Although the reviewed literature offers vital insights that help us better comprehend the role played by social networks in knowledge sharing, however, there is still needs to be more clarity on their effects, among others. The dimensions of social network linkages in knowledge sharing or learning among actors still need to be well understood, regarding the informal social networks and how they are influenced by interpersonal processes in shaping fish harvest among smallholder cage fish farmers in fishery-dependent communities. In this paper, the focus was to test whether informal sources of information can impact smallholder cage fish farmers' Fish harvest.

Literature exploring the comparison of the effects of informal and formal sources of information among smallholder farmers is still limited. Thus, the study intends to bridge the gap implying that both informal and formal sources of information are equally important, however, they may have differential effects agricultural information sharing and the and fish harvest. Further, the study aimed at contributing to the studies done in this area in the following ways: First It describes the state of the cage fishing farming system. Secondly, it apprehends the potential differences between smallholder cage fish farmers who use informal sources of information and those in comparison (users of formal information sources). Thirdly, the study will increase information to the limited information on the factors influencing of informal networks on Fish harvest among smallholder cage fish farmers. Hence, the study is organized into a literature review, methodology, empirical results, and a conclusion.

6.2 Methodology and Analytical framework

The study employed multistage stratified random sampling techniques to select a sample size of 384 respondents from fourteen districts along the shores of Lake Victoria in Uganda (mentioned in Chapter 3). Lists of smallholder cage fish farmers were generated per district with the help of area fisheries extension officers. Secondly, smallholder cage fish farmers were stratified into two groups depending on the source of information about cage fish farming technologies: (i) from the farmer–to–farmer sources (informal sources) and (ii) from change agents–to–farmer sources (formal sources).

The study conceptualised smallholder cage fish farmers who solely rely on their peers (social networks) as sources of information pertaining to cage culture to be "*informal information users*" and referred to as the treated group. The comparison group comprises farmers who rely on formal institutions such as government and private extension services. They are considered "formal information users" and are referred to as the untreated group. The sample of smallholder cage fish farmers who participated in this study was selected using a simple random sampling technique. To determine the required sample size at a 95% confidence level, a simplified formula presented by Edwards and Gaber (2014) was used, with a degree of variability = 0.5 and a level of precision = 5% (0.05).

(6.1)

Where n = the desired sample size; Z = Standard normal variable at the required level of confidence; p = the proportion in the target population estimated to have characteristics being measured; d = the level of tactical significance set; and $q = 1 - p$. Hence, the assignment of the treated and control groups was based on the sources of information used by cage fish farmers in the study area.

6.2.1 Propensity Score Matching (PSM).

This study applied the *PSM* techniques to select, match, and compare informal information users (social networks) and formal information users (government/hired extension services) as well as their similar characteristics. The purpose of the study was to measure the impact of informal social networks on the smallholder fish farmers' fish harvest. Matched the treated group (*smallholder cage fish farmers who solely depend on their peers' social networks*) and untreated group *(smallholder cage fish farmers who rely on the government/hired extension services)*. Hence, observations on the estimated probability of being treated (propensity score) allowed not only for mean matching but also for balancing the distribution of observed characteristics between the two groups and the average differences in the outcome variables.

6.2.2 Estimation of PSM.

This study focused on two outcomes *(treated and untreated groups)*. A probit model was assumed to be the best way to carry out estimations since the dependent variable was a dummy variable (Caliendo & Kopeining, 2008). Thus, the treated group took a value of one if the respondent is an informal information user (social network) and zero otherwise. The impact of the Probit model is that it transforms probability into coefficients and then takes the logarithm of the coefficient (Boateng & Abaye, 2019). In addition, it gives each predictor a coefficient, which measures its independent contribution to variation in the dependent variable.

(6.2)

where; = the probability of a respondent using informal information sources (social networks/treated group).

(6.3)

Where; = intercept, = regression coefficient to be estimated, = variable and = Error term. The probability that a respondent belongs to the untreated group or using formal information sources is

(6.4)

And the odds ratio is expressed as

(6.5)

Hence, to estimate the average impact of social networks on the cage fish harvest was expressed as

(6.6)

Where Y is the harvest of fish in kg, and D takes the value of 1 for the treated group and zero for the untreated group (control group). Hence, the outcome of our interest is the average difference in . Therefore, this study followed Rosenbaum and Rubin (1989) to calculate the average treatment effect on the treated (ATT) as follows:

(6.7)

where: = Probability of selection conditional to Z or the propensity score (*pscore*), expressed as

In this study, the matching was done in two steps using the Stata software version (15). The first step was to calculate the *(P-scores)* using Stata's *"pscore"* command. This first step was critical because of the need to estimate the balance of the observed distribution of covariates between the two groups. In the process, the matching test was performed to check whether or not there were differences in the covariates between the two groups. In the second stage, ATT was estimated using matching algorithms (psmatch2) specifically, considering the nearest neighbour (NN), kernel, and radius matching techniques. Hence, the model specification for the matching algorithm in this study was expressed as follows:

Step 1: Kernel matching

(6.8)

Hence, the associated outcome (of the treated unit

Step 2: Nearest neighbour model specification

In this study, the control group (*users of formal institutions as sources of information*) were denoted by , was matched with the treated group (*users of informal social networks as sources of information*) denoted by . Hence,

(6.9)

Step 3: Radius matching

In this study, each treated unit (*i*) was matched with only the control unit whose propensity score was under the predefined neighbourhood of the propensity score of the treated unit. Hence, it is expressed as:

(6.10)

Table 6.1: Description, Measurement, and Expected Sign

Variable name	*Measurement unit*	*Expected Sign*
Dependent variable		
Fish harvest (Kgs)	1 if the farmer uses informal sources of information and 0 otherwise.	
Independent variables		
Age	Age of the cage farmer (in years)	+
Gender	0 for female and 1 for male	+/-
Experience in cage culture	in years	+
Education level	in years	+
Cage units	Number of cage units owned by farmer	+
Type of cage units used	2=HDE plastics; 1=Metallic; 3=Wooden	+/-
Location of cage units	Distance to the cage in km	+/-
Target market	Type of market targeted	+/-
Group membership	Membership	+/-
Group size	Number of members in a group	+/-
No. of extension visits	1=Once a month, 2=Twice a month, 3=Once in a season	+/-
Distance to market	Distances of the market in kilometres	
No. of training	Number of attended trainings on cage culture	

This study believes that a farmer's decision to use informal sources of information or not is influenced by a number of factors associated with demographic, socioeconomic characteristics, and resource endowments (CIMMYT, 1983: Wafula *et al.,* 2022), as presented in Table 6.1.

6.3. Results and Discussion

6.3.1 Socioeconomics Characteristics of the Respondents

In Table 6.2, the socioeconomic characteristics of the 384 respondents who took part in the study are presented. The findings show that 65% of the respondents relied on farmer-to-farmer contacts, while 35% depended on farmer-to-change agent contacts. Both the treated and untreated groups exhibited variations in different attributes. As shown in Table 6.2, the overall mean age of the participants was (45±8.36) years. The mean age of the treated group was (44.82±8.06) years, and (45.29±8.66) years for the untreated group. The overall mean years of experience in cage fish farming was 3.64±1.18, with the treated and untreated categories reporting (3.74±1.16) and (3.53±1.19) years, respectively.

Table 6.2: Socioeconomic characteristics of respondents.

Types of Variables	Informal network users (n=251)		Formal network users (n=133)		Combined (n=384)		*t*-value	*p*-value
	Mean	Std.	Mean	Std.	Mean	Std.		
Age (*years*)	44.82	8.06	45.29	8.66	45.05	8.36	0.53	0.29
Experience (*years*)	3.74	1.16	3.53	1.19	3.64	1.18	-1.76	0.04**
Education (*years)*	11.92	2.92	11.55	3.36	11.74	3.14	0.17	0.43
No. of cage units owned	5.02	2.98	4.13	2.18	4.56	2.58	-3.07	0.00***
Distance to market *(km)*	20.44	19.40	21.68	19.54	21.06	19.47	0.59	0.27
Knowledge scores	2.07	0.37	2.09	0.43	2.08	0.40	0.43	0.33
Attitudes scores	1.65	0.64	1.56	0.64	1.60	0.64	-1.24	0.21
Perception scores	2.39	0.55	2.51	0.55	2.45	0.55	1.89	0.04**

*The symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.*

Additionally, results in Table 6.2 show that farming experience among sampled two groups of respondents who participated in the study had a significant difference at less than a 5% significance level. The total mean of the number of cage units owned by individual fish farmers sampled was (4.56±2.58). The mean number of cage units owned under the treated category was (5.02±2.98) whereas for the untreated was (4.13±2.18). The number of cage units owned by the sampled respondents showed a significant difference at less than a 1% significance level in the two categories. The total mean score for perception towards cage fish farming was (2.45±0.55). The mean scores for perception for the treated and untreated groups were (2.40±0.55) and (2.51±0.55), respectively, and there was a significant difference at less than 5% significance level in the two groups.

The results presented in Table 6.3 indicate that the total number of male respondents who participated in the study was (64.58%) and only (35.95%) were female. The gender difference between the treated and untreated groups was significantly different at a significance level of less than 1%. As regards membership in fish farmers' groups, the majority (65.36%) of the total sampled respondents belonged to farmers' groups, whereas only (34.63%) were not. The difference in group membership in both the treated and their counterparts was statistically significant at less than 5% significance level.

The majority (82.81%) of sampled respondents reared fish using metallic cage units, followed by those who used wooden (11.46%) and HDE plastics (5.73%), respectively. The difference in the type of cage units used in the study area was statistically significant at less than 1% significance level. For the targeted market, results in Table 6.2 revealed that the majority of the sampled respondents (73.17%) of the sampled respondents sell their fish produce in markets within their communities, which is followed by fish processing companies (16.16%) and export markets (10.67%). The difference in targeted markets between the two groups was statistically significant at less than 10% significance level. Furthermore, the majority of the sampled respondents from the study area were Christians (91.67%), whereas Muslims were only 8.33%. The religion of the sampled respondents had a significant difference at less than 5% significance level in the two groups.

Table 6.3: Characteristics of categorical variables

Variables	Informal users	Formal users	Combined (%)	Chi²	*p*-value
Gender (%)					
Male	70.12	54.14	64.58	9.71	0.00***
Female	29.88	45.86	35.42		
Smart Phone Access (%)					
Yes	56.18	52.63	54.95	2.70	0.10
No	43.82	47.37	45.05		
TV Access (%)					
Yes	54.98	45.02	65.36	0.33	0.56
No	51.88	48.12	34.63		
Group Membership (%)					
Yes	67.53	33.47	65.36	5.03	0.02**
No	54.89	45.11	34.63		
Type of cage used (%)					
Metallic	90.98	78.49	82.81		
HDE Plastics	0.75	8.37	5.73	12.24	0.00***
Wooden	0.27	13.15	11.46		
Location of cages in the Lake (%)					
Within 200m from the shoreline	35.07	24.81	30.21		
Between 201 to 500m	24.30	27.07	25.26	3.86	0.27
Between 501to 1000m	22.72	21.80	22.39		
Beyond 1000m	19.93	26.32	22.14		
Target market (%)					
In community	12.35	15.04	13.28		
Nearby markets	56.97	65.41	59.89	6.77	0.07*
Fish Company	19.52	9.77	16.16		
Direct export	11.16	9.77	10.67		
Farmer's Religion (%)					
Muslim	4.78	15.04	8.33	13.48	0.00**

Christian	95.22	84.94	91.67

*The symbols *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively*.

6.3.2 Pre-estimate tests

Before conducting empirical analyses, we first performed variance of inflation factor (VIF) and pair-wise correlation tests to assess the degree of multicollinearity for the selected continuous and categorical variables, as shown in Tables 6.4 and 6.5. The goal was to identify correlated predictors that could impact the overall significance of the model used in the study (Yang & Wu, 2016).

Table 6.4: Variance inflation factor results for the continuous explanatory variables.

Variable	VIF	1/VIF
Age of the respondent	1.11	0.90
Years in formal education	1.11	0.90
Distance to market	1.35	0.74
Number of Cage units owned	1.21	0.82
Years in cage fish farming	1.09	0.92
Number of extension visits/month	1.10	0.91
Knowledge score	1.23	0.87
Attitude scores	1.14	0.85
Perception score	1.16	0.83
Mean VIF	**1.17**	

Multicollinearity is a statistical situation where several independent variables used in the regression model are correlated with Yang and Wu (2016). The existence of multicollinearity leads to the statistical insignificance of the explanatory variables, even though the overall model may be significant. Thus, according to Shrestha (2020), the recommended threshold value for the VIF test is less than 10, though the ideal should be less than 5 (Belsley, 1991: Young, 2017). Based on the results presented in Table 6.4, multicollinearity was not a concern for this study, implying that all the tested explanatory variables were fit to be used in the regression model.

Table 6.5: Results for Pairwise correlation test

	Gender	Cage type	Target Market	Religion
Gender	1.00			
Cage type	-0.00	1.00		
Target Market	-0.06	0.00	1.00	
Religion	0.01	0.10	0.02	1.00

The pairwise correlation test values presented in Table 6.5 ranged from 0.0026 to 0.1026, which is within the accepted range of 0.5. Hence, all the values exhibited weak relationships among the categorical variables.

Table 6.6: White test results for heteroscedasticity

Source	Ch^2	df	*p*-value
Heteroscedasticity	138.87	116	0.00
Skewness	179.01	17	0.00
Kurtosis	0.22	2	0.11
Total	318.10	135	0.00
Chi2 (1)	0.14		
Prob>Chi2	0.00		

As Irum and Sohail (2022) have pointed out, heteroscedasticity is a situation where the residuals for a regression do not have constant variance. In our study, we chose to apply the White test over the Breusch–Pagan test, primarily because the former is capable of detecting more general forms of heteroscedasticity among the explanatory variables, as recommended by Boyd (2020). This decision was significant as it allowed us to gain a deeper understanding of the data and make more informed interpretations. However, the results revealed no robust standard errors, necessitating the computation of *t* statistics as shown in Table (6.6).

6.3.3 Estimations of Probit Regression Model

Probit regression model was employed in the first stage to estimate the propensity scores for matching purposes (Titus, 2007). Further the explanatory variable was applied to fulfill the conditions of matching the propensity. Afterwards the second stage involved matching the propensity, using the predicted odds values from the binary estimation and a matching set of rules (Shenyang *et al*., 2020). Our matching algorithm was based on comprehensive data collected from both the treated and untreated groups, ensuring a thorough and robust process. The regression results for the first step estimates in Table 5.4 indicate that a number of explanatory variables were statistically significant at different levels, further validating the effectiveness of our matching algorithm.

Attitudes were statistically non-significant. The finding implies that educated people are expected to have more favourable attitudes toward agricultural skills, knowledge, and information as compared to uneducated ones (Habib *et al.,* 2007; Hassan, 1991). In contrast to the study by Mburu *et al.* (2007) found that education significantly influence the, social change, where it increases knowledge and skills that are helpful in data collection and interpreting information that influence the best decision making for making more decisions. The farmers who are learned are likely to adopt social network as well as promoting knowledge transfer and information sharing (Durmusoglu, 2013; Wairimu *et al*., 2022; Wasserman & Faust, 2009). It is also supported by the findings of Mittal and Mehar (2015), who opined that farmers with less education are more dependent on the social networks of other farmers, input dealers, and commission agents. The perception of the usage of informal networks among cage fish farmers was negative and statistically significant at a 5% level.

Table 6.7: Propensity score estimation (Probit Regression outputs)

Treatment	Coef.	Std. Err.	Z	P>|z|	95% Conf.	Interval
Knowledge scores	0.04	0.19	0.23	0.81	-0.34	0.43
Attitude scores	0.09	0.11	0.78	0.43	-0.14	0.32
Perception scores	-0.27	0.13	-1.97	0.04*	-0.54	-0.00
Fish farming exp.	0.16	0.06	2.51	0.01*	0.03	0.28
Gender	0.50	0.14	3.38	0.00**	0.21	0.80
Age of fish farmer	-0.00	0.00	-0.65	0.51	-0.02	0.01
Education level	-0.02	0.02	-0.99	0.32	-0.07	0.02
Extension visits	0.08	0.03	2.65	0.00**	-0.02	0.14
Social capital	0.04	0.05	0.69	0.48	-0.07	0.15

Phone access	-0.22	0.15	-1.47	0.14	-0.51	0.07
Tv access	0.12	0.14	0.85	0.39	-0.16	0.41
Cage units owned	0.05	0.03	1.81	0.07**	-0.00	0.11
Fish farm location	-0.00	0.00	-0.43	0.67	-0.00	0.00
HDE Plastic cages	1.37	0.55	2.46	0.01*	0.27	2.46
Wooden cages	0.27	0.25	1.07	0.28	-0.22	0.76
Farm gate market	-0.63	0.27	-2.28	0.02*	-1.18	-0.09
Nearby market	-0.65	0.22	-2.93	0.00**	-1.08	-0.21
Export market	-0.60	0.31	-1.93	0.05*	-1.21	0.00
Muslim faith	-0.71	0.25	-2.78	0.00**	-1.21	-0.21
Christian faith	0.67	0.20	0.33	0.74	-0.33	0.46
_cons	0.28	0.83	0.34	0.73	-1.35	1.92

No. of Obs = 384; LR Ch2 (21) = 72.91; Prob>Chi2 = 0.00; Pseudo R2 = 0.14; Log likelihood = -211.28

The farming experience was positive and statistically significant at a 1% level in terms of the usage of Informal Networks among cage fish farmers. The finding is attributed to the fact that farmers who have spent many years in a group are more knowledgeable about fish farming. Farmers join groups for several reasons, including extension services, collective sales, and social reasons. Through this relationship smallholder farmers are able to create a long-lasting relationship that in the long run influence their knowledge and experience in cage fish farming, hence increasing their need to participate in the social network and increased fish harvest. Ideally, the higher a farmer participate in the social networks the more they are exposed to information access, leading to competitive gains (Pigatto *et al.,* 2020).

On factors influencing the participation of informal social networks, gender had a positive and statistically significant level of 5% implying that women and men have differential access to information if social networks differ on gender lines. Several attributes of social networks are expected to determine their degree of satisfaction for influencing awareness, and research has shown that social networks are often segregated based on gender, as described, for example, by Aryeetey (1995) for seed technology diffusion in Ghana and Magnan *et al.* (2015) for laser land leveling diffusion in India. Where social networks are highly gender-segregated, existing gaps in men's and women's access to information are likely to be reinforced (Fletschner & Mesbah, 2011).

Extension visits were 1% positively and statistically significantly level in terms of the usage of informal networks to access production information. This implied that farmers who had access to several extension services were more likely to understand more market outlets that offer better prices for their products, such as the collector market. Similar, the find from Wosene *et al.* (2018), supported that extension service increases the likelihood of farmer to accessing important agricultural and market information, enabling pepper producers to improve production methods, thus leading to more output.

Age is statistically insignificant, and this is contradictory with the findings of (Jenkins *et al.,* 2011), who argue that an increase in age makes a farmer less likely to spend time and money searching for information from various sources. Older farmers may be less invested in modern formation from various sources without the confidence of getting results on their investment in the short run (Mittal & Mehar, 2015). Young farmers are keener to get knowledge and information than older farmers. Age is also associated with farming experience (Jenkins *et al.,* 2011), and experienced farmers might rely on information acquired through experience.

Social capital was positive and statistically insignificant in the use of informal networks to access information among cage fish farmers. Significantly, the social capital negatively influences the smallholder farmers participation in the social networks (Gargiulo & Benassi, 1999; Kawachi, 2017; Portes, 1998). For instance, Portes (1998) notes that adverse factors such as, excess claims on group members, restrictions on individual freedom, excluding outsiders, and downward leveling norms were found to influence farmers participation in social networks. Further, in relation to this study the, scholars have noted several implications in relation to the flow of the type of information and knowledge associated with the negative side of social capital (Treagar and Cooper state, 2016).

However, this could prevent smallholder farmers from acquiring new knowledge and new information from other social capital types (Eklinder-frick *et al.,* 2012; McFadyen & Cannella, 2004; Smith *et al.,* 2012). Furthermore, when social networks are strengthened with the bond created by social capital, translating into a lower capacity to make changes on the farm and develop a platform that encourages innovation (Eklinder-frick *et al*., 2012; Fisher, 2013; Smith *et al*., 2012; Tregear & Cooper, 2016). Farmers often mention other farmers as their most crucial information source (Rogers, 2010).

Phone access was negative and statistically insignificant in the usage of Informal Networks among Cage Fish Farmers. The finding by Benard *et al.* (2019), contradicts with the studies finds that farmers who are less exposed to various ICT training, are less likely to utilize phones usage for information sharing. Further, the finding could have been explained by the fact that training exposure to any ICT is a crucial aspect in motivating and increasing the level of technology usage. The results also disagreed with the study conducted by Syiem and Raj (2015) in India, indicating that lack of training and practical exposure to using mobile phone applications as well as the internet detained farmers from using them in sharing agricultural information from time to time.

The results found that TV access was insignificant and positively related to the degree of television use in information sharing. This suggestion is in contradiction with studies by (Benard *et al.*, 2019) that found that as the level of illiteracy of farmers increases, their degree of television usage in sharing information decreases. He attributed this to the fact that some televisions have menus that are sometimes complicated, and some operations instructions have been written in the English language, whereby because of the problem of illiteracy among farmers, it becomes challenging for them to use it at a certain level. Similar findings by Okello *et al.* (2014) reported that a unit increase in a farmer's literacy level increases the degree of television use by a farmer by 0.55, holding other factors constant. Additionally, geographically distant networks are attributed to the available information and communication technology (internet, smartphones, and other communication mediums) (ICT), as indicated (Mills *et al.,* 2019: Šūmane *et al.,* 2018). ICT has facilitated young farmers with the available information enhancing their development of a networking culture, specifically for soil, crop production and marketing of their produce (Milone & Ventura, 2019). Mills *et al.* (2019) noted how social media greatly enhance smallholder farmers with the sharing of experiential learning about soil management.

The number of cage units owned and Cage type 2 (metallic cages) were positive and statistically significant at 10% and 5% levels, respectively, on the usage of informal networks among cage fish farmers. Therefore, the findings are attributed the fact that farmers with the highest degree of centrality in a social network have greater impact within the network and are important in promoting knowledge transfer and information sharing (Durmusoglu, 2013; Faust, 2009; Scott & Wasserman, 2017). In addition, the high-level relationships which is friendship significantly contribute to their degree of centrality and promotion in the development of these networks. in relation to the observations of Adler and Kwon (2002) and Borgatti *et al.* (2009), the findings implies that friendship plays a vital role in the formation of social capital that are applied in the used to creating and strengthening social relations. According to Granovetter (2007), personal relationships and the networks formed are essential in building trust, hence acting as a rational factor for actors to make decisions based on the knowledge acquired through relationships established with other actors.

Target markets 1,2,4 were positive and statistically significant at 5 %, 1%, and 10%, respectively, on the usage of Informal Networks among Cage Fish Farmers (Pigatto *et al.,* 2020). The three individuals with the highest levels of competitiveness were also the ones with the highest degree of centrality. Therefore, the competitiveness of fish farmers is related to internal and external factors, such as production volume, prices, market and institutions, and the relations established within their social network (Dyer & Singh, 1998).

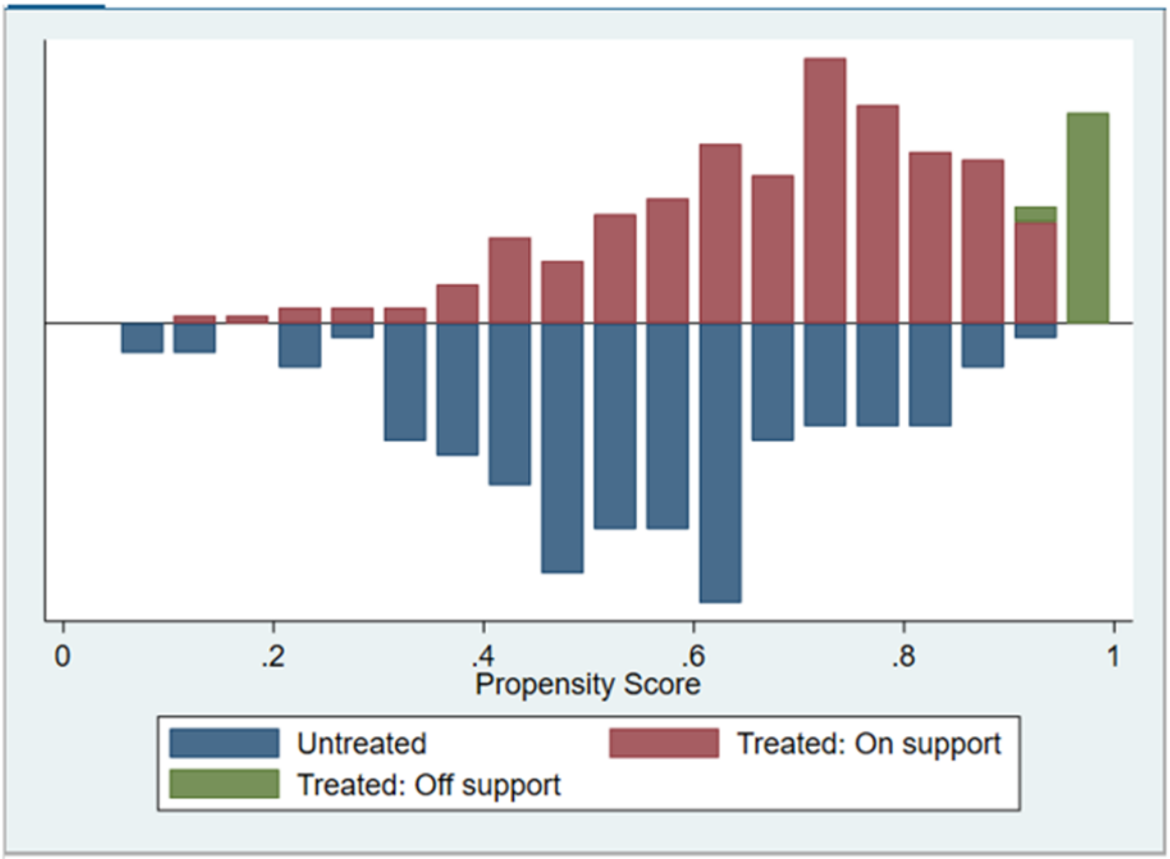

Figure 6.1: Propensity Score histogram for treated and untreated

6.3.4 Effect of informal sources of information on fish harvest.

The histogram was used to understand the propensity score distribution of the two groups based on identical common characteristics. In addition, the histogram helped to check the presence of overlap or any common supporting conditions between the two groups (informal network users) and their counterparts (Pan, 2014). Accordingly, the results in Figure 6.1 display the two regions of the informal network users (treated group) and formal network users (untreated group). The bottom half of the histogram showed the common support region for the treated group and ranged between 0.012 and 0.956. The y-axis showed the frequency of the propensity score distribution. Consideration of the propensity scores and the overlaps displayed on the histogram revealed that the propensity scores for the two groups, the untreated (formal network users) and the untreated (informal network users), were within the region of the joint support. Despite the few observations noticed as off-support, which can be rejected from the analysis, it can be concluded that a good match was achieved for the study.

Table 6.8: Post estimation of PSM

Sample	Pseudo R^2	Lr chi^2	P>chi^2	Mean bias	Med bias	Beta	R
Unmatched	0.41	218.46	0.00	62.7	58.0	214.6	28
Matched	0.00	52.60	0.86	4.2	3.6	24.0	0

Similarly, the post-estimation results presented in Table 6.8 revealed that the pseudo-R2 value was very low (0.002) and insignificant in the *t*-test. Additionally, the values of pseudo R2, mean bias, and beta guarantee that the matching process created a good balance between the treated and untreated groups. Thus, an estimation of the average treatment effect on the treated (ATT) was conducted.

6.3.5 Estimating Treatment Effects (ATT)

To check for the robustness of the regression model's results, different matching techniques, such as kernel-based matching (KBM), nearest neighbour matching (NNM), and radius matching (RM), were performed on the outcome variable, namely the fish output in Kilograms, as shown by the difference in ATT in Table 6.9.

Importantly, all three matching techniques (KBM, NNM, and RM) demonstrated a significantly higher fish output among the treated group compared to their counterparts, with a statistically significant difference at *the p*=0.001 level. This underscores the effectiveness of the matching techniques and suggests that better fish production techniques were gained through proper exploitation of informal sources of information. The result also confirms the appropriateness of the selected matching algorithm for the study, leading to the estimation of the ATT for the sampled respondents.

Table 6.9: Performance criteria of matching algorithms

Outcome variable	Matched algorithms	Matched Samples		ATT (impact)	Std. Err.	*t*-test
		Treated	Untreated			
Fish output (Kgs)	Kernel-based matching	251	133	2336.42	1404.19	1.66
	Nearest neighbour matching	251	133	189.32	2049.82	0.09
	Radius matching	251	133	2727.04	2804.03	0.97

6.3.6 The impact of informal networks on the fish harvest (Kgs)

Table 7.0 displays the results of the estimated average treatment effect (ATT), which revealed a statistically significant difference of 4539.216 Kilograms of fish annually over the control group (*t*=2.32; *p*=0.00). The treated group harvested (24627.716) kilograms of fish annually, compared to (20088.52) for the untreated. These findings confirm a significant increase in fish production among informal network users, reinforcing the credibility of the study and the potential of these networks as a viable alternative in areas with limited access to formal extension services.

Table 7.0: Estimation of ATT for fish output (Kgs/annum)

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Output	Unmatched	24484.07	21354.30	3129.77	1266.00	2.47
	ATT	24627.71	20088.51	4539.21	1955.47	2.32

Table 7.1: Estimation of regression adjustment for fish output (Kgs/annum)

	Fish output	Coef.	Robust Std. Err	Z	p>|z|
ATET	Adoption				
	Treated Vs. Control	2384.31	1530.72	1.56	0.00
POmean	Treated				
	Control	1655.88	615.84	2.86	0.00

In addition to the PSM method applied to estimate the ATT on the fish harvest, regression adjustment was performed. The estimated results of the average treatment effect on the treated (ATET) revealed that informal sources of information (informal networks) produced positive and statistically significant fish output differences between the treated and control groups, as presented in Table 7.1. Hence, the study demonstrates that cage fish farmers who exclusively depend on informal networks to access information pertaining to fish rearing were better advantaged compared to their counterparts. In addition, the results from the ATET also substantiated that informal network users produce significantly more fish than the comparison group (Table 7.1).

6.3.7 Testing for Hidden Bias Sensitivity Analysis

The presentation of propensity-matching estimates should be accompanied by sensitivity analysis due to bias from unobservable characteristics (Ichino *et al.,* 2006). The assumption we make is that in case of a significant ATT. We might be overestimating it due to a hidden bias we failed to consider. Accordingly, the study employed the *'mhbounds'* procedure by Becker and Caliendo (2007) in Stata for sensitivity testing. This procedure uses the matching estimates to determine the confidence intervals of the outcome variables of different values of Γ (gamma).

Table 7.2: Sensitivity Analysis with Rosenbaum bounds

Gamma	Q_mh+	Q_mh-	P_mh+	P_mh-
1	18.08	18.08	0	0
1.1	17.58	18.65	0	0
1.2	17.12	19.2	0	0
1.3	16.72	19.67	0	0
1.4	16.35	20.15	0	0
1.5	16.02	20.61	0	0
1.6	15.72	21.06	0	0
1.7	15.45	21.49	0	0
1.8	15.19	21.91	0	0
1.9	14.96	22.31	0	0
2	14.74	22.71	0	0

Gamma, odds of differential assignment due to unobserved factors; Q_mh+, Mantel–Haenszel statistic (assumption: overestimation of treatment effect); Q_mh−, Mantel–Haenszel statistic (assumption: underestimation of treatment effect); P_mh+, significance level (assumption: overestimation of treatment effect); P_mh−, significance level (assumption: underestimation of treatment effect).

Table 7.2 reports the Mantel-Haenszel (mh) bounds result indicating, under the assumption of no hidden bias, the Q_mh test statistics are highly significant at 1%, as indicated by their respective p-values (0). The finding indicates a highly significant treatment effect for informal social network interventions on the Fish harvest of the cage fish farmers. The Q_mh statistics indicate that the study is insensitive to the hidden bias at a 1% confidence interval. The closer the Q_mh to 1, the more sensitive the results are. Therefore, the observed results on the impact of informal social networks on the Fish harvest are insensitive to unobserved factors, indicating that any unobserved factor did not influence the relationship between the treatment and outcome variables in the study.

6.4 Policy Implications and Conclusions

The focus of this study evaluated the impact of using informal sources of information among smallholder farmers in rearing fish in cages. Randomly, 384 respondents were selected from fourteen districts sharing the waters of Lake Victoria in Uganda. The study employed PSM procedures to estimate the average treatment effect (ATE) and average treatment effect on treated (ATET) among the treated and control groups. The key findings revealed that the treated group (informal network users) accessed and shared pertinent information on cage fish rearing. That enabled them to scale up their production potentials significantly compared to their counterparts. More specifically, the PSM estimates showed that the treated group produced a greater quantity of fish (kgs/annum) than the comparison group. This finding was supported by significant results from all algorithms used in this study.

Therefore, this study has important policy recommendations. To start with, it advocates for the enhancement of the use of informal sources of information (informal networks) among smallholder farmers, majorly in fishery-dependent communities, contributing to increased fish production and farmers' income level. This could influence the adoption of caged fish farming helping fish farmers to attain increased production and optimum income for improved livelihood. In addition, social ties enhance information flow, mostly related to fish rearing due to social interactions. This calls for a need to encourage more group formations among the smallholder farmers, where formal extension services seem to be limited. This entails guaranteeing support for the development of more effective conventional methods for information sharing among smallholder fish producers.

Hence, a model information-sharing platform and a well-organized policy content should be ensured to integrate informal sources of information platforms used in cage fish rearing and efficient resource utilization. Lastly, there should be a change in thinking from the traditional single formal extension service approach to the blended one, which accommodates other social platforms that strengthen social ties and group formation initiatives among the smallholder farmers. This, in turn, could lead to a significant increase in fish productivity and income among smallholder cage fish farmers, thereby fostering growth in the fishery sector.

CHAPTER SEVEN

GENERAL DISCUSSION, CONCLUSIONS AND POLICY RECOMMENDATIONS

7.1 General Discussion

The global demand for fish products is on the rise, necessitating a significant increase in production. Smallholders, who form the majority of fish-dependent communities worldwide, are key players in this production growth. Their involvement is crucial in shifting from depleting capture fishery resources to adopting modern technologies like cage fish farming, which is believed to be essential for sustainable and improved fish production and productivity. However, in Uganda, the adoption of cage fish farming technologies remains low despite its potential benefits. Research shows that limited agricultural information to fish smallholder farmers significantly creates barriers that limits smallholder farmers from embracing modern technologies. Various studies done in the research area attributed the variation impact of the specific technology adoption level with the available social networks which significantly influence the technology adoption rate of cage fish farming. Significantly, various studies on social networks to the technology adoption rate mainly focus on commercial farmers, moreover, only a significant number explored market aspects of agricultural produce. Therefore, it is evidence that social networks are imminent factors where extension systems are weak or non-existent and are not well understood. Therefore, the purpose of the study is to fill this gap. Additionally, social networks bridge the gap between the specific role in deepening farmers' insights with modern technologies, even though exposure is a prerequisite for the adoption of modern technology. Furthermore, social networks act as the platform to disseminate information that greatly impacts agricultural production, however, studies done in these areas have not yet examined their role in farm-level production outcomes. Lastly, the evidence indicates that social networks exceed geographical boundaries, including villages, however, most of agricultural social network studies have only focused on networks within villages, neglecting the potential impact of inter-village networks. Therefore, this study evaluated information shared through social interactions among smallholder fish farmers along the shores of Lake Victoria in Uganda.

The study aimed to improve the livelihoods of fishery-dependent communities in Uganda by promoting cage fish farming technology adoption rate. Significantly, the purpose of the study setup was achieved through several specific objectives. First, the study examined factors such as e knowledge, attitudes, and perceptions and the impacts among smallholder farmers towards the adoption of fish farming using cage fish technologies on the shores of Lake Victoria in Uganda. Second, it assessed how social networks influence the information flows among smallholder fish farmers and how it impacts the adoption rate of cage fish farming technologies. Third, the study focused on social networks as a way of introducing smallholder farmers to the technology of caged fish farming. Lastly, it determined the social network influence on caged fish harvest among smallholder farmers along the shores of Lake Victoria in Uganda.

The study was conducted using a variety of statistical and econometric techniques, including descriptive and inferential statistics, Multinomial logit (MNL), a combination of Probit and Tobit (DH) models, Social Network Analysis (SNA), and Propensity Score Matching (PSM). The focus of the study applied the qualitative and quantitative research methods for both data collection and triangulation. The study involved 384 smallholder cage fish farmers from 14 districts, who were selected using multi-stage random sampling techniques. This rigorous methodology provided valuable information on social interactions, information flow, socioeconomic characteristics, and the knowledge, attitudes, and perceptions of smallholder fish farmers on cage fish farming.

The results of the Multinomial logit analysis showed that several factors were significantly associated with knowledge outcomes in cage fish farming. Specifically, experience in cage fish farming, education level, type of cage technology used, access to television, social capital, and market distance were all found to be significantly connected with knowledge results in the medium category. The significance levels for these factors were 10%, 10%, 10%, 10%, 5%, and 10% respectively. Additionally, gender, education level, type of cage, aggregate extension services received visits, and social capital were statistically and significantly associated with high category level of knowledge outcomes in the high category, with 10%, 5%, 5%, 5%, and 10% significance levels respectively.

Significantly, other factors that were found to be statistically significant and associated with farmer attitudes toward cage fish farming were farmer's age, type of wooden cage, social capital, access to television, location of cage units in the lake, and number of cages owned, all had an impact on attitudes in the medium category by 1%, 1%, 5%, 10%, 1%, and 5% respectively. In addition, only the type of wooden cage was statistically significant and associated with attitudes in the high category by 1%. Regarding perception outcomes, the type of wooden fish caged technology, several farmers' extension visits, and access to television were significantly associated with both medium and high categories by 5% in all cases. Therefore, it is recommended that policymakers target these significant variables and provide incentives to intensify cage fish farming practices in the study area. Furthermore, the findings suggest a need to integrate extension approaches with social networks when promoting agricultural technologies.

The second objective of the study used a double hurdle regression model. The results showed that an increase in a cage fish farmer's experience and group membership by one unit increased the likelihood of participating in social networks by 0.43 and 0.70 units, respectively. On the other hand, a one-unit increase in extension visits and credit access decreased the probability of using social networks by 0.59 and 1.06 units, respectively. The study recommends an increase in extension services to smallholder fish farmers to influence smallholder farmers' utilization of social networks as well as expanding their use to other agricultural sectors. It also suggests improving financial services for cage fish farmers to enhance credit access and emphasizes the importance of group membership in promoting intensive cage fish.

The third objective of the study used the egocentric approach and UCINET software to visualize information flow among smallholder cage fish farmers' social networks. The findings revealed that centrality (degree, closeness, and betweenness) and kinship ties are critical factors in information flow. Farmers with high centrality played a crucial role in transferring information within cage fish farmers' social networks. Correspondingly, village social networks were significant in generating awareness about cage fish farming technologies compared to intra-village social networks. Moreover, the finding confirms the potential role played by inter-village social networks in awareness creation may have been missed evidence-based past studies on caged fish farming.

Significantly, integrating the public extension officers, village administrators, and smallholder caged fish farmers through social networks greatly enhance their exposure to modern fish technologies. In this case, the influence of extension officers on the adoption of caged fish technology is greater compared to the impact of farmers' social networks. Therefore, this implies that informal information channels positively influence the adoption level however they cannot completely the awareness creation through formal channels. Therefore, understanding the ties between fish smallholder farmers with the extension service officers can enhance the effective diffusion of information about these technologies in the study area.

In addition to this, comparing the influence of different sources of information on smallholder cage fish farming and their level of fish harvests, two groups of farmers - one that received information from fellow farmers and one that did not - were evaluated using the Propensity Score Matching (PSM) technique. The results showed that the estimated average treatment effect (ATT) revealed a significant difference in fish production, with the treated group yielding an average of 4539.21 kilograms more fish annually compared to the control group (t=2.32; p=0.00). Specifically, the treated group harvested an average of 24627.71 kilograms of fish annually, while the untreated group harvested an average of 20088.5 kilograms annually. In addition, the finding suggests that informal network information sources can lead to increased fish production, especially in areas where formal extension services are limited.

7.2 Conclusions and Policy Recommendations

Empirically, the findings raise several suggestions based on the policy recommendations and for future research. To start with, the study suggested the increase of the social networks among smallholder fish farmers simply for they were found to significantly influence the spreading and efficiently utilizing modern Agricultural technologies. Second, the impact of social networks significantly contributed to spreading and creating awareness of the efficiency in the utilization of modern technologies, however, it differs with different types of new technologies. In the same vein, social networks are considered more critical in the dissemination of modern technologies that are not always supported by the both the private sector and formal institutions. Therefore, this calls for the enhancement of these networks to continually influence the dissemination of the upcoming modern technologies. Third, it is essential to note that inter-village networks play an imminent role in the flow of information through social connections.

Therefore, highlights the potential impact of facilitating information exchange between villages in raising awareness and spreading new technologies. Future studies should focus on thoroughly analyzing the creation and operation of inter-village social networks. Additionally, the research findings indicate that general farmers tend to have more conversations about agricultural farming with contact farmers rather than with community leaders and other connections. Therefore, it would be advantageous to harness the influence of contact farmers' networks. Hence, such could involve focusing on the model farms of these contact farmers to serve as demonstration sites and training grounds. The study also found that extension agents play a positive role in facilitating discussions about cage fish farming technologies, raising awareness, and enhancing production and productivity. Further, the study suggests that formal extension programs are valuable and should complement informal social networks rather than replace them.

Therefore, it is important to conduct further research to understand the most cost-effective extension model for specific situations. The study findings also suggest that providing extensive training will increase farmers' willingness to share the information with other farmers, contributing to the effective flow of information among these farmers across multiple network nodes. Some potential approaches recommended from this study involve strengthening farmer groups and promoting the model cage fish farm at the village level.

7.3 Limitations of the study and further research

The results of our study have important general implications, as mentioned previously. However, there is a need to address various vital limitations for future research:

i. Our research outcomes are based on a case study that may only represent some of the country or fishery-dependent communities. Consequently, Uganda is a heterogenous country with more than 45 cultural settings, implying that the social networks formation may vary on how they function across different regions. More study should be conducted in different parts of the country, where by the findings will enhance our outcomes, further contributing to the development of national aquaculture, there should be the implementation of extension policies that supports the incorporation of social networks in the systems.

ii. The focus of this study was based on cross-sectional data, and specific circumstances may have influenced some of the results at that time. Therefore, a panel study could be conducted to capture the social network longer-term effects of social networks on caged fish farming and to help in the reduction of unobserved heterogeneity influenced by time-invariant factors.

iii. The farmer-to-farmer network concepts applied in this study were only sampled and may not fully represent real networks. Some farmers may rely on particular networks that were not adequately captured by our sampling method. Future studies should improve the methodology for sampling network actors in order to influence more comprehensive data on specified networks.

iv. Another significant factor is that our study did not assess the specific mode of farming information that farmers use to exchange information beyond the fish reared and technologies use. Therefore, in the future, it would be beneficial to investigate the mode of information exchange among smallholder fish farmers in cage fish farming technologies and assess the application impacts of such information. Understanding which information can be efficiently and effectively exchanged among farmers and which requires specialized dissemination could be valuable for aquaculture extension agents and other providers of farmer advisory services.

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APPENDICES

Appendix A: Questionnaire

0.0 Survey quality control		
Date of interview: Day	Month	Year ....
Interviewed by:		
Starting time: ……..............…	Ending time:	
Date entered: Day:	Month	Year ....
Entered by:		

Introductory Statement

Dear Sir/Madam,

My name is **Mutyaba John Livingstone**, and I am part of a team from Egerton University studying aspects of cage fish farming technology in Uganda. This questionnaire is meant to collect solely academic data to be used for this PhD study. You will be briefed on the findings of this study. Any contribution given will be highly appreciated, and your responses will be treated with utmost confidentiality. If you have any questions or comments about this survey, in that case, you may contact the Project coordinator through the following address: **Mr. Mutyaba John Livingstone, Dept. of Agricultural Economics and Agribusiness Management, Egerton University, P.O. Box 536, Egerton. Cell phone: +256751349343/+254716921303.** Email address: jlmutyaba@yahoo.com.

Thank you.

SECTION A: GENERAL INFORMATION

A1. District ____

A2. Sub-County ____

A3. Beach Name ____

SECTION B: SOCIO-ECONOMIC AND INSTITUTIONAL CHARACTERISTICS

B1.1 Gender of Respondent	**B1.2** Age	**B1.3** Religion	**B1.4** Education Level
1. Female 0. Male	In years	1= Muslim 0=Christian	Years in school

B1.5 Experience (years) in practicing cage fish farming: ......

B1.6 Community responsibility of a respondent: 0=none; 1=Village Chairperson; 2=Defence Secretary 3=Local council Member 4=Secretary Women Affairs

B1.7 Do you have off-farm income?

1=Salary income; 2=Business; 3=Casual labourer; 4=None

B1.7 Household composition

Males (0)		Number	Females (1)		Number
0.1	Less than 5 years		1.1	Less than 5 years	
0.2	6-15 years		1.2	6-15 years	
0.3	16-25 years		1.3	16-25 years	
0.4	26-35 years		1.4	26-35 years	
0.5	36-45 years		1.5	36-45 years	
0.6	46-55 years		1.6	46-55 years	
0.7	Above 55 years		1.7	Above 55 years	

B1.8 What is the distance to the nearest fish market from your homestead? ....(km)

B2.1 Do you belong to any fish farmers' association in your community? 1=Yes**:** 0=No

B2.2. If No Why: ………………….

B2.3 How many members are in your association? …………..........……...

B2.4 How many times do you meet in a month?.....................................

B2.5 What have you benefited from the association?................................

B2.6 Are you satisfied with the objectives of the association? (1) = Yes; (0) = No

B2.7 Do you belong to any other association? (1) = Yes; (0) = No.

B2.8 If yes, specify..

B2.9 If **Not** in any fish farmers' association give a reason (s)……………………………

B2.10 Would you like to join the fish farmers' association? (1). Yes; (0). No

B2.11 If **No in B2.10**, What hinders you from joining fish farmers' associations?

(1). High membership fees; (2). Lack of trust with members; (3). Do not meet the quality requirements; (4). Lack of time to attend meetings; 5. If other, specify…………….

<u>SECTION C: FARMERS' KNOWLEDGE, ATTITUDES, AND PERCEPTIONS TOWARDS CAGE FISH FARMING TECHNOLOGIES</u>

C1.1 Mention the types of fish cages you know.

1) ....

2) ....
3) ....
4) ....

C1.2 Mention the fish species reared in cages at this beach management unit.

1) ....
2) ....
3) ....
4) ....

C1.3 What is the duration you take to harvest your fish? In months...............................

C1.4 When (year) did you first hear about fish cage farming**?**......................................

C1.5 From whom did you hear about it first? (1) Progressive fish farmer; (2) extension agent; (3) BMU leaders; (4) a visit; (5) Research official; (6) Neighbour; **(7) Media:** (i) *Radio,* (ii) *Television*, (ii) *Phone,* (iv) *Internet,* (v) *Newspapers.* (8) other specify....................

If first source of information about cage fish farming technologies was a farmer (Others Skip to (C2.1)

C1.6 What is the gender of farmer who gave you first information about cage fish farming?

1=Female 0=Male.

C1.7 How were you related to that farmer? 1= Friend; 2=Parent; 3=Brother/Sister; 4=Church leader; 5=In law; 6=Uncle/aunt 7=Other specify...

C1.8 Was that farmer your agemate? 1= Yes; 0= No.

C1.9 Were you known to each other before? 1=Yes; 0=No

C1.10 Do you both stay within the same BMU? 1=Yes; 0= No

C1.11 How far does that farmer stay from your homestead?

In terms of minutes when walking..

C1.12 Which year did that farmer start fish cage farming?....................................

C1.13 What type of cage unit does the farmer use? ....

C1.14 How many units did that farmer start with? ....

C1.15 How many cages does the farmer own now? ....

C1.16 Are you using a similar cage type? 1=Yes; 0=No

C1.17 How many do you own now? ....

C1.18 Are still sharing information concerning cage fish farming with that farmer?

1=Yes; 0= No. (i) If ***yes***, how often do you interact with that farmer? Number of times in a month...

C1.19 Do you have other farmers with you to share information concerning cage fish farming? 1=Yes; 0=No. (i) If ***Yes***, how many do you have? ....

C2.0 Verifying Farmer's knowledge on cage fish farming technologies

Please put a tick in the box which you think is correct (True=3; False=2; Do not know=1)

Farmers' Knowledge Level	**3**	**2**	**1**
C2.1 Fish cage units are difficult to assemble			
C2.2 Fish reared in cages take more than a year to mature			
C2.3 Fish reared in cages is not given formulated feeds			
C2.4 Cage fish farming is not a profitable venture			
C2.5 Fish cage units are too expensive			
C2.6 Cage fish farming is a labour-intensive job			
C2.7 Cage fish technologies destroy breeding places for wild fish			

C3.0 Farmers' Attitudes Towards Cage Fish Farming Technologies.

(Strongly agree=4; Agree=3; Disagree=2; Strongly disagree=1)

Famers' Attitude levels	4	3	2	1
C3.1 Cage fish farming is not a viable business				

C3.2 Cage fish farming is not better than wild fishing				
C3.4 Cage fish farming does not address food insecurity				
C3.5 Cage fish farming technologies is a very good innovation				
C3.6 I consider cage fish farming a desirable career option				
C3.7 Cage fish farming is a time-consuming job				

C4.0 Farmers' Perception Towards Cage Fish Farming Technologies

(Strongly agree=4; Agree=3; Disagree=2; Strongly disagree=1)

Perceived **Usefulness** of cage fish farming technologies	**4**	**3**	**2**	**1**
C4.1 Requires comparatively low capital outlay				
C4.2 Harvesting is very simple				
C4.3 Easy to observe and sample fish any time				
C4.4 Less labour intensive				
C4.5 It is not a risky technology				
C4.6 It is a very affordable technology				
C4.7 Fish grows faster				
Perceived **ease of use** of cage culture technology	**4**	**3**	**2**	**1**
C5.1 Cage fish farming technology is easy to use				
C5.2 It does not require highly skilled labour				
C5.3 It is not gender insensitive				
C5.4 It is very simple to master				
C5.5 It is user friendly.				
C5.6 I learnt to use it in a short time				
C5.7 I can train people interested in using cages				
C5.8 I can easily identify the problem and fix it myself				
C5.9 It gives tangible results				
C5.10 I highly recommend it to anybody interested in fish farming.				
C5.11 It is a wonderful technology.				

C6.0 Verification of the attributes of cage fish farming technologies

List the most **Positive aspect(s)** you know about cage fish technologies

C6. 1...

C6.2...

C6.3..

C6.4..

List the most **Negative aspect(s)** you know about cage fish technologies

C6. 5..

C6.6...

C6.7...

C6.8...

SECTION D: SOCIAL NETWORKS

Questions about a farmer's interactions with a number of farmers, as well as key individuals (officers and organizations) who promote cage fish farming activities in this BMU).

D1.0 Relationships and Interactions among smallholder farmers.

(A) Fellow cage fish famer(s)	Since when (years) have you known (A)	Do you belong to the same association? (1=Yes; 0=No)	How many times do you discuss matters concerning cage fish farming in a month?	Do you visit each other? (1=Yes; 0=No)	How many times in a month?	Does (A) inform you about training on fish farming? (1=Yes; 0=No)
D1.1 Farmers from the same BMU						
1.						
2.						
3.						
4.						
D1.2 Farmers from other BMUs						
1.						
2.						
3.						
4.						
D1.3 BMU Leaders						
1.						
2.						
3.						

(B) Change Agents	Since when (Year) have you known (B)?	How often does (B) visits you in a month?	Does (B) gives you free technical assistance? (1=Yes; 0=No)	How often does (B) conduct trainings on fish farming in a year?	How related are you with (B)?	What other form of assistance do you get from (B)?
D1.4 Agric. Extension worker						
D1.5 Fisheries officer						
D1.6 Research official						
D1.7 Ministry official						
D1.8 NGO official						
D1.9 Input dealers						
D1.10 Fish Company official						
D1.11 Finance institution						

D2.0 Information exchange (flow) among social network members

Fellow farmers or change agents	Have you ever given (abbreviated as G) or received (abbreviated as R) any of the following for fellow farmers or change agents? Where ***(G; 1=Yes; 0=No and R; 1=Yes; 0=No)***													
	Information on sources and types of fish cages.		Information on fish fry. (stocking)		Information on fish feeding practices		Information on fish harvesting practices		Information on post-harvest handling		Information on fish marketing practices		Information on financial assistance	
	G	R	G	R	G	R	G	R	G	R	G	R	G	R
D2.1 Fish farmers from the same BMU														
1.														
2.														
3.														

4.														
D2.2 Fish farmers from other BMUs														
1.														
2.														
3.														
4.														
D2.3 BMU Leaders														
1.														
2.														
3.														
Change Agents														
D2.4 Agric. Extension worker														
D2.5 Fisheries officer														
D2.6 Research official														
D2.7 Ministry official														
D2.8 NGO official														
D2.9 Input dealers														
D2.10 Fish Company official														
D2.11 Finance institution														

D3.0 Credit Access

D3.1 If you get a financial crisis to buy inputs for your fish, would you go for a loan it at present? (1=Yes; 0=No).

D3.2 If ***Yes***, would you get a loan from any of the following sources?

Credit Sources	**Would you borrow from? (1=Yes; 0=No)**
1. Registered SACCO	
2. Banks	
3. Microfinance institutions	
4. Fish farmer in my BMU	
5. Fish farmer outside my BMU	
6. Trader in my BMU	
7. Trade outside my BMU	
8. Money lenders	

Appendix B: Focus group discussion guide with fisheries officers

No.	Theme	Questions
1.	Cage fish farming Technologies	1. How would describe cage fish farming system? 2. What are the most types of cage units you use and why? 3. Has there been any difference since you started participating in cage fish farming? Please elaborate on its attributions. 4. Do you see any difference between you and the non-participants? 5. Have you ever helped one to join cage fish farming? If yes what was his/her reaction when you first met? 6. Do you form farmers groups? If yes how do get your leaders?
2.	Social Networks	1. As fish farmers do you visit one another and how often? 2. What benefits have you achieved through such interactions? 3. What type of information do you share pertaining fish farming? 4. Explain how you benefited from information sharing? 5. Has there been any difference since you started interacting with your fellow farmers in terms of skills development and innovativeness? If yes describe. 6. How many cage fish farmers do you regularly interact with?
3.	Knowledge, Attitude and Perception	1. Do you think any person can easily use cage units to rear fish or requires highly specialized training or knowledge? 2. Are cage units easy to use and repair? 3. How would rank the different types of cage units in terms of usage? 4. How do non-participants generally talk about cage fish farming technologies (Are they pro or against these technologies)? Explain please. 5. What is your opinion as regards to these cage fish farming technologies? 6. Do you also give information about cage fish technologies to non-participants? 7. How do you perceive cage fish farming technologies? 8. Would you switch to a different enterprise if a new opportunity arises? 9. IF yes. Why and what are the main advantages? If not why? What are the disadvantages? And or the barriers? 10. What are the main constraints you are experiencing as cage fish farmers?
4.	Sustainability and Environmental aspects.	1. Are cage fish farming technologies safe to be used by anybody? 2. Can cage fish farming technologies help to improve people's livelihoods and address environmental issues? 3. What could be used as the driving factors to promoting cage fish farming technologies in your locality?

		4. What are the major problems that can be critically observed /highlighted /addressed associated with cage fish farming technologies in your locality? 5. Any suggestions/contributions you can put up in order to improve on cage fish farming sub sector? 6. How best can cage fish farming technology campaign be integrated in the community development programmes in our communities and attract more small-scale farmers and yield very good results. 7. How can the issue of sustainability be approached in cage fish farming?

Appendix B: Consent Form for sampled respondents

Title of the study: EFFECT OF INFORMATION LINKS AND FLOW THROUGH SOCIAL NETWORKS IN EXPOSING SMALLHOLDER FARMERS TO CAGE FISH FARMING TECHNOLOGIES IN UGANDA.

Investigator(s): Mutyaba John Livingstone

Institution(s): Egerton University

Introduction

Dear Sir/Madam,

My name is **Mutyaba John Livingstone**, a student from Egerton University. Currently I'm for data collection for my research on ***EFFECT OF INFORMATION LINKS AND FLOW THROUGH SOCIAL NETWORKS IN EXPOSING SMALLHOLDER FARMERS TO CAGE FISH FARMING TECHNOLOGIES IN UGANDA***. This questionnaire is meant to collect solely academic data to be used for this PhD study. You will be briefed on the findings from this study during the result dissemination phase which will be communicated after writing the final report. Any contribution given will be highly appreciated and your responses will be treated with utmost confidentiality.

This informed consent explains the study to you. After the study has been explained, any questions you may have are answered, and you have decided to participate in the study, you will be asked to sign a consent, which you will be given a copy to keep.

A brief description of the sponsors of the research project

This academic research is funded by the Regional Universities Forum for Capacity Building in Agriculture located at Makerere University Hill, P.O. BOX 16811, Wandegeya, Kampala, Uganda. Or E-mail to: secretariat@ruforum.org

Purpose:

The study seeks to explore the Effect of information links and flow through social networks in exposing smallholder farmers to Cage Fish Farming Technologies in Uganda. Therefore, the findings of this study will help in providing relevant information that may be useful in improving Uganda's aquaculture sector and in enhancing the smallholder farmers' welfare. This study intends to contribute to the existing body of knowledge and also explore areas for further research. Furthermore, the study intends to provide empirical findings which are necessary in updating the existing aquaculture and marine policies.

Procedures:

Your participation in this study will involve responding to the prepared set of questions on this questionnaire.

Who will participate in the study?

You have been chosen to participate in this study because you are above 18years and either a cage fish farmer or wild catch fisherman carrying out your activities in Lake Victoria, Uganda. The interview will last for approximately 25 minutes.

Risks/discomforts:

There is no foreseeable risk of harm or discomfort that will arise from your participation in this study. The only risk or discomfort will be the inconvenience in terms of time spent during the interview.

Benefits:

The findings of this study will help in providing relevant information that may be useful in improving Uganda's aquaculture sector and in enhancing the smallholder farmers' welfare. As a participant, you will be updated time to time on the progress of the study and findings after writing the final report.

Confidentiality:

Your identity will not be revealed to any one as we shall only use codes to identify participants. Information obtained will only be accessible by the research team. Soft copies of the data will be protected by password and hard copy files will be kept under lock and key. Confidential information will only be accessed by the principal investigator.

Alternatives:

You do not have to participate in this study if you are not interested. You will not lose any benefit in case of no participation.

Cost:

There will not be any additional cost incurred as a result of participating in this study.

Questions:

If you have any questions related to the study, or your rights as a research participant, you can contact the principal investigator, Mr. Mutyaba John Livingstone on telephone number +256 751 349 343 or via email on jlmutyaba@yahoo.com

Statement of voluntariness:

Participation in the research study is voluntary and you may join on your own free will. You have a right to withdraw from the study at any time without penalty.

If you have any issues pertaining to your rights and participation in the study, please contact the Chairperson, Gulu University Research Ethics Committee, **Dr. Gerald Obai** Tel: No., 0772305621; email: lekobai@yahoo.com / lekobai@gmail.com; or the Uganda National Council for Science and Technology, on plot 6 Kimera road, Ntinda, Kampala on Tel 0414705500.

Statement of consent

.... has described to me what is going to be done, the risks, the benefits involved and my rights as a participant in this study. I understand that my decision to participate in this study will not affect me in any way. In the use of this information, my identity will be concealed. I am aware that I may withdraw at any time. I understand that by signing this form, I do not waive any of my legal rights but merely indicate that I have been informed about the research study in which I am voluntarily agreeing to participate. A copy of this form will be provided to me.

Name ……………………Signature/Thumb of participant…………………Date …......……

Name………………………. Signature of interviewer……………..…Date…………….……...

Witnessed by .... Signature.............................Date ....

Appendix D: Consent for focus group discussion participants

Title of the study: EFFECT OF INFORMATION LINKS AND FLOW THROUGH SOCIAL NETWORKS IN EXPOSING SMALLHOLDER FARMERS TO CAGE FISH FARMING TECHNOLOGIES IN UGANDA.

Investigator(s): Mutyaba John Livingstone

Institution(s): Egerton University

Introduction

Dear Sir/Madam,

My name is **Mutyaba John Livingstone**, a student from Egerton University. Currently I'm for data collection for my research on ***EFFECT OF INFORMATION LINKS AND FLOW THROUGH SOCIAL NETWORKS IN EXPOSING SMALLHOLDER FARMERS TO CAGE FISH FARMING TECHNOLOGIES IN UGANDA***. This questionnaire is meant to collect solely academic data to be used for this PhD study. You will be briefed on the findings from this study during the result dissemination phase which will be communicated after writing the final report. Any contribution given will be highly appreciated and your responses will be treated with utmost confidentiality.

This informed consent explains the study to you. After the study has been explained, any questions you may have are answered, and you have decided to participate in the study, you will be asked to sign a consent, which you will be given a copy to keep.

A brief description of the sponsors of the research project

This academic research is funded by the Regional Universities Forum for Capacity Building in Agriculture located at Makerere University Hill, P.O. BOX 16811, Wandegeya, Kampala, Uganda.

Purpose:

The study seeks to explore the Effect of information links and flow through social networks in exposing smallholder farmers to Cage Fish Farming Technologies in Uganda. Therefore, the findings of this study will help in providing relevant information that may be useful in improving Uganda's aquaculture sector and in enhancing the smallholder farmers' welfare. This study intends to contribute to the existing body of knowledge and also explore areas for further research. Furthermore, the study intends to provide empirical findings which are necessary in updating the existing aquaculture and marine policies.

Procedures:

Your participation in this study will involve participating in an organised focus group discussion which will take a maximum of 2 hours (9:00am to 11:00am).

Who will participate in the study?

You have been chosen to participate in this study because you are above 18years and either a cage fish farmer or wild catch fisherman carrying out your activities in Lake Victoria, Uganda. The interview will last for approximately 2 hours and this study targets 14 participants to take part.

Risks/discomforts:

There is no foreseeable risk of harm or discomfort that will arise from your participation in this study. The only risk or discomfort will be the inconvenience in terms of time spent during the interview.

Benefits:

The findings of this study will help in providing relevant information that may be useful in improving Uganda's aquaculture sector and in enhancing the smallholder farmers' welfare. As a participant, you will be updated time to time on the progress of the study and findings after writing the final report.

Confidentiality:

Your identity will not be revealed to any one as we shall only use codes to identify participants. Information obtained will only be accessible by the research team. Soft copies of the data will be protected by password and hard copy files will be kept under lock and key. Confidential information will only be accessed by the principal investigator.

Alternatives:

You do not have to participate in this study if you are not interested. You will not lose any benefit in case of no participation.

Cost/Compensation:

You will be given fifty thousand (Ushs 50,000/=) to compensate for your time and transport refund of twenty-five thousand (Ushs 25,000/=) based on the local public transport rates in the study area.

Questions:

If you have any questions related to the study, or your rights as a research participant, you can contact the principal investigator, Mr. Mutyaba John Livingstone on telephone number +256 751 349 343 or via email on jlmutyaba@yahoo.com

Statement of voluntariness:

Participation in the research study is voluntary and you may join on your own free will. You have a right to withdraw from the study at any time without penalty.

If you have any issues pertaining to your rights and participation in the study, please contact the Chairperson, Gulu University Research Ethics Committee, **Dr. Gerald Obai** Tel: No., 0772305621; E-mail: lekobai@yahoo.com /lekobai@gmail.com; or the Uganda National Council for Science and Technology, on Plot 6 Kimera road, Ntinda, Kampala on Tel 0414705500.

Statement of consent

.... has described to me what is going to be done, the risks, the benefits involved and my rights as a participant in this study. I understand that my decision to participate in this study will not affect me in any way. In the use of this information, my identity will be concealed. I am aware that I may withdraw at any time. I understand that by signing this form, I do not waive any of my legal rights but merely indicate that I have been informed about the research study in which I am voluntarily agreeing to participate. A copy of this form will be provided to me.

Name ………………………Signature/Thumb of participant…………………Date …........

Name………………………. Signature of interviewer……………..…Date…………….…...…

Witnessed by.. Signature................................ Date..................

Appendix E: Stata commands used in the analysis

***** MNL regression**

mlogit knowledgescores farmingexperience gender age educ cagetype extvisits socialcapital phoneaccess tvaccess cageunits farmlocation distance targetmarket, baseoutcome(1) rrr

mlogit attitudescores farmingexperience gender age educ cagetype extvisits socialcapital phoneaccess tvaccess cageunits farmlocation distance targetmarket, baseoutcome(2) rrr

mlogit perceptionscores farmingexperience gender age educ cagetype extvisits socialcapital phoneaccess tvaccess cageunits farmlocation distance targetmarket, baseoutcome(2) rrr

***** Double Hurdle regression**

***** UCINET Analysis**

***** PSM Regression**

psmatch2 treatment farmingexperience gender age cagetype extvisits cageunits farmlocation targetmarket religion group_membership, out (output) common

psgraph

pstest farmingexperience gender age cagetype extvisits cageunits farmlocation targetmarket religion group_membership

pscore treatment farmingexperience gender age cagetype extvisits cageunits farmlocation targetmarket religion group_membership, pscore (pscores)

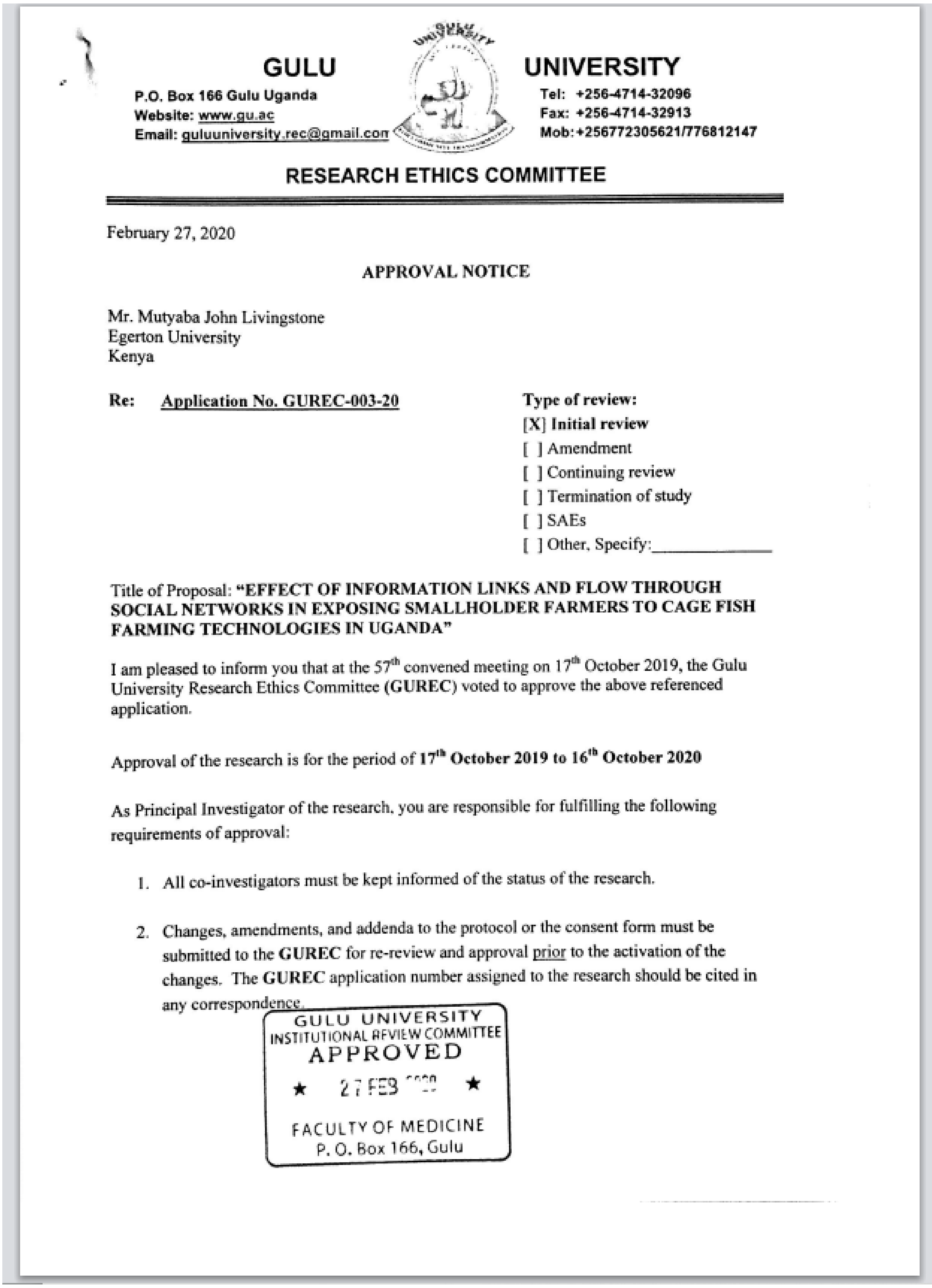
attnd output treatment farmingexperience gender age cagetype extvisits cageunits farmlocation targetmarket religion group_membership, pscore (pscores) comsump

teffects nnmatch (output farmingexperience gender age cagetype extvisits cageunits farmlocation targetmarket religion group_membership) (treatment)

attnd output treatment farmingexperience gender age cagetype extvisits cageunits farmlocation targetmarket religion group_membership, pscore (pscores)

mhbounds treatment, gamma (1, 1.1,1.2,1.3,1.4,1.5,1.6,1.7,1.8,1.9,2)

Appendix F: Research Ethical Committee approval



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RESEARCH ETHICS COMMITTEE

February 27, 2020

APPROVAL NOTICE

Mr. Mutyaba John Livingstone
Egerton University
Kenya

Re: Application No. GUREC-003-20

Type of review:
[X] **Initial review**
[ ] Amendment
[ ] Continuing review
[ ] Termination of study
[ ] SAEs
[ ] Other, Specify:______________

Title of Proposal: **"EFFECT OF INFORMATION LINKS AND FLOW THROUGH SOCIAL NETWORKS IN EXPOSING SMALLHOLDER FARMERS TO CAGE FISH FARMING TECHNOLOGIES IN UGANDA"**

I am pleased to inform you that at the 57th convened meeting on 17th October 2019, the Gulu University Research Ethics Committee (**GUREC**) voted to approve the above referenced application.

Approval of the research is for the period of **17th October 2019 to 16th October 2020**

As Principal Investigator of the research, you are responsible for fulfilling the following requirements of approval:

1. All co-investigators must be kept informed of the status of the research.

2. Changes, amendments, and addenda to the protocol or the consent form must be submitted to the **GUREC** for re-review and approval prior to the activation of the changes. The **GUREC** application number assigned to the research should be cited in any correspondence.

GULU UNIVERSITY
INSTITUTIONAL REVIEW COMMITTEE
APPROVED
★ 27 FEB 2020 ★
FACULTY OF MEDICINE
P. O. Box 166, Gulu

3. Any unanticipated problems involving risks to participants must be promptly reported to the **GUREC**. New information that becomes available which could change the risk: benefit ratio must be submitted promptly for the **GUREC** review.

4. Only approved and stamped consent forms are to be used in the enrollment of participants. All consent forms signed by participants and/or witnesses should be retained on file. The **GUREC** may conduct audits of all study records, and consent documentation may be part of such audits.

5. Regulations require review of an approved study not less than once per 12-month period. Therefore, a continuing review application must be submitted to the **GUREC** eight (**8**) weeks prior to the above expiration **date of 16th October 2020** in order to continue the study beyond the approved period. Failure to submit a continuing review application in a timely manner may result in suspension or termination of the study, at which point new participants may not be enrolled and currently enrolled participants must be taken off the study.

6. You are required to register the research protocol with the Uganda National Council for Science and Technology (UNCST) for final clearance to undertake the study in Uganda.

The following documents have been approved in this application by the **GUREC:**

	Document	**Language**	**Version**	**Version Date**
1	Protocol	English	Version 3.0	9th January 2020
2	Data Collection Tools	English/Luganda	Version 3.0	9th January 2020
3	Informed consent Document	English/Luganda	Version 3.0	9th January 2020

GULU UNIVERSITY
INSTITUTIONAL REVIEW COMMITTEE
APPROVED
★ 27 FEB 2020 ★
FACULTY OF MEDICINE
P. O. Box 166, Gulu

Signed,

Dr. Gerald Oba
Chairperson
Gulu University Research Ethics Committee

Appendix G: NCST Research Clearance

UNCST

Uganda National Council for Science and Technology

(Established by Act of Parliament of the Republic of Uganda)

Our Ref: SS 5218

2nd June 2020

Mr. John Livingstone Mutyaba
Principal Investigator
Regional Universities Forum for Capacity Building in Agriculture
Kampala

Dear Mr. Mutyaba,

Re: Research Approval: Effect of Information Links and Flow Through Social Networks in Exposing Smallholder Farmers to Cage Fish Farming Technologies in Uganda

I am pleased to inform you that on **20/03/2020**, the Uganda National Council for Science and Technology (UNCST) approved the above referenced research project. The Approval of the research project is for the period of **20/03/2020** to **20/03/2021.**

Your research registration number with the UNCST is **SS 5218.** Please, cite this number in all your future correspondences with UNCST in respect of the above research project. As the Principal Investigator of the research project, you are responsible for fulfilling the following requirements of approval:

1. Keeping all co-investigators informed of the status of the research.
2. Submitting all changes, amendments, and addenda to the research protocol or the consent form (where applicable) to the designated Research Ethics Committee (REC) or Lead Agency for re-review and approval prior to the activation of the changes. UNCST must be notified of the approved changes within five working days.
3. For clinical trials, all serious adverse events must be reported promptly to the designated local REC for review with copies to the National Drug Authority and a notification to the UNCST.
4. Unanticipated problems involving risks to research participants or other must be reported promptly to the UNCST. New information that becomes available which could change the risk/benefit ratio must be submitted promptly for UNCST notification after review by the REC.

LOCATION/CORRESPONDENCE

Plot 6 Kimera Road, Ntinda
P.O.Box 6884
KAMPALA, UGANDA

COMMUNICATION

TEL: (256) 414 705500
FAX: (256) 414-234579
EMAIL: info@uncst.go.ug
WEBSITE: http://www.uncst.go.ug

Uganda National Council for Science and Technology
(Established by Act of Parliament of the Republic of Uganda)
UNCST

5. Only approved study procedures are to be implemented. The UNCST may conduct impromptu audits of all study records.
6. An annual progress report and approval letter of continuation from the REC must be submitted electronically to UNCST. Failure to do so may result in termination of the research project.

Please note that this approval includes all study related tools submitted as part of the application as shown below:

No.	Document Title	Language	Version Number	Version Date
1.	Research proposal	English	3.0	January 2020
2.	Informed consent document	English and Luganda	3.0	N/A
3.	Focus group discussion guide	English and Luganda	3.0	N/A
4.	Survey questionnaire	English and Luganda	3.0	N/A

Isaac Makhuwa
For: Executive Secretary
UGANDA NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Copied: Chair, Gulu University, Research Ethics Committee

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KAMPALA, UGANDA

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EMAIL: info@uncst.go.ug
WEBSITE: http://www.uncst.go.ug

Appendix H: Field Pictures


FILA

Appendix I: Publication

EISSN: 2707-0425

East African Journal of Science, Technology and Innovation, Vol. 5 (1): December 2023

Effect of Information Flow through Social Networks on Adoption of Cage Fish Farming Technologies in Uganda

[1*]MUTYABA J L., [1]NGIGI M W., [1]INGASIA O A

[1]Department of Agricultural Economics and Agribusiness Management, Egerton University, Kenya

***Corresponding Author**: jlmutyaba@yahoo.com

Abstract

The philosophy of interpersonal interaction plays a significant role in facilitating learning processes between actors sharing a social network. It is a platform where actors actively share knowledge, skills and ideas, which affect their behaviour. Thus upon that premise, this study was conducted to understand the nature of smallholder farmers' social networks and their effect on the adoption of cage fish farming in Uganda. A cross-sectional survey was carried out across fourteen districts that share the waters of Lake Victoria in Uganda. A total of 384 respondents were selected using multistage sampling techniques and after seeking each one's consent. Semi-structured questionnaires were used to collect data from the respondents, which was entered into an Excel sheet and exported to STATA (version 15) for analysis. Inferential statistics and a double hurdle regression model were used in this study. The study results revealed that an increase in the experience and group membership of a cage fish farmer by one-unit change increased the probability of using social networks by 0.43 and 0.70 units, respectively. Additionally, a unit increase in extension visits and credit access decreased the probability of using social networks by 0.59 and

Appendix J: Publication

African Journal of Rural Development, Vol. 6 (3): Jan-March, 2023: pp.191-216 ISSN 2415-2838

Impact of Informal Networks among Cage Fish Farmers on Catch Potential

J. L MUTYABA[1], M. W. NGIGI[2] and O. A. INGASIA[3]

Department of Agricultural Economics and Agribusiness Management, Egerton University, P.O. Box 536-20115, Egerton, Nakuru, Kenya

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ABSTRACT

Access to agricultural information is a critical factor, particularly among smallholder farmers in Sub-Saharan Africa. Many smallholder farmers in this region struggle on their own to access formal extension services, which limits their production potential. To circumvent this, many smallholder farmers are relying on information they share with their peers. To evaluate the impact of these information sources used by smallholder cage farmers the study employed a propensity score matching technique to compare farmers' groups relying on informal and formal sources. A comprehensive survey involved the selection of 384 respondents from thirteen distinct districts located near Lake Victoria in Uganda. The findings revealed that smallholder are cage fish farmers who rely on informal sources of information were sharing timely and relevant agricultural information with their peers about cage fish technologies. Additionally, the result from the estimated average treatment effect (ATT) revealed a difference of 4539.21622 Kilograms of fish annually over the control group and was statistically significant at t=2.32; p=0.006. In terms of fish harvested in kilograms annually for the treated group was 24627.7162, compared to 20088.5 for the untreated. Therefore, recognizing and integrating social networks into the existing policy interventions, can help in

Appendix K: Publication

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Determinants of knowledge, attitude and perception towards cage fish farming technologies among smallholder farmers in Uganda

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ABSTRACT

Cage fish farming is essential to increasing fish output, alleviating the declining capture fishery resources, and advancing aquaculture development in Uganda. There are limited studies assessing farmers' knowledge, attitude, and perceptions towards cage fish farming technology. This study assessed the knowledge, attitude, and perceptions (KAP) of fishery-dependent communities around Lake Victoria towards cage fish farming technology. Using a simple random sample approach, 384 respondents from fourteen districts provided information on demographic traits, knowledge, attitudes, and perceptions towards cage fish farming. The analysis utilized descriptive statistics and a multinomial logit model. Results revealed that cage fish farmers' knowledge, attitude, and perceptions were significantly associated with age, level of education, extension visits, social capital, experience, and television access. In conclusion, this study recommends that extension visits be enhanced to develop farmers' knowledge, attitudes, and perceptions towards cage fish farming. The study's implications underscore the importance of developing and implementing farmer-centered policies in the aquaculture sector.

PUBLIC INTEREST STATEMENT

This study focuses on the aquaculture sector in Uganda, specifically the emerging cage fish farming sub-sector and its contribution to national development under the blue economy. The study findings presented are from the 384 smallholder cage fish farmers interviewed during a survey conducted between July 2021 and February 2022. The aim was to understand their knowledge, attitudes and perceptions towards cage fish farming technologies. The study found out that Age, years in practicing cage fish farming, extension services, social capital, access to market information, number of stocked cage units owned by an individual and type of cage technology used had an effect on the fish farmers' knowledge, attitude and perceptions. The study highlights the need for an increase in extension services, education and training on marketing information related to fish produce, and appropriate policy frameworks that favour smallholder fish farmers for inclusiveness and sustainable development

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