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

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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 1.06 units, respectively. Therefore, the study recommends a paradigm shift in extension services received by smallholder farmers to embrace the use of social networks and replicate them in other agricultural sectors. Additionally, financial services should be improved among cage fish farmers to promote credit access, and the role of group membership in promoting intensive cage fish farming should be considered as well.

Keywords: *Cage fish farming; Social Interaction; Smallholder; Social network; Double hurdle*

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Introduction

In Uganda, the fisheries sector is an important foreign income earner. In 2020, the fisheries sector accounted for 2.5% of the national budget and 12.5% of agricultural gross domestic product (GDP) (Uganda Bureau of Statistics (UBOS), 2021). The sector employs 1.2 million people, generates over 100 million dollars in exports, and provides less than 50% of dietary proteins to Ugandans (Catherine, 2021). Although the sector is still significant in Uganda's economy, its performance has worsened because of continuous overfishing in the natural water bodies (FAO, 2016, 2020).

Cage fish farming is a method of growing fish intensively using locally fabricated materials such as metallic pipes, bamboo wood, and imported HDE plastics. According to Mbowa et al. (2017) and NaFiRRI (2018), there are two types of cages used in this method: High Density in

Low Volume (LVHD) cages, which have a volume of less than or equal to 30 m^3, and Low Density in High Volume (HVLD) cages, which have a volume of more than 30 m^3. These cages are suspended and secured in water, allowing for free exchange between the enclosure and the water body.

Cage fish farming has the potential to increase fish production and meet the deficit in fish supply (LVFO, 2016). The advent of cage fish farming in Uganda has been linked to the increasing demand for fish products within and outside the country (Lake Victoria Fisheries Organization (LVFO), 2021; GoU/MAAIF, 2021). The cage fish farming sub-sector is one of the fastest growing sectors in the country, contributing, on average, to about 2.3% of Uganda's GDP annually. According to FOA/FishStat (2022), cage fish production is exponentially growing at 4.6%, attracting about US$ 690 million worth of fish exported.

Although the cage fish farming sub-sector has the potential to address food insecurity and unemployment among the rural poor, more needs to be known about its key players. Smallholder cage fish farmers, who constitute the majority of players in the sub-sector, play a significant role (FAO/FishStat, 2021). A report by the Government of Uganda (GoU/MAAIF, 2022) indicates a steady annual increase in smallholder farmers participating in cage fish farming. The report also indicates that approximately 419,249 metric tonnes of fish were produced from the cage farming sub-sector.

In other words, cage fish farming technologies have demonstrated tangible results among fish-dependent communities. Cage fish farming is a source of income (Ataei. *et al*., 2019) and food security, especially in rural areas (Owani *et al*., 2022), and it also boosts marine biodiversity (Dalsgaard *et al*., 2012). Although the benefits of cage fish farming technologies are numerous and scientifically proven (Mbowa *et al*., 2017; National Fisheries Resource Research Institute (NaFiRRI), 2016a), little is empirically known about the performance of smallholder cage fish farmers.

Reviewed literature on the cage fish farming sub-sector revealed the presence of many factors that influence farmers' performance. For instance, Diiro (2013), Egge (2005), Ogada *et al*., (2014) Shiferaw *et al*. (2009, 2014), and Teklewold, (2013) 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, labour 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 the institutional factors; access to agricultural information, credit, markets for products and inputs factors, and access to extension support. In those studies, enabling policies, market access, credit access, and access to information contacts were found to play a positive role in stimulating 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), revealed that in many rural settings, access and dissemination of agricultural information is a crucial factor in determining farmer's performance. According to FAO, (2021a), around 81% of smallholder farmers in Uganda have no access to extension and advisory services. Many smallholder farmers in rural areas struggle to access agricultural information (Ssebaggala and Matovu, 2020). A report by GoU/MoFPED (2020), indicates that only 15% of generated technologies, developed 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 (GoU/MoFPED, 2020).

Ataei e*t al*. (2021), found that social networks play a critical role in diffusing agricultural information. Social networks are informal platforms that facilitate information sharing on the diversity of subjects and actors in a nonlinear manner. 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 role 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 that social networks and social learning play a role in creating awareness and dissemination of information. Additionally, Ramirez (2013), highlighted the importance of social networks in disseminating information about innovations. However, scanty literature is available on how information flows through the social links among actors and their effects in the context of the technologies they use. This study needed to explore the role of information links and flow through social networks in exposing smallholder farmers to new technologies.

In consideration of the existing knowledge gap, this study thought to explore the potential of social networks among smallholder cage fish farmers in Uganda. Specifically, it aimed to understand the role of social interactions among smallholder farmers' social networks in the adoption of cage fish farming technologies. The factors that affect the intensity of cage fish farming among smallholder farmers in Uganda were also studied. Therefore, the novelty of the study relies on the application of econometric models that show the degree to which smallholder cage fish farmers using social networks have intensified their farming activities.

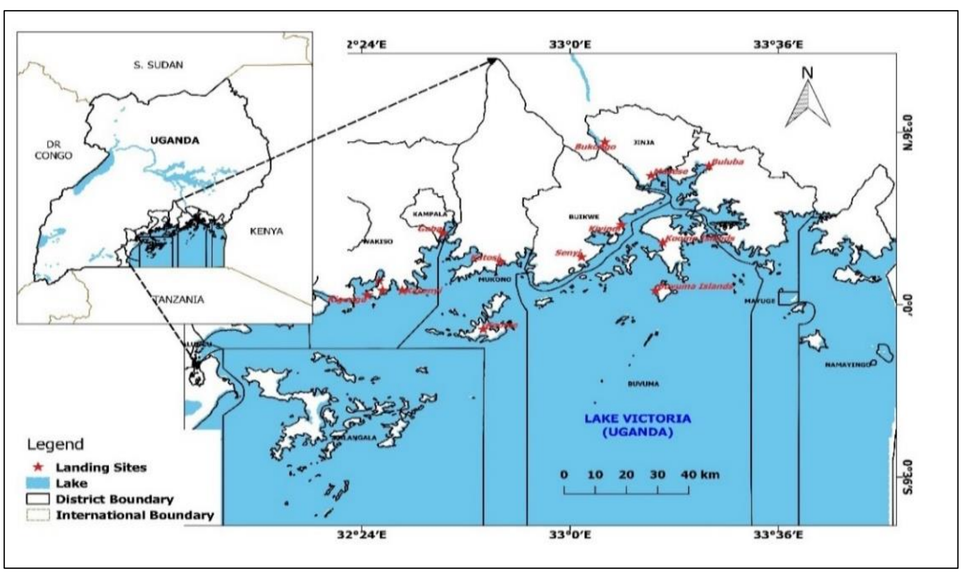
Materials and Methods

Study area

The study conducted a cross-sectional survey in fourteen districts namely; Bugiri, Buikwe, Busia, Buvuma, Jinja, Kalangala, Kampala, Kyotera, Masaka, Mayuge, Mukono, Namayingo, Rakai and Wakiso as shown in Figure 1. The fourteen districts are located along the Lake Victoria shoreline where cage fish farming is majorly practised together with capture fishing. In addition, the study area is a base of several economic activities which include trading, tourism, agriculture and water transport.

Figure 1

Map of the study area



Sample size determination

The study used a combination of purposive and random sampling techniques to determine the sample size of 384 respondents from lists of smallholder cage fish farmers generated by fisheries officers from the fourteen respective districts as presented in an, (1977) and Polonia (2013).

Table 11. Lake Victoria and the respective districts were purposively selected because cage fish farming has been promoted for years. The population of smallholder cage fish farmers in each district, formed a cluster from which a proportionate sample size was drawn using simple random techniques following Cochran, (1977) and Polonia (2013).

Table 1

Number of Smallholder cage fish farmers per district

District	**Population (N)**	**Proportionate to size (10%)**
Bugiri	271	27
Buikwe	301	30
Busia	292	29
Buvuma	262	26
Jinja	291	29
Kalangala	259	26
Kampala	302	30
Kyotera	221	22
Masaka	232	23
Mayuge	291	29
Mukono	272	27
Namayingo	290	29
Rakai	271	27
Wakiso	302	30
Total	**3,857**	**384**

Therefore, the unit of analysis for the study 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 within Lake Victoria waters in Uganda. Lastly, 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 data from the respondents was collected using semi-structured questionnaires, entered into an Excel sheet and analysed using STATA version 15 to generate statistical outputs for the study.

Measuring the nature of social interaction in a study context

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 aim was to ascertain how the individual's communication network influences decision-making (behaviour) towards the adoption of cage fish farming technologies through the formation of an intervening impact pathway (Inkoom *et al.* 2020; Kendall and Babington, 1939). The study assumed that social interaction leads to the spread of information and knowledge about cage fish farming technologies that shape a farmer`s inherent decision-making factor and thus cause the technology`s adoption and utilisation.

In addition, to assess the quality and intensity of social interaction in the farmer`s communication network, the study used a Likert scale of 1-to-5. Consequently, farmers were interviewed using questions formulated in a 1-to-5 Likert scale-based format, focusing on four main indicators of their interactions with other social actors such as fellow farmers, input dealers, extension agents, cage unit manufacturers, fish buyers, local leaders, transporters and researchers regarding cage fish farming technological issues.

Accordingly, indicative variables used to measure social interactions in the farmers` communication networks were grouped into four main components: frequency, usefulness, effectiveness, and degree of trust (Monge, 2008). The choice of the measurement scale was to allow for the possibility of estimating an approximate index of social interaction in the farmers` communication network based on the four main components. In addition, using the rating scale was considered much more effective for farmer-self assessment of the quality and intensity of their interactions with other actors regarding cage fish farming technological issues (IFAD, 2014).

Consequently, the data collected from the survey on the social interaction matrix, was summed up and mean scores were generated. To ensure the accuracy of the analysis, the Kendall coefficient of concordance (Kendall's W) was applied for a robustness check. Hence, Kendall's W is a descriptive measure that evaluates the concordance within an individual scoring structure among assessors (Kendall and Babington, 1939). It picks a value between zero and one, where zero means no agreement among assessors on the concept being evaluated, and a value of one means complete agreement. The formula used for the computation of Kendall's W was as follows:

$$w = \frac{12s}{M^2(N)(N^2-1)} \quad \ldots\ldots(1)$$

Where:

W = Coefficient of Concordance

S = sum of squared deviates from the mean rank

M = number of respondents

N = number of attributes being evaluated by the respondents.

Estimating the Intensity of adoption (number of cage units by farmers

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 assumed 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.

As a result, we used the double-hurdle model rather than Heckman's and Tobit's since they do not provide us with as much flexibility for the modelling of the two sequential decisions as in the double-hurdle model (Greene 2003). In the double-hurdle model, a farmer must go through the first hurdle (use of social networks) before choosing to increase the total number of cage units owned. To identify the variables influencing the selection of information contacts in the first tier, a probit regression is computed (decision whether or not to use social networks). In the second tier, intensity in the number of cages is determined by applying a multiple regression model. The first hurdle is a double equation estimated with a probit model which represents the probability of a limit observation and is given by:

d_i= 1 if $d_i^* > 0$ and 0 if $d_i^* \leq 0$

$d^*= Z_i\alpha + \varepsilon_i$ ……………………………………………………………………..………... (2)

Where

d_i^* = Latent variable describing whether or not adoption occurs

z = a vector of explanatory variables hypothesized to influence the choice to participate (Table 2)

α= a vector of parameters

ε =the standard error term.

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

$y_i= y_i^*$ if $y_i^* >0$ and $d_i^* >0$

y_i= 0 otherwise

$y^*= x_i\beta + \mu_i$ ……………………………………………………………………...……… (3)

Where

y_i = the observed response on the intensity of cage fish farming (number of cage units owned by the i^{th} farmer)

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.

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 to 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).

Table 2

Description of Explanatory Variables used in Analysis

Variables	Description	Expected signs
Explanatory		
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).	+/-

Results

Demographics of the Respondents

The results presented in Table 3 indicate that cage fish farmers in the study area had a mean age of (45±8.167) years, with an average education level of (12 ± 3.078) years. The respondents also had a mean household size of (5±2.109) and a mean value of (5±1.170) years of cage fish farming. In addition, the study found that the average number of cage units owned by fish farmers in the study area was (5±3.096). The average number of extension visits was (4±1.021), while the average number of social contacts was (4±1.021).

Regarding gender, male respondents constituted the majority 76.30%, while female respondents were only 23.70%. Most of the surveyed cage fish farmers (82.55%) used metallic cages, while 9.11% and 8.33% used HDE plastic cages and wooden cages, respectively. The study also explored the location of cage units in water. It found that 55.47% of the sampled respondents carried out cage fish farming within 500 meters from the lake shoreline, 22.40% between 501 to 1000 meters, and only 22.14% had cage units located beyond a kilometre away from the shoreline. The results indicated that 73.18% of the sampled farmers sold their fish produce in local markets within their communities, 16.15% to fish processing companies, and only 10.68% exported directly. Finally, the study examined the type of labour used by fish farmers. It found that 69.27% of fish farmers worked on their farms, while only 30.73% used hired labour.

Table 3

Demographic characteristics of the respondents

Variable	Obs	Mean	Std. Dev.	Min	Max
Age of a respondent	384	45	8.167	32	63
Education level	384	12	3.078	7	18
Household size	384	5	2.109	1	11
Experience in fish farming	384	4	1.170	2	8
Number of cage units owned	384	5	3.096	1	16
Extension visits	384	4	1.259	1	6
Number of social contacts	384	4	1.021	1	9

Variable	Attribute	Freq. (n=384)	Per cent (%)
Gender	Male	91	23.70
	Female	293	76.30
Type of Cages used	HDE plastic cages	35	9.11

	Metallic cages	317	82.55
	Wooden cages	32	8.33
Cage location in waters	200m away from shoreline	116	30.21
	201 to 500m away from shoreline	97	25.26
	501 to 1000m away from shoreline	86	22.40
	Beyond 1000m from shoreline	85	22.14
Target fish Market	Direct export	41	10.68
	Fish processing company	62	16.15
	Local market	281	73.18
Type of labour used	Hired	118	30.73
	Cage fish farmer	266	69.27

Analysis of farmers' social interactions
The results presented in Table 4, indicate that the frequency of farmer–to–farmer interactions at the village level was rated high with a mean score of 6.82, followed by farmers' interactions with input dealers with a mean score of 6.65. In addition, farmers' conversations on technological issues ranked third with a mean score value of 6.56. On the other hand, the farmer's social interactions which lowest included the farmers' interactions with the change agents (extension and research agents) with a mean score of 4.57 and farmers' access to information about cage fish farming technologies through media, with a mean score of 5.35.

The findings on farmers' interactions with fellow farmers at the intra-village level ranked the highest with a mean score of 6.16. That was followed by farmers' interactions with the input dealers with a mean score of 5.96. The farmers' interactions with fellow farmers at the inter-village level and Farmer's conversations with fellow farmers on technological issues each with a mean score of 5.84. On the other hand, the least ranked items were the farmers' interactions with community leaders with a mean score of 4.20. Then, followed by farmers' participation in association meetings with a mean score of 4.26. It was also observed that farmers' interaction with the change agents was among the poorly ranked items with a mean score of 4.55.

Under the category of effectiveness of social interaction, the findings, show that farmers' intra-village interactions had a mean value of 6.10, which was followed by farmers' interactions with the promoters of the cage technologies with 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).

1

Table 4

Assessing the nature of information links among the cage fish farmers' social networks

Farmers' information links in their social networks	**Frequency**		**Usefulness**		**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 (Extensionists/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**

Econometric analysis
As presented in

Table **5**, the Variance Inflation Factor (VIF) test was performed to ascertain the existence of multicollinearity in the variables used. The results indicated that all the values of categorical variables ranged from 1.02 to 1.98. All the explanatory variables tested were suitable to be included in the model since none was equal to or above 10.

Table 5

Estimation of Variance Inflation Factors (VIF)

Variable	VIF	1/VIF
Age of respondent	1.980	0.505
Target market	1.750	0.571
Group membership	1.690	0.590
Credit access	1.440	0.693
Farm location	1.040	0.961
Gender	1.030	0.974
Education level	1.020	0.981
Mean VIF	**1.421**	

Table **6** shows the results of a two-tier double hurdle model. The maximum likelihood estimates indicated that the overall Chi-square = 25.27, p-value = .0049, was significant at a 1% level showing that the model was fit to analyse the data for this study. The results showed that in the first tier, extension services, credit access, experience in cage fish farming, group membership and location of cage units in waters were statistically significant and were associated with the use of social networks among cage fish farmers.

The results further show that for the first tier, the number of extension contacts and access to credit had a negative and significant effect on the probability of cage fish farmers engaging in social networks. The results implied 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. On the other hand, a unit increase in extension visits and credit access decreased the probability of using social networks by 0.59 and 1.06 units respectively. Lastly, a unit increase location variable (distance from the shoreline into deep waters) decreases the probability of using social networks by 0.17 units.

In the second tier, credit access, type of cage unit owned, farm location, farming experience, targeted fish market and age of the respondent were statistically 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 and age increases the likelihood of decreasing the number of cage units by 5.11 and 2.14 units respectively. Additionally, a unit increase in farming experience increased the probability of cage farmers having more cage units by 1.26 units. Also, a unit change in the type of cage used from metallic to either HDE plastics or wooden increases the probability of a farmer's decision to increase the number of cage units by 0.63 units.

Table 7 shows the post-estimation results of a double hurdle model indicating the marginal effects of unit change in each explanatory variable. Results reveal that six explanatory variables, namely experience in cage farming, type of cage units used, and group, had a significant positive influence on farmers' social networks. The Wald Chi2 was 35.17 with Prob.>Chi2=0.0057, indicating that the equation explains six per cent of the variance in the model used.

Table 6

Factors influencing the use of social networks and intensity of cage fish farming

Variables	First Tier		Second Tier	
	No. of Social Contacts		**Number of Cages**	
	Parameter	**P-Value**	**Parameter**	**P-Value**
Gender	0.031	.878	0.132	.861
Extension Visit	-0.598	**.010**	0.645	.125
Credit access	-1.063	**.000**	-5.113	**.000**
Farming experience	0.431	**.056**	1.258	**.000**
Target market	0.634	.098	2.235	**.001**
Type of cage	-0.492	.217	-2.142	**.013**
Group membership	0.702	**.023**	1.958	.115
Market distance	-0.003	.577	-0.345	.312
Location of the cage units	-0.170	**.057**	-0.099	.416
Education level	0.056	.122	0.008	.698

Number of observations = **384,** Wald Chi^2 = 25.27, Prob>Chi^2 = 0.0049

Table 7

The marginal effects estimation after the double-hurdle model

Variables	dy/dx	Std. Error	z	P>z
Gender	0.031	0.201	.150	.878
Extension Visit	-0.438	0.231	-2.590	**.010**
Credit access	-1.306	0.291	-3.660	**.000**
Farming experience	0.134	0.225	1.910	**.056**
Type of cage	0.432	0.382	1.660	**.098**
Target market	-0.492	0.399	-1.230	.217
Group membership	0.302	0.308	2.280	**.023**
Market distance	-0.003	0.005	-0.560	.577
Farm location	-0.017	0.089	-1.900	**.057**
Education level	0.056	0.036	1.550	.122

Number of observations = 384, Wald Chi^2 = 35.17, Prob.>Chi^2 = 0.057

Discussions

The results from this study show that the number of extension contacts had a negative association with social networks. This means that extension visit decreases the probability of farmers engaging in social networks and was therefore 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. But in situations where extension services are limited, as portrayed in this study, then farmers would opt to use social networks as the alternatives for information. The results are consistent with the findings by (Kassa et al., 2021) who found that extension contact is one of the most critical policy variables, which favourably influences adoption intensity among smallholder farmers.

Access to credit was also negatively influenced by the decision to use social networks and the number of cage units owned. This could imply that farmers who had more access to credit were less likely to use social networks and were also less likely to increase the number of cage units. This finding indeed shows that farmers who were more credit-constrained utilized more social networks maybe as a way to find alternative financial support from fellow farmers. Credit-constrained farmers were also less likely to increase cage units owned due to the significant cost implication. This therefore means that the use of social networks is key, especially among credit-constrained farmers.

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. This 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. This 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.

The results show that Cage type was a significant factor in the intensity of cage units. As the type of cage changes from metallic to either HDE plastics or Wooden, it increases the number of cage units used by the fish farmers. 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.

Farmers’ groups had a positive and statistically significant impact at 5% on social networks as a proxy for farmers’ information contacts but had no impact on the number of cage units owned by the fish farmers. Group membership has played an essential role as an information exchange platform, sharing transaction costs, such as transport costs, allowing farmers to connect to buyers at a lower cost, thereby reducing the fixed transaction costs of participating in the market. The study results are aligned with previous studies (Shikuku, 2019) and (Mulwa et al., 2017). This had similar findings. The finding on the positive effect of members' association on intensity is consistent with those of Ghimire & Huang, (2015) on the adoption intensity of agricultural technology of maize smallholder farmers in Nepal.

Farmers who located their cage units at longer distances from the shorelines were less likely to use social networks. Farm location was found to decrease the probability of farmers engaging in social networks. This could be because the majority of these farmers tend to operate individually and not in groups as compared to those who are located close to the shoreline. This could be because farmers who were located close to the shores were able to collectively feed and harvest the fish together. So far, no literature has investigated the effects of the location of cage units on social networks.

Conclusion

This study explored the significance of social interactions among cage fish farmers in Uganda. The research was conducted in fourteen districts that share the waters of Lake Victoria. A total of 384 smallholder cage fish farmers participated in the study, selected through multistage sampling techniques and with their consent. The survey data was analysed using inferential statistics and a double hurdle model.

The findings demonstrated that social networks were utilized by the cage fish farmers if they had access to extension services, credit, farming experience, a certain type of cage, group membership, and farm location. On the other hand, credit access, farming experience, type of cage, and the target market were found to be associated with the number of cage units owned by the fish farmers.

Therefore, the study highlights the importance of social interactions in the cage fish farming sector as a means of exchanging knowledge and skills. It is recommended that appropriate extension strategies be employed to encourage the use of social networks among producers, such as farmer field schools and model farmer strategies. Additionally, financial services should be improved among cage fish farmers to promote credit access, and the role of group membership in promoting intensive cage fish farming should be considered as well.

Authors' contributions

This study was conceptualized and developed by all three authors listed on the first page.

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Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

Data for this study are available from the Department of Agricultural Economics and Agribusiness Management, Egerton University in Kenya and the authors. Data can be accessed on special request with the department's and the authors' permission.

Ethics approval and consent to participate

Ethics approval for the study was received from the Office of the President and Uganda National Council for Science and Technology (UNCST), Kampala. The smallholder cage fish farmers interviewed were also asked for consent before the commencement of the interviews.

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References

Ataei1, P., Sadighi, H., Chizari, M. and Abbasi, E. (2021). Analysis of Farmers' Social Interactions to Apply Principles of Conservation Agriculture in Iran: Application of Social Network Analysis. *J. Agr. Sci. Tech. Vol. 21(Suppl.): 1657-1671.*

Bandiera, O. and Rasul, I. (2006). Social networks and technology adoption in Northern Mozambique. *The Economic Journal, 116*, 869–902. https://doi.org/10.1111/j.1468-0297.2006.01115.x

Catherine. N. (2021). Financial Analysis of Tilapia Cage Fish Farming on Lake Victoria, Uganda: A Case Study of Pearl Aquatics Fish Farm. Thesis for the Degree of Master of Fisheries Science. Pukyong National University.

Cochran, W.G. (1977).Sampling Techniques, Wiley, New York.

Conley, T. G., & Udry, C. R. (2010). Learning about a New Technology: Pineapple in Ghana. *American Economic Review*, *100*(1), 35–69. https://doi.org/10.1257/aer.100.1.35

Cragg, J. G. (1971). Some statistical models for limited dependent variables with application to the demand for durable goods. Econometrica 39

Dalsgaard, J.P.T., Dickson, M., Jagwe, J. and Longley, C. (2012). Uganda aquaculture value chains: Strategic planning mission: Summary report, 11– 62. https://digitalarchive.worldfishcenter.org/handle/20.500.12348/1063#:~:text=https%3A//hdl.handle.net/20.500.12348/1063

Danso-Abbeam, G., Bosiako, J. A., Ehiakpor, D. S., & Mabe, F. N. (2017). Adoption of improved maize variety among farm households in the northern region of Ghana. Cogent Economics and Finance, 5(1), 0–14. https://doi.org/10.1080/23322039.2017.1416896

Diiro, G. M., (2013). Impact of off-farm income on agricultural technology adoption intensity and productivity evidence from rural maize farmers in Uganda. https://ebrary.ifpri.org/digital/api/collection/p15738coll2/id/127369/download

Egge, M., (2005). Farmers' evaluation, adoption and sustainable use of improved sorghum varieties in Jijiga Woreda, Ethiopia. https://doi.org/10.1007/s43615-021-00119-9

FAO. (2016). *The State of World Fisheries and Aquaculture. Contributing to food security and nutrition for all*. Rome. https://www.fao.org/3/a-i5555e.pdf

FAO. (2020). The State of World Fisheries and Aquaculture 2020. Rome. doi.org/10.4060/ca9229en.

FAO. (FishStat) (2022). *Global Aquaculture Production (FishStat). Food and Agriculture of United Nations,* Fisheries and Aquaculture Department. Aquaculture production (fao.org)

FAO/FishStat. (2021). *Fisheries and Aquaculture Information and Statistics Branch Rome,* FAO. Fisheries and Aquaculture Department. FAO Fisheries & Aquaculture.

FAO/FishStat. (2021). *Fisheries and Aquaculture Information and Statistics Branch Rome,* FAO. Fisheries and Aquaculture Department. FAO Fisheries & Aquaculture

Ghimire, R., & Huang, W. C. (2015). Household wealth and adoption of improved maize varieties in Nepal: a double-hurdle approach. Food Security, 7(6), 1321–1335. https://doi.org/10.1007/s12571-015-0518-x

GoU/MAAIF. (Republic of Uganda/Ministry of Agriculture Animal Industry and Fisheries). (2021). Situational Analysis of the Agriculture Sector in Uganda: Final Report; Kampala, Uganda.

GoU/MoFPED Republic of Uganda, Ministry of Finance Planning and Economic Development (2020). ANNUAL BUDGET PERFORMANCE REPORT FY 2019/20

Greene, W. H. (2003.). Seventh Edition.

Greene, W.H. (2003) Econometric Analysis. 5th Edition, Prentice Hall, Upper Saddle River.

Heckman, J. J. (2015). Chapter 5. Sample Selection Bias as a specification error with an application to the Estimation of Labor Supply Functions. Female Labor Supply, June 1975, 206–248. https://doi.org/10.1515/9781400856992.206

Heemskerk, E., Young, K., Takes, F. W., Crown, B., Javier. G. B., Henriksen L. F., Kindred. W. K., Povov. V. & Laurin. A. (2018). The promise and perils of using big data in the study of corporate networks: problems, diagnostics and fixes. Global Networks 18, 3–32. ISSN 1470–2266.

IFAD. (2014). Supervision report. Rome.

Inkoom EW, Dadzie SKN, Ndebugri J. (2020). Promoting improved agricultural technologies to increase smallholder farm production efficiency: Ghanaian study of cassava farmers. Int J Food Agric Econ. 8(3):271–94.

Kassa, Y., Giziew, A., & Ayalew, D. (2021). Determinants of adoption and intensity of improved faba bean cultivars in the central highlands of Ethiopia: a double-hurdle approach. CABI Agriculture and Bioscience, 2(1), 1–12. https://doi.org/10.1186/s43170-021-00045-8

Kendall, M.G. and Babington Smith, B. (1939) The Problem of m Rankings. The Annals of Mathematical Statistics, 10, 275-287. http://dx.doi.org/10.1214/aoms/1177732186

LVFO (Lake Victoria Fisheries Organisation). (2021). State of Lake Victoria Dagaa (Rastrineobola argentea): quantity, quality, value addition, utilisation and trade in the East African Region for improved nutrition, food security and income. Regional Synthesis Report. Jinja, Uganda, Lake Victoria Fisheries Organisation.

Mbowa S., Odokonyero, T. and Munyaho, A. T. (2017). Harnessing floating cage technology to increase fish production in Uganda. NaFiRRI, Research Series No. 138. http://dx.doi.org/10.22004/ag.econ.262886

Monge M, Hartwich F, Halgin D. (2008). How change agents and social capital influence the adoption of innovations among small farmers: Evidence from social networks in rural Bolivia. IFPRI Discussion Paper 00761, Intl Food Policy Res Inst. Washington DC, USA.

Muange, E. N. Schwarze, S., and Qaim, M., (2014). Social networks and uptake of improved cereal varieties in central Tanzania. *Journal of European Association of Agricultural Economists.* DOI: 10.22004/ag.econ.182645.

Mulwa, C., Marenya, P., Rahut, D. B., & Kassie, M. (2017). Response to climate risks among smallholder farmers in Malawi: A multivariate probit assessment of the role of information, household demographics, and farm characteristics. Climate Risk Management, 16(January), 208–221. https://doi.org/10.1016/j.crm.2017.01.002.

NaFiRRI (National Fisheries Resource Research Institute) (2016). Fishing effort and fish yield over 15 years on Lake Victoria, Uganda: management implications.

NaFiRRI (National Fisheries Resources Research Institute). (2021). Guidelines for cage fish farming in Uganda.

Owani, S., Hishamunda, N. and Cai, J. (2022). Report of the Capacity Building Workshop on Conducting Aquaculture as a Business, Mukono, Uganda, 30 July – 3 August 2012 Report/Rapport: SF-FAO/2012/06. October 2012. FAO-Smart Fish Programme of the Indian Ocean Commission, Ebene, Mauritius. Pp:10 – 25. https://www.fao.org/3/bq772e/bq772e.pdf

Polonia, A., Bonatti, E., Camerlenghi, A. (2013). Mediterranean mega turbidite triggered by the AD 365 Crete earthquake and tsunami. *Sci Rep* **3**, 1285. https://doi.org/10.1038/srep01285

Ramirez, A. (2013). The Influence of social networks on agricultural technology adoption. *Procedia - Social and Behavioural Sciences*, *79*, 101–116. https://doi.org/10.1016/j.sbspro.2013.05.059

Republic of Uganda, Ministry of Agriculture, Animal Industry and Fisheries (GoU/MAAIF) (2022). Aquaculture Road Map Uganda. Opportunities in the Aquaculture value chain.

Republic of Uganda/Ministry of Finance Economic Planning and Development. (GoU/MoFPED). (2021). Agriculture Sector Annual Budget Monitoring Report. Financial Year 2019/2020.

Sebaggala, R. and Matovu, F. (2020) Effects of Agricultural Extension Services on Farm Productivity in Uganda. Working Papers No. 379, African Economic Research Consortium, Nairobi.

Shiferaw, B. A., Okello, J., & Reddy, R. V. (2009). Adoption and adaptation of natural resource management innovations in smallholder agriculture: Reflections on key lessons and best practices. *Environment, Development and Sustainability*, *11*(3), 601–619. https://doi.org/10.1007/s10668-007-9132-1

Shiferaw, B., Kassie, M., Jaleta, M., & Yirga, C. (2014). Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food Policy*, *44*, 272–284. https://doi.org/10.1016/j.foodpol.2013.09.012

Shikuku, K. M. (2019). Information exchange links, knowledge exposure, and adoption of agricultural technologies in northern Uganda. World Development, 115, 94–106. https://doi.org/10.1016/j.worlddev.2018.11.012.

Teklewold, H., Kassie, M., & Shiferaw, B. (2013). Adoption of multiple sustainable agricultural practices in rural Ethiopia. *Journal of Agricultural Economics*, *64*(3), 597–623. https://doi.org/10.1111/1477-9552.12011.

Uganda Bureau of Statistics (UboS) (2021). Statistical Abstract Report on Annual Gross Domestic Product.