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Drivers of aquaculture adoption and disadoption: the case of pond aquaculture in Ghana

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Abstract

Although 80% of the entire terrestrial space of Ghana has the potential for pond aquaculture, ponds contribute only 7% of total aquaculture production due to low adoption, abandonment and low productivity. Successfully addressing these challenges requires empirical data on the dynamics of pond aquaculture adoption and disadoption. The study investigated determinants of pond aquaculture adoption and disadoption decisions in five regions of Ghana. A total of 400 farmers were selected from the five regions using multi-stage sampling. The Heckprobit model was employed for the analysis. Results from the selection equation indicate that age, gender, extension service, household size, water availability, membership of farmer-based groups, availability of suitable land and knowledge of pond aquaculture positively influenced adoption. The outcome equation also revealed that disadoption is negatively influenced by formal education, gender, extension service, household size, water availability and land ownership, while distance to the nearest commercial town, land tenure, experience and the transition zone (farm location) showed a positive correlation with disadoption. It is concluded that pond aquaculture adoption decisions are significantly driven by these social, economic and institutional variables and must be considered in policy formulation and in the design of extension services.

Keywords Pond · Aquaculture · Determinants · Adoption · Disadoption

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Introduction

Population increase across the world, increasing urbanization and changes in the dietary preferences of consumers, which favours fish and fish products as the most important source of protein in parts of the world, has led to a substantial increase in fish demand globally (FAO 2016a). Globally, fish constitutes 16% of the total protein intake from animal sources (World Bank 2013). Meanwhile, capture fisheries in some parts of the globe are fluctuating (FAO 2021; FAO 2018). Consequently, global marine capture registered a decrease of 5% in 2019 compared to 2018 (FAO 2021). Thus, the potential of aquaculture to address the supply deficit, contribute meaningfully to GDP, as well as reducing poverty and hunger in developing regions (Kaliba et al. 2007) has become more critical than before. Moreover, various types of aquaculture production have supported many economically vulnerable families as their source of livelihood (Golden et al. 2017; Little et al. 2016; Rashid et al. 2016).

Fortunately, Ghana is endowed with conducive edaphic, climatic and socioeconomic conditions suitable for a vibrant aquaculture industry. Furthermore, based on topography, altitude, temperature, precipitation, river networks and soils, it is estimated that 80% of the total land area of Ghana (i.e., 191,854km^2) has the potential for pond aquaculture (Asmah 2008). However, the country depends heavily on the capture fishery as over 80% of total fish production comes from marine and inland capture (Akpalu & Egert 2021; Kassam 2014; Asmah 2008; FAO 2005). Ghana supplements its domestic production of fish and fish products with over 50% imported product (Tall and Failler 2012). In fluctuating capture fisheries coupled with challenges such as increasing population, pollution of main water bodies due to mining that compromise fisheries and reduction of water levels due to climate change, output from capture sources is insufficient to deliver enough affordable protein for the increasing population (Ameyaw et al. 2021; Asiedu et al. 2021; Ragasa et al. 2018; Rurangwa et al. 2015; Tanner et al. 2014).

The aquaculture sector is considered globally as the means to significantly bridge this demand–supply gap (Ragasa et al. 2018). Consequently, Ghana is making efforts to develop the aquaculture industry to reduce fish deficit, unemployment, food insecurity and pressures on wild fishery resources and to contribute meaningfully to GDP. The two main production systems in Ghana are cage-based aquaculture (CBA) and pond-based aquaculture (PBA). Ghana's venture into aquaculture started with PBA which is still the predominant fish culture system around southern and the middle belt of the country (Amenyogbe et al. 2018; Cobbina & Eiriksdottir 2010). However, there are reports of slow growth and increasing abandonment of pond aquaculture in Ghana (Asiedu et al. 2017; Kassam 2014; Ragasa et al. 2018). An extrapolation from Ragasa et al. (2018) showed 0.6% growth for PBA, whereas CBA grew by 90% within the same period, i.e. between 2009 and 2016.

Many studies and reviews have been conducted on pond aquaculture in Ghana in the areas such as the potentials, production, profitability and constraints but not in the area of the factors that influence the decision of farmers to adopt or disadopt pond aquaculture. Although Ansah (2014) looked at the determining factors of the simultaneous adoption of two best management practices (water reuse and commercial fish feed) in ponds, a broad investigation into the determinants of the adoption and disadoption of pond aquaculture as a whole in Ghana is not available.

This study sought to fill that knowledge gap by providing information on the factors that drive pond aquaculture adoption and disadoption decisions for policy direction and growth of the sector.

Materials and methods

The study made use of both primary and secondary data. Quantitative and qualitative approaches were employed in analyzing the data. Descriptive statistics such as means and percentages were used for the analyses to enhance better understanding of the sociodemographic characteristic of the respondents, while an econometric model (Heckprobit) was employed to identify the determinants of adoption and disadoption.

Study area

The research was carried out in the southern (specifically the forest zone) and the Middle belt (the transition zone) of Ghana. The transition zone which falls within the agro-climatological Zone C as shown in Fig. 1 comprises the Bono, Bono East and the Ahafo regions.

The Transition Zone stretches from the tropical forest in the south-west to the Guinea Savanna areas of the north. According to Egyir et al. (2014), "It runs from west to east from approximately 5°N to 8°N in accordance with the regional rainfall pattern". The zone is characterized by erratic rains at the beginning of each rainy season and similarly so at the start of the short dry spell (Asare-Nuamah and Botchway 2019; Owusu and Waylen 2013). According to Owusu and Waylen (2013), this variability is due to the effects of global climate change. The transition zone (zone C) has annual rainfall of 1300 (mm/year) compared

Fig. 1 Ghana's Agro-Ecological Zones indicating the Transitional Zone (C) and the Forest Zone (B) according to the Meteorological Agency of Ghana (Egyir et al. 2014)

to the forest zones (zone B) which ranges from 1500 to 2200 (mm/year). The variability in temperature, rainfall and the reduction in the amount of rain in the zone poses a serious threat to sustainable pond aquaculture. Southern Ghana falls within the agro-climatological zones A and B as shown in Fig. 1. It consists of seven (7) administrative regions, including the Greater Accra, Eastern, Volta, Central, Western, Western North and Ashanti.

Literature indicates that aquaculture is concentrated mostly in five regions of Ghana: Ashanti, Western, Volta, Brong-Ahafo (now divided into the Ahafo, Bono and Bono East regions) and Eastern regions (Anane-Taabeah et al. 2015; Asmah 2008). The Ahafo, Bono and Bono East regions were selected from the transition zone (zone C) while the Eastern and the Western regions were selected from the forest zone (i.e. zone B). These regions have been purposively chosen due to their suitability for pond aquaculture and the higher number of fish farmers in those regions (Ansah 2014; Kassam 2014; Asmah 2008). Additionally, issues of low adoption, abandonment and low output have been reported from these areas (Asiedu et al. 2017; Kassam 2014). The transition zone was selected to assess and predict any unique trend in the adoption and disadoption situations vis a vis the climate variability and change associated with the zone.

Sampling and data collection

A semi-structured questionnaire coded in the Open Data Kit (ODK) tool was administered face to face to the randomly selected respondents. Due to the nature of pond aquaculture whereby ponds are mostly found where geographical conditions are favourable, two regions from southern Ghana and three regions from the middle belt (transition zone) of Ghana were purposively selected. The locations of pond owners in these regions were mapped through the help of the Ministry of Fisheries and Aquaculture Development (MoFAD) field officers. The list was used to firstly conduct a stratified random sampling of the pond owners into adopter and disadopter strata. Per the location information, 150 respondents from each stratum were selected through simple random sampling. A systematic random sampling was subsequently used to select 100 non-adopters, giving a total of 400 respondents. The calculation of the total sample size followed Anderson et al. (2011) under the unknown population scenario.

The survey targeted small- to medium-scale commercial farmers involved in crop or animal husbandry as major or minor occupation. These famers were selected as adopters, disadopters and non-adopters. The adopters category is made up of people who were practising pond aquaculture for at least the past two production cycles. Disadopters were people who ever practiced pond aquaculture but stopped within the past 2 years. Non-adopters were people involved in farming who are potential adopters but had never practiced pond aquaculture. The selection was not based on whether the land was owned or otherwise. However, respondents in the adopters and disadopters groups were all pond owners who are in charge of the decision to adopt or abandon pond aquaculture rather than the labourers.

Method of analyses

The study employed both descriptive and econometric procedures in analysing the data. Collected data was exported to Microsoft Excel and analysed using STATA 15. A qualitative and quantitative assessment of the level of awareness of pond aquaculture was performed as part of the study. The product, Knowledge Level Index (KLI), was used in the two stage Heckman model as an explanatory variable. Similarly, a Weighted Mean Index

(WMI) on the perception of respondents about pond aquaculture was obtained through a five-point Likert scale and the index was added to the explanatory variables. To satisfy basic assumptions of the econometric models employed in this study, pairwise correlation matrix, heteroscedasticity and multicollinearity tests were conducted on data sets before the regression. The socioeconomic and institutional variables for the regression analysis with the a priori expectations are presented in Table 1 below.

Modelling of the Knowledge Level Index (KLI)

Knowledge level is very crucial at the persuasion and decision-making stages of technology adoption (Blythe et al. 2017; Rogers 1995, 2010). The study therefore performed a quantitative assessment of the level of awareness, and the outcome was included in the independent variables to understand its influence on adoption. Respondents who were aware of pond aquaculture were further engaged on the extent of knowledge using ten key important aquaculture production practices. These parameters included cultured species, culture units, site selection, pond construction, stocking, fingerling production, water management, feeds and feed formulation, feeding and harvesting. Knowledge on each parameter from the respondents was weighted and coded on a Likert scale of one to five (1–5) as no knowledge (NK) = 0, very low = 1, low = 2, high = 3 and very high = 4. A check list was provided on expected basic knowledge on each practice or process for the rating. The Knowledge Level Index (KLI) from a five-point scale was modelled as specified below in Eq. (1) to analyze the responses.

$$\mathrm{KLI} = \sum \left(\mathrm{P}_i/\mathrm{W}_i\right) \tag{1}$$

Table 1 Socioeconomic and institutional variables used in the regression

Variable	Description	A priori expectation	
		Adoption	Disadoption
Age	Age of respondent	-	+
Education	Years of schooling	+	-
Gender	Male 1 = female = 0	+	-
Extension	Access to regular extension service (yes = 1, no = 0)	+	-
Experience	Years in fish farming	+	-
Memgrp	Membership of farmer groups (yes = 1, no = 0)	+	-
Knowledge	Mean knowledge of pond aquaculture	+	-
Watersupply	Months of enough water for pond culture in a year (yes = 1, no = 0)	+	-
Landsize	Size of land owned (acre)	+	-
Labour	Hand or ability to hire labour (yes = 1, no = 0)	+	-
Occupation	Major: Fish farming = 1, no = 0	+	-
Distcomcity	Distance to major commercial town (km)	-	+
Fishprice	Sales price/kg (Gh¢)	+	-
Pondsize	Pond size (m^2)		-
Location	Ecological zone (transition = 1 forest = 0)	-	+
Perception	On risk, profit, labour, financing, complexity	±	±

where Pi denotes the level of response to the ith parameter, and Wi represents the highest value of the ith parameter.

The Weighted Mean Index (WMI) for perception

Perception about pond aquaculture was also assessed and included in the independent variables due to its reported influence on adoption and disadoption decisions (Kumar et al. 2018; Wandji et al. 2012; Adesina and Zinnah 1993). Farmers' perception about pond aquaculture was evaluated using five key parameters on a normal 1 to 5 Likert scale where 1, 2, 3, 4 and 5 were the scores for strongly agree, agree, neutral, disagree and strongly disagree, respectively.

Farmers were asked if pond aquaculture was less profitable, complex, labour intensive, capital intensive and risky. The responses were used in calculating a perception index for the regression.

Following Onumah et al. (2020), a Weighted Mean Index (WMI) computed as expressed in Eq. (2) from the answers provided by respondent.

$$\mathrm{WMI} = \left(\varnothing_i^* \beta_i\right) / \delta \quad (2)$$

where $\varnothing i$ is the rate of response to the ith parameter, βi is the weight of the ith parameter and δ is the summation of responses.

Modelling of adoption and disadoption

Previous researchers applied the multinomial logit and the logit models to investigate the factors that influence the adoption of technologies. For example, Grabowski et al. (2016) used the multinomial model to examine factors that affect the uptake and abandonment of conservation agriculture in Zambia. Yet, the decision to abandon an innovation can only take place if the farmer in the first place had accepted the innovation. Thus, the decision by the farmer to adopt or abandon pond aquaculture is a two-step procedure.

Therefore, it would be more appropriate to model such a study after a two-stage model such as the Heckman's sample selection model (Heckman 1976) to take care of possible biases that could arise during decision-making by the farmer. Since the Heckman model truncates the process in the second stage (i.e. dropping non-adaptors), there is the likelihood that the sub-sample is non-random. As this situation could create a condition of sample selection bias (Mantey et al. 2020;Deressa et al. 2011), the Heckman's sample selection estimator is particularly modelled to correct any biasness in the selection process. This clearly affirms the appropriateness of the Heckman's sample selection model over the multinomial logit regression.

This study consequently chose the Heckprobit model with the Inverse Mills Ratios (IMR) embedded in the outcome equation to address any selection bias (Heckman 1979; Van de Ven and Van Praag 1981). Previous researchers including Asrat and Simane (2018), D'Souza and Mishra (2018) and Deressa et al. (2011) settled on the Heckprobit to examine perception, climate change adaptation and adoption of partial conservation agriculture by farmers. As the Heckprobit necessitates, at least a single explanatory variable which was not part of the outcome equation (i.e. the exclusion restriction) was incorporated in the selection equation to ensure non-collinearity (Bushway et al. 2007; Sartori 2003).

Specification of the Heckman sample selection model

One property of The Heckman sample selection model is the assumption of the presence of an in-built interaction (the latent equation).

$$Y_j^* = X_j\beta + u_{1j} \tag{3}$$

This means that observation is only made of the binary outcome, i.e. an image of a probit model:

$$Y_j^{probit} = (Y_j^* > 0) \tag{4}$$

X_j is a vector of the socioeconomic and institutional variables that may influence adoption and disadoption decisions, β is a vector of the estimated parameters and u_{1j} is the error term. The dependent variable is mostly unobserved but an observation is made of the independent variable:

$$Y_j^{select} = (z_j\gamma + u_{2j} > 0) \tag{5}$$

where:

$$\mathrm{u}_1 \sim \mathrm{N}(01)$$

$$\mathrm{u}_2 \sim \mathrm{N}(0,1)$$

$$\mathrm{corr}\left(\mathrm{u}_1, \mathrm{u}_2\right) - \rho$$

where Y_j^{select} denotes the dependent variable (adoption), i.e. if the respondent is an adopter of pond aquaculture or not, and z represents independent variables which are supposed to have an effect on adoption; γ depicts the estimated parameter, u_{2j} is the error term, while u_1 and u_2 are the normally distributed error terms with zero mean and unit variance. The decision to adopt pond aquaculture is assessed at the first stage by the selection equation (Eq. 5), while the abandonment is assessed at the second stage by the outcome equation (Eq. 3). Thus application of the standard probit to the first stage would possibly produce a biased results where $\rho \neq 0$ (Asrat and Simane 2018; Van de Ven and Van Praag 1981). The Heckprobit therefore offers reliable, asymptotically unbiased and accurate estimates for all the variables in models of this kind.

Results and discussion

Socioeconomic and demographic characteristics of respondents

Table 1 presents the sociodemographic profile of the respondents. The mean ages were 50.16, 42.15 and 48.11 for adopters, non-adopters and disadopters, respectively. The pooled mean age was 47.29. Those between the ages of 18–39 constitute only 26% of pond farmers (Table 2). This is an indication that up to 60% of respondents are above the youth category (i.e. 15–35 years) as per the definition of GSS (2020).

This confirms the Ghana Statistical Service report (2020) which stated that 82.9% of persons engaged in aquaculture are 36 years or older and those within the age group of 15–35 forms only 16.2% of persons involved in pond aquaculture in Ghana. The

Table 2 Demographic and socioeconomic background of respondents

Variable	Number	Percentage	Mean	SD
Age			47.29	11.76
20–29	20	5.61		
30–39	78	21.92		
40–49	96	26.98		
50–59	103	28.95		
60–69	51	14.31		
70–79	7	1.96		
80 +	1	0.28		
Total	356	100.00		
Gender				
Male (Yes = 1)	287	81.18	0.811	0.39
Educational background				
None	24	6.74	11.33	5.08
Primary	30	8.43		
Junior high/middle school	98	27.53		
Secondary/senior high school	86	24.16		
Tertiary	118	33.15		
Total	356	100.00		
Household size				
1–5	160	44.93	6.35	3.39
6–10	165	46.35		
11–15	22	6.17		
15–20	6	1.68		
20 +	3	0.84		
Total	356	100.00		
Experience				
1–10	220	86.18	6.80	5.40
11–20	31	11.88		
21–30	3	1.20		
31 +	2	0.79		
Total	356	100.00		
Pond size (m^2)				
1–100	10	6.51	1583.35	2255.81
101–500	55	35.87		
501–1000	29	18.89		
1001–5000	48	31.28		
5001–10,000	8	5.2		
10,001–15,000	3	1.95		
Total	152	99.7		

Authors' field survey, 2020

mean age for adopters (50.16) is confirmed by Blythe et al. (2017) and also Agberkpornu et al. (2019) who reported that majority of those who practice aquaculture in Ghana are above the active labour force category. The decision to adopt or reject an innovation demands maturity and risk tolerance which are attributes of the older age group (Okoronkwo and Ume 2013). This could be explained as the consequence of the perception that fish farming is labour and capital intensive. It is therefore possible that family labour, availability of land and financial capacity of older farmers means they are better positioned to adopt pond aquaculture than the youth.

Pond sizes range between 12 and 13,500m^2. The average pond size was 1,547.32m^2 (0.15 ha). The figures, as shown in Table 2, indicate a very high number of smallholdings. This could be attributed to the many complains by farmers regarding lack of capital for expansion. Literacy is typically critical for the growth of the fisheries and aquaculture sub-sector because the farmer's level of educational is expected to influence dexterity, knowledge level, adoption and the intensity of adoption (Asmah 2008). The highest mean years of schooling (13.07) among adopters and the lowest (9.63) among non-adopters confirm that education is a potential determinant of adoption.

This study further reveals that 33.15%, 27.53% and 24.16% of the respondents have attained tertiary, Junior High and Senior High School education levels, respectively. This result, in line with Agberkpornu et al. (2019), indicates that most of the farmers interviewed have good education up to tertiary level. Next to tertiary is the Junior High school (including Middle school) level while very few (6.74%) are illiterate.

The study again found the average household size to be 6.35 persons. The findings confirm Agberkpornu et al. (2019), who found an average of 6 person per household among fish farmers in Ghana. The result indicates that the adopters have the biggest average household size, while those with the smallest are the non-adopters. The mean household size for adopters, disadopters and non-adopters were 7.39, 5.92 and 5.37, respectively. This result may be attributed to the availability of family labour and financial support from family members (Agbekpornu et al. 2019).

The majority (81%) of the farmers were males. Specifically, 97% of adopters and 92% of disadopters were male. This finding agrees with the Ghana Statistical Service (GSS) report, GSS (2020) which stated that about 95% of persons engaged in aquaculture are males. The probable cause of male dominance is the assertion that fish farming is considered laborious and energy demanding (Agbekpornu et al. 2019; Obiero et al. 2019). Thus just a limited number of women are able to use their own energy or to solely employ external labour. Some associated tasks with pond aquaculture activities such as pond construction, feed preparation and harvesting may discourage many women from adopting pond aquaculture. This result agrees with Antwi et al. (2017), Nunoo et al. (2014) and Asmah (2008) on the male dominance in the sector. According to GSS (2020), women contribution to the industry is rather significant at the post-harvest level, mostly as processors and marketers.

The results show that 58% and 36% of the adopters and disadopters, respectively, were members of farmer-based associations (Table 3).

This finding is confirmed in similar studies (Mantey et al. 2020; Joffre et al. 2019; Kirsten et al. 2008) where the affiliation of respondents to farmer-based groupings has a positive influence on their decision to adopt pond aquaculture. Additionally, Chuchird et al. (2017) found that being a member of a group positively influenced the acceptance of agricultural irrigation technologies by Thailand rice farmers.

Table 3 Sociodemographic and institutional parameters by category

Variable	Adopters $N=146$	Disadopters $N=106$	Non-adopters $N=104$	Pooled $N=356$
	Mean/Std. Dev			
Age	50.36 (12.13)	48.11 (11.53)	42.15 (9.66)	47.29 (11.76)
Gender (male = 1)	0.97 (0.18)	0.92 (0.28)	0.49 (0.50)	0.811 (0.39)
Years spent in school (education)	13.07 (4.65)	10.613 (5.37	9.63 (4.67)	11.33 (5.09)
Household size (persons/HH)	7.39 (4.29)	5.92 (2.21)	5.38 (2.48)	6.36 (3.39)
Access to extension (days/Yr)	7.82 (4.62)	3.95 (4.35)	1.94 (3.12)	5.04 (4.86)
Access to credit (yes = 1)	0.56 (0.50)	0.52 (0.50)	0.423 (0.50)	0.51 (0.50)
Water supply (months/Yr)	10.64 (2.42)	9.33 (2.58)	7.85 (2.84)	9.43 (2.84)
Access to suitable land (yes = 1)	0.93 (0.25)	0.86 (0.35)	0.57 (0.50)	0.81 (0.40)
Land ownership (owned = 1)	0.82 (0.38)	0.43 (0.50)	0.34 (0.47)	0.56 (0.50)
Distance to nearest commercial town (Km)	5.99 (20.73)	7.23 (33.63)	2.52 (10.80)	5.35 (23.392)
Member of farmer-based group(s) (Yes = 1)	0.58 (0.49)	0.55 (0.50)	0.35 (0.48)	0.50 (0.50)
Awareness level index (0–1)	0.459 (0.14)	0.51 (0.11)	0.31 (0.09)	0.43 (0.14)
Perception index (0–1)	0.78 (0.11)	0.80 (0.11)	0.67 (0.10)	0.75 (0.12)
Annual income (Gh. Cedis)	33,794.54 (60,409.09)	19,079.91 (34,720.56)	19,370.15 (53,320.33)	25,199.36 (52,187.26)

Authors' field survey, 2020. **Standard errors are in parentheses*

Reasons for abandonment

Table 4 reports the reasons given by farmers as to why they abandoned pond aquaculture. The most common reason given by farmers for abandonment was financial constraints (40%). This is followed by fish mortality (29%). Poor market structure for selling output was the third reason and scored 10%. Low profits and input constraints also constituted 6% and 4%, respectively. Meanwhile, 9% of respondents cited a combination of financial constraints and fish mortality, whist 2% mentioned financial constraints, input constraints and fish mortality.

Financial constraints emerging as the principal precursor of abandonment is in line with Ansah (2014), who reported the absence of finance for aquaculture as one of the biggest challenges of fish farmers in Ghana. The nonexistence of financial support for fish farmers was also identified by Asiedu et al. (2017) as one of the key grounds of pond rejection in the Sunyani zonal fishing area of Ghana. The second most frequent reasons for abandonment is consistent with Chinabut (2002) and Mantey et al. (2020) who reported abandonment of cages by fish farmers in Thailand and Ghana, respectively, owing to tilapia mortality.

Determining factors of pond aquaculture adoption and disadoption

The assumptions and fitness of the model adopted for the analyses (the Heckprobit) was verified to validate its appropriateness. The Wald test of independence of specifications and the significance level of the coefficient for artrho (wald chi^2 (1) 4.80, $p > 0.029$) is consistent and suggests that the null hypothesis which postulates absence of a relationship between the error terms of the outcome and the selection equations is overruled. Thus controlling for selection bias in estimating determinants of disadoption is appropriate. Moreover, the log likelihood was 1 percent significant (− 191.071), Wald chi^2 (15) = 107.63, prob > chi2 = 0.000), signifying a high explanatory capability and fitness of the model. Table 5 presents the estimates and marginal effects of the factors that determine adoption and abandonment of pond aquaculture, respectively.

Determinants of pond aquaculture adoption

The first stage of the Heckprobit model (Table 5) determined the factors that influence the adoption of pond aquaculture. Out of fifteen explanatory variables, eight variables were significant. These were gender, extension service, household size, water availability, membership of farmer based groups, availability of suitable land, knowledge of pond aquaculture and distance to nearest commercial city.

Age was positively correlated with the selection equation (adoption). This result indicates that as age increases, the likelihood of adopting pond aquaculture increases. Specifically, an increase in age by 1 year increases the probability to adopt pond aquaculture by 0.2%. The largest age group (50–59) and the mean age (47 years) confirm that farmers who are older are more likely to adopt pond aquaculture than the younger farmers (15–35 years).

The result is consistent with Asmah (2008) and Anane-Taabeah et al. (2015) who stated that "fish farmers in Ghana are among the active and productive population". This trend could be as a result of the older respondents having access to natural and capital resources such as land and larger household sizes as alluded to by Blythe et al. (2017) and Kapanda

Table 4 Reasons for disadoption of pond aquaculture

	Reason	Frequency	Percent
1	Financial constraints	40	40.0
2	Fish mortality	29	29.0
3	Poor market structure	10	10.0
4	Financial constraints and fish mortality	9	9.0
5	Low profit	6	6.0
6	Input constraints	4	4.0
7	Financial constraint, input constraint and fish mortality	2	2.0
Total		100	100.0

Authors' field survey, 2020

et al. (2005). It is also asserted by Okoronkwo and Ume (2013) that adoption decisions require maturity and adventure, attributes which are characteristic of persons within the older age group.

The result reveals that gender (the respondent being male) has a positive correlation with adoption of pond aquaculture. This implies that male respondents particularly have higher probability of adopting pond aquaculture compared to female counterparts. The selection equation revealed that an increase in male population by one increases adoption by 16%. This possibly is as a result of the perception of pond aquaculture being complex and labour intensive (Mantey et al. 2020; Wandji et al. 2012). Additionally, capital and natural resources are usually controlled by household heads who are mostly men in most African cultures (Obiero et al. 2019; Kapanda et al. 2005).

The results of the selection equation (adoption) showed that frequency of extension service is positively correlated with adoption of pond aquaculture. An increase in access to extension services by one additional day enhanced the probability to adopt by 2%. This finding is attributable to the understanding that extension services timeously provide knowledge on policies, incentives, skills and on new technologies (Mantey et al. 2020; Kumar et al. 2018; Engle 2017). Moreover, the information and technical assistance offered by extension services possibly increased awareness and knowledge which led to a reduction in negative perceptions regarding profitability, risk, complexity and compatibility.

Household size which was a proxy for workforce had a positive relationship with the selection equation. The result indicates that an increase in household size by one person increases adoption by 1%. This implies that labour availability is a determinant of sustainable pond aquaculture since households with sufficient labour supply are likely to adopt pond aquaculture. This result agrees with the assertions of Agbekpornu et al. (2019) and Danso-Abbeam et al. (2018) that bigger households are inclined to have greater labour capacity and financial support from family members towards the adoption of an innovation compared to smaller households.

Water supply had a strong positive correlation with the selection equation. An increase in water availability by 1 additional month will increase adoption by 2%. This implies that the duration of sufficient water for filling of the pond plays a relevant role in the adoption of pond aquaculture. This is because if the duration of sufficient water is long, it should be possible for farmers to produce bigger fish or grow fish more than once in a year (Assefa

Table 5 Parameter estimates of the Heckprobit for adoption and disadoption

	Selection equation (adoption)			Outcome equation (disadoption)		
Independent variables	Coef./St. Err	$P>\|z\|$	dy/dx	Coef./St. Err	$P>\|z\|$	dy/dx
Age	0.017 (0.011)	0.089*	0.002	0.001 (0.008)	0.873	0.002
Education	0.019 (0.023)	0.395	0.003	−0.032 (0.019)	0.083*	−0.006
Gender (Male)	1.215 (0.261)	0.000***	0.162	−0.556 (0.305)	0.068*	−0.051
Extension	0.115 (0.025)	0.000***	0.015	−0.126 (0.022)	0.000***	−0.032
Income	−2.123 (3.055)	0.487	−0.000	2.111 (2.633)	0.424	−0.000
Household	0.067 (0.039)	0.085*	0.009	−0.088 (0.034)	0.011**	−0.019
Watersupply	0.107 (0.044)	0.015**	0.014	−0.137 (0.040)	0.001***	−0.033
Membfgrp	0.414 (0.228)	0.069*	0.055	−0.225 (0.205)	0.272	−0.035
Suitland	0.794 (0.277)	0.004***	0.106	−0.526 (0.318)	0.057*	−0.115
Knowindx	6.736 (0.911)	0.000***	0.900	0.145 (0.770)	0.850	0.461
DistComCity	0.006 (0.008)	0.481	0.001	0.007 (0.003)	0.040**	0.002
Lndowned	0.043 (0.241)	0.858	0.006	−0.801 (0.198)	0.000***	−0.233
NegPercIndx	60.588 (0.514)	0.253	0.079	2.090 (0.861)	0.015**	0.608
Landsiz	0.007 (0.012)	0.558	−0.001			
Experience	-	-		0.039 (0.015)	0.011**	0.008
Location (Trans. zone)	−0.139 (0.256)	0.588	0.018	0.355 (0.211)	0.092*	0.086

*** $p<0.01$, ** $p<0.05$, * $p<0.1$; standard errors are in parentheses; dy/dx for factor levels is the discrete change from the base level.

and Abebe 2018). This will motivate them to stay in business and encourage other farmers to adopt pond aquaculture.

Membership of farmer groups was positively related with adoption of pond aquaculture. A unit increase in farmers belonging to a farmer group will increase adoption by 6%. This relationship implies that group membership is an excellent mechanism in the promotion and sustainability of pond aquaculture. This is due to the fact that farmers who belong to farmer-based organization (especially fish farmer groups) are likely to benefit from information sharing, method and result demonstration, economic and technical cooperation and other benefits from group members (Ankrah-Twumasi et al. 2021; Mantey et al. 2020; Joffre et al. 2019). This finding is in agreement with Caviglia-Harris (2003) who found the role played by local cooperatives and associations in the adoption of apiculture, pisciculture and agroforestry as very significant.

The availability of suitable land for pond aquaculture had positive correlation with adoption of pond aquaculture. This implies that the decision to practice pond aquaculture is determined by the availability of land that has the right chemical and physical properties for pond aquaculture. The result indicates that an increase in suitable land by 1 ha will increase adoption by 11%.

The level of knowledge of pond aquaculture was a strongly significant and a positively correlated with adoption. The implication of this result is that pond aquaculture adoption increases as the level of its knowledge increases among potential adopters. The study reveals that 1% increase in the knowledge of pond aquaculture among respondents will increase the probability of adoption by 90%. Insufficient knowledge was identified by Thierfelder et al. (2015) as an impediment to embracing conservation agriculture in southern Africa. Absence of technical knowhow was recognized as a major obstacle in adopting aquaculture technologies in Malawi (Dey et al. 2006; Pemsl et al. 2006) and the USA (Kumar 2015). It was also identified as a precursor for the disadoption of aquaculture technologies in Malawi (Dey et al. 2006). This finding could be attributed to the fact that sufficient knowledge about an innovation results in favourable perceptions, easy execution of technical operations and the making of informed managerial decisions. Knowledge of pond aquaculture is therefore a key determinant of adoption and disadoption of pond aquaculture.

Determinants of pond aquaculture disadoption

The second stage of the two stage regression model (Table 5) analysed the determinants of disadoption of pond aquaculture. Out of fifteen explanatory variables, eleven variables were significant and therefore are said to influence the disadoption of pond aquaculture. Seven (7) variables, namely formal education, gender, extension service, household size, water availability, membership of farmer based groups, availability of suitable land, knowledge of pond aquaculture and land tenure showed negative correlation with disadoption while the remaining four (4) i.e. distance to nearest commercial town, perception about pond aquaculture, experience, and geographical location (the transition agro-ecological zone of Ghana) showed a positive relationship with disadoption.

The results of the outcome equation (disadoption) indicate a negative correlation between formal education and disadoption. This result indicated that the better the education level of the respondent, the lower the probability that he or she will disadopt pond aquaculture. An increase by 1 year in the number of years spent in school will reduce the likelihood of disadopting pond aquaculture by 0.6%. The results is in agreement with D'Souza and Mishra (2018), whose findings suggested that household heads who are better educated have less probability to abandon partial conservation agriculture in South Asia. According to Spenser and Byerlee (1976), aquaculturists who have highly skilled labour often exhibit high technical efficiency due to their ability to reduce technical complexities. Such farms will usually accept innovations because they have expertise to make an innovation productive (Dey et al. 2005). Thus, a higher level of education gives farmers better standing in accessing, interpreting and applying information relating to management of seemingly complex innovations and technologies. This leads to efficient operation and lower tendency to abandon or disadopt.

The results of the outcome (disadoption) equation showed that frequency of extension service negatively correlated with disadoption. This relationship is attributable to the role of extension services in educating beneficiaries on policies, incentives, practices and innovation (Mantey et al. 2020; Kumar et al. 2018). Furthermore, the information and technical assistance offered by extension services possibly increased knowledge level and productivity. All other factors held constant, the existence of effective extension services should increase farmers' knowledge and dexterity for desirable profit margins thereby reducing the tendency to disadopt pond aquaculture.

Analysis of gender (respondent being a male) showed a negative correlation with disadoption of pond aquaculture. The result indicates that an increase by one additional male adopter will reduce the probability of disadoption by 5%. The higher probability of disadoption among women adopters is possibly due to labour demanding nature of some activities such as pond preparation and harvesting especially if the farmer lacks the financial resources for hired labour. Quddus et al. (2018) reported 20% participation of women in both pond preparation and harvesting compared to feeding for instance which recorded 60% participation.

Household size which was used as a proxy for labour availability had a negative relationship with the outcome equation. The result indicates that an increase in the household size by one person will decrease disadoption by 2%. This implies that the likelihood of households with sufficient labour supply not disadopting pond aquaculture is higher. Danso-Abbeam et al. (2018) asserted that labour availability is a characteristic of lager households which gives them better leverage to adopt innovations than farmers with smaller household sizes. The high labour demand could also be as a result of over dependence on obsolete and labour intensive aquaculture practices. Manually digging of ponds instead of using excavators, aerating ponds with long bamboo sticks instead of motorised aerators and manual preparation of self-made feeds which were discovered during the survey are all high labour demanding activities.

Water supply (duration of sufficient water availability in months per year) had a strong negative correlation with disadoption in the outcome equation. This finding implies that the seasonality of water supply for filling of the pond plays a relevant role in the decision to disadopt or not to disadopt pond aquaculture. The result revealed that a unit increase in water supply will decrease disadoption by 3.3%. This is because if the duration of water availability is adequately extended, farmers are able to produce standard size fish and possibly produce at least two cycles in a year (Assefa and Abebe 2018). This will reduce disadoption because as farmers are motivated by the good output, they will be willing to continue practicing pond aquaculture.

The availability of suitable land for pond aquaculture is negatively correlated with disadoption of pond aquaculture. The results indicate that the availability of suitable land could reduce disadoption of pond aquaculture by 12%. This finding is in line with Obiero et al. (2019) who reported that inaccessibility of land by women and young people was a serious limitation to their participation in the aquaculture sector. Disadoption based on unavailability of suitable land was partly due to unfavourable leasehold condition and the emerging rapid use of wetlands for building purposes.

Freehold land ownership was also found to have a negative correlation with the outcome equation (disadoption). The result reveals that 1% increase in freehold land tenure will decrease disadoption by 23%. This result is consistent with other studies where limited land and unfavourable tenure arrangements were reported as some of the key factors that hindered aquaculture adoption in Zambia (Harrison 1995) and in rural India (FAO 2005).

Distance from farms to the nearest commercial town had a positive correlation with disadoption. An increase by 1 km in the distance from the farm to nearest commercial town will lead to a 0.2% increase in the disadoption of pond aquaculture. This can be attributed to the accessibility difficulties encountered by extension workers and fish buyers who are mainly stationed in the big towns. It also can be as a result of the difficulty in conveying inputs from these commercial cities to the farm and output from the farms to the bigger markets in those cities. This fact confirms assertions by earlier researches that proximity to research centres, innovation and experimental centres (Kumar 2015), fingerlings and feed suppliers (Csavas 1994) facilitates aquaculture adoption and operations. Meanwhile, this study revealed that most of these institutions and facilities are mostly available in commercial towns rather than in the rural farming communities where most farms are located.

Unfavourable perception about pond aquaculture (complexity, labour intensiveness, capital intensiveness and riskiness) showed a positive relationship with disadoption. Risk and complexity were similarly found to have a negative correlation with adoption probability in a study to examine the socioeconomic challenges that are hindering the development of aquaculture in West Cameroon (Wandji et al. 2012). One percent increase in negative perception about pond aquaculture will increase the tendency to disadopt pond aquaculture by 60%. Low adoption of modern aquaculture technologies, low frequency of extension visits and inadequate capital injection could be the reasons for the negative perception among the respondents. This is because detailed analysis of data on perception among respondents reveals that some farmers see pond aquaculture as risky, labour intensive, capital intensive and complex. The results confirmed the findings of Kumar et al. (2018) and Adesina and Zinnah (1993) who asserted that farmers' view of the nature of an agricultural technology significantly influence their attitude towards its adoption.

Contrary to the a priori expectation, experience (the number of years in fish farming) had a positive relationship with disadoption. Precisely, one additional year of experience increases the probability of pond aquaculture disadoption by 0.08%. This implies that farmers who practice pond aquaculture for years are more likely to disadopt than new entrants. The higher disadoption among those who have practiced pond aquaculture for more years could be attributed to the numerous challenges facing the aquaculture subsector as highlighted by the Fisheries Commission of Ghana (FCG 2012) which potentially affected smooth operation, profitability and sustainability of the farms. This could be possible if the quality of experiences with extension agents and from general experience fails to equip farmers with the necessary expertise to deal with the prevailing challenges (Singas and Manus 2014).

The transition ecological zone of Ghana is positively related with disadoption of pond aquaculture compared to the forest zone part of the country. The results revealed that fish farmers from the transition zone have 9% probability of pond aquaculture disadoption. One reason for this may be that the viability, cost-effectiveness and means of livelihoods of the small-scale fish farmer can be significantly affected by localized climate change impacts (Asiedu et al 2019). Owners of abandoned farms may have considered investing in alternative enterprises with more satisfying utility due to these climate-related challenges. The positive relationship could therefore be attributed to operational, profitability and sustainability challenges emanating from fluctuations in temperature and availability of water since the transition zone is characterized by relatively higher climate variability compared to the forest zone (Santos et al. 2016).

Conclusions and policy recommendation

Conclusions

The result of the regression for the selection equation (adoption) indicates that age, gender (male), extension service, household size, water availability, being a member of a farmer-based group, availability of suitable land and knowledge of pond aquaculture positively and significantly affect the probability of adopting pond aquaculture. The outcome equation (disadoption) on the contrary revealed with strong significance a negative relationship between disadoption and formal education, gender (male), extension service, household size, water availability and land ownership, while distance to nearest commercial town, land tenure, experience and the transition agro-ecological zone of Ghana showed a positive relationship with disadoption. Thus these variables are very important drivers of pond aquaculture adoption and disadoption and therefore determine the sustainability of pond aquaculture in the study area.

Financial constraints, fish mortality and poor marketing structures emerged as the three most important reasons for abandonment of pond aquaculture.

The result of this study revealed huge gender and age disparities. Women composed only 18.82% of pond aquaculture practitioners in the survey area while those between the ages of 18–39 were only 26%.

Policy recommendations

Firstly, the study recommends swift policy intervention geared towards identifying and removing barriers to the participation of women and the youth in pond aquaculture.

Programmes to enhance access to information on pond aquaculture methods, innovations and economic benefits must be rolled out due to the strong positive influence of both the knowledge of pond aquaculture and negative perception on adoption and disadoption. To facilitate the realisation of the above, we recommend more institutional support to boost the activities of fish farmers associations and aquaculture extension agents who can expedite the dissemination and the adoption processes.

Financial constraint, fish mortality and poor marketing structures which emerged as the first three precursors of pond aquaculture disadoption must be prioritized and addressed through special policy instruments. Specifically, the research recommends policies that will facilitate access to affordable credit, training of more fisheries extension officers, establishment of vibrant fish health units that are closer to the fish producers and improvement of infrastructure in centralised fish markets.

Lastly, a broad-based research to establish an optimal pond aquaculture intensification protocol is highly recommended to address the challenges regarding insufficient water supply, limited suitable land and proximity to source of inputs.

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Author contribution Charles Narteh Boateng:

Conceived and designed the work; collected data; analysed and interpreted the results; contributed materials, analysis tools and wrote the paper.

Austin Mtethiwa:

Contributed to designing the work, data collection, results analysis; contributed materials and analysis tools, supervised the work.

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Contributed to designing the work, data collection, results analysis; contributed materials and analysis tools; supervised the work.

Declarations

Conflict of interest The authors declare no competing interests.

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