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Determinants and Willingness to Adopt Intelligent Marketing and IoT-Based Water Quality Monitoring Technology Among Fish Farmers in Ogun State

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Abstract

Integration of Information and Communication Technology in intelligent marketing and Internet of Things (IoT)-based water quality constitutes a neglected problem in the developing countries of the world, in particular Nigeria, where it is expected to have a significant positive impact on the fisheries sector, community, and country at large. Intelligent marketing as a component of the fishery enterprise helps effectively manage the output through a developed relationship between the fish farmers (producers) and the consumers to manage fish output as effectively as possible. Furthermore, the adoption of new technologies helps improve fish production, adaptability, and effective management. To this end, this study was conducted using a population of fish farmers at the Ijebu Development Initiative on Poverty Reduction, Eriwe, Ijebu-Ode, Ogun State, Nigeria. Primary data were obtained from 40 respondents who were randomly chosen. A focus group discussion was employed to elicit information that met the study objectives. The data were analyzed with descriptive statistics and a logit regression model. The results showed that the fish farmers were predominantly (89.5%) male, with an average age of 43 years. Very few (3.3%) respondents use Internet adverts while the majority (96.7%) use local adverts for their activities. It was also found that all the farmers are more willing to adopt the use of IoT. This study concludes that IoT is becoming popular within the agricultural sector. Hence, there is a need to create more awareness of the benefits of adopting IoT in the agricultural sector in Nigeria, thereby promoting intelligent marketing potentials among fish farmers.

Categories: IoT Applications, IoT Applications and Use Cases, IoT Integration with Emerging Technologies
Keywords: intelligent marketing, internet of things, fish farming, monitoring technology, water quality

Introduction

Nigeria represents one of the greatest in Africa in terms of production and economic activities [1]. Nigeria's agricultural industry is extensive and diverse, and it is an important source of both food and jobs. Nigeria has a significant fisheries and aquaculture sector, with fish farming playing a role in its expansion [2]. The industry does, however, face several difficulties that have a detrimental effect on its sustainability and profitability. Poor water quality, which can cause disease outbreaks and low productivity, is one of the main problems [3]. Furthermore, the lack of proper monitoring has also led to the death of the fish, eventually leading to huge financial losses for the farmers. Also, efforts that have been taken to combat these issues have not been sufficient; thus, farmers in the sector suffer losses as a result, leading to unemployment. Many young people who should have developed an interest in fish farming are losing interest as a result of these challenges [4]. It is therefore crucial to create sustainable practices like water quality enhancement that prevent mortalities in fish farming, among others. Aside from the issue of water quality monitoring, fish farmers also face lots of issues with accountability and effective marketing. Fish farmers have not met their marketing goals as a result of ineffective communication between the farmers and the customers. Promoting education and training programs for farmers could aid in boosting the industry's production and profitability [5]. By putting these suggestions into practice, Nigeria's fisheries and aquaculture sectors might grow more sustainably, feeding its people and creating jobs [6].

In this study, information was gathered from fish farmers to identify their attitudes and perceptions about intelligent marketing and Internet of Things (IoT)-based water quality monitoring systems, with the use of Participatory Impact Pathway Analysis (PIPA). PIPA is employed in the field of impact evaluation and social development. It involves having stakeholders in the analysis process to understand and track the pathways through which a development intervention or project is expected to produce its outcomes and impacts. The approach seeks to understand the interconnections between activities, outcomes, and impacts and to identify the potential risks, opportunities, and uncertainties associated with the implementation of a project [7]. PIPA is considered a valuable tool for ensuring that interventions are designed and implemented in a participatory and inclusive manner and for promoting a more comprehensive and nuanced understanding of the potential impacts of development programs. Additionally, PIPA can help identify potential unintended consequences and inform decision-making about how best to mitigate or avoid negative impacts. Overall, the participatory nature of PIPA leads to increased ownership, commitment, and sustainability of the intervention, making it a useful approach for promoting positive social and environmental outcomes [8].

In recent years, the adoption of intelligent marketing and IoT-based water quality monitoring has emerged as potential solutions to the challenges of fish farming [9,10]. Intelligent marketing and IoT-based water quality monitoring technologies have the potential to address some of the challenges facing the Nigerian fish farming industry [11]. Intelligent marketing can help fish farmers target specific audiences and improve marketing efficiency, while IoT-based water quality monitoring systems can provide real-time data on water quality to improve fish health and productivity. However, the adoption of these technologies in Nigeria is still limited, and there is a need to investigate the factors that influence the adoption of these technologies [12]. The use of intelligent marketing and IoT-based water quality monitoring systems has been increasingly proposed as a means of improving the efficiency and sustainability of fish farming practices [13]. Arising from these backgrounds, this study investigated fish farmers' willingness to adopt these technologies through a PIPA approach. The study was conducted using a population of fish farmers at the Ijebu Development Initiative on Poverty Reduction (IDIPR), Eriwe, Ijebu-Ode, Ogun State, Nigeria. The data were collected using a questionnaire administered to the farmers. Focus group discussions was also carried out.

PIPA is an approach that involves working with stakeholders, including fish farmers, to identify the drivers and challenges to the adoption of new technologies and to develop strategies to overcome the challenges. The PIPA approach is particularly useful in complex problems involving multiple stakeholders, such as the adoption of new technologies in the fisheries and aquaculture industry [14].

The findings from this study provide valuable insights into the factors that influence the adoption of intelligent marketing and IoT-based water quality monitoring technologies in the Nigerian fish farming industry. The study contributes to the development of targeted interventions that promote the adoption of these technologies among fish farmers in Nigeria. This will potentially improve the productivity and profitability of the industry while minimizing the environmental impact of fish farming [15]. The study's results also have implications on other countries with similar fish farming industries, especially in Africa, where the fish farming sector is rapidly expanding. It will also inform policy decisions and contribute to the development of a sustainable and profitable fish farming industry in Nigeria and other African countries [16].

Participatory impact pathway analysis (PIPA)

PIPA is a participatory approach used to evaluate and understand the impact of development projects, programs, or policies [17]. PIPA is designed to incorporate the perspectives of stakeholders and beneficiaries in the analysis, making it a valuable tool for assessing the success of development initiatives. PIPA uses social network analysis, program theory evaluation [18], and ongoing development research to understand and foster innovation. It is related to designing strategies and serves as a foundation for developing a framework for monitoring and evaluating progress [19]. It was used for evaluating Public-Private Partnership (PPP) in the veterinary domain using impact pathway methodology. This was employed for conducting an in-depth case study in the poultry sector in Ethiopia by Poupaud et al. [20]. The authors discussed the interests and challenges in the evaluation of PPP in the veterinary domain using PIPA. It was used to evaluate between EthioChicken and the public veterinary services of Ethiopia. The investigation revealed the collaboration between the public and private sectors at various administrative levels. The actors took into account a range of effects on the economy, business, trust, and health, which were then assessed using several metrics. Singh et al. [21] employed the impact pathway framework in the development of a framework through soil connectivity. The first step employed revealed that the participants' full participation in soil management is small. This is a serious flaw in the administration of the cocoa block. The authors concluded that the framework is adaptable to be used across different food systems.

Blundo-Canto et al. [22] used the French Agricultural Research Institute for International Development to develop ImpresS, a participatory, theory-driven, ex-post evaluation technique (Cirad). By examining behavioral processes connected to stakeholders' individual reactions and responses as well as underlying process mechanisms at a group level, ImpresS reconstructs the innovation history and its impact pathway.

To ensure internal validity and boost credibility by allowing many players to express their opinions, ImpresS focused on iterative update and refining as well as triangulating data sources and gathering methods. The authors realized that the approach had the ability to separate the factors that cause changes in a particular environment and to generate research questions about the external validity of mechanism hypotheses. It was able to employ this in differentiating between behavioral and process mechanisms.

PIPA has been used in a variety of contexts, including community development [23], agriculture, and health. In a study conducted in Kenya, Schmid et al. [24] used PIPA to evaluate the impact of an agricultural intervention program. The study found that PIPA provided a comprehensive understanding of the impact of the program, highlighting both positive and negative impacts on the community. Another study conducted in Sri Lanka by Oetzel et al. [25] used PIPA to evaluate a maternal and child health intervention program. The study found that PIPA provided a useful framework for understanding the impact of the program, particularly in terms of how the program affected the lives of women and children in the community. PIPA has also been used in disaster risk reduction (DRR) programs. Reed et al. [26] evaluated the impact from research using the methodological framework. They realised the upcoming activities that have been used to carry out social learning concepts in DRR for developed and developing countries. PIPA was found to be very useful and pivotal in impacting communities and revealing the possible means of progress. The PIPA approach has also been used to investigate the potential impact of intelligent marketing and IoT-based water quality monitoring on fish farmers' livelihoods in Nigeria. For example, a study by Kiranmayi et al. [27] used the PIPA approach to assess the potential impact of a mobile app-based marketing platform on fish farmers' income and market access. The study found that the platform could significantly increase fish farmers' income and market access, but that the success of the platform depended on factors such as the availability of finance, the quality of the app, and the marketing strategies used.

Studies have investigated the factors influencing fish farmers' willingness to adopt these technologies in Nigeria. For example, a study by Olagunju et al. [28] found that fish farmers' age, education, and access to information and communication technologies (ICTs) significantly influenced their willingness to adopt intelligent marketing. Similarly, a study by Bacco et al. [29] found that fish farmers' access to finance and ICTs, as well as their perceptions of the benefits and risks of IoT-based water quality monitoring, influenced their willingness to adopt the technology. In summary, PIPA is a valuable participatory approach to understanding the impact of development projects, programs, and policies. It incorporates the perspectives of stakeholders and beneficiaries, providing a comprehensive understanding of the impact of development initiatives. PIPA has been used in a variety of contexts and has been found to be useful in evaluating both positive and negative impacts on the community [30].

Materials And Methods

Study area

The study location was Ijebu-Ode in Ogun State. It lies between latitude 6°49′47.95″N and longitude 3°54′59.25″E. The respondents are fish farmers at IDIPR, Eriwe, Ijebu Ode Ogun State, Nigeria. It is a 156-ha farm village that was created under the IDIPR's supervision and is situated in Ogun State, southwest Nigeria. The fish farm in Eriwe has a cooperative management style that focuses on collaboration, teamwork, and mutual support, among others. The cooperative style emphasizes open communication, inclusiveness, and a shared sense of responsibility for the success of the farm.

Data collection procedure

PIPA was employed to collect data from the farmers. This entailed setting up a workshop where participants expressed their expectations about how the initiative would have an impact. The community of fish farmers was visited, and 40 representative farmers were selected randomly. Questionnaires designed to capture the objectives of the study were administered to these set of representatives after the discussion to express their opinions about the subject matter been discussed. The willingness of the farmers to participate was first established before questionnaire administration.

The PIPA process

PIPA provides two approaches for defining project impact paths:

i. A list of problems or objectives that illustrates the linear logic and demonstrates how, by addressing certain difficulties, the project will move on to solving other issues and finally reach its aim; and,

ii. Network diagrams that depict how the many players interact, influence one another, and affect the environment in general for the new knowledge or technology under development.

The PIPA workshop

The workshop involved brainstorming sessions where each stakeholder groups practically expressed their opinions on possible problems and challenges confronting them. This was done in anticipation of developing the problem trees by the facilitators of the workshop. Four groups were created with at least 10 farmers per group. Figure 1 shows the image of participants of the PIPA workshop conducted.

FIGURE 1: PIPA workshop session

The four stages were as follows: general problems identification, main problem identification, identification of the causes of the main problem, and identification of the consequences of problems. Each group was named according to fruits type, which were Banana, Apple, Watermelon, and Papaya groups, respectively. Figure 2 shows an outcome of participants' activities during the PIPA workshop.

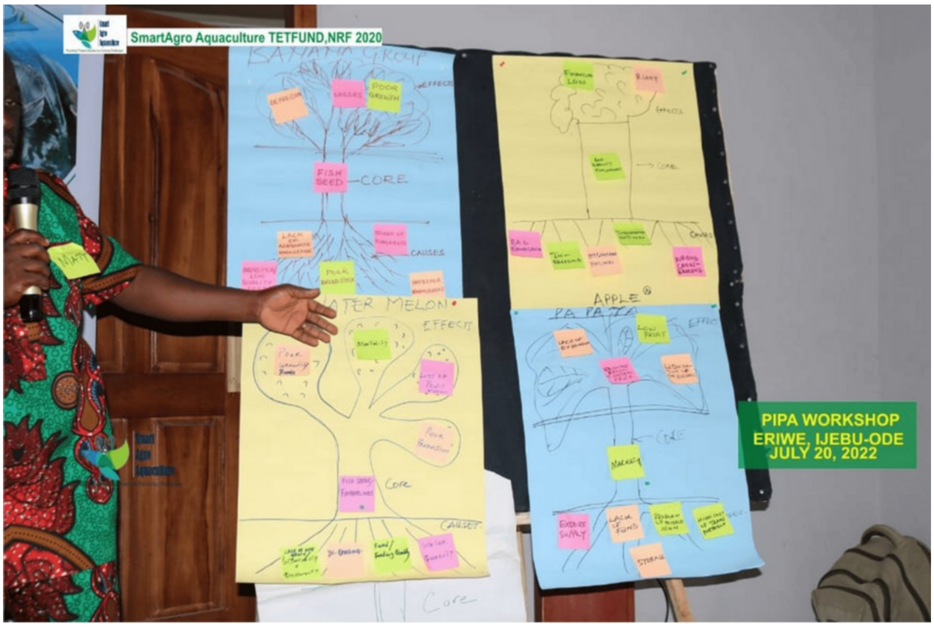

FIGURE 2: Classification of groups based on general problem identification

Each group developed a problem tree that links the problems the study is directly addressing with the social, environmental, and/or economic conditions it wishes to improve (Figure 2). Once an issue that the research will specifically address has been discovered, the branches of the problem tree come to an end. These determining issues aid in defining the study's necessary outputs. Identifying the core problem after discovering the problem tree is essential, and it maps out how to address challenging areas. As shown in Figure 3, the main/core problem highlighted was the problem of marketing and sourcing fish seed (fingerlings), which are mostly bad and of low quality. The problems facing fish farmers need to be addressed by identifying the causes of the problem and the challenges faced by them. Some of these challenges mentioned were water quality, lack of fund, storage, etc., and this study provides possible ways of solving these challenges, as shown in Figure 4. Table 1 shows the variable description used in the PIPA questionnaire.

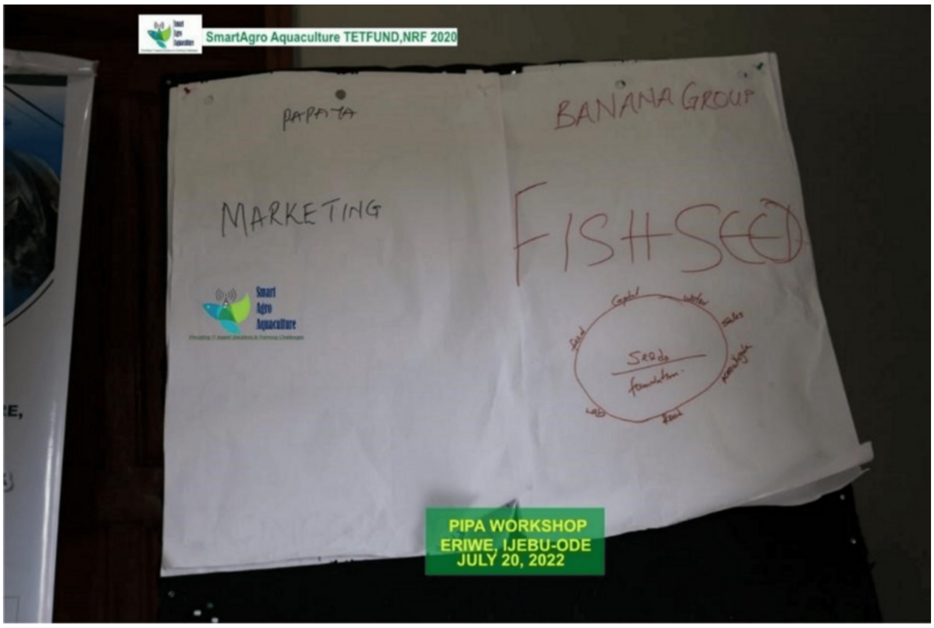

FIGURE 3: Identification of core/main problem

FIGURE 4: Identification of causes of problem/challenges of fish farming

Model specification

The model specification used for this theory was based on consumer random utility theory (RUT). This theory postulates individual’s utility function (U). The mind of the consumer was depicted by a latent construct, which was decomposed into a systematic or deterministic component (X) and unobserved or stochastic component (ε) [31]. The binary model in the form of Logit was specified for the study to investigate the willingness of the farmers to adopt the technology of IoT and intelligent marketing in their fish business. This method of modeling willingness has been used widely to investigate the factors of influence in adoption studies [32]. Equations 1-5 show how the model was employed in this study.

$U_i = \beta x_i + \varepsilon_i$ ...... (1)

Ui = willingness to adopt IoT usage among fish farmers,

β = vector of estimable parameters,

xi = vector of individual explanatory variables,

εi = error term.

The probability of using IoT is given as:

P(IoT use) = $\dfrac{exp^{\beta x_i}}{1 + exp^{\beta x_i}}$ ..... (2)

U_j = $\beta x_j + \varepsilon_j$ ...... (3)

U_j = willingness to adopt intelligent marketing among fish farmers,

β = vector of estimable parameters,

x_j = vector of individual explanatory variables,

ε_j = error term.

The probability of adopting intelligent marketing is given as:

P(intelligent marketing use) = $\dfrac{\exp^{\beta x_j}}{1 + \exp^{\beta x_j}}$ ..... (4)

The model is explicitly stated as follows:

$$Yi = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + +\varepsilon_i \text{ ..... (5)}$$

where:

Y = Internet of Thing (IoT): A dichotomous variable of 1 and 0 indicating the famer's willingness to adopt the IoT technology

β_0 = Intercept

x_1 = Age of famers (years)

x_2 = Farmer's level of education (number of years spent in school)

x_3 = Farmer's marital status (married = 1; 0 otherwise)

x_4 = Number of ponds operated by the farmer (number)

x_5 = Number of fingerlings stocked by the farmer (number)

x_6 = Harvest frequency, that is number of times the fish farm is cropped at maturity (number)

ε_i = error term

Results

Sociodemographic profile of fish farmers

The sociodemographic characteristics of the sampled fish farmers from the Eriwe fish farming population are presented in Table *1*. The fish farming business is male-dominated, with 87.50% of the farmers being male. This might be due to the nature of the business, which requires a certain level of physical energy. A greater proportion (83.32%) of the farmers are within the active age group of 21 to 60 years, with an average age of 42.5 years. As expected, the fish farmers should be active and productive, given adequate opportunities and resources.

All the farmers had one form of education or the other, ranging from non-formal (5%) to tertiary (65%). This level of education suggests that the farmers are expected to be well informed and would be able to diligently consider innovations, adopt them, and rightly apply them to the business of fish farming. Adoption of innovations/technologies is expected to be positively correlated with the level of education.

The fish farmers constitute as much as 85% of married people, whereas just a few (15%) are single; hence, the fish farming business can be taken as a source of livelihood for the family. The household size ranged between 1-3 and 7-9, with a greater proportion (69%) having 4-6 individuals in their household, with a mean household size of five people. The farmers have varying years of experience in the fish farming business. About 51.35% of the farmers have between 1 and 5 years of experience in the business, which resulted in the highest frequency. The average years of experience (7 years) are sufficient for learning the tricks in the fish farming business.

Socioeconomic Variable	Frequency	Percentage	Mean
Sex			
Male	35	87.50	
Female	5	12.50	
Age (years)			
< 21	2	5.56	
21–30	4	11.12	
31–40	12	33.36	
41–50	6	16.67	
51–60	8	22.24	
>60	4	11.12	42.5
Educational level			
Non-formal	2	5.00	
Secondary	12	30.00	
Tertiary	26	65.00	
Marital status			
Single	6	15.00	
Married	34	85.00	
Household size (number)			
1–3	9	23.08	
4–6	27	69.23	
>7	3	7.69	4.62
Fish farming experience (years)			
1–5	19	51.53	
6–10	8	21.62	
>10	10	27.03	7.08

TABLE 1: Distribution of fish farmers by socioeconomic characteristics

Fish production activities among farmers

In Table 2, the fish production activities among the farmers are presented. On the average, farmers have roughly 3,600 fingerlings in their stock, while the majority (91.66%) had fingerlings between 1,000 and 5,000 in their stock. In order to obtain their fish seeds, the majority (about 68%) depended on other fish farmers (who are involved in hatching), while about 18.42% turned to markets or brokers. The majority of farmers typically harvest between one to three times in a year. A larger percentage of the farmers (45.16%) harvest twice a year, whereas very few (22.58%) harvest only once a year. In terms of source of water for fish rearing, the farmers largely utilize water from the borehole.

However, some of the farmers closed their pond for some reasons. About 43% of the farmers closed some of their ponds as a result of lack of funds. This is followed by lack of labour (16%), marketing problem (13.5%), and water problem (10.8%). These factors highlight the challenges and underlying causes the farmers face in the fish farming business. Some of these challenges mentioned were water quality, lack of fund, storage, problem of marketing, and fish seed. This study provides possible solutions to some of these challenges.

The fish farmers source fund from various sources, as shown in Table 2. Of these sources, funds from personal savings of the farmers form the major source with about 62%. This could be a limitation regarding financing the fish farming business, which in turn restricts production and consequently affects the output level.

Variable	Frequency	Percentage	Mean
Stock size (number of fingerlings stocked)			
1,000–3,000	18	50.00	
3,001–5,000	15	41.66	
Above 5,000	2	5.56	3638.89
Sources of fingerlings			
Ministry of Agriculture	1	2.63	
Wild water	1	2.63	
Marker/trader	7	18.42	
Other farmers	26	68.42	
Own fish pond	3	7.89	
Frequency of harvest per year			
Once	7	22.58	
Twice	14	45.16	
3 times	4	12.90	
4 times	3	9.68	
6 times	1	3.23	
12 times	2	6.45	
Sources of water			
Borehole	35	100.00	
Well	-	-	
Streams/Springs		-	
Reason for pond closed-down			
Lack of fund	16	43.24	
Lack of labour	6	16.22	
Marketing problem	5	13.51	
Water problem	4	10.81	

Human conflict	3	8.11	
Bad fish seed	1	2.50	
Source of fund			
Personal savings	23	62.16	
Loan from commercial bank	2	5.41	
Microfinance bank loan	6	16.22	
Government support	3	8.11	
Support from IDIPR Eriwe farm	5	13.51	
Ajo (Contribution)	1	2.70	
Cooperatives	7	18.92	
Family and Friends	8	21.62	

TABLE 2: Distribution of farmers according to fish production information

Fish management practices carried out by the farmers

The various management practices carried out by the farmers are shown in Table 3. Proper water management in a fish farming business would go a long way in ensuring better productivity and yield for the farmer. Water dislodge is a common practice among the farmers with as much as 54.84% carrying out the exercise every day apart from feeding, which is expected to be an everyday affair. Good water quality maintenance is paramount to knowing the state/condition of the water for optimal production; however, only 16.13% engage in this practice on daily basis, while another 25.81% do it within 1-3 days per week and about 29% made it a monthly practice affair. This scenario raises concerns that can be addressed using IoT solutions.

Production management practices	Every day	1-3 days per week	1-3 days per month	Twice a year	Never
Pond fertilization	27.59	6.90	17.24	27.59	20.69
Water quality maintenance	16.13	25.81	29.03	9.68	19.35
Weeding	6.67	40.00	33.33	13.33	6.67
Liming	10.34	27.59	24.14	27.59	10.34
Cleaning	14.81	25.93	37.04	14.81	7.41
Disease control	15.38	34.62	30.77	7.69	11.54
Feeding	75.00	10.71	10.71	3.57	-
Water flushing	54.84	22.58	6.45	9.68	6.45

TABLE 3: Fish production management practiced by farmers (%)

Fish farming challenges

In Table 4, the level of challenges the farmers are facing is shown. Quite a number of challenges are militating at varying degrees. The most serious problems, with very high levels of concern, include high cost of fish feed (97.30%), poor parent stock (69.44%), consistent increases in feed prices (89.19%), poor fish seeds (86.84%), middlemen (77.78%), insufficient laboratory facilities for fish analysis by professional technicians (80.56%), and consistent increases in fuel prices (81.08%).

Challenges	Serious problem	Moderate problem	Minor problem	Not a problem
High cost of fish feed	97.30	2.70	-	-
Poor water management	27.03	43.24	24.32	5.41
Poor parent stock	69.44	19.45	11.11	-
Flooding	56.76	13.51	13.51	16.22
Predator/pilfering/theft	22.22	41.67	30.56	5.56
Consistent increase in feed price	89.19	10.81	-	-
Scarcity of farm labour	18.92	24.32	45.95	10.81
Improper record keeping	13.51	27.03	35.14	24.32
Poor-quality fingerling	86.84	13.16	-	-
Bad accessible road network	35.14	45.95	13.51	5.41
Market gluts	56.76	29.73	13.51	-
Foreign investors	54.55	12.12	18.18	15.15
Lack of cooperation among farmer	48.57	25.71	20.00	5.71
Problem of middlemen	77.78	19.44	2.78	-
Insufficient laboratory for fish analysis	80.56	16.67	2.78	-
Lack of fish-related technical know-how	58.33	33.33	8.33	-
Consistent increase in fuel price	81.08	13.51	2.70	2.70

TABLE 4: Level of challenges that militates the farm

Production and technical needs of fish farmers

Table *5* shows the distribution of the extent to which the farmers reported that they need production and technical supports. It is evident from the table that a larger frequency (94%) of the farmers require technical assistance in the fish farming business. The degree of the technical and production information needed is highlighted in Table *5*. Highly needed technical assistance is in the areas of maggot fish meal production (84.21%), pond water quality and management (73.68%), growth parameters indices monitoring (75.68%), intelligent market for sales of fish (83.78%), fish meal supplements (86.11%), IoT mobile-based fish water quality management system (82.86%), supplement formulation (75.00), production of maggot on a large scale (81.08%), and water treatment and fish harvest (62.16%). These areas of need can be summarized into three broad categories, namely, feeding, water quality management, and marketing. These three areas can be handled with the adoption of IoT technology.

Need for technical assistance	Freq.	Percent		
Yes	32	94.12		
No	2	5.88		
Total	34	100.00		
Needs of fish farmers	Highly needed	Moderately needed	Rarely needed	Not at all
Maggot fish meal production	84.21	7.89	5.26	2.63
Pond water quality and management	73.68	21.05	2.63	2.63
Fish weight monitoring system	75.68	18.92	2.70	2.70
Intelligent market for sales of fish	83.78	13.51	-	2.70
Fish meal supplement	86.11	13.89	-	-
IoT mobile-based fish water quality management system	82.86	8.57	5.71	2.86
Supplement formation	75.00	19.44	5.56	-
Production of maggot on a large scale	81.08	13.51	5.41	-
Pond construction	32.43	32.43	21.62	13.51
Fish preservation and processing	54.05	37.84	8.11	-
Fish pond fertilization	51.35	40.54	8.11	-
Water treatment and fish harvest	62.16	37.84	-	-
Spawning operation	37.14	45.71	17.14	-

TABLE 5: Need for technical and production information

Fish marketing information

The distribution of responses regarding fish sales is shown in Table 6. A majority of the farmers (94.6%) sell their harvested fish in bulk, with local advertisements being the primary method of information dissemination (96.77%). Although they have diverse customers, market men/women and individuals form the major customer segments, accounting for 38.99% and 30.56%, respectively.

Marketing	Freq.	Percent
Mode of sales		
Wholesale/Bulk	35	94.6
Retail/Pieces	2	5.4
Total	37	100
Advertisement		
Local advert	30	96.77
Internet advert	1	3.23
Social media	-	-
Total	31	100
Customers		
Individual	11	30.56
Group(s)	4	11.11
Hotels	6	16.67
Market men/women	14	38.89
Eateries	3	8.33
Middlemen	2	5.56
Agents	1	2.78
Total	37	100
Challenges		
Market information	4	14.28
Glut	3	10.71
Poor pricing, buying on credit	14	49.98
Middlemen prank	12	42.84
Storage	2	7.14

TABLE 6: Mode of sales of harvested fish

Participatory impact pathway analysis

A PIPA analysis is shown in Table *7*. In Figure *5*, the adopted pathway analysis description is shown. The adoption of the PIPA method yielded the results below, indicating the challenges/problems faced by the fish farmers. Four different pathways were identified by the stakeholders.

	Group 1 (Apple)	Group 2 (Banana)	Group 3 (Papaya)	Group 4 (Watermelon)
General problems identified	High cost of feeding Scarcity of good fish seeds Lack of financial support Inadequate security Price irregularity Unavailability of quality feed ingredient Natural disaster (flooding) Water problem Inaccessibility to final consumer Issue of technical know-how	Inbreeding Small size of brood stock High cost of production (fuel) Poor Pricing/Selling on credit Water quality test kit Flooding Extension services Issue of technical know-how Laboratory Road network	Sourcing for fingerlings Decrease in water volume High price of feed Disease control Flooding problem High cost of fuel Market problem Issue of middlemen Lack of funds Bad road within farm village Inadequate security Lack of proper market information Lack of cooperation among farmers Lack of proper laboratory information for feeds and drugs	Problem of good fingerlings Insecurity/theft Flooding Environmental pollution Water management/quality Over stocking
Main problem pin-pointed	Bad quality fish seeds	Fish seed	Marketing	Fish seed (fingerlings)
Causes of main problem	Bad brood stock Inbreeding Wrong cross-breeding	Lack of technical know-how Poor brood stock while growing from fingerlings Low-quality feed to reduce cost Improper production management	Lack of finance Excess supply Middlemen exploitation High cost of transportation	Inbreeding Water quality Feeding/feed quality
Consequences of problems	Underdevelopment of the fish or production of runts, leading to financial loss	Poor growth Losses Demotivation	Selling below normal price Low profit Lack of expansion Liquidation of the farm	Poor production Poor growth/runts Mortality Loss of profit

TABLE 7: PIPA analysis

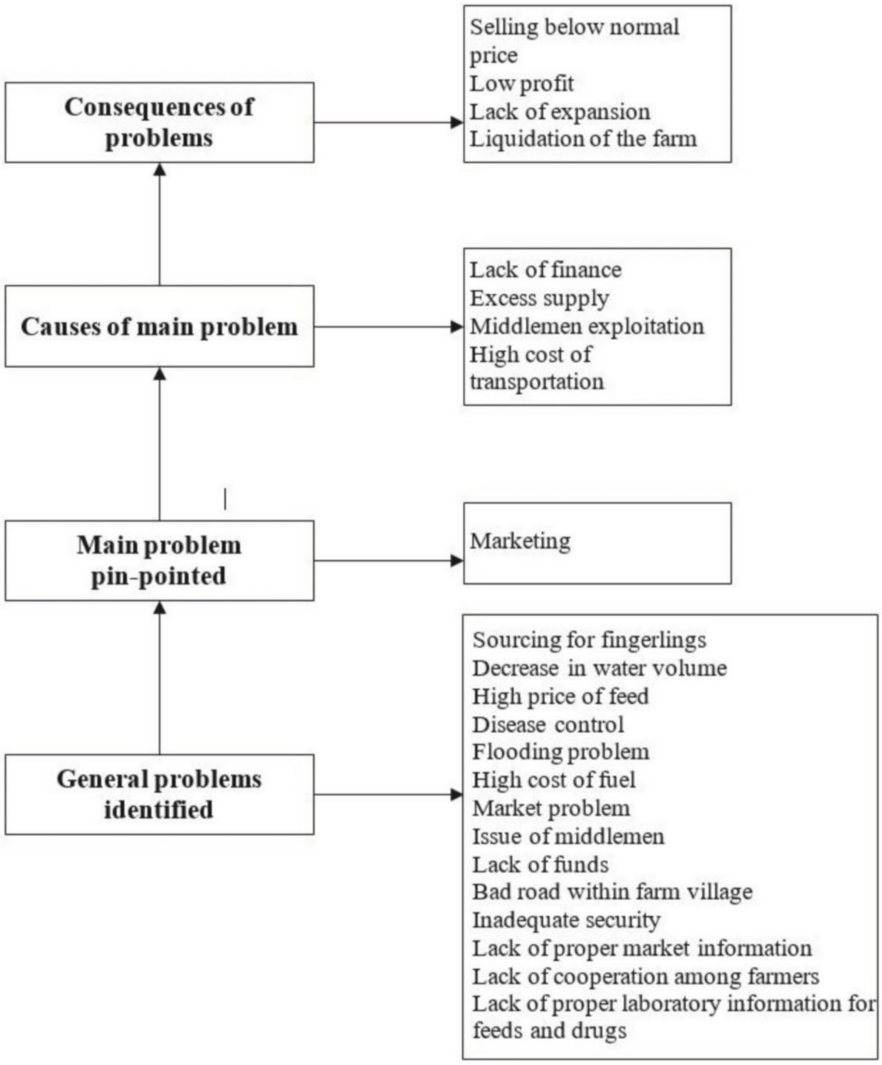

FIGURE 5: The pathway analysis adopted in the research

Willingness to adopt IoT

The willingness to adopt IoT and intelligent marketing as well as the associated determinants was analyzed using the logit model. The logit model for the IoT adoption is shown in Table 8. The logit model shows that farmers' age, number of ponds owned, and harvest frequency are statistically significant variables influencing IoT adoption among the fish farmers. Age was significant at the 5% probability level and had a negative relationship with IoT adoption, implying that younger farmers are more willing to adopt IoT than their older counterparts. This may be due to the fact that younger generations are generally more inclined to use computers and related devices, which form the basis of IoT.

Also, the number of ponds managed by the farmers had a positive relationship with IoT adoption, indicating that a unit increase in the number of ponds managed by the farmers increases the likelihood of IoT adoption by 64.5%. Frequency of harvest had a significant and a negative relationship with IoT adoption. This means that the lower the harvest frequency, the lower the probability of IoT adoption among the fish farmers.

Variable	Coefficient	Std. Error	Z	P>Z
Cons	4.645	2.847	1.63	0.103
Age	-0.155**	0.061	-2.54	0.011
Education	2.176	1.490	1.46	0.144
Marital status	2.153	1.745	1.23	0.217
Number of ponds	0.645*	0.388	1.66	0.096
Fish seed	-0.001	0.003	-0.33	0.634
Harvest frequency	-0.400*	0.229	-1.74	0.081
LR $chi^2(6)$	12.87			
Prob > chi^2	0.045			
Log likelihood	-13.58			
Pseudo R^2	0.322			
Observation	40			

TABLE 8: Logit model result for Internet of Thing adoption among the fish farmers

**Estimates statistically significant at 0.05 or 5%.

*Estimates statistically significant at 0.10 or 10%.

Willingness to adopt intelligent marketing

Table 9 presents the results of the logit model for intelligent marketing adoption among the fish farmers. The result indicates that farmers' age significantly influences the adoption of intelligent marketing, with a significance level of 5%.

Variable	Coefficient	Std. Error	Z	P>Z
Cons	2.933	4.031	0.73	0.467
Age	-0.165**	0.077	-2.16	0.031
Education	2.210	2.187	1.01	0.312
Marital status	3.220	2.276	1.41	0.157
Number of ponds	1.394	0.895	1.56	0.120
Fish seed	-0.001	0.003	-0.29	0.769
Harvest frequency	-0.379	0.705	-0.54	0.591
LR $chi^2(6)$	11.33			
Prob > chi^2	0.0787			
Log likelihood	-7.339			
Pseudo R^2	0.436			
Observation	40			

TABLE 9: Result of the logit model for intelligent marketing adoption among the fish farmers

**Estimates statistically significant at 5%.

Discussion

Feasibility of the study

The feasibility of the study using fish production management practices, challenges/problem of fish farming, technical/production information needs, and perceived usefulness of modern disruptive innovations as metric variables was determined by pilot test using Cronbach alpha value. The result is shown in Table *10*. In this research, PIPA was employed in investigating fish farmers' willingness to adopt intelligent marketing and IoT-based monitoring system. Based on the findings from the approach, it can be concluded that fish farmers in Nigeria are generally willing to adopt the system. However, the research identified several challenges to the adoption of these technologies, including high initial costs, lack of technical expertise, and inadequate infrastructure. These challenges need to be addressed to enable more widespread adoption of intelligent marketing and IoT-based water quality monitoring among fish farmers in Nigeria. Therefore, it is recommended that the government, at all levels, and other relevant stakeholders in the fish farming industry in Nigeria take concrete steps to address these barriers. This may include providing financial support and technical assistance to fish farmers to help them acquire and install the necessary equipment, as well as investing in the necessary infrastructure, such as high-speed internet and electricity, to support the adoption of these technologies. In terms of the perceived usefulness of IoT-based water quality monitoring, the study found that fish farmers who perceived the technologies as having a positive impact on their farm management and profitability were more likely to adopt them. Similarly, fish farmers who perceived the technologies as being easy to use and requiring minimal technical knowledge were also more likely to adopt them. The study also found that the availability of technical support and training was important, as fish farmers who felt confident in their ability to use the technologies were more likely to adopt them. Moreover, awareness campaigns and training programs should be organized to educate fish farmers on the benefits of these technologies and how to use them effectively. This will help to increase their confidence in using these technologies and improve their overall productivity and profitability. By taking these steps, the adoption of intelligent marketing and IoT-based water quality monitoring can be accelerated, leading to a more sustainable and profitable fish farming industry in Nigeria.

SN	Variables	Cronbach alpha	No. of items	Remark
1	Fish production management practices (PM)	0.86	7	Reliable/Significant
2	Challenges/problem of fish farming (CF)	0.65	13	Not reliable/Not significant
3	Technical/production information needs (TP)	0.83	13	Reliable/Significant
4	Perceived usefulness of modern disruptive innovations (PU)	0.87	13	Reliable/Significant

TABLE 10: Result of the pilot test for PM, CF, TP, and PU

Conclusions

Intelligent marketing involves the use of modern technologies such as social media, mobile apps, and e-commerce platforms to increase market reach and efficiency. IoT-based water quality monitoring uses sensors to monitor water quality parameters such as temperature, pH, and dissolved oxygen, providing real-time data that enables fish farmers to take timely action to prevent fish mortality and disease outbreaks. From this study's findings, it can be concluded that several factors influenced fish farmers' willingness to adopt intelligent marketing and IoT-based water quality monitoring systems. These factors included the perceived usefulness and ease of use of the technologies, the availability of technical support and training, the perceived costs and benefits of adopting the technologies, and the influence of social norms and peer pressure. The study also found that market intermediaries and government officials played an important role in promoting the adoption of these technologies. The intelligent marketing and IoT-based monitoring system can be implemented and validated by fish farmers to compare their perception from this study with their eventual belief from the testing.

Additional Information

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All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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References

1. Muhammad ID: A comparative study of research and development related to nanotechnology in Egypt, Nigeria and South Africa. Technology in Society. 2022, 68:101888. 10.1016/j.techsoc.2022.101888
2. Nwuba LA, Ude EF, Ogbonnaya HF: Current trends in fisheries and aquaculture. International Journal of Agriculture, Food and Biodiversity. 2022, 1:64-69. 10.13140/RG.2.2.11898.26560
3. Prapti DR, Mohamed Shariff AR, Che Man H, Ramli NM, Perumal T, Shariff M: Internet of Things (IoT)-based aquaculture: An overview of IoT application on water quality monitoring. Reviews in Aquaculture. 2022, 14:979-992. 10.1111/raq.12637
4. Osuizugbo IC, Kukoyi PO, Abisuga AO, Ibrahim K: Choosing to be a craftsperson: Factors influencing career decision-making among apprentices. Engineering, Construction and Architectural Management. 2023, 30:2026-2047. 10.1108/ecam-03-2021-0198
5. Ankrah MT, Asante D, Wang P, Ntiamoah EB, Jiang Y: Can the use of the internet improve fish farmers' financial performance? Evidence from Ghana. Marine Policy. 2023, 149:105494. 10.1016/j.marpol.2023.105494
6. Adeleke B, Robertson-Andersson D, Moodley G, Taylor S: Aquaculture in Africa: A comparative review of Egypt, Nigeria, and Uganda vis-à-vis South Africa. Reviews in Fisheries Science & Aquaculture. 2020, 29:167-197. 10.1080/23308249.2020.1795615
7. N'souvi K, Sun C, Che B: Aquaculture technology adoption and profitability of the polyculture system practiced by prawn and crab farmers: Case study of Anhui Province in China. Aquaculture Reports. 2021, 21:100896. 10.1016/j.aqrep.2021.100896
8. Sharma IK, Di Prima S, Essink D, Broerse JE: Nutrition-sensitive agriculture: A systematic review of impact pathways to nutrition outcomes. Advances in Nutrition. 2021, 12:251-275. 10.1093/advances/nmaa103
9. Kaleem O, Sabi AFBS: Overview of aquaculture systems in Egypt and Nigeria, prospects, potentials, and constraints. Aquaculture and Fisheries. 2021, 6:535-547. 10.1016/j.aaf.2020.07.017
10. Kumar G, Engle C, Tucker C: Factors driving aquaculture technology adoption. Journal of the World Aquaculture Society. 2018, 49:447-476. 10.1111/jwas.12514
11. Zhou Y, Xia Q, Zhang Z, Quan M, Li H: Artificial intelligence and machine learning for the green development of agriculture in the emerging manufacturing industry in the IoT platform. Acta Agriculturae Scandinavica, Section B — Soil & Plant Science. 2022, 72:284-299. 10.1080/09064710.2021.2008482
12. Ayaz M, Ammad-Uddin M, Sharif Z, Mansour A, Aggoune EHM: Internet-of-Things (IoT)-based smart agriculture: Toward making the fields talk. IEEE Access. 2019, 7:129551-129583. 10.1109/access.2019.2932609
13. Gao G, Xiao K, Chen M: An intelligent IoT-based control and traceability system to forecast and maintain water quality in freshwater fish farms. Computers and Electronics in Agriculture. 2019, 166:105013. 10.1016/j.compag.2019.105013
14. Cheruiyot JK, Adhiaya M: Adoption of aquaculture technologies and management practices, challenges and productivity of fish ponds in Kakamega County, Kenya. Asian Journal of Fisheries and Aquatic Research. 2023, 22:25-36. 10.9734/ajfar/2023/v22i1563
15. Babalola TE, Babalola AD, Goroti AV: Development of an IoT-based water quality monitoring device for domestic fish ponds. ABUAD Journal of Engineering Research and Development. 2024, 7:82-90. 10.53982/ajerd.2024.0701.08-j
16. Mustapha UF, Alhassan AW, Jiang DN, Li GL: Sustainable aquaculture development: a review on the roles of cloud computing, internet of things and artificial intelligence (CIA). Reviews in Aquaculture. 2021, 13:2076-

2091. 10.1111/raq.12559

17. Tawfeeq A, Al Wahaibi HAS, Vijayalakshmi K: IoT based aquaculture system with cloud analytics. International Journal of Applied Engineering Research. 2019, 14:4136-4142.
18. Rockwell K, Bennett C: Targeting outcomes of programs: A hierarchy for targeting outcomes and evaluating their achievement. Faculty Publications: Agricultural Leadership, Education & Communication Department, University of Nebraska, Lincoln. Paper 48. (2004). https://digitalcommons.unl.edu/aglecfacpub/48/.
19. Alvarez S, Douthwaite B, Thiele G, Mackay R, Córdoba D, Tehele K: Participatory impact pathways analysis: A practical method for project planning and evaluation. Development in Practice. 2010, 20:946-958. 10.1080/09614524.2010.513723
20. Poupaud M, Dieuzy-Labaye I, Asfaw YT, Wieland B, Tesfu F, Daniel U, Peyre M: Evaluation of public-private partnership in the veterinary domain using impact pathway methodology: In-depth case study in the poultry sector in Ethiopia. Frontiers in Veterinary Science. 2022, 9:10.3389/fvets.2022.735269
21. Singh K, Yu F, Sanderson T, Fidelis C, Yinil D, Field DJ: Building an impact pathway framework for a project through soil connectivity. Soil Security. 2022, 6:100045. 10.1016/j.soisec.2022.100045
22. Blundo-Canto G, Devaux-Spatarakis A, Mathé S, Faure G, Cerdan C: Using a participatory theory-driven evaluation approach to identify causal mechanisms in innovation processes. New Directions for Evaluation. 2020, 2020:59-72. 10.1002/ev.20429
23. Cattarinich X: Pro-poor tourism initiatives in developing countries: Analysis of secondary case studies. PPT Working Paper No. 8. (2001). http://www.tanzaniagateway.org/docs/initiatives_cs.pdf.
24. Schmid O, Quiédeville S, Sterly S, Barjolle D, Midmore P: Analysis of impact pathways of research on agriculture. IMPRESA Research Brief. 2016, 1:10.13140/RG.2.2.21000.52484
25. Oetzel JG, Wallerstein N, Duran B, Sanchez-Youngman S, Nguyen T, Woo K, Alegria M: Impact of participatory health research: A test of the community-based participatory research conceptual model. BioMed Research International. 2018, 7281405:12. 10.1155/2018/7281405
26. Reed MS, Ferré M, Martin-Ortega J, Blanche R, Lawford-Rolfe R, Dallimer M, Holden J: Evaluating impact from research: A methodological framework. Research Policy. 2021, 50:104147. 10.1016/j.respol.2020.104147
27. Kiranmayi D, Sharma A, Prasad KP, Sharma R, Sharma SK: Development of an Android-based application system for fish farmers. Agricultural Research. 2021, 11:240-248. 10.1007/s40003-021-00558-8
28. Olagunju O, Oluwaseun A, Gbenga FK, Adewumi TO, Isah SN: Digitization of agricultural extension system for effective management of emergency in Nigeria. Journal of Agricultural Extension. 2021, 25:81-91. 10.4314/jae.v25i4.9
29. Bacco M, Barsocchi P, Ferro E, Gotta A, Ruggeri M: The digitisation of agriculture: A survey of research activities on smart farming. Array. 2019, 3-4:100009. 10.1016/j.array.2019.100009
30. Faure G, Blundo-Canto G, Devaux-Spatarakis A, Le Guerroué JL, Mathé S, Temple L, Hainzelin E: A participatory method to assess the contribution of agricultural research to societal changes in developing countries. Research Evaluation. 2020, 29:158-170. 10.1093/reseval/rvz036
31. Crouch GI, Louviere JJ: A review of choice modelling research in tourism, hospitality and leisure. Consumer psychology of tourism, hospitality, and leisure. Mazanec JA, Crouch GI, Brent Richie JR, Woodside AG (ed): CABI, Oxfordshire, UK; 2001. 2:67-86. 10.1079/9780851995359.0067
32. Chen X, Shang J: Analysis of farmers' willingness to use blockchain and influencing factors based on the binary logit model. Wireless Communications and Mobile Computing. 2022, 7412261:10. 10.1155/2022/7412261