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Research Article
(Araştırma Makalesi)

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Enhancing fish farmers' welfare through digital agricultural innovation platforms: Evidence from Nigeria

Yenilikçi dijital tarım uygulamaları aracılığıyla balıkçıların refahının artırılması: Nijerya örneği

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ABSTRACT

Objective: Despite the potential of digital innovation platforms to improve farmers' welfare its adoption is low due to scanty empirical evidence on the subject matter. Therefore, this study examined the contribution of digital innovation platforms to fish farm output and income in Nigeria.

Material and Methods: Data gathered from 187 catfish farmers were analysed using descriptive statistics and t-tests.

Results: The results revealed that digital innovation platform provides credit facilities to fish farmers to boost their production activities. Before fish farmers adopted the digital innovation platform, they stocked an average of 733.12 fingerlings, which increased to 952.83 fingerlings after adopting digital innovation. Also, the adoption of digital innovation platforms significantly increased fish farm output from 742.28 kg to 1,057.81 kg. Fish farmers' revenue from fish farming consequently increased from ₦540,905.11 Nigerian Naira(USD 1,307.01) to ₦780,444.98 Nigerian Naira(USD 1,885.82) after adopting the digital innovation. Therefore, the adoption of digital innovation significantly increased farm output and income by 42.51% and 44.29%, respectively.

Conclusion: Digital innovation platforms significantly improved farmers' welfare. Based on this, this study advocates that fish farmers should be encouraged to adopt digital innovation platforms by creating awareness and providing more funds through digital innovation platforms.

ÖZ

Amaç: Dijital inovasyon platformlarının çiftçilerin refahını artırma potansiyeline rağmen, konuyla ilgili ampirik kanıtların yetersiz olması nedeniyle benimsenmesi düşüktür. Bu nedenle, bu çalışmada dijital inovasyon platformlarının Nijerya'daki balık çiftliği üretimine ve gelirine katkısı incelenmiştir.

Materyal ve Yöntem: 187 yayın balığı çiftçisinden toplanan veriler, tanımlayıcı istatistikler ve t-testleri kullanılarak analiz edilmiştir.

Araştırma Bulguları: Sonuçlar, dijital inovasyon platformunun, balık çiftçilerine üretim faaliyetlerini artırmaları için kredi kolaylığı sağladığını ortaya koymuştur. Balık çiftçileri dijital inovasyon platformunu benimsemeden önce ortalama 733,12 yavru balık stoklarken; bu rakam dijital yeniliği benimsedikten sonra 952,83 yavruya yükselmiştir. Ayrıca dijital inovasyon platformlarının benimsenmesi, balık çiftliği üretimini 742,28 kg'dan 1.057,81 kg'a anlamlı bir şekilde artırmıştır. Balık çiftçilerinin balık yetiştiriciliğinden elde ettiği gelir, dijital yeniliği benimsedikten sonra 540.905,11 Nijerya Nairası'ndan (1.307,01 ABD Doları) 780.444,98 Nijerya Nairası'na (1.885,82 ABD Doları) yükselmiştir. Dolayısıyla, dijital inovasyonun benimsenmesi, çiftlik üretimini ve gelirini sırasıyla %42,51 ve %44,29 oranında önemli ölçüde artırmıştır. .

Sonuç: Dijital inovasyon platformları çiftçilerin refahını önemli ölçüde artırmıştır. Buna göre, bu çalışma, farkındalık oluşturmak ve dijital inovasyon platformları aracılığıyla daha fazla fon sağlayarak balık çiftçilerinin dijital inovasyon platformlarını benimsemeye teşvik edilmesi gerektiğini savunmaktadır.

INTRODUCTION

Rearing animals remains a major source of protein needed to boost the body's immune system, fight against diseases, and live a healthy life globally (Cevher et al., 2022; Mukaila, 2023). This is in addition to its economic importance, employment generation, contribution to people's livelihoods, and ability to solve the problem of malnutrition facing developing nations, especially sub-Saharan African countries (Achoja & Nwokolo, 2021; Koç & Uzmay, 2022; Akouegnonhou & Demirbaş, 2023; Mukaila et al., 2023a). This is particularly true for Nigeria, where malnutrition and food insecurity are widely spread (Falola et al., 2023; Mukaila et al., 2024). The consumption of animal-sourced food is considered a way out of the menace of malnutrition globally (Headey et al., 2018).

Fish farming is a crucial component of the animal farming sector, capable of improving food security, nutrition (Ogundari, 2017; Kent, 2019; Garlock et al., 2020; Song et al., 2023; Bjørndal et al., 2024; Kaminski et al., 2024; Ye et al., 2024), the income of people (Aheto et al., 2019; Adeleke et al., 2021) and nations' GDP (Elzaki et al., 2024). Expansion of fish production is crucial for readily available nutrients such as protein, fats and oils, minerals, and vitamins needed to alleviate undernourishment and nutrient deficiency diseases in sub-Saharan Africa (Falola et al., 2022a, b). Fish and other aquatic products and their derived products are widely consumed due to their nutritional values (Chan et al., 2019; Liverpool-Tasie et al., 2021; Nissa et al., 2021; Sroy et al., 2021).

Fish production is largely on a small-scale level in Nigeria and is practiced using earthen ponds, concrete ponds, and plastic ponds (Iruo et al., 2018; Oluwatayo & Adedeji, 2019; Folorunso et al., 2021), but the output is not enough to meet the local demand. Currently, in Nigeria, the demand (3.6 million metric tons) for fish is higher than the local supply (1.1 million metric tons), thereby creating a wide demand-supply gap. Despite the wide gap, most fish farmers are unable to move from small-scale farming to large-scale farming. This is a result of some constraints limiting fish farm expansion and aquaculture development. The major ones are poor access to funds, low adoption of technology, mortality, disease outbreaks, and small-size holdings (Kaleem & Sabi, 2021; Mukaila et al., 2023b). Taking this into consideration, some agricultural technology digital platforms in Nigeria connect individual or working-class people as farm sponsors with catfish farmers to increase fish production. This innovation seeks to improve fish production, farmers' income, and general well-being. Digital farming technology also aims to transform agriculture from traditional methods to modern and improved methods to achieve high productivity (Mondejar et al., 2021; Baumüller & Kah, 2022; Ingram et al., 2022; Yaghoubi & Niknami, 2022; Arthur et al., 2024; Bekee et al., 2024; Kitole et al., 2024). Despite its great potential, its usage is still very low in developing countries, especially in Africa, which could be linked to limited empirical research on its welfare contribution.

Studies (e.g., Aker & Mbiti, 2010; Halewood & Surya, 2012; Iliyas, 2014; El Bilali & Allahyari, 2018; Falola et al., 2021) have shown that ICT-based innovations improve farmers' income and access to information. Agricultural innovation has also been shown to improve farm output and income (Ogunniyi et al., 2017; Akanbi et al., 2024). However, the role of digital innovation platforms in fish farmers' welfare is lacking in the literature, especially in Nigeria. This implies that more studies are needed on the effects of digital innovation on farmers' welfare. Therefore, this study aims to examine the contribution of digital innovation platforms to farmers' access to credit and to investigate the effect of digital innovation on fish farmers' output and income in Nigeria. This is needed to promote the adoption of digital innovation platforms among farmers in Nigeria and other African countries.

MATERIALS and METHODS

Study area

This study was conducted in Nigeria using digital innovation provider located in Lagos and Ogun State. The states are bounded by the Atlantic Ocean, which makes them a good place for fish farming

Sampling techniques

The catfish farmers under the FARMKART agritech company were used for this study. Out of the 205 registered farmers with FARMKART, 187 were available and able to successfully fill out the questionnaire administered. Thus, the study used 187 fish farmers for the analysis, which is enough to give a good representation of the population.

Data collection method

The data was collected primarily by the researchers. This was achieved through the use of a well-structured questionnaire. The questionnaire consists of four different sections. The survey involved the collection of information on individuals, household numbers, farming experience, average monthly income, age, gender, and education, among other socioeconomic and demographic characteristics. Other information collected included their knowledge of digital innovation, the benefits of digital innovation platforms, their income and productivity, and how they have improved since the adoption of digital innovation platforms.

Data analysis

In analysing the data obtained for the study, descriptive statistics and t-tests were employed.

Descriptive statistics: Descriptive statistics (such as means, tables, frequency distribution, and percentages) were used to analyse, summarize and describe the socioeconomic characteristics of the catfish farmers. It was also used to examine the contribution of digital innovation to fish farmers' access to financial facilities, productivity, and income.

T-test: The t-test statistic was used to compare the welfare indices of the catfish farmers before and after the adoption of the digital innovation platform. The indices compared include the number of fingerlings stocked in the ponds, catfish yield, and catfish farmers' income. The t statistic was used to test whether the means of all the indices before and after the adoption of the digital innovation platform were significantly different or not. It was estimated as:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_{X1X2}\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} \quad (1).$$

Where:

t = t-test value

$\bar{X}_1$ and $\bar{X}_2$ are the mean values of group 1 (before the adoption of the digital innovation platform) and group 2 (after the adoption of the digital innovation platform) compared.

S_{X1X2} is the standard deviation of the two groups.

n_1 and n_2 = number of catfish farmers (n_1 = Before the adoption of digital innovation platforms, and n_2 = after the adoption of the digital innovation platform).

RESULTS and DISCUSSION

Socio-economic characteristics of catfish farmers

This section mainly describes the socio-economic and demographic characteristics of fish farmers who adopted digital innovation in their farming activities. The statistical summary of the catfish farmers' socio-economic characteristics is presented in Table 1. The results revealed that a larger proportion of the catfish farmers (43.3%) in the study area were between 35 and 44 years of age. They had an average age of 38.51 years, indicating an economically active age where they can adopt technology. Younger farmers understand the benefits of innovation in their farming activities and, thus, have a higher level of technology adoption compared to the old farmers (Nechar et al., 2021; Foguesatto & Machado, 2022).

The majority of fish farmers (80.7%) were males, while only 19.3% were females. This indicates that fish farming is a male-dominated venture and could be due to the energy requirement of farming. The majority (81.8%) were married, followed by singles (11.8%) and widows (6.4%).

Table 1. Socioeconomic characteristics of catfish farmers

Tablo 1. *Yayın balığı yetiştiricilerinin sosyoekonomik özellikleri*

Variable	Categories	Frequency	Percentage
Age (years)	25-34	67	35.8
Mean 38.5	35-44	81	43.3
	45-54	39	20.9
Gender	Male	151	80.7
	Female	36	19.3
Marital status	Single	22	11.8
	Married	153	81.8
	Widowed	12	6.4
Educational qualification	SSCE	61	32.6
	ND/NCE	49	26.2
	HND/University Degree	71	38
	Postgraduate	6	3.2
Major occupation	Fish farming	138	73.8
	Trading	28	15
	Civil servant	6	3.2
	Artisan	15	8
Years of Fish farming	Less than 4	43	23
Mean = 8.3	4-7	47	25.1
	8-11	56	29.9
	12-15	20	10.7
	Above 15	21	11.2
Monthly income (₦)	Less than 50,000	18	9.6
Mean = 140,855.12	50,001-100,000	48	25.7
	100,001-150,000	70	37.4
	Above 150,000	51	27.3
Household size	Less than 4 members	40	21.4
Average = 5.6	4-7 members	114	61
	Above 7 members	33	17.6

Regarding their educational qualification, all of the catfish farmers had formal education: 38 percent were Higher National Diploma (HND) or university degree holders, 32.6 per cent were Senior School Certificate Examination (SSCE) holders, 26.2% were Nigeria Certificate in Education (NCE) or National Diploma (ND) certificate holders, and 3.2 per cent were postgraduate degree certificate holders. This could be a reason why they adopted this technology. This is because education enhances decision-making and the adoption of technology as they will be aware of its benefits (Akanbi et al., 2024; Boyacı, 2022; Gbigbi & Ndubuokwu, 2022; Mukaila et al., 2022). In addition, the use of ICT technology requires some level of education (Nechar et al., 2021), at least to read the information and operate the technology. The majority (73.8%) had catfish farming as a primary occupation. They had about eight years of farming experience, which indicates that they are experienced farmers who are knowledgeable about fish farming. Farming experience could positively influence farmers' use of ICT-related innovation (Mansour, 2022). The catfish farmers had an average monthly income of ₦140,855.12 (USD 340.35), which is an indication that fish farming under the use of digital innovation platforms gives the farmers a high income. Frequency distribution according to household size revealed that they had an average household size of about six members. This is relatively large, which is a result of the polygamous and extended nature of rural farming households in Nigeria and for them to have cheap family labour in their farming operations (Chiemela et al., 2022; Falola et al., 2022c).

Access to financial support by catfish farmers from digital innovation

Table 2 presents catfish farmers' access to financial support from digital innovation providers. Access to external finance is crucial for farmers to enhance their productivity and investment in the farming business because personal funds are never enough for farmers to boost their production in Nigeria and other African countries (Falola et al., 2022d; Gbigbi, 2023). In addition, smallholder farmers required financial assistance to adopt technology. Therefore, farmers need sustainable, accessible, and affordable external financial facilities to increase their level of operations. Table 2 shows that all of the catfish farmers accessed credit facilities through digital innovation. The majority of catfish farmers (74.9%) indicated that they had access to over ₦400,000 (USD 966.53) in credit from digital innovation platforms, 21.4 percent had access to less than ₦300,000 (USD 724.90), and 3.7 per cent had access to between ₦200,000 (USD 483.27) and ₦300,000 (USD 724.90). This indicates that fish farmers accessed a significant proportion of their production capital from digital innovation platforms, which was used to boost their productivity. The loan repayment period ranges from a few months to a year. This allowed the farmers to use the loan for at least a production cycle before they paid back to the digital innovation providers. This gives the farmers enough time without being bothered about how to pay back the loan when their fish have not reached marketable size. The majority of the fish farmers pay the loan to the digital innovation provider at the end of six months, which is usually the period of harvest among the farmers. This indicates that digital innovation platforms give fish farmers a moratorium period of about six months, which is longer than commercial banks in Nigeria. These results imply that digital innovation platforms provide farmers with financial facilities in the form of credit to ease fish productivity activities and expand their ventures. Thus, the digital innovation platform plays a significant role in financing fish farmers' production activities and investment. Kudama et al. (2021) also found that the use of digital solutions enhanced farmers' access to financial facilities in sub-Saharan Africa.

Table 2. Access to financial support by catfish farmers from digital innovation

Tablo 2. *Yayın balığı çiftçilerinin dijital inovasyondan mali desteğe erişimi*

Variables	Categories	Frequency	Percentage
Access to credit facilities through digital technology platforms	Yes	187	100
	No	0	0
Amount borrowed	Less than ₦300,000	40	21.4
	₦300,001-₦400,000	7	3.7
	Above ₦400,000	140	74.9
Duration of the loan obtained through digital technology	6 months	146	78.1
	1 year	41	21.9

Welfare of catfish farmers before and after the adoption of digital innovation

This section disintegrates the survey samples before and after the intervention of digital innovation. This section explored the welfare of farmers before and after using digital innovation platforms. Welfare was measured by five key indicators: income from fish farming, the size of ponds, the number of ponds, the number of fingerlings, and farm output. Table 3 presents the number of ponds, the size of ponds, the number of fingerlings stocked by farmers, the yield of the farms, and farmers' income from the sale of fish before they adopted digital innovation technology and after the adoption of digital innovation technology.

As regards the number of ponds, the average number of ponds among fish farmers, before they adopted digital agricultural innovation platforms, was two, while it was three after they adopted digital technology. Thus, there exists a significant difference of one pond in the number of ponds of fish farmers before and after the adoption of digital innovation platforms at a one percent significant level. The adoption of a digital innovation platform resulted in a 59.90 percent increase in catfish farmers' number of ponds on their farms. Thus, fish farmers in the study area are better off in terms of the number of ponds they have after they

adopt digital innovation platforms. This is due to the financial assistance gotten from digital agricultural innovation platforms by the adopters of the innovation, which was used to increase their investment through the construction of more ponds. This indicates the need for fish farmers who are currently not using digital innovation technologies to adopt digital innovation platforms to increase their investment.

From the pond size analysis, it is revealed that fish farmers had an average pond size of 798.4 m^3 before the adoption of the digital agricultural innovation platform. After adopting digital technology in their fish farming activities, they had an average of 925.67 m^3 pond size. On average, the difference between the pond size of fish farmers before and after the adoption of the digital agricultural innovation platform was 127.27 m^3, which is significant at a 1% statistical level. Therefore, the adoption of a digital innovation platform resulted in a 15.94 percent increase in catfish farmers' pond size. This implies that the adoption of digital innovation platforms increased the pond size, which was a result of financial assistance from digital innovation platforms to expand their farm business. Thus, there exists a significant difference in the pond size of fish farmers before and after the adoption of digital innovation platforms. This would allow the fish farmers to increase their production level as they would have enough pond space to increase the number of fingerlings stocked. This further suggests the need to promote the adoption of digital innovation platforms among fish farmers.

Before the adoption of digital innovation in fish farming, the catfish farmers stocked an average of 733.12 fingerlings in the ponds. After adopting digital technology in their fish farming activities, they stocked an average of 952.83 fingerlings in the ponds. The number of fingerlings stocked before and after the adoption of digital innovation increased by 219.71 fingerlings. Therefore, the adoption of a digital innovation platform resulted in a 29.97 percent increase in catfish farmers' number of fingerlings stocked in their ponds. It can be deduced that there is a significant difference in the number of fingerlings stocked by catfish farmers before and after the adoption of digital innovation at a 1% level of significance, as indicated by the t-value of the t-test. This implies that the catfish farmers were able to stock an additional 248 fingerlings on average in the ponds after adopting digital innovation. Thus, the adoption of digital innovation in agriculture increased farmers' access to farming input (fingerlings) among catfish farmers. The reason behind this is due to the financial benefits derived from digital innovation platforms. Furthermore, the digital agricultural innovation platforms also supply fingerlings to the adopters of the innovation at a good price, which prompts the adopters to get more improved fingerlings. Hence, the adoption of digital innovation platforms should be encouraged among fish farmers.

Before the adoption of digital innovation in fish farming, catfish farmers had an average yield of 742.28 kg per production cycle. After adopting digital technology in their fish farming activities, they had an average yield of 1,057.81 per production cycle. The quantity of fish output before and after the adoption of digital innovation increased by 315.53 kg. This indicates that the adoption of a digital innovation platform resulted in a 42.51 percent increase in catfish yield or output. Thus, there exists a significant difference in the catfish yield of the farmers before and after the adoption of digital innovation at a 1% statistical level of significance, as indicated by the t-value of the t-test. In other words, catfish farmers in the study area experienced an increment of about 315.53 kg after adopting digital innovation. This result implies that the adoption of digital innovation in agriculture has increased farm output among catfish farmers. This is due to the financial assistance and farming advice received by farmers from the digital innovation platform. It is also due to the improved fingerlings obtained from the digital agricultural innovation platform providers, which give a higher yield than other sources of fingerlings in the study area. Thus, the adoption of digital innovation platforms is required to boost fish farms' productivity. Its adoption would consequently increase food and nutrition security due to its contribution to the outputs of the farms. This corroborates the arguments of previous studies (for example, Iliyas, 2014; Lioutas et al., 2019; Arouna et al., 2020; Quandt et al., 2020; Kudama et al., 2021) that digital technology increases agricultural productivity.

Furthermore, before the adoption of digital innovation in fish farming, the catfish farmers had an average revenue of ₦540,905.11 (USD 1,307.01) from the fish farm. After adopting digital technology in their fish farming activities, they had an average revenue of ₦780,444.98 (USD 1,885.82) from their fish farms. The revenue generated from the fish farm before and after the adoption of digital innovation increased by ₦239,539.87 (USD 578.81) in a production cycle. This is an indication that the adoption of the digital innovation platforms resulted in a 44.29 percent increase in catfish farmers' income. Thus, there exists a significant difference in catfish revenue or income to the fish farmers before and after the adoption of digital innovation at a 1% statistical level of significance, as indicated by the t-value of the t-test. In other words, catfish farmers in the study area experienced an increment of about ₦239,539.87 (USD 578.81) after adopting digital innovation in fish farming. These results imply that digital innovation in agriculture is a critical tool to enhance fish farms' output and farmers' income, and its adoption must be encouraged among farmers. Its adoption would consequently reduce farming households' poverty due to its contribution to the outputs of the farms. This is in line with previous findings, such as those of El Bilali & Allahyari (2018) and Falola et al. (2021), that ICT-based innovations enhance farmers' income and improve farmers' livelihoods in developing countries. Hence the adoption of digital technologies must be encouraged among farmers to boost their income.

Table 3. Welfare indices of catfish farmers before and after the adoption of digital innovation

Tablo 3. *Dijital yeniliğin benimsenmesinden önce ve sonra yayın balığı çiftçilerinin refah endeksleri*

Welfare Indices	Before adoption	After adoption	Mean Difference	t-value	Percentage increase
Pond size (m^3)	798.4	925.67	127.27***	12.8522	15.94%
Number of ponds	2.02	3.22	1.21***	18.3505	59.90%
Number of fingerlings	733.12	952.83	219.71***	8.5155	29.97%
Catfish yield (Kg per harvest)	742.28	1,057.81	315.53***	7.1594	42.51%
Farmers' income or revenue from catfish production (₦)	540,905.11	780,444.98	239,539.87***	6.8538	44.29%

*** shows the mean difference is significant at a 1% statistical level.

CONCLUSION

The study explored the digital agricultural innovation and welfare of catfish farmers in Nigeria. This study shows that the adoption of digital innovation platforms enhances catfish farmers' access to credit needed for their farming activities. Furthermore, the study reveals the outcome effect of using digital innovation on catfish farming productivity and catfish farmers' income, which was significantly higher than before the digital innovation platform was introduced to them. This study therefore concludes that the adoption of digital innovation platforms by catfish farmers is an important way for farmers to have access to credit, increase their production level, and improve their welfare. Thus, the adoption of digital innovation by other farmers will boost their standard of living since it has been proven to increase the productivity and income of the adopters significantly.

To achieve more participation in the digital innovation platforms by fish farmers to improve their productivity and income, this study recommends that catfish farmers should be motivated and encouraged to adopt digital innovation in agriculture. Such motivations include increasing financial support from the digital innovation platform providers and investors given to the farmers. Provision of fish farming inputs, especially improved variety of fingerlings, by digital innovation providers will further motivate farmers to adopt the technologies. More awareness creation of digital innovation in agriculture for the farmers is needed by the agricultural extension agents and digital innovation providers so they can be well informed about the benefits of adopting the innovation.

Data Availability

Data will be made available upon reasonable request.

Author Contributions

Conception and design of the study: AF, RM, ONY; analysis and interpretation of data: ONY, AF, RM, ASO, FEA, IIU; statistical analysis: RM, AF, ONY; visualization: AF, RM, ONY, ASO, FEA, IIU; writing manuscript: AF, RM, ONY, ASO, FEA, IIU.

Conflict of Interest

There is no conflict of interest between the authors in this study.

Ethical Statement

This research was approved by the ethics committee of University of Nigeria, Nsukka, Department of Agrıcultural Economics Ethical Review Committee with document number UNN/AGEC/19/EGAP/21, dated 11th July, 2022.

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