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# Farmers' willingness to adopt digital application tools in Ogun State, Nigeria

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## Abstract

**Purpose** – The agricultural sector has experienced a transformative impact through the adoption of digital technologies, particularly mobile applications designed for farmers. This study investigates the factors influencing smallholder farmers' willingness to adopt digital application tools in Ogun State, Nigeria, focusing on the IITA herbicide calculator and Akilimo mobile applications.

**Design/methodology/approach** – Data were gathered from 572 smallholder farmers participating in the Zero Hunger project. This research contributes to the limited empirical evidence in Nigeria concerning farmers' willingness to adopt digital application tools. The study analyzes the effects of education, training, access to internet services, smartphone ownership, willingness to use paid applications, awareness of application tools and the cost of digital tools on farmers' willingness to adopt. Gender differentials in willingness to adopt were also explored.

**Findings** – The results indicate positive and statistically significant effects of education, training, internet access, smartphone ownership, willingness to use paid applications, awareness of application tools and the cost of digital tools on farmers' willingness to adopt. However, female farmers exhibited a lower willingness to adopt digital application tools.

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**Practical implications** – Policymakers are urged to create supportive policies promoting basic formal education and provide effective extension services to enhance farmers' training. Additionally, efforts should be made to reduce the cost of digital applications and improve internet accessibility in rural areas. Encouraging female farmers to adopt advanced agricultural technologies is essential. Stakeholders are advised to raise awareness of digital application tools to expedite the adoption of agricultural technologies in the country.
**Social implications** – This study will be helpful for the government to determine the state's readiness for digital agriculture, it will help technology developers and agricultural technology startups to understand the factors determining farmers willingness to adopt digital application tools.
**Originality/value** – This study offers insights into the readiness of Ogun State, Nigeria, for digital agriculture. It provides valuable information for technology developers and agricultural startups to understand the determinants of farmers' willingness to adopt digital application tools, contributing to the advancement of the agricultural technology landscape.

**Keywords** Willingness to adopt, Digital application, Technology adoption, Logistic regression, IITA herbicide calculator, Akilimo

**Paper type** Research paper

## Introduction

Digital technologies have proved useful in various sectors such as health, manufacturing, finance, and agriculture (Muhamad *et al.*, 2021; Massaro *et al.*, 2021; Mohapatra *et al.*, 2022). Digital technologies increase productivity, enhance quality, and promote environmental sustainability in the agricultural sector (Saiz-Rubio and Rovira-Más, 2020). Digital transformations through "Industry 5.0" are transforming agriculture through precise and real-time decision-making in farming activities (Hrustek, 2020; Saiz-Rubio and Rovira-Más, 2020). Internet applications and mobile phones, among other digital technologies, are changing how people communicate (Boateng *et al.*, 2017) and its prospects in agriculture have advanced significantly (FAO and ITU, 2017). According to Sturgeon *et al.* (2017), there is a chance that the "New Digital Economy" may lead to the creation of digital solutions for numerous problems facing agricultural development. The integration of digital technologies in agriculture not only enhances efficiency within agricultural value chains but also supports the three pillars of Industry 5.0: human-centricity, resilience, and sustainability. This approach prioritizes the needs of farmers, empowering them to adapt to a changing environment and ensuring sustainable production (Bukht and Heeks, 2018).

The availability and adoption of technological innovations by farmers are imperative for sustained agricultural productivity (De Janvry *et al.*, 2016). This is particularly important for the Nigerian economy, where the sector contributes about 23.4% to the Gross Domestic Product (GDP) (Worldbank, 2021) and employs over 70% of Nigeria's labour force (NITDA, 2020). The application of digital technologies is, therefore, a welcome development for Nigeria's agricultural development, considering the current realities in the country. New digital technologies are being generated; however, the adoption process remains a challenge (Dissanayake *et al.*, 2022). This paper, therefore, focuses on assessing the awareness and willingness to adopt weed management and agronomy advisory digital application tools in Nigeria. The digital application tools considered in this study are the IITA Herbicide calculator and Akilimo. These tools were developed by the International Institute of Tropical Agriculture (IITA) in 2019. Digital technologies are central to disseminating real-time information to farmers about weather, farming, and harvesting techniques (Kumar *et al.*, 2021). Nyarkoa and Kozárib (2021) posited that adopting agricultural technology leads to increased efficiency and productivity through improved extension service delivery. Consequently, the productivity gains and income increase resulting from technology adoption significantly enhance the livelihoods of agricultural households in the country.

According to reports, $63 million was reportedly spent on agricultural technologies in Africa in 2019. About 60% of the investment and operational startups were in Kenya, Nigeria, and Ghana. Nigerian agricultural technology companies use digital solutions to increase farmers' access to markets, financing, assets, and data-driven information (Raithatha, 2020). According to

Shapshak (2018), some of Nigeria's leading agricultural technology companies include Thrive Agric and Farmcrowdy, which provide platforms for public investment in agribusiness. AgroMall creates economic identities for farmers using farmer data, whereas Crop2Cash digitizes the entire value chain and offers digital payments. To help farmers have more negotiating power, AFEX generates tradeable electronic warehouse receipts that can be used as money. It also provides services like connecting farmers with agronomic training, input access, and loans. To enhance farmers' productivity, BeatDrone uses drones for pesticide spraying, crop monitoring, and farmland mapping. On the other hand, Hello Tractor uses an online platform to connect tractor owners and smallholder farmers. Verdant AgriTech provides farmers with a mobile-based digital solution that offers market information, managerial support, and market access for smallholder farmers. TradeBuza is another cloud-based web and mobile-based platform that assists clients in managing the visibility of their out-grower schemes and trading commodities more effectively (Shapshak, 2018). Agricultural technology firms are fast offering innovative technology solutions to farmers. This brings to the fore the issues of awareness and adoption of these technological solutions by farmers.

The motivation of this study is premised on the importance of the agricultural sector to the Nigerian economy, in terms of food production and livelihood. Smallholder farmers are integral to achieving this goal. However, smallholder farmers in most developing countries, including Nigeria face barriers to accessing the knowledge, skills, and market information necessary to increase their income (Chapagain and Raizada, 2017; Misaki *et al.*, 2018; Petcho *et al.*, 2019). The emergence of the internet and increased global connectivity present a significant opportunity for the country to leverage technological innovation, such as mobile applications, to accelerate farmers' livelihood and ensure responsible food production. Utilizing information and communication technology (ICT), such as mobile phone applications, is one strategy farmers can use to manage and address problems that impede agricultural productivity and development (Mandi and Patnaik, 2019; Krell *et al.*, 2021; Sharma *et al.*, 2020). Despite these opportunities, Diaz *et al.* (2021) reported that most farmers have not taken full advantage of these benefits. The efficient use of ICTs in developing nations is hampered by issues including a lack of knowledge and expertise in using mobile phones and applications, the inability to purchase mobile devices, the use of foreign languages in applications, and network issues, among other things (Emeana *et al.*, 2020; Hoang, 2020; Sadekur Rahman *et al.*, 2020).

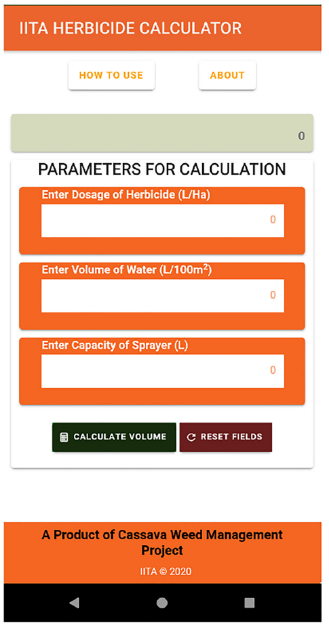
In addition, the knowledge, services, and technologies available to smallholder farmers are limited. In most cases, they require assistance to adopt improved farming techniques. The main thrust of agriculture technology solutions is the extension services that help farmers accept new technologies and innovation. ICTs can support extension agents' work in assisting farmers with crop planning, locating inputs for crop cultivation, and local market sales. With individualized and tailored services, ICT communication technologies can be critical in helping farmers access new inputs, credit, and markets. As a result of the poor adoption of many fee-based ICT subscription models (Alshubiri *et al.*, 2019), many digital technology efforts, despite their promise, fail to scale up (Ebad, 2018). When predicted advantages from information outweigh the costs, it is generally considered that people will invest in getting that information. Considering this, the observed limited uptake of agricultural technologies by farmers, even at reasonable prices, could be easily explained by low expected returns. Although many digital technology services are available, farmers are unaware of or unwilling to adopt them, among other related problems, limiting their use (Mhlanga and Ndhlovu, 2023). This study contributes to the limited literature on the willingness to adopt mobile application tools by farmers, especially in Nigeria. Similar studies in other countries include Diaz *et al.* (2021) who investigated farmers' willingness to use a mobile app for bamboo product marketing in the Philippines; Krell *et al.* (2021) investigated the factors influencing Kenyan farmers' likelihood to adopt mobile phone services; Kabbiri *et al.* (2018) used data from Ugandan dairy farmers to examine the adoption of mobile phones

in the agri-food sector in Sub-Saharan Africa. This study was done to determine whether farmers would be willing to accept digital technology tools and what factors would influence their decision in the Nigerian case.

To appropriate the benefits of digital innovation and technologies, it is espoused in different national, regional, and global policy objectives. The current study aligns with the sustainable development goals of ending poverty (SDG1), zero hunger (SDG2), and sustainable consumption and production (SDG12). Considering the regional policy objectives, it aligns with the Agenda 2063 of the African Union (Goal 5) of increasing agricultural productivity through the modernization of agriculture (AUC and AUDA-NEPAD, 2020). At the national level, the study will proffer policy direction to the achievement of the Nigeria Digital Agriculture Strategy (NDAS), which was developed in 2020 as an offshoot of the Nigeria Smart Initiative and the Nigeria Digital Economy Policy and Strategy (NDEPS). The current National Development Plan (2021–2025) also aims to increase agricultural productivity by introducing technology and innovative agriculture solutions. In what follows are the description of the agricultural digital technology tools considered in the study and the methodology. The results and discussion section follow this, along with the concluding remarks and policy recommendations.

## Description of selected agricultural digital technology tools

IITA Herbicide Calculator and Akilimo were selected for this study because cassava is a major staple crop in Nigeria, and eradicating weeds takes over 60% of the cost of producing cassava. In addition, with the high cost of fertilizer, there is a need for effective usage, hence, the focus on Akilimo as fertilizer optimization for maximum yield.




*Herbicide calculator*

The IITA Herbicide Calculator is a mobile app created and released by IITA and the Cassava Weed Management Project, financed by the Bill and Melinda Gates Foundation. It has been used in Nigeria and other African nations to manage weeds in cassava. The App, which functions on a basic smartphone and is available online and offline, assists farmers (who grow cassava primarily) in estimating the appropriate amount of herbicides to put in knapsack sprayers. This prevents farmers from under- or overdosing, which can result in environmental pollution and weed resistance.

There is an ongoing evaluation on the impact of the application on farmers' cost of production but feedback from the farmers using the technology in Ogun State revealed that it contributes to a reduction in the cost of herbicide purchase and effective weed management.


*Akilimo*

The African Cassava Agronomy Initiative (ACAI), coordinated by IITA, created the mobile agronomy advisory tool Akilimo. Cassava growers receive agronomic guidance from Akilimo. The tools offer specific advice to farmers on how to cultivate cassava, including how to apply fertilizer, steps to manage weeds, use the best planting techniques, and intercrop cassava with sweet potato (for Tanzania) and maize (for Nigeria). As of September 2022, AKILIMO recommendations have been deployed on 370,000 Hectares in Nigeria and Tanzania, 6,504 extension agents have been trained, and 809,396 people have been reached with the technology (Akilimo, 2022). Preliminary results from the field revealed that Over 75% of Akilimo users reported increases in yield and profit on their cassava production (Laborde, 2022).

## Technology acceptance model

This study rests on the technology acceptance model as proposed by Davis (1989). This theory has been adopted in several empirical studies (Chuttur, 2009; Kabbiri *et al.*, 2018; Rezaei *et al.*, 2020). This theory is useful in informing relevant stakeholders/technology developers, implementers, and policymakers whether a newly developed technology would be accepted or not (Kabbiri *et al.*, 2018). The main elements of this theory are perceived use, perceived ease of use, attitude, and behavioural intentions to use new technology. This model helps to understand the factors that influence human behaviour towards potential technology acceptance or rejection. Critics of the model reported that the model does not fully reflect the specific contextual and technological factors that may influence users' acceptance of technology (Wang *et al.*, 2003; Kabbiri *et al.*, 2018). For the current study, the main elements of the theory may not fully explain the willingness of the farmers to pay for the digital application tools. As with other studies such as Kabbiri *et al.* (2018), other factors can predict the uptake of the mobile digital application tools by farmers. These factors include adoption factors, behavioural intention, and technology usage (Park and del Pobil, 2013). Hence, the inclusion of these factors will enhance the applicability of the model (Rind *et al.*, 2017). This study extends the technology acceptance model by including some variables, namely innovativeness, perceived cost, socio-demographic characteristics, innovating factor

for mobile phone technology in the agri-food sector, and information awareness, as additional constructs to analyse motivating factors for the adoption of digital application tools by farmers.

## Review of empirical studies

Farmers' willingness to use a mobile app for bamboo product marketing in the Philippines was investigated by Diaz *et al.* in 2021. The research modified the technology acceptance model by examining farmers' perceptions of cost, socio-demographic characteristics, innovativeness, simplicity of use, and social influence in addition to information awareness and affordability. According to the findings, there was a statistically significant positive association between these variables and the propensity to adopt mobile apps for bamboo marketing. Still, farmers' worries about total costs, including mobile data, transaction, and downloading costs—had a major detrimental impact on their WTA due to the perceived cost. Based on the findings, the government should create laws that lower the expenses associated with adopting technology to encourage farmers to use apps like Bamboost. This could lead to a decrease in rural poverty.

Krell *et al.* (2021) investigated the factors influencing Kenyan farmers' likelihood to adopt mobile phone services. These services included information about purchasing and selling goods, notifications regarding activity relating to agriculture or livestock, and information about agriculture and animals. The findings showed that the use of mobile services is more likely among those who own a personal smartphone and are members of agricultural organizations. According to the study, mobile service providers should design their products for basic or feature phone customers to increase the distribution of agro-meteorological information to the farmers.

According to Mandi and Patnaik (2019), the introduction of mobile apps in the agriculture and allied sectors has sped up the pace at which farmers are transferring technology to one another. It has developed into a channel through which farmers can obtain information about farming, including seeds, crop selection, crop cultivation, weather, fertilizer, pesticides, and other related topics, from a variety of sources that are dispersed across different regions based on the product's origin, processors, producers, or vendors who use the app. The app provides a simple way to manage and communicate with farmers efficiently.

Kabbiri *et al.* (2018) used data from Ugandan dairy farmers to examine the adoption of mobile phones in the agri-food sector in Sub-Saharan Africa. According to the study, one of the main factors influencing the adoption of mobile phones is perceived ease of use. However, perceived benefit and perceived utility have a negative impact on the uptake of mobile phones. This was somewhat expected, as most of the farmers in the research used their phones primarily for everyday communication rather than to market their produce by looking up and exchanging pricing information. For these reasons, awareness campaigns by pertinent parties are necessary to alter these farmers' perspectives regarding the use of mobile phones. Hoang (2020) on the factors that influence Vietnamese farmers' use of mobile phones for fruit marketing. The study found that young male farmers with high incomes who live far from local markets and take part in training programs are more likely to use ICT tools—mobile phones—for fruit marketing. When choosing marketing information strategies to distribute to small-scale farmers in developing nations, as well as when encouraging farmers to adopt ICT tools for agricultural produce marketing, it is important to consider their demographic, socioeconomic, situational, and institutional characteristics. Farmers' adoption of ICTs (mobile phones) for fruit marketing is hampered by the high cost of using them and their lack of experience or skill in using applications.

## Materials and methods

### *The study area and period*

The research was carried out in Ogun State, Nigeria. Ogun State is located in the southwest of the country and has 20 Local Government Areas (LGAs). Agriculture is the mainstay of the state's economy, and cassava is a major crop. Therefore, this state was chosen because it is a major cassava-producing state in Nigeria. The study was conducted in 10 Local government areas (LGAs) out of the 20 LGAs in Ogun State, Nigeria. These LGAs were purposively selected as the LGAs involved in the Zero Hunger Project. The data were collected from November 2, 2021, to April 7, 2022.

### *Sampling procedure and sample size*

Ogun State was chosen being a major cassava producing state in Nigeria. In addition, the Cassava Weed Management Project (CWMP) which developed the IITA Herbicide Calculator, and the ACAI, which developed Akilimo were implemented in this state.

The Zero Hunger project, funded by the International Fund for Agricultural Development (IFAD), aims to contribute to Zero Hunger initiatives in the rice and cassava value chains of Nigeria and Togo. Among other technologies deployed under the project, the baseline study in 2021 focused on examining the status of established mobile applications, such as the IITA Herbicide Calculator and Akilimo, to address farmers' knowledge gaps and enhance productivity. This research specifically investigates the willingness of farmers in selected LGAs in Ogun State to adopt these digital tools.

To conduct this study, a sample size was drawn from a pool of 9,000 farmers, purposively selected and profiled from 10 Local Government Areas (LGAs) in Ogun State. The choice of these ten LGAs was purposeful, considering factors such as the concentration of cassava farmers, previous deployment of digital tools, security considerations, and accessibility. Interactions with the extension agents helped the team to identify and exclude high-risk or inaccessible areas. In all, a total of 572 cassava farmers were randomly selected. The data collection was conducted using the Open Data Kit (ODK) (see Table 1).

### *Analytical techniques*

Descriptive statistics such as frequency tables, means, and standard deviation were used to describe the socio-economic characteristics of the cassava farmers in the study area. Also, the awareness, availability, and use of digital technologies/infrastructure were analysed using descriptive statistics.

The logit regression was used to isolate the factors influencing farmers' willingness to adopt weed management and agronomy advisory digital application tools in Nigeria. The choice of the logit regression is premised on the nature of the dependent variable being dichotomous, which is the willingness of the farmer to adopt the digital mobile app or not. The logit regression model is presented as follows:

The regression model is expressed as follows in equation (1):

$$will\_adpt_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ldots + \beta_n X_n + \varepsilon_i \quad (1)$$

Where $will\_adpt_i$ is defined as:

$$will\_adpt_i = \begin{cases} 1 & if\ a\ farmer\ is\ willing\ to\ adopt\ digital\ application\ tools\ (\text{IITA Herbicide calculator and Akilimo}) \\ 0 & Otherwise \end{cases}$$

### *Motivation for choice of variables*

The explanatory variables are described in the Table 2:

| LGA | Total No of farmers | Female | Male | Youth | Adult | Number of communities | Names of the communities |
|---|---|---|---|---|---|---|---|
| Ado odo ota | 25 | 11 | 14 | 11 | 14 | 3 | Arobieye, Oko omi and the Bells University |
| Ijebu East | 24 | 2 | 22 | 3 | 21 | 5 | Tibgori, Odomefi, odole, Ijebu mushin and Ojowo |
| Ijebu North | 39 | 2 | 37 | 17 | 22 | 7 | Odo-ejogun, Ago iwoye, Kegbo, Ojowo, Enigbokowa, Amula and Farm Settlement |
| Ijebu North East | 10 | 4 | 6 | 3 | 7 | 3 | Odogbolu apunren and Imuroko |
| Ikenne | 49 | 15 | 34 | 11 | 38 | 4 | Ilisan, Ikenne, Iperu and Irolu |
| Obafemi Owode | 85 | 34 | 51 | 29 | 56 | 5 | Oyebola, Owode, Oduro, Omileragu and Ayiwere |
| Odeda | 105 | 28 | 77 | 33 | 72 | 8 | Agbaje/Eweje, Sanusi, Ijo Agbe, Kugba Ajagbe, Itoko, Oluga, Ajegunle, Rogun Rogun |
| Odogbolu | 74 | 25 | 49 | 12 | 62 | 6 | Idowa, Aiyepe,Imodi, Ibefun, Ala and Eyinwa |
| Yewa North | 80 | 13 | 67 | 32 | 48 | 7 | Ayetoro, Igbogila, Gbokoto Isale, Ibooro, Igan Alade, Ijoun (Ijale Ketu Community) and Ayetoro (Saala Orile Community) |
| Yewa South | 81 | 13 | 68 | 33 | 48 | 6 | Itaegbe, Ihunbo, Okeodan, Ilaro, Eyekanse And Eredo |
| | *572* | *147* | *425* | *184* | *388* | *54* | |

**Source(s):** Authors' calculation from the Zero Hunger Project baseline survey, 2022

**Table 1.** Sampling distribution of farmers

Sex of farmer (1 = male; 0 = female)
Age of farmer (years)
Level of education (1 = No formal education; 2 = primary education; 3 = secondary education; 4 = tertiary education)
Years of experience in cassava farming (years)
Attended training (1 = Yes; 0 = No)
Access to internet service (1 = Yes; 0 = No)
Access to extension services (1 = Yes; 0 = No)
Awareness of IITA herbicide calculator (1 = Yes; 0 = No)
Awareness of Akilimo (1 = Yes; 0 = No)
Ownership of smartphone (1 = Yes; 0 = No)
Usage of paid phone application (1 = Yes; 0 = No)
Heard of calibration spraying (1 = Yes; 0 = No)
Cost of digital application tool (1 = Yes; 0 = No)
Ease of use of digital application tool (1 = Yes; 0 = No)
Innovativeness of digital application tool (1 = Yes; 0 = No)
Digital application tool used by other farmers (1 = Yes; 0 = No)

**Table 2.** Explanatory variables

Empirical evidence exists that the use of mobile phones in delivering agricultural information leads to the adoption of technologies (Cole and Fernando, 2016; Hoang, 2020) and improved production (Casaburi *et al.*, 2019; Haruna *et al.*, 2018; Mwita *et al.*, 2020). Following Kabbiri *et al.* (2018) and Diaz *et al.* (2021), our research model rests on an extension of the TAM model, where the willingness to adopt mobile digital applications is jointly determined by perceived use, ease of use, innovativeness, information awareness, perceived cost, and socio-economic characteristics. It is evidenced in the literature that individuals/farmers will adopt a technology if they find such technologies useful (Kabbiri *et al.*, 2018; Diaz *et al.*, 2021). Chuttur (2009) and Wu and Wang (2005) reported that for a given technology to be adopted, it must be easy to use. The perceived cost of a technology is a crucial component. If using a technology has an expense associated with it, farmers are less likely to adopt it. Accordingly, adoption and perceived cost are expected to have a negative relationship (Wu and Wang, 2005; Rehman *et al.*, 2016; Okoroji *et al.*, 2021). Furthermore, it is proposed that farmers are more likely to adopt a technology if they believe it to be innovative (Hung *et al.*, 2003; Alalwan *et al.*, 2018; Diaz *et al.*, 2021). The age, educational attainment, and size of a farmer's farm are sociodemographic factors that affect the adoption of smartphone applications (Michels *et al.*, 2020). Differences in the adoption of technology between smallholder farmers and their counterparts may also be caused by factors like farm size and education (Caffaro and Cavallo, 2019). According to Aker (2011) and Hakkak *et al.* (2013), farmers consider the advice of friends, fellow farmers, and family when deciding which technology to use. Research on ICT adoption has shown that smallholder farmers are generally cost-conscious and sensitive to even small changes in the services fees associated with a particular commodity or technology (Okoroji, 2019). This submission was also put forward by Arslan *et al.* (2014), Jumbe and Nyambose (2016), and Ntshangase *et al.* (2018). They emphasized that farmers who received regular visits and support from extension workers were more likely to implement new farming techniques or technologies. Additionally, using mobile applications is positively correlated with smartphone ownership (Krell *et al.*, 2021; Thar *et al.*, 2021).

## Results and discussion

### *Socio-economic characteristics of cassava farmers*

According to Table 3, 74.3% of the cassava farmers are male. Most of the farmers are between 25–54 years of age (64.5%), followed by those between 55–64 years. The average age of sampled cassava farmers was 45.1 years. This shows that most of the sampled cassava farmers are in their economically active years and might be willing to adopt digital technologies. Interestingly, about 23.6% of cassava farmers have tertiary education, while 33.2% have secondary education, followed by those with primary education, which was put at 31.6%. This is a reflection that cassava farmers in the sampled areas are largely educated. This is in contrast to the notion that most farmers in Nigeria have no form of formal education. This will have implications for the willingness of the farmers to adopt digital technologies in their production activities and in making informed production decisions. For farming experience, most of the farmers had 1–5 years of experience in cassava farming (67.5%), while 32.5% had between 6–10 years of farming experience. The average years of farming were 18.5 years.

The sampled farmers are all producers and do not process or market cassava at the time of collecting this data. About 91% of sampled farmers reported that either of the parents was involved in farming. Similarly, about 57% of the farmers also reported that their children were also involved in farming. The probable reason is that farming is an inter-generational occupation among the respondents. The sampled cassava farmers belong to one association or the other, with varying years of membership, the least number of years being 1–5 years (52.9%). At least 75.8% of the farmers cultivate 2 hectares or less, with the average area under cultivation being 1.9 hectares. This is typical of smallholder farmers in Nigeria, as also put

| Socio-economic characteristics | Frequency | Percentage (%) |
|---|---|---|
| *Sex of respondent* | | |
| Male | 425 | 74.30 |
| Female | 147 | 25.70 |
| Total | 572 | 100.00 |
| *Age (years)* | | |
| 15–24 years | 38 | 6.64 |
| 25–54 years | 369 | 64.51 |
| 55–64 years | 114 | 19.93 |
| 65 years and above | 51 | 8.92 |
| Total | 572 | 100.00 |
| Mean = 45.1 years | | |
| *Years of experience* | | |
| 1–5 years | 386 | 67.48 |
| 6–10 years | 186 | 32.52 |
| Total | 572 | 100.00 |
| Mean = 18.6 years | | |
| *Level of education* | | |
| None | 66 | 11.5 |
| Primary | 181 | 31.64 |
| Secondary | 190 | 33.22 |
| Tertiary | 135 | 23.60 |
| Total | 572 | 100.00 |
| *Did any of your parents (father or mother) practise farming?* | | |
| Yes | 501 | 90.93 |
| No | 50 | 9.07 |
| Total | 551 | 100.00 |
| *Is any of your children or members of your family (if a youth) interested in far* | | |
| Yes | 312 | 56.93 |
| No | 236 | 43.07 |
| Total | 548 | 100.00 |
| *Have you ever attended training in cassava production or processing?* | | |
| Yes | 321 | 56.12 |
| No | 251 | 43.88 |
| Total | 572 | 100.00 |
| *Is the household head a member of an association/cooperative?* | | |
| Yes | 344 | 60.14 |
| No longer | 62 | 10.84 |
| Never | 166 | 29.02 |
| Total | 572 | 100.00 |
| *Do you have access to extension services?* | | |
| Yes | 527 | 93.44 |
| No | 37 | 6.56 |
| Total | 564 | 100.00 |

(*continued*)

**Table 3.** Socio-economic characteristics of cassava farmers

| Socio-economic characteristics | Frequency | Percentage (%) |
|---|---|---|
| *The area under cultivation (Ha)* | | |
| <=1 ha | 310 | 54.20 |
| 1.01–2 ha | 124 | 21.68 |
| 2.01–3 ha | 44 | 7.69 |
| 3.01–4 ha | 35 | 6.12 |
| 4.01–5 ha | 59 | 10.31 |
| Total | 572 | 100.00 |
| Mean = 1.93 Ha | | |

**Table 3.** **Source(s):** Authors' computation

forward by UNCTAD (2015), that smallholder farmers in Nigeria cultivate less than 2 hectares of land.

Concerning training on cassava production, 56.1% of the farmers have attended training on cassava production. Only 43.8% have not attended any form of training on cassava production. The training received by these farmers is likely to affect the decision to adopt new technologies. This is because the training will expose the farmers to recent trends in cassava production and available technologies and innovations that could drive productivity among farmers. It was also reported that 83.7% of the farmers derive their income from agriculture. Sampled cassava farmers belong to an association or a cooperative group (60.1%), and 20% have never been a member of any association.

*Access and use of digital technologies/infrastructure*

Access to the internet and the availability of smartphones are important, influential factors in smallholder farmers' willingness to adopt digital technologies. Table 4 presents the evidence from the sampled cassava farmers on access and use of digital infrastructure in the study area. Results revealed that about 72.7% of the farmers had access to the Internet in their respective communities. However, only 39.2% of the farmers had smartphones. This is likely to affect these farmers' willingness to adopt a digital application tool for improved productivity. Among the sampled farmers who owned smartphones, about 88% of them use their smartphones for WhatsApp, a digital communication application tool. Other uses are for Facebook (6.3%) and online businesses (3.6%). A slightly above-average proportion of the farmers currently use paid phone applications on their phones (51.4%). About 48.6% do not use any paid application on their smartphones. A further question was asked on the areas of use or preference of any digital application tool downloaded with the smartphone. The sampled farmers responded that they would download or use an application that gives weather forecasts (64.5%), supports pests and disease management (12.2%), weed management (7.0%), value addition, or crop processing (7.0%), among other uses. This reflects the areas of need of the farmers, where digital application tools can help improve productivity at the farm level.

The farmers also reported on some characteristics and features they looked for before using a digital application tool. The characteristics and features considered are the cost of the application, ease of use, innovativeness, already used by other farmers, and whether it helps solve a problem. About 46.8% of the farmers alluded that the cost of the application is a factor they look out for before using any digital application tool; this is followed by ease of use of the application (31.3%) and if the application tool helps in solving a problem (17.2%). Others are innovativeness (2.8%) and digital application being used by other farmers (1.4%). The farmers also reported that the language of instruction is integral to their willingness to adopt any digital application tool. The majority of the farmers (87.2%) were affirmative of this

| | Frequency | Percentage (%) |
|---|---|---|
| *Do you have access to the internet in your community?* | | |
| Yes | 416 | 72.7 |
| No | 156 | 27.3 |
| *Total* | *572* | *100* |
| *Do you have a smartphone?* | | |
| Yes | 224 | 39.2 |
| No | 348 | 60.8 |
| *Total* | *572* | *100* |
| *If you have a smartphone, what do you use it for?* | | |
| WhatsApp | 197 | 88.0 |
| Facebook | 14 | 6.3 |
| IG | 2 | 0.9 |
| Online business | 8 | 3.6 |
| Other Apps | 3 | 1.3 |
| *Total* | *224* | *100* |
| *Do you currently use any paid phone applications?* | | |
| Yes | 113 | 51.4 |
| No | 107 | 48.6 |
| *Total* | *220* | *100* |
| *If not, have you used any paid phone applications before?* | | |
| Yes | 14 | 13.1 |
| No | 93 | 86.9 |
| *Total* | *107* | *100* |
| *If you were to download or use an application, which of the following areas would* | | |
| An application that gives the weather forecast | 369 | 64.5 |
| An application that supports pests and disease management | 70 | 12.2 |
| Application on weed management | 40 | 7.0 |
| An application that supports farm records | 11 | 1.9 |
| An application that supports payment (receiving and paying out) | 31 | 5.4 |
| An application that gives fertilizer recommendation | 5 | 0.9 |
| An application that supports farmers' profiling(showing age, sex, location and business | 6 | 1.1 |
| An application that teaches value addition or how to process crops | 40 | 7.0 |
| *Total* | *572* | *100* |
| *What do you look out for before using an application?* | | |
| Cost of application | 264 | 46.8 |
| Ease of application | 179 | 31.7 |
| Innovativeness | 16 | 2.8 |
| If it is to be used by other farmers | 8 | 1.4 |
| Solving a problem | 97 | 17.2 |
| *Total* | *564* | *100* |
| *Does the language of instruction in an Application matter to you?* | | |
| Yes | 492 | 87.2 |
| No | 72 | 12.8 |
| *Total* | *564* | *100* |

(*continued*)

**Table 4.** Access and use of digital technologies/ infrastructure

| | Frequency | Percentage (%) |
|---|---|---|
| *Which of the following languages will you prefer to use as an Application?* | | |
| English | 104 | 19.1 |
| Yoruba | 296 | 54.1 |
| Pidgin | 12 | 2.2 |
| English and Yoruba | 116 | 21.3 |
| Either English, Yoruba or Pidgin | 16 | 2.9 |
| *Total* | *544* | *100* |

**Table 4.** **Source(s):** Authors' computation

position. They also added that their preferred language of instruction is their mother tongue, the Yoruba language (52.5%). Followed by those who preferred both English and Yoruba languages (20.6%) and English language alone (18.4%). This further reinforces that digital application developers should take into cognizance the preferred language of farmers before developing any application for them. This will go a long way to foster their acceptability and usage of such tools.

*Awareness and use of digital application tools*

This section considers the awareness of the farmers about the digital application tools considered in this study, which are the weed management (IITA Herbicide calculator) and agronomy advisory (Akilimo) digital application tools in Nigeria. Results in Table 5 revealed that the level of awareness of the IITA herbicide calculator and the Akilimo is still quite low, as only about 21.8% and 26.6% of the farmers have heard of the weed management and the agronomy advisory tools, respectively. The reason adjudged for this low awareness of the IITA Herbicide calculator despite its importance to the farmers was that it was developed and deployed towards the end of a donor-funded intervention. As such, the follow-up with the

| | Frequency | Percentage (%) |
|---|---|---|
| *Have you heard about IITA Herbicide Calculator Application before?* | | |
| Yes | 125 | 21.8 |
| No | 447 | 78.2 |
| *Total* | *572* | *100* |
| *If yes, have you used it before?* | | |
| Yes | 28 | 22.4 |
| No | 97 | 77.6 |
| *Total* | *125* | *100* |
| *Have you heard about the Akilimo Application before?* | | |
| Yes | 152 | 26.6 |
| No | 420 | 73.4 |
| *Total* | *572* | *100* |
| *If yes, have you used it before?* | | |
| Yes | 47 | 30.9 |
| No | 105 | 69.1 |
| *Total* | *152* | *100* |

**Table 5.** Awareness and use of digital application tools

**Source(s):** Authors' computation

farmers was not sustained. Furthermore, among farmers who were aware of both tools, only 22.4% and 30.9% of the farmers used the IITA herbicide calculator and the Akilimo, respectively. Considering the period the digital application tools were developed, these proportions are still quite low, and the adoption lag needs to be minimized significantly. The adoption lag advanced by some of the farmers for the IITA herbicide calculator was caused primarily by the need for the farmers to calibrate the Knapsack before usage. This proved an arduous task for the farmers.

*Factors influencing farmers' willingness to adopt digital application tools*

The logistic regression results for the factors influencing farmers' willingness to adopt digital application tools are presented in Table 6. The model was significant at 1%. The significant variables are sex, level of education, access to training, access to the internet, awareness of digital application tools, smartphone ownership, use of paid phone applications, and cost of digital application tools.

Results revealed that the coefficient of sex, with reference to female farmers was negative and statistically significant ($p < 0.1$) with the willingness to adopt farmers. This implies that female farmers are less likely to adopt digital application tools. This likelihood decreases by 8.1% points. This finding is consistent with that of Murage *et al.* (2015), who reported that male smallholder farmers adopted improved technologies faster than their female counterparts. The level of education is positive and statistically significant with the willingness to adopt (secondary education at $p < 0.05$ and primary education at $p < 0.1$). This means that as farmers' level of education increases, the probability that such a farmer will adopt the digital application tools increases. For instance, the results revealed that with

| | | | | Marginal effects | | |
|---|---|---|---|---|---|---|
| | Coefficient | Standard error | *t*-value | dy/dx | Standard error | *t*-value |
| Female | −0.466* | 0.242 | −1.92 | −0.081* | 0.041 | −1.950 |
| Age | −0.005 | 0.01 | −0.45 | −0.001 | 0.002 | −0.450 |
| Primary education | 0.591* | 0.329 | 1.79 | 0.104 | 0.059 | 1.770 |
| Secondary education | 0.762** | 0.355 | 2.15 | 0.133** | 0.063 | 2.100 |
| Tertiary education | 0.274 | 0.477 | 0.57 | 0.049 | 0.086 | 0.570 |
| Years of experience in farming | 0.021* | 0.012 | 1.80 | 0.004* | 0.002 | 1.820 |
| Training | 0.51** | 0.235 | 2.18 | 0.088** | 0.040 | 2.210 |
| Access to internet | 0.743*** | 0.241 | 3.08 | 0.129*** | 0.040 | 3.200 |
| Access to extension services | 0.15 | 0.403 | 0.37 | 0.026 | 0.070 | 0.370 |
| Awareness of the IITA herbicide calculator | 0.654** | 0.324 | 2.02 | 0.113** | 0.055 | 2.040 |
| Awareness of Akilimo | −0.779** | 0.303 | −2.57 | −0.135** | 0.051 | −2.630 |
| Ownership of smartphone | 1.64*** | 0.361 | 4.54 | 0.284*** | 0.059 | 4.860 |
| Use a paid phone application | 1.183** | 0.497 | 2.38 | 0.205** | 0.085 | 2.400 |
| Calibration spraying | 0.162 | 0.242 | 0.67 | 0.028 | 0.042 | 0.670 |
| Cost of application | 0.78*** | 0.286 | 2.73 | 0.135*** | 0.048 | 2.800 |
| Ease of use of the application | 0.274 | 0.292 | 0.94 | 0.047 | 0.050 | 0.940 |
| Innovativeness of application | −0.652 | 0.646 | −1.01 | −0.113 | 0.112 | −1.010 |
| The application used previously by other farmers | 0.599 | 0.816 | 0.73 | 0.104 | 0.141 | 0.740 |
| Constant | −1.788*** | 0.635 | −2.81 | | | |
| Pseudo r-squared = 0.211 | | | Number of observations = 564 | | | |
| Chi-square = 155.869 | | | Prob > $\chi^2$ = 0.000 | | | |

**Note(s):** ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

**Table 6.** Factors influencing farmers' willingness to adopt digital application tools

increasing levels of education, the likelihood of farmers adopting digital application tools increases. The likelihood increases by 10.4 and 13.3% points for farmers with primary and secondary education, respectively. This might be the case because educated people are inherently more willing to experiment with new ideas and adopt new practices than non-educated farmers. This outcome is in line with Oyinbo *et al.* (2019) results that higher levels of education had a favourable impact on the rate of technology adoption. Similar to this, Diaz *et al.* (2021) found that farmers' propensity to use a mobile app for bamboo marketing is influenced by their degree of education.

Years of experience in farming were positive and statistically significant ($p < 0.1$) with the probability of willingness to adopt digital application tools. This implies that as farmers gain experience in cassava farming, they are more likely to adopt digital application tools. This likelihood increases by 0.4% points. Another key variable influencing adoption is access to training. The training was positive and statistically significant ($p < 0.05$). Results revealed that farmers with access to training are more likely to adopt digital application tools. This means that as farmers have access to training on the importance of digital technologies, they are more likely to adopt digital application tools for their production activities. This likelihood increases by 8.8% points.

ICTs have emerged as a powerful tool to help smallholder farmers overcome production barriers through mobile phone applications (Krell *et al.*, 2021; Sharma *et al.*, 2020; Khan Tithi *et al.*, 2021). Through technical advancements like mobile applications, internet services give farmers a platform to improve their livelihood. Access to internet services was positive and statistically significant ($p < 0.01$) with smallholders' willingness to adopt digital application tools. This is obvious as access to the internet is very important to the adoption of digital technologies. The results imply that farmers with access to internet service within their community are more likely to be willing to adopt digital application tools considered in this study. The likelihood increases by 12.9% points. Therefore, internet services are needed in farm communities to facilitate the uptake of these digital technologies. The ownership of smartphones is also an integral factor influencing farmers' willingness to adopt digital technologies. Ownership of smartphones was positive and statistically significant ($p < 0.01$) with the probability of willingness to adopt digital application tools. This implies that farmers who owned smartphones were more likely to be willing to adopt digital application tools. This likelihood increases by 28.4% points. Another salient factor is the use of paid phone applications by farmers. Results revealed that farmers' willingness to use paid phone applications was positive and statistically significant ($p < 0.05$) with the probability of willingness to adopt digital application tools. This is an implication that farmers who are willing to bear some cost in the download and use of an application are more likely to be willing to adopt digital application tools. This likelihood increases by 20.5% points.

Awareness of any technology is key to its adoption. The variables of awareness considered here are the awareness of the IITA herbicide calculator and the Akilimo. Results revealed that awareness of the IITA herbicide calculator was positive and statistically significant ($p < 0.05$) with the willingness to adopt these digital application tools. In contrast, the awareness of the Akilimo was negative and statistically significant ($p < 0.05$) with the willingness to adopt. This means that farmers who were aware of the Akilimo digital application tool are less likely to adopt the technology. The probable reason advanced by some farmers for this is that they still need the help of an extension officer to use the Akilimo mobile application. Additionally, it was observed that since most farmers were unaware of the application, this lack of awareness could have possibly slowed its eventual adoption. This outcome is similar to the observations made by Ochieng *et al.* (2019), who noted that smallholder farmers accepted technology when they were aware of it or familiar with its applications. Abdul-Hanan (2017) concluded that only being aware of technology might not

result in its adoption. To increase adoption, smallholder farmers must be aware of the technology, its use, and its advantages. Smallholder farmers must, therefore, be taught how to utilize and, in some cases, maintain these new technologies for them to be adopted long-term (Krah *et al.*, 2019).

The cost of digital application tools was positive and statistically significant ($p < 0.01$) with the willingness to adopt digital application tools. The findings indicate that the lesser the cost of the digital application tool, the greater the likelihood that farmers are willing to adopt the digital application tool. This likelihood increases by 13.5% points. The reason for this may be due to the apprehension of farmers on the cost attached to the App before downloading. According to Okoroji (2019), the majority of smallholder farmers are sensitive to technology costs and other service charges. A further point Akrofi *et al.* (2019) made was that the high cost of agricultural innovations and technology has hampered their implementation. Senyolo *et al.* (2018) found that smallholder farmers in Africa tended to avoid technology that required high upkeep costs.

## Conclusion and recommendations

This study assessed the willingness of smallholder farmers in Ogun State, Nigeria, to adopt digital application tools, the IITA herbicide calculator, and the Akilimo. We found that farmers were willing to adopt the digital application tools, although the awareness of these tools was still low. The willingness to adopt is positively affected by the level of education of farmers, training, access to internet services, ownership of smartphones, willingness to use paid phone applications, awareness of the application tools, and the cost of digital application tools. On the other hand, female farmers were less willing to adopt the technology, and the low awareness of the Akilimo also affected their willingness to adopt the technology. The government must create enabling policies to encourage farmers to acquire at least some basic formal education. Also, training should be provided to farmers through regular and efficient extension services. These would promote the usage of these digital application tools. Additionally, efforts should be made to lower the cost of smartphones while expanding access to internet services in rural areas. This might be accomplished through a Public-Private Partnership (PPP) program, in which the necessary parties could work with the private sector to offer smallholder farmers an effective and reasonably priced internet infrastructure. Female farmers should be encouraged to adopt improved agricultural technologies. To reduce the adoption lag of agricultural technologies in the country, the relevant stakeholders should raise awareness of the digital application tools to enhance acceptance. It is important that policymakers develop pertinent strategies to empower smallholder farmers in rural areas by harnessing the advantages of these improved technologies in raising agricultural productivity and enhancing the quality of life of smallholder farmers. This study will be helpful for the Government to determine the country's readiness for digital agriculture. It will help technology developers and agricultural technology startups to understand the factors determining farmers' willingness to adopt digital application tools. Harnessing these benefits would also enhance the gains of the National Agricultural Technology and Innovation Policy (2022–2027) which aims to ensure the rapid deployment of knowledge and technology to improve the productivity and livelihood of smallholder farmers.

This study contributes to our understanding of agricultural technology adoption; however, some limitations exist. First, the cross-sectional nature of the study, using the baseline data from the Zero Hunger project is a limitation of the study. Future research should examine these issues with multiple rounds of data or longitudinal studies to present a dynamic set of results and draw stronger conclusions about the uptake of agricultural technologies in the country. Secondly, more study locations and a larger sample size would be

useful in understanding how farmers are utilizing agricultural technologies for informed policy-making in the country.

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