

EFFECT OF DIGITAL TECHNOLOGIES ON THE PRODUCTIVITY OF RICE FARMERS IN KWARA STATE, NIGERIA

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ABSTRACT

Aim: Rice production in Nigeria falls short of domestic demand, increasing reliance on imports. Digital technologies could enhance productivity through improved information sharing, planning, and decision-making, yet adoption among rice farmers is limited and underexplored. This study examines the effect of digital technologies on rice productivity in Kwara State, Nigeria. **Methods:** Primary data were collected from 151 farmers using a three-stage sampling procedure. Analysis employed descriptive statistics, regression models, sigma scoring, and Likert scales. **Results:** Results indicate mobile phones are the most widely adopted digital tool; their use, particularly for communication with extension agents, was significantly associated with higher rice productivity. Key determinants of adoption include age, household size, digital awareness, farming experience, and access to finance. Despite its benefits, adoption is constrained by the high cost of digital technologies, poor network coverage, unreliable power supply, limited access to extension services, and poor access to credit. **Conclusions:** The study concludes that digital technologies are associated with higher rice productivity, but their transformative potential is curtailed by infrastructural and institutional limitations. Policy recommendations include strengthening digital literacy, expanding rural network coverage, and improving access to credit to promote wider adoption, increase productivity, and support food security and sustainable agricultural development in Nigeria.

Key words: productivity, sigma scoring approach, the logit regression model, ordinary least square regression, digital technology, rice farmers, Kwara State

JEL codes: O33, Q12, Q16

INTRODUCTION

Agriculture remains central to Nigeria's economy and food security. It supports rural livelihoods, contributes substantially to GDP, accounting for roughly 23% to 24.45% between 2016 and 2023, and employs about

34% of the workforce, thereby underpinning economic growth (National Bureau of Statistics [NBS], 2023; World Bank, 2025a; World Bank, 2025b). Despite abundant arable land and natural resources (African Development Bank [ADB], 2023), Nigeria's population has grown rapidly, from approximately 213.9 million

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in 2020 to about 237.5 million in 2025, with an annual growth rate of about 2.1% in 2024 (United Nations [UN], 2025; United Nations Population Fund [UNFPA], 2025; World Bank, 2025c). This rapid growth has made Nigeria the most populous country in Africa and has intensified food demand. However, domestic rice production has lagged behind demand, necessitating substantial imports and exposing the economy to foreign exchange pressures (Federal Ministry of Agriculture and Rural Development [FMARD], 2016; United States Department of Agriculture Foreign Agricultural Service [USDA FAS], 2023).

Oryza sativa (rice) is a major staple consumed by over half of the world's population, including more than 150 million people in Africa (Opeyemi et al., 2015; Fang et al., 2021). In Nigeria, rice is grown across most agro-ecological zones and remains central to the diet, but domestic production still falls short of demand, leading to substantial imports (Banjoko et al., 2016; Olasehinde et al., 2022). In 2016, local output was 2.3 million metric tons while national consumption was 6.3 million metric tons, leaving a shortfall of about 4.0 million tons that had to be met through imports; between 2012 and 2015, the government spent over USD 2 billion on rice imports (Premium Times, 2015; FMARD, 2016). More recently, in the 2023/24 marketing year, Nigeria produced approximately 5.61 million metric tons of milled rice against a forecast consumption of 7.8 million tons, leaving a projected import gap of about 2.19 million tons (USDA FAS, 2023). Meeting rising food demand will therefore require marked improvements in agricultural productivity rather than mere expansion of cultivated area (Trendov et al., 2019; Tavershima et al., 2022). At the same time, the associated social and environmental repercussions must be carefully evaluated (Connolly-Boutin & Smit, 2016). The digital revolution in agriculture has opened up new ways for this transformation to be achieved.

Digital technologies, particularly mobile-based information services, decision-support applications, and precision tools, are widely touted as possible levers to raise productivity by improving access to mar-

ket, weather, input, and advisory information, and by enabling better planning, logistics, and procurement (Arunachalam et al., 2018; World Economic Forum [WEF], 2020). They also support sustainability by optimizing resource use, reducing greenhouse gas emissions, and promoting efficiency, equity, and collaboration across the food chain (WEF, 2022). Platforms like GeoFarmer enable timely feedback, performance monitoring, and knowledge sharing, enhancing productivity and reducing risks for rural communities (Eitzinger et al., 2019).

However, the evidence on whether and how digital technology adoption translates into measurable productivity gains for smallholder rice producers in Nigeria is limited. Most empirical work has focused on awareness, diffusion patterns, or single technologies (e.g., mobile phones) rather than estimating the causal effect of digital adoption on farm productivity at the crop (rice) level. This empirical gap weakens the evidence base available to policymakers seeking to design interventions that could increase domestic rice output and reduce import dependence.

This study addresses that gap by empirically examining the relationship between digital technology adoption and rice productivity among smallholder rice farmers in Kwara State, Nigeria. Using primary farm-level data, the study identifies the digital technologies used by rice farmers, measures adoption intensity, i.e., the extent of farm-level uptake of digital technologies, assesses determinants of adoption, estimates the effect of adoption on rice productivity, and identifies the constraints to rice farmers' utilization of digital technologies in the study area. The results are intended to inform targeted policies to scale up effective digital solutions in Nigeria's rice sector.

Research questions:

1. What digital technologies are used by rice farmers in Kwara State, and at what intensity?
2. What are the determinants of digital technology adoption?
3. What is the effect of digital technology adoption on rice productivity?
4. What constraints limit rice farmers' utilization of digital technologies?

LITERATURE REVIEW

Digitalization research in agriculture draws on diffusion/adoption and sustainable-agriculture frameworks and uses a wide range of methods, from large-scale econometric analyses to micro-level regressions and qualitative case studies. Empirical work includes Liu and Liu (2023), who analyzed panel data from 276 prefecture-level (and higher) Chinese towns between 2005 and 2020 to assess the effects of digital technologies on sustainable agriculture (SA). They found that digitalization significantly improves SA and its subsystems, with larger effects in peripheral towns and in China's more developed eastern region. At the micro-level, Zeng et al. (2024) used Probit models and the KHB mediation technique on China Land Economic Survey (CLES) data to show that greater digital access raises the probability of land transfer. The probability of land transfer increased by 6.2% for every unit increase in digital technology accessibility.

Addison et al. (2024) examined the causes of agricultural digitalization (AD) and its effects on smallholder farmers' lives in rural Ghana. To address endogeneity, they combined probit and tobit estimators with inverse-probability weighting and regression adjustment to investigate both the determinants and the intensity of digital-technology adoption. They found that higher education, positive attitudes toward digitalization, membership in groups and cooperatives, more employed household members, and access to reliable internet, mobile money, and energy significantly increased the use of digital technology in agricultural operations. The study also reported a positive association between AD and smallholders' perceived improvements in livelihoods and household well-being.

Mhlanga and Ndhlovu (2023) reviewed the literature on digitalization in African agriculture, assessing its extent, effects on productivity and sustainability, key drivers and barriers, and policy options to accelerate uptake. They found widespread variation across the continent and highlighted several important issues, such as connectivity, affordability, energy, skills, and institutional gaps that require attention. In qualitative research, Fourati-Jamoussi et al. (2023) assessed

the effect of digital technologies like vineyard robots (Vitirover) and mapping drones (Airinov) on farm business models. Their findings showed that farmers adopt or develop digital tools primarily to solve practical problems such as improving production conditions, entering new markets, or adding value. Farmers who used these technologies displayed diverse skills, curiosity, and flexibility in adapting business models. Jarial and Sachan (2021), in an analysis of agricultural extension, observed a lack of gender responsiveness in Extension Advisory Services, particularly for women farmers. They emphasized that unprepared farmers, especially women, may struggle to adjust to digital agriculture without tailored support, calling for gender-sensitive strategies in digital innovation.

Furthermore, several studies find that digital technologies can improve agricultural performance. They play a vital role in processing and disseminating agricultural information and in improving supply chain operations (Arunachalam et al., 2018). Digital tools can enable a more circular economy and improve efficiency, equity, and environmental sustainability in the food chain. Large-scale country analyses show positive links between digitalization and indicators of sustainable agriculture (Liu & Liu, 2023). Digital technologies can be used to measure and track sustainability progress, optimize resource use, minimize greenhouse gas emissions, and drive innovation and collaboration (WEF, 2022).

Around the world, a plethora of smartphone applications promote agriculture on many levels. A variety of technologies, from simple offline farmer advisory tools to intricate precision agriculture systems, are revolutionizing the agricultural sector when farmers have access to real-time, actionable information. These tools help reduce economic disparities and generate opportunities for rural communities (WEF, 2020). Mobile phones give farmers access to bank accounts, market prices, weather forecasts, and extension contacts; platforms such as GeoFarmer enable real-time knowledge exchange among farmers, experts, and practitioners, reducing risks, increasing production, and improving livelihoods (Eitzinger et al., 2019). The mobile phone has surpassed all other technologies in terms of public acceptability (Nakasone & Torero, 2016; Baumüller,

included both closed and open-ended questions. Secondary data were sourced from textbooks, journal articles, online databases, reports, and previous studies.

The study focused on rice farmers in Kwara State, Nigeria. A three-stage selection technique was used to select 151 respondents. First, two rice-producing local government areas (LGAs) were purposively selected. Ten communities were selected at random from these LGAs for the second stage. Finally, 151 rice farmers were randomly selected from the ten communities. Only fully completed questionnaires were retained for data entry and analysis, resulting in a final analytical sample of 151 observations. A summary of the sample procedure is presented in Table 1.

Table 1. An overview of the methods used in sampling

Local government areas	Community	Number of respondents
Edu	Bokungi	15
	Patidzuru	15
	Abu Efu	15
	Ndamaraki	15
	Takogabi	16
Patigi	Lalagi	15
	Sakpefu	15
	Dzwajiwo	15
	Godiwa	15
	Edogi-Kpansanko	15
Total = 2	10	151

Source: authors' research.

All returned questionnaires were checked for completeness, and only fully completed questionnaires ($N = 151$) with complete information on all variables used in the models were retained for analysis. No further treatment of missing data was required. Data entry was performed in Microsoft Excel, and descriptive statistics and econometric analyses were conducted using Stata.

Data was analyzed using methods appropriate to the study objectives. Descriptive statistics, in-

cluding frequency distribution tables and measures of central tendency, were used to describe respondents' socioeconomic characteristics and to identify the digital technologies used. The sigma scoring system measured the level of adoption of digital technologies, while binary logit regression and ordinary least squares regressions, along with the Likert-type scale, were used for further analysis. Given the cross-sectional and observational nature of the data, estimated relationships reflect statistical associations and should not be interpreted as causal effects.

Sigma scoring method

The level of adoption of digital technologies at the farm level among rice farmers in the research area was evaluated using the sigma scoring technique, following the approach described by Agbamu (2006). The method was adopted because it standardizes frequency counts and percentages into normalized scores, thereby providing information on the relative level and intensity of adoption beyond simple adoption rates. This approach has also been applied in previous agricultural adoption studies (Ovwigho, 2013; Adejoh et al., 2017). Steps for applying this technique are as follows:

- Step 1: Determine the proportion of farmers using the digital technologies: $\{(\text{number of farmers utilizing digital technologies} / \text{total number of responders}) \times 100\} = A\%$.
- Step 2: Take the percentage ($A\%$), divide it by two, and deduct the result from 100: $100 - (A\% / 2) = B\%$.
- Step 3: Get the sigma distance (X) by checking $B\%$ in the statistical table of normal deviates.
- Step 4: Add a constant figure of two (2) to the value of the sigma distance and multiply the result by the same constant: $(X + 2) \times 2 = Y$.
- Step 5: The correct sigma score would be 10 minus the outcome (Y), as the sigma technique assigns weight on a 10-point scale in the reverse direction: $10 - Y = Z$.

Decision rule: The adoption of digital technology was judged to be at a low level if the mean score (Z) was less than 5.

Logit regression

The factors influencing rice farmers' usage of digital technologies in the study area were analyzed using logit regression. Logistic regression was used to estimate the probability that rice farmers adopt digital technology as a function of the independent parameters in the model.

Let Q_i be a binary indicator of adoption ($Q_i = 1$ if farmer i used digital technology for rice production and $Q_i = 0$ otherwise). We model the probability of adoption as:

$$P_i = P_r(Q_i = 1|X_i) \quad (1)$$

and estimate the canonical logit specification:

$$\text{logit}(P_i) = \ln \left(\frac{P_i}{1 - P_i} \right) = \beta_0 + X_i^T \beta \quad (2)$$

$$\text{Equivalently, } p_i = \frac{\exp(\beta_0 + X_i^T \beta)}{1 + \exp(\beta_0 + X_i^T \beta)}$$

where:

P_i – probability that the farmer i adopts a digital technology,

β_0 – intercept or constant,

β – vector of coefficients on the explanatory variables X_i ,

X_i – vector of independent variables,

$\left(\frac{P_i}{1 - P_i} \right)$ – odds of adoption (probability of adopting divided by probability of not adopting).

Dependent variable $Q = 1$ for usage of digital technologies for rice production and 0 otherwise.

The independent/explanatory variables are:

- X_1 – farmers' age [years],
- X_2 – income [NGN],
- X_3 – access to credit (1 means access and 0 otherwise),
- X_4 – level of education [years],
- X_5 – awareness of digital technologies (1 means aware and 0 otherwise),
- X_6 – size of the household (category number according to number of people in household),
- X_7 – years of farming experience.

Ordinary least squares regression

The effect of digital technologies on the productivity of rice farmers in the research area was analyzed using ordinary least squares regression (OLS) analysis. The dependent variable used in the regression was an output-variable-cost ratio, used as a productivity proxy, defined as:

$$Y = \frac{A}{TVC}$$

where:

Y – output-variable-cost ratio (productivity index),

A – value of rice output [NGN] per farmer,

TVC – total variable cost [NGN], computed

$TVC = \sum P_i X_i$, with P_i denoting the unit price of the i -th variable input and X_i its quantity.

The regression model is $Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_6 X_6$.

Independent variables are:

- X_1 – communication with extension agent via mobile phones (1 means yes, 0 no),
- X_2 – frequency of usage of digital technology in days/week,
- X_3 – purpose of usage of digital technology (1 means rice production, 0 others),
- X_4 – age of farmers [years],
- X_5 – number of network access/usage per farmer,
- X_6 – educational level of the farmer [years of schooling].

Likert scale analysis

The constraints preventing rice farmers in the study areas from embracing digital technology were rated using a Likert scale. Using a four-point rating scale technique, the mean, frequency, and percentage were calculated. The scoring mechanism for the four-point rating was as follows:

- strongly agree (SA) = 4,
- agree (A) = 3,
- disagree (D) = 2,
- strongly disagree (SD) = 1.

Based on a four-point rating system, the mean score of the respondents was determined as follows: $4 + 3 + 2 + 1 = 10$, $10/4 = 2.50$, the threshold point.

Variables with mean values of 2.50 and above were regarded as constraints for rice farmers in the research area, with a threshold criterion of 2.50 being employed for decision-making. Conversely, variables with mean values below the 2.50 threshold value were found to be unrelated to rice farming growth in the research area.

In addition, multicollinearity was assessed using the variance inflation factor (VIF) for all regression models, and the results indicated that multicollinearity was not a concern among the explanatory variables. All VIF values were below 5.

RESULTS AND DISCUSSION

Rice farmers' socio-economic features

Most respondents (39.74%) were aged 20–30, with a mean age of 36, indicating that a sizable portion of respondents in their middle years were engaged in rice farming. Nearly all respondents were male (99.34%), which might suggest that males dominate rice farming. This is consistent with Chekene and Chancellor (2015), who reported that most rice growers in Nigeria are men. However, this finding must be interpreted with caution. The high male representation in the sample may also reflect response bias, with men more likely to participate in the survey, rather than fully excluding the role of women in production. Men often serve as household heads and landowners, making them the visible decision-makers and primary respondents, while women may have been less available or less approached during the interview. Kolawole et al. (2012) also noted that women complement men's roles and are major contributors to rice production, even if underrepresented in surveys.

A large share of respondents (82.12%) was married, which aligns with Henri-Ukoha et al. (2015), who found that married individuals are more engaged in farming activities. This likely explains why children were available for domestic employment. The prevalence of married farmers among the respondents may be linked to the desire to care for their families. Household sizes were relatively large, with the modal household comprising 6–10 persons (45.70%) and a mean size of 7, which enabled considerable family labor.

This makes it possible for everyone in the family to help with the rice farming, potentially reducing the need for paid labor. Larger households using family labor were also found to improve the adoption of agricultural technologies (Ehiakpor et al., 2019).

The statistics also showed that 98% of the respondents had at least some formal education, with 60% attaining university education, 30.46% having secondary education, and about 7% having primary education. The average number of years of formal education was 13.34 years, suggesting that most respondents were educated and possessed a high level of comprehension regarding the problems involved in transmitting information using mobile phones. This supports Kolawole et al. (2012) and Paltasingh and Goyari (2018), who found that farmers' literacy enhanced the pace at which new technology is implemented. Education, therefore, likely strengthens farmers' ability to implement practices that increase yields and minimize environmental risks.

Farming was the main occupation for 97.35% of respondents, while only 2.65% were civil servants. This indicates that the great majority of respondents rely considerably on farming as their main source of income. 88.74% had been engaged in farming for ten years or more, 63.58% had 10–20 years' rice farming experience, and 21.85% had more than 20 years, with an average of 17.43 years in rice production. The degree of productivity on farms can be enhanced by experienced farmers (Adeagbo et al., 2021). In terms of landholding, 54.30% cultivated between 6 ha and 10 ha, suggesting small- to medium-scale farming, consistent with Sodiya and Oyediran (2014), who found that most Nigerian rural farmers live subsistence-level lives.

Approximately 55.63% of respondents belonged to cooperatives or farmer groups, a form of social capital that can improve access to inputs and information (Ogunleye et al., 2021). Regarding extension services, 69.54% of respondents reported contacting extension agents at least once during the most recent farming season, while 30.46% did not; interaction with extension agents and access to timely information were reported to help adjust farming practices and improve productivity.

Digital technologies used by rice farmers and how they are used

Table 2 lists the digital technologies rice farmers employ during the production process. Nearly all respondents (97.35%) used mobile phones, while very few owned computers (1.99%) or tablets (1.99%), and none reported using drones. This overwhelming reliance on mobile phones reflects their affordability and multifunctional role in everyday farming activities. This finding is consistent with previous studies, which highlight the dominant role of mobile phones in agricultural communication and information access. For example, Nzonzo and Mogambi (2016) reported that mobile phones (45.8%) were the most helpful ICT among rice farmers, followed by radio (26.0%), mobile phones/TV/mobile phones (20.8%), and PCs and the Internet (7.3%). Okoedo-Okojie and Omoregbee (2012) similarly found that farmers mainly use global system for mobile communications (GSM) phones, while personal computers (PCs), email, and the internet were used sparingly. Chhachhar et al. (2014) and Sennuga et al. (2020) also reported that mobile phones, radio, and television are channels for agricultural information. The near-universal ownership of phones among respondents highlights mobile devices as the most accessible and affordable entry point into digital agriculture for smallholder farm-

ers. Unlike more capital-intensive technologies such as drones or computers, phones provide low-cost access to market prices, weather forecasts, and extension services.

Table 2. Digital technologies used by rice farmers

Types of digital technology used	Frequency	Share [%]
Mobile phones	147	97.35
Computers	3	1.99
Tablets	3	1.99
Drones	0	0.00
Total	151	100.00

Source: authors' research.

As shown in Figure 2, Android smartphones were the most common (43.05%), followed by common phones; these are basic/feature phones that support call/SMS but lack browsing capability (33.77%). 22.52% reported using both Android and common phones, while only 0.66% combined Android and iPhone usage. Together, about two-thirds of respondents (66.23%) had access to internet-enabled devices, yet a substantial proportion still relied on non-internet feature phones. This mixed-device reality matters

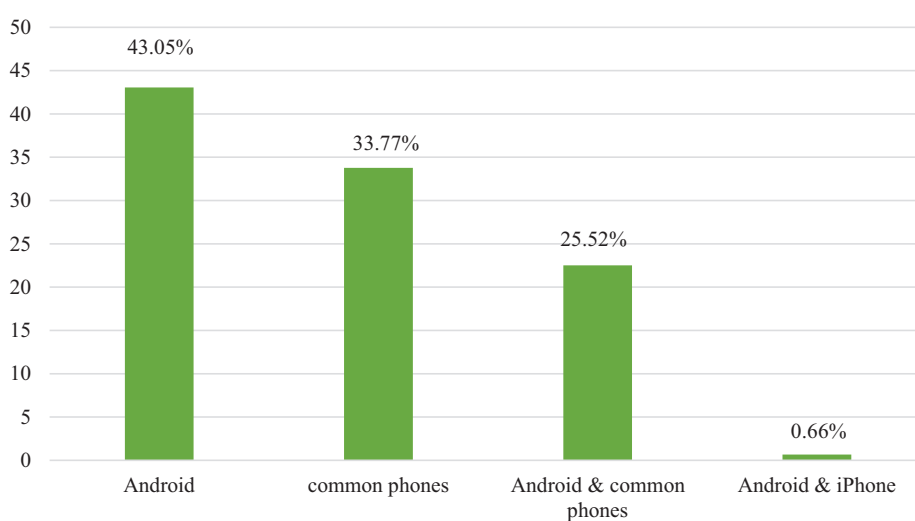


Fig. 2. Mobile phones used by rice farmers ($N = 151$)

Source: authors' research.

because internet access enables advanced agricultural applications, mobile banking, and e-extension services beyond simple SMS or voice communication. Therefore, digital interventions should be device-inclusive: app-based services for smartphone users and SMS/USSD or call-based services for common-phone users. This finding underlines the need to design inclusive platforms that work across device types rather than assuming universal smartphone adoption.

Table 3 presents the number of years the respondents had been using mobile phones. Most had long-term usage, with 44.37% using phones for 6–10 years, 39.07% for over 10 years, and only 17% for 1–5 years, giving an overall mean of 11.33 years. This shows that farmers in the study area are not new to mobile technologies and already possess digital familiarity, which supports a higher potential for technology adoption.

Table 3. Mobile phone usage by rice farmers ($N = 151$)

Mobile phone usage [years]	Frequency	Share [%]	Mean
1–5	25	16.56	11.33
6–10	67	44.37	
11–15	36	23.84	
>15	23	15.23	
Total	151	100	

Source: authors' research.

Questions were asked about their spending pattern, and it showed that 54% of farmers spent between NGN 3,000 and NGN 4,000 monthly on internet services, while 8.61% spent less than NGN 3,000, and 3.97% spent more than NGN 4,000. Most internet users (83%) accessed 3G services, 16% used 4G, and less than 1% used E-internet, with 96% reporting daily use. Despite this high level of connectivity, only a limited proportion applied internet services directly to rice production. This reflects a key gap between access and productive utilization. While familiarity with phones might reduce adoption barriers, turning access into productive use requires targeted capacity building and context-relevant applications.

Farmers reported using mobile phones primarily for calls and SMS, as well as for accessing agricultural information. Key areas of information search included pest and disease control, weather forecasts, improved rice varieties, input availability, credit facilities, market prices, and new cultivation methods. High usage rates were reported for contacting extension agents (70.2%), marketing (94.0%), and farmer-to-farmer communication (98.0%), showing that mobile phones are already integrated into some essential agricultural functions. Some farmers also employed PCs, tablets, or laptops to interact with extension agents (6.62%), other farmers (7.95%), and buyers (7.95%). However, more advanced digital tools and internet-enabled services (e.g., mobile advisory apps, e-extension platforms) remain underutilized, indicating that interventions should prioritize practical, task-oriented tools that align with farmers' needs and device types and encourage the usage of more advanced tools/internet-enabled services.

These findings align with Malsha et al. (2011), who showed that ICT tools were widely used to obtain information on new growing techniques, pest and disease management, and agrochemicals. Similarly, Nzonzo and Mogambi (2016) found that ICTs such as mobile phones, televisions, radios, the Internet, and computers were used to gather information on paddy seed varieties, costs, pests and diseases that affect paddy and the necessary control measures, planting and management techniques, and market opportunities.

Farm level of adoption and uptake of digital technologies

The findings in Table 4 indicate that mobile phones are the most widely adopted digital tool among rice farmers in the study area (sigma score of 5.94), which reflects a high level of adoption and a relatively high intensity of uptake. In contrast, the use of computers, tablets, and drones remains limited, with adoption scores below 5, indicating a low level of adoption. This pattern likely reflects the relatively high awareness of mobile phone applications in agricultural activities. Awareness and knowledge are essential precursors to adoption, as they stimulate farmers' interest

in new technologies and enhance their capacity to use and apply them effectively.

Table 4. Adoption level of digital technologies among the rice farmers ($N = 151$)

Digital technology	Frequency	Share [%]	Sigma score	Remark
Mobile phones	147	97	5.94	High
Computers	3	2	1.34	Low
Tablets	3	2	1.34	Low
Drones	0	0	0.00	Low

Source: authors' research.

These results align with Mwangi and Kariuki (2015), who found that farmers are more likely to adopt technologies they are familiar with or have been informed about. Similarly, Agbamu (2006) noted that access to high-quality information plays a critical role in the uptake of agricultural innovations. The widespread use of mobile phones may also be linked to their role in facilitating communication with extension agents, who provide farmers with timely advice on the availability, benefits, and practical use of improved technologies. Overall, while basic digital tools like mobile phones are being embraced, the low adoption of more advanced technologies highlights significant opportunities to further enhance rice productivity through broader digital technology use.

Determinant of digital technology usage among rice farmers

Findings from the logit regression model used to evaluate the factors influencing rice farmers' usage of digital technology are provided in Table 5. The age, household size, access to credit, digital awareness, and rice farming experience of the respondent substantially affect the decision to apply digital technology.

The coefficient on age was negative and significant at the 1% level. In logit terms, each additional year of age was associated with a 0.177 decrease in the log-odds of adoption, equivalent to about a 16% reduction in the odds of adopting digital technology [$\exp(-0.177) \approx 0.84$], holding other factors constant. In plain terms, older farmers in our sample were less likely to adopt digital tools than younger farmers. This likely reflects differences in digital literacy, prior expo-

sure, and risk preferences. Younger farmers tend to be more familiar with mobile and internet technologies, more comfortable learning new interfaces, and more willing to experiment with digital tools in the process of rice farming operations. This lowers perceived complexity and raises perceived usefulness. These patterns align with diffusion of innovation and technology-acceptance theories, in which perceived ease of use and perceived usefulness accelerate adoption (Davis, 1989; Rogers, 2003).

This is also consistent with the results of Masuka et al. (2016), who discovered that younger farmers employed mobile technology more frequently than their older counterparts ($p < 0.05$). Similarly, the study by Ma et al. (2023) discovered that age had a negative effect on farmers' smartphone usage. In particular, the likelihood of smartphone use drops by 1.3% for every extra year of age, implying that mobile technologies were more likely to be adopted by younger farmers. In addition, Michels et al. (2020) and Michels and Musshoff (2022) noted that older farmers were less likely to use smartphones since they have lower levels of digital literacy. They suggested that younger farmers were more inclined to adopt digital technologies earlier since they have been exposed to them from an early age. Oladimeji et al. (2013) stated that labor productivity was proportional to age when all other parameters were maintained constant. They noted that there was a presumption that younger individuals were more receptive to adopting new technology to enhance productivity, whereas elderly people tended to cling to traditional production procedures. These studies support the results of the current research, which also found that younger farmers were more inclined to adopt mobile technologies for agricultural purposes. The generation in which improved technologies are introduced and adopted tends to understand and utilize them more effectively.

Furthermore, household size was significant and negative ($\beta = -0.408, p < 0.05$), suggesting that larger households were less likely to adopt digital technologies. This may be because farmers had a lot of dependents to feed; hence, fewer disposable resources to spend on devices, data, or other adoption costs. Adoption often requires an upfront investment (device, data, training), and households with

Table 5. Determinant of digital technology usage among rice farmers ($N = 151$) (logit regression)

Variable	Coefficient β	SE	p	Odds ratio [OR = exp(β)]
Age	-0.177***	0.061	0.004	0.838
Size of households	-0.408**	0.166	0.014	0.665
Income from rice farming	-5.270	0.783	0.969	0.005
Access to credit	2.337**	0.929	0.012	10.346
Level of education	0.219	0.205	0.283	1.246
Awareness of digital technologies	2.131***	0.804	0.008	8.423
Farm size	0.010	0.179	0.954	1.107
Rice farming experience	0.144**	0.070	0.039	1.155
Constant	2.082	3.489	0.551	8.019

McFadden pseudo $R^2 = 0.687$; log likelihood = -26.622; LLR statistic $p < 0.001$.

Note: *** and ** represent significance at 1% and 5%, respectively. Odds ratios are computed as $OR = \exp(\beta)$.

Source: authors' research.

limited liquidity or competing consumption needs may underinvest, consistent with human capital and credit-constraint logic (Becker, 1964). Household size could also increase on-farm labor availability, which might reduce the perceived need for time-saving technologies.

Access to credit was significant at the 5% level and positively associated with farmers' likelihood of using digital technology. The data revealed that rice farmers who could obtain financing were over 10 times more likely to adopt digital technology than those without, as demonstrated by the odds ratio of 10.35. This research correlates with the findings of Mohammed and Temu (2008) and Amin et al. (2020), who discovered that financial accessibility has been proven to boost the adoption of new technologies. It removes a major affordability barrier, since liquidity constraints could hinder adoption. It might also connect farmers to formal networks (cooperatives, markets) that expose them to new technologies and reduce informational frictions.

Awareness of digital technology was strongly associated with adoption ($OR = 8.4, p < 0.01$). Farmers who were aware of digital technologies were 8.4 times more likely to accept and use them than those unaware. This underscores the central role of information and awareness as prerequisites for uptake. According to diffu-

sion of innovation theory, awareness (knowledge) is the first step in the adoption process, as it allows farmers to perceive the relative advantage and compatibility of digital tools, thereby reducing uncertainty and encouraging uptake (Rogers, 2003). Rice farming experience demonstrated a positive significance at 5% and an odds ratio of 1.16, meaning that each additional year of experience increased the odds of adoption by roughly 16%. More experienced farmers may better appreciate the practical benefits of specific digital tools and integrate them into existing routines.

Effect of digital technologies on the productivity of rice farmers

The regression outcome in Table 6 used the output-variable-cost ratio (value of output/total variable cost) as a productivity proxy. The model explained 54.5% of the variance in this productivity proxy ($R^2 = 0.545$), and the F-statistic was significant ($p < 0.01$). Key variables associated with productivity of the rice farmers were the purpose of use of digital technologies, frequency of use, and communication with extension agents via the use of digital technologies (i.e., mobile phones) for receiving and delivering information.

The purpose of using digital technologies was positively associated with the productivity proxy ($p < 0.01$). *Ceteris paribus*, farmers who used digi-

tal technologies for rice production had a 1.927-unit higher productivity proxy than those who did not. The purposeful use of digital tools for rice production allows farmers to convert information into more accurate and effective farm-level decisions. Similarly, frequency of digital technology use was positively associated with productivity ($p < 0.01$). Farmers who used digital technologies more regularly (e.g., daily during rice cultivation) had a 1.258-unit higher productivity proxy than infrequent users. Frequent use of digital tools keeps farmers updated on rapidly changing conditions, enabling them to apply recommendations more quickly and accurately. Consequently, this increased use enhances the intensity and reliability of information flow, which can contribute to higher productivity.

Communication with extension agents via mobile phones was also positively associated with productivity at the 1% level. Farmers who consulted extension agents by phone about rice cultivation recorded a higher productivity proxy score than those who did not. Mobile-phone contact with extension agents may shorten the feedback loop between field observations and expert advice, enabling general recommendations to be adapted into context-specific actions. Dagunga et al. (2018) reported that extension services provide farmers with knowledge of improved farming techniques and strategies to better manage agricultural risks and uncertainties.

Conversely, productivity was not significantly as-

sociated with age, years of schooling, and the number of network usage. These findings indicate that how and how often digital technologies are used, especially for production and extension-related purposes, matter more for productivity outcomes. These results were consistent with Khatun and Haider (2016), who noted potential productivity gains from purposeful manipulation of technology adoption in different phases of agricultural production. Similarly, Ali et al. (2016) found that there was a favorable influence of ICTs on agricultural productivity. This also aligns with evidence that phone use specifically for agricultural activities was associated with higher yields (Quandt et al., 2020).

Constraints to the utilization of digital technologies among rice farmers

Table 7 identifies the challenges rice farmers in the research area face when utilizing digital technologies. Ranked by mean score, the top barriers were little or no internet network access (2.95), inadequate power supply (2.94), poor access to credit (2.76), high mobile phone costs (2.74), poor access to extension agents (2.25), and lack of literacy (2.09). These results indicated that infrastructure (network connectivity, electricity) and affordability (credit, device cost) were the primary constraints to digital adoption among rice farmers in the study area, with institutional factors

Table 6. Effect of digital technologies on rice farmers' productivity

Variable	Coefficient	SE	p
Age [years]	-0.031	0.020	0.131
Level of education [years of schooling]	-0.029	0.039	0.469
Purpose of usage of digital technology	1.927***	0.342	<0.001
Number of networks used	-0.294	0.183	0.109
Frequency of usage of digital technologies	1.258***	0.356	0.001
Communication with extension agents via mobile phones	1.396***	0.454	0.003
Constant	5.083	1.149	<0.001

$R^2 = 0.545$; adjusted $R^2 = 0.526$; $F = 31.76$; $p < 0.001$; $N = 151$.

Notes: The dependent variable is the output-variable-cost ratio (A/TVC), used as a productivity proxy. Robust standard errors (HC1) were reported to correct for heteroskedasticity, as confirmed by the Breusch–Pagan test ($p < 0.05$). This ensures valid statistical inference without affecting coefficient estimates. Multicollinearity was assessed using variance inflation factors (VIF), and all values were below the commonly accepted threshold of 5, indicating no serious multicollinearity concerns. *** and ** represent significance at 1% and 5% levels, respectively.

Source: authors' research.

(limited access to extension agents) and skills/literacy gaps also playing a role.

These findings corroborate earlier studies. Mwakaje (2010) reported that 68% of respondents lacked funds to purchase ICT services or facilities, 8.5% could not cover associated operating costs, and 4% admitted a lack of ICT knowledge. Kituyi-Kwake and Adigun (2008) found that expensive services accounted for 32% of barriers to ICT adoption. Similarly, Jayathilake et al. (2008) studied ICT adoption and its effect on Sri Lankan agriculture and found that high technology costs were the largest barrier, while farmers' limited capacity and lack of training further hindered implementation. Furthermore, Musa et al. (2012) indicated that 50.8% of farmers had little or no access to energy (solar or grid), which made it difficult for them to use ICTs. This discovery was based on the restrictions associated with poor infrastructure support.

STUDY LIMITATIONS

Despite these useful insights, the findings should be interpreted within certain limitations. The study was conducted in a single region (Kwara State), which restricts the geographical generalizability of the results. In addition, the sample was overwhelmingly male, which may reflect either male dominance in rice farming or a response bias, in which men were more

likely than women to participate in the survey rather than the actual gender distribution of rice farmers. This distinction should be considered when interpreting gender-related implications of the results. Future studies should therefore include more diverse samples across regions and genders to improve representativeness. The dependent variable used in the productivity regressions was the output-variable-cost ratio (A/TVC), which serves as a proxy for productivity rather than a formal total factor productivity (TFP) measure. This was because detailed input quantity data required for TFP estimation were not sufficiently available for all sampled farmers. Given these data constraints and the cross-sectional, observational nature of the survey, the estimated relationships are associations and should not be interpreted as causal effects. Future research with richer input data or panel datasets could estimate TFP using production function or index number approaches and strengthen causal inference.

CONCLUSIONS AND RECOMMENDATIONS

This study examined how digital technology affects rice production among farmers in Kwara State, Nigeria. A total of 151 rice farmers were sampled in three stages using a structured questionnaire to obtain primary data. Descriptive statistics, the sigma scoring method, the logit regression model, ordinary least

Table 7. Constraints to utilize digital technologies among rice farmers ($N = 151$)

Constraint	Strongly disagree	Disagree	Agree	Strongly agree	Mean	Rank
Little or no internet network access	0(0.00)	33(21.85)	93(61.59)	25(16.56)	2.95	1 st
Inadequate power supply	1(0.66)	32(21.19)	93(61.59)	25(16.56)	2.94	2 nd
Poor access to credit	2(1.32)	41(27.15)	99(65.56)	9(5.96)	2.76	3 rd
High cost of mobile phones	3(1.99)	50(33.11)	82(54.30)	16(10.60)	2.74	4 th
Poor access to extension agent	1(0.66)	116(76.82)	30(19.87)	4(2.65)	2.25	5 th
Lack of literacy	3(1.99)	133(88.08)	14(9.27)	1(0.66)	2.09	6 th

Note: Values in parentheses are percentages.

Source: authors' research.

squares regression, and a Likert-type scale were used to analyze the data.

Based on the study's findings, approximately 74.17% of the respondents were middle-aged (20–40 years old) with an average age of 35. Most respondents (99.34%) were male, and 59.60% had a tertiary education. Household sizes typically ranged from 6 members to 10 members, with around 82.12% of respondents being married. Additionally, 97% of participants identified farming as their primary occupation. Most farmers were small to medium-sized, owning 5–10 ha of land. The average rice farming experience was 17 years, and 55.63% of respondents belonged to at least one cooperative or farm organization. With a high sigma score of 5.94, the study concluded that mobile phones were the most extensively used digital tools among farmers. Adoption of digital technology was significantly influenced by age ($p < 0.01$), level of digital awareness ($p < 0.01$), household size ($p < 0.05$), access to finance ($p < 0.05$), and rice farming experience ($p < 0.05$). Further analysis indicated that the purpose of digital technology use, frequency of use, and the use of mobile phones for communication with extension agents had a statistically significant positive association with rice output. The main challenges to adopting digital technology among rice farmers included limited network connectivity, inadequate power supply, poor access to funding, high cost of mobile phones, limited access to extension agents, and low literacy levels.

The research indicated that rice farmers' digital technology adoption was largely mobile phones, and it was associated with higher productivity. The usefulness of mobile phone usage has been impeded by inadequate access to network, insufficient power supply, low access to credit, high cost of mobile phones, poor access to extension agents and lack of literacy.

The following suggestions were provided considering the research findings:

1. Since digital technologies (purpose of usage and frequency of usage) were positively associated with productivity, there is a need for targeted awareness and digital literacy training among farmers on the uses and benefits of digital technologies for improved productivity.
2. The Nigerian government and development partners should create an enabling environment

and improve digital rural infrastructure to enhance farmers' adoption of digital technologies.

3. To enable farmers (especially smallholder farmers) to use digital technologies to access modern information sources, the government should create accessible credit facilities.

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WPŁYW TECHNOLOGII CYFROWYCH NA WYDAJNOŚĆ PRODUKCJI RYŻU W STANIE KWARA W NIGERII

STRESZCZENIE

Cel: Produkcja ryżu w Nigerii nie zaspokaja krajowego popytu, co zwiększa zależność od importu. Technologie cyfrowe mogą zwiększać produktywność poprzez usprawnienie przepływu informacji, planowania i podejmowania decyzji, jednak ich wykorzystanie wśród rolników uprawiających ryż jest ograniczone i słabo zbadane. Niniejsze badanie analizuje wpływ technologii cyfrowych na produktywność ryżu w stanie Kwara w Nigerii. **Metody:** Dane pierwotne zebrano od 151 rolników przy użyciu trzystopniowej procedury doboru próby. W analizie zastosowano statystyki opisowe, modele regresji, metodę punktacji sigma oraz skalę Likerta. **Wyniki:** Wyniki wskazują, że telefony komórkowe są najczęściej wykorzystywanym narzędziem cyfrowym; ich użycie, szczególnie do komunikacji z doradcami rolniczymi, było istotnie związane z większą produktywnością ryżu. Do głównych czynników determinujących to wykorzystanie należą wiek, wielkość gospodarstwa domowego, świadomość cyfrowa, doświadczenie rolnicze oraz dostęp do finansowania. Pomimo korzyści wykorzystanie technologii cyfrowych jest ograniczane przez wysokie koszty, słabe pokrycie siecią, niestabilne dostawy energii elektrycznej, ograniczony dostęp do usług doradczych oraz utrudniony dostęp do kredytu. **Wnioski:** Dzięki badaniom udowodniono, że technologie cyfrowe sprzyjają zwiększeniu produktywności ryżu, jednak ich potencjał transformacyjny jest ograniczony przez bariery infrastrukturalne i instytucjonalne. Rekomendacje obejmują wzmocnienie kompetencji cyfrowych, rozwój infrastruktury telekomunikacyjnej na obszarach wiejskich oraz poprawę dostępu do finansowania, co może przyczynić się do szerszego wykorzystania technologii, wzrostu produktywności oraz wsparcia bezpieczeństwa żywnościowego i rozwoju zrównoważonego rolnictwa w Nigerii.

Słowa kluczowe: produktywność, metoda punktacji sigma, model regresji logitowej, klasyczna metoda najmniejszych kwadratów, technologia cyfrowa, rolnicy uprawiający ryż, stan Kwara