

Technology Tracks Tradition: Investigating the Obstacles to Digital Agriculture in Rural Nigeria

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Abstract

This research investigates the obstacles to the adoption of digital agriculture among smallholder farmers in Nigeria, utilizing a qualitative mixed-methods approach. Data were obtained through a literature review of peer-reviewed studies, policy documents, and case studies, further enriched by primary information from semi-structured interviews with 40 farmers, five leaders of cooperatives, and five extension officers, alongside four focus group discussions in four states representing Nigeria's major agro-ecological zones (Kano, Benue, Ogun, and Ebonyi). The results indicate that the acceptance of digital agriculture is influenced by socioeconomic factors, including education, gender, and farm size. Nonetheless, infrastructural and institutional challenges such as inadequate internet connectivity, the high expense of digital tools, low levels of digital literacy, and insufficient extension support further hinder uptake. Additionally, regional variances were noted, with farmers in the South-West reporting better access and utilization than those in the North-East and South-East. The study concludes that, although digital agriculture offers significant opportunities for transforming farming in Nigeria, specific interventions aimed at enhancing digital inclusion, literacy, infrastructure, and policy coherence are crucial for realizing its full potential.

Keywords: Digital Agriculture; Smallholder Farmers; ICT; Adoption Barriers; Rural Nigeria; Agricultural Extension.

1. Introduction

Agriculture continues to be the cornerstone of Nigeria's rural economy, making considerable contributions to national food security, employment, and livelihoods (Adekoya, Magaji, & Ismail, 2025), and involving almost 70 percent of the rural population while significantly impacting national food security, employment, and livelihoods (National Bureau of Statistics [NBS], 2022). In addition to its role in securing household food supplies, agriculture represents a substantial portion of Nigeria's GDP and provides essential raw materials for agro-industrial development (Magaji & Yisa, 2023). Despite its importance, the sector is characterised by minimal productivity, subsistence farming methods, limited market access, and a fragile ability to withstand climate-related disruptions such as droughts, flooding, and unpredictable rainfall patterns (Yakubu, Magaji, & Magaji, 2025). These issues have underscored the vulnerability of smallholder farmers, who make up the majority of agricultural producers in rural Nigeria (Ogunlela & Mukhtar, 2021).

In the last twenty years, digital agriculture has emerged globally as a vital solution to these enduring challenges. Digital agriculture can be broadly understood as the use of information and communication technologies (ICTs). These technologies range from mobile devices, satellite-based tools, and geographic information systems (GIS) to drones, big data analytics, and mobile applications (Eke, Magaji, & Osi, 2022). They can be applied across agricultural production, marketing, and extension services (World Bank, 2020; Aker, Ghosh, & Burrell, 2021), as well as in financial services (Abdullahi, Magaji, & Musa, 2024). There is a growing consensus that digital tools can significantly enhance the productivity, income, and resilience of smallholder farmers by addressing gaps in information, resources, and decision-making.

Worldwide, digital innovations have dramatically changed farming methods. For instance, in East Africa, mobile phones have enabled mobile money systems like M-Pesa, allowing farmers to access credit, savings, and insurance options that were previously unavailable in rural areas (Jack & Suri, 2016). Precision farming technologies have helped farmers in Europe and North America optimize resource use, minimize waste, and boost yields (FAO, 2019). Satellite imagery and remote sensing have provided climate-responsive guidance to help farmers cope with variability in weather, while e-wallet systems have established transparent methods for distributing fertilisers and seeds (Fabregas, Kremer, & Schilbach, 2019). These global examples illustrate the transformative potential of digital agriculture in improving efficiency, inclusion, and sustainability.

In Nigeria, there have been parallel efforts to leverage digital tools for the transformation of agriculture. A significant example is the Growth Enhancement Support (GES) Scheme, launched in 2012, which employed an e-wallet system to provide subsidised fertilisers and inputs directly to farmers, thereby minimizing distribution leaks and corruption (Liverpool-Tasie, Omonona, Sanou, & Ogunleye, 2017). Additional initiatives include mobile weather advisory systems, commodity trading platforms that link farmers directly with buyers, and digital extension services that utilise SMS and voice technologies to offer customized agronomic guidance (Ogunleye, Akinwale, & Ojo, 2021). Despite these encouraging initiatives, the uptake in rural Nigeria remains inconsistent and limited in scope.

Several obstacles hinder the effective implementation of digital agriculture in rural Nigeria. Issues related to infrastructure, such as poor internet access, inconsistent electricity supply, and insufficient telecommunication coverage in rural areas, create barriers to entry (Akinwumi & Okunlola, 2020). Moreover, socioeconomic challenges, including low literacy rates, gender inequalities, and poverty, further restrict inclusivity (Enaberue, Musa, & Magaji,

2024). Cultural and institutional hindrances, such as doubt regarding modern technologies (Magaji & Eke, 2015), reliance on conventional farming practices, and inadequate policy coordination, significantly influence adoption outcomes (Adegbite, Adeniran, & Yusuf, 2022). These issues exemplify that the interaction between technology and tradition is not solely a technical concern but also encompasses socio-cultural and economic factors.

To comprehend the barriers to digital agriculture in rural Nigeria, a multifaceted perspective is necessary. It is inadequate to view the issue purely through a technological framework; it is essential to acknowledge the wider socio-economic conditions, cultural traditions, and institutional structures within which farmers function. For instance, while mobile devices can provide market price information, farmers might still opt to depend on local market intermediaries due to established trust dynamics that have evolved over the years. Likewise, although weather advisory applications can improve climate resilience, adoption may be hindered by farmers' difficulties in interpreting scientific forecasts without localized translation or contextualization (Magaji & Musa, 2024).

This research adds to the expanding discourse by investigating the particular obstacles that impede the uptake of digital agriculture in rural Nigeria. Utilizing both desk-based research and fieldwork data gathered from four agro-ecological zones, the study highlights significant barriers related to infrastructure, socioeconomic traits, gendered access, cultural perceptions, and institutional shortcomings. In this way, the research not only sheds light on technological deficiencies but also underscores the socio-cultural and economic contexts that influence the adoption landscape. The results aim to guide policymakers, development practitioners, and private sector stakeholders in crafting inclusive, context-appropriate digital agricultural strategies that can enhance rural livelihoods and contribute to the achievement of the Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty) and SDG 2 (Zero Hunger).

2. Conceptual Review

2.1 Concept of Digital Agriculture

Digital agriculture involves the incorporation of digital technologies—including information and communication technologies (ICTs), precision tools, and artificial intelligence—into agricultural production and food systems to improve efficiency, sustainability, and resilience (Klerkx, Jakku, & Labarthe, 2019). These technologies encompass mobile advisory services, satellite-based weather predictions, online market platforms, mobile financial services, and digital record-keeping tools. The primary potential of digital agriculture lies in its capability to provide smallholder farmers with timely information, facilitate access to credit and inputs, lower transaction costs, and enhance market connections.

In Nigeria, digital agriculture has been mainly promoted through mobile platforms like FarmCrowdy and Thrive Agric, in addition to e-wallet schemes for input distribution and digital financial solutions that link farmers to wider markets. However, the uptake remains low due to gaps in infrastructure, affordability challenges, and sociocultural barriers (Nwaobiala & Adesope, 2020).

2.2 Socioeconomic and Cultural Determinants of Adoption

Various socioeconomic aspects, such as age, education, gender, income level, and the size of farming operations, affect the adoption of digital agricultural innovations. Research conducted in Sub-Saharan Africa indicates that younger and more educated farmers are more inclined to adopt digital technologies when compared to their older counterparts (Aker et al.,

2016). Additionally, men generally have greater access to mobile devices and internet services than women, which exacerbates gender disparities in agricultural productivity (World Bank, 2021).

In addition to socioeconomic factors, cultural practices significantly influence farmers' views on digital technologies. In many rural areas of Nigeria, farming methods are closely tied to established cultural norms and decision-making processes that tend to resist outside influence. Trust in traditional extension agents or community leaders often surpasses faith in digital platforms, especially in regions with low literacy rates (Munyua, Adera, & Jensen, 2009).

2.3 Barriers to Digital Agriculture in Rural Nigeria

The challenges to digital agriculture in rural Nigeria can be categorized into infrastructural, institutional, and socio-cultural barriers. Infrastructural issues encompass unreliable internet access, inconsistent electricity supply, and lack of access to smartphones. Institutional barriers stem from weak extension services, insufficient policy frameworks, and minimal private sector investment (Ogunlela & Mukhtar, 2009). Socio-cultural barriers consist of low digital literacy, gender norms that limit women's access to technology, and distrust towards formal financial and digital systems (Magaji, Usman, & Yusuf, 2023).

2.4 Linking Digital Agriculture to Sustainable Development Goals (SDGs)

Digital agriculture has significant implications for achieving several SDGs, especially SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 8 (Decent Work and Economic Growth). By enhancing productivity, improving access to markets, and fostering financial inclusion, digital agriculture can empower rural households and aid in poverty reduction. However, without tackling the contextual challenges that obstruct its adoption, digital agriculture risks exacerbating inequalities and marginalizing vulnerable groups (Barrett et al., 2021).

2.3 Empirical Review

This section integrates empirical research and documented experiences concerning digital agriculture in Nigeria and similar African contexts, focusing particularly on transparency, traceability, and the barriers that hinder widespread adoption. The review is organized into five categories of digital innovation: (i) mobile information and digital extension; (ii) digital financial services (DFS) and e-vouchers for input subsidies; (iii) platform marketplaces and mechanization-on-demand models; (iv) blockchain-enabled traceability systems; and (v) Internet of Things (IoT)/digital sensing for post-harvest management and logistics.

Mobile Information and Digital Extension

Mobile communication has emerged as the most common entry point for digital agriculture across Africa. Aker and Mbiti (2010) provided initial evidence that the proliferation of mobile phones diminished information gaps in rural markets, enhancing farmers' negotiating power. Expanding on this, studies from Nigeria confirm that mobile-based services improve farmers' access to market and weather information. Olayemi, Oboh, and Adekunle (2021) found that SMS and USSD technologies assisted rice farmers in Kogi State with better price discovery and more effective negotiation with traders. Likewise, Yusuf and Salami (2022) reported that farmers using smartphone applications showed greater awareness of input markets and improved participation in cooperative sales.

Pilot initiatives like AgroMall's digital advisory modules and m-Agri-style platforms have noted increased adoption of enhanced agricultural practices. A synthesis of evidence by Fabregas, Kremer, and Schilbach (2019) suggests that digital extension can lead to more timely input application and improved yields as compared to control groups. In other countries, Tadesse and Bahiigwa (2015) demonstrated that mobile access in Ethiopia significantly cut search costs and influenced farmers' marketing channel decisions. Similarly, Kenyan initiatives such as iCow and Safaricom's DigiFarm have been shown to boost input adoption and record-keeping among smallholder farmers (GSMA, 2020).

Implications: Although there is consistent evidence that mobile information services can enhance price transparency and extend outreach, the effects are varied. Factors like literacy, the quality of handsets, gender-related access, and availability of rural broadband often influence results, leading to unequal adoption among different socioeconomic groups.

Digital Financial Services (DFS) and Input Subsidy E-Vouchers

Nigeria's Growth Enhancement Support (GES) Scheme (2012–2015) represented a significant advancement in the digital distribution of subsidized fertilizer and seeds. By utilizing e-wallets sent via mobile phones, the program minimized losses in input delivery and increased the percentage of intended beneficiaries who received aid (Liverpool-Tasie, Olumakinde, & Banful, 2017). Evaluations by the World Bank (2021) highlighted the efficiency improvements and enhanced accountability compared to traditional paper-based methods.

Building upon this groundwork, digital financial service providers like Paga and FirstMonie have broadened cashless payment options for farmers, allowing purchases of inputs and sales of produce through traceable transaction records (Central Bank of Nigeria [CBN], 2022). At the continental scale, Jack and Suri (2014) showed that M-Pesa in Kenya improved household welfare and fostered better risk-sharing, while GSMA (2020) and IFAD (2019) found that merging DFS with advisory services boosted repayment rates and sped up smallholder adoption of credit offerings.

Implications: DFS and e-voucher systems considerably enhance transparency by recording "who received what and when," while also strengthening the traceability of financial transactions. Nonetheless, challenges remain, including know-your-customer (KYC) requirements, liquidity issues among rural agents, and persistent gender discrepancies in phone ownership that hinder women's engagement.

Platform Marketplaces and Mechanisation-on-Demand

Platform-driven solutions are transforming service delivery within Nigerian agriculture. Hello Tractor, commonly referred to as the "Uber for tractors," employs IoT-equipped devices to monitor tractor usage and create a pay-as-you-go system. This has established greater trust between tractor owners and farmers while producing verifiable service records that minimize conflicts (International Food Policy Research Institute [IFPRI], 2020; GSMA, 2020).

Crowdfunding and agritech investment platforms, such as FarmCrowdy, have linked urban investors with rural farmers, offering not only financial support but also dashboards that ensure traceability of actions along financed value chains. However, the World Bank (2021) warns that the longevity of such models relies heavily on effective unit economics and risk management practices.

Platforms from other countries, like Kenya's Tulaa, have exhibited quicker sales cycles and reduced side-selling among enrolled farmers (GSMA, 2020).

Implications: Marketplace and on-demand service platforms can formalize transactions and generate logistics data flows that enhance transparency. However, their success depends on dependable internet access, last-mile agent networks, and farmers' willingness to trust the platform operators.

Blockchain-Enabled Traceability

Emerging studies indicate that blockchain technology can secure provenance and simplify documentation in Nigeria's export value chains. Oladokun and Ajayi (2022) discovered that adopting blockchain in cocoa export chains decreased fraud and helped meet European Union traceability standards. Similarly, Ogunleye and Akinwale (2021) found that blockchain systems utilized in sesame seed supply chains supplied verifiable data that bolstered buyer confidence in global markets.

On a broader scale across Africa, Kamilaris, Fonts, and Prenafeta-Boldú (2019) observed that blockchain can enhance visibility along the entire supply chain and build consumer trust, especially when certifications (e.g., organic, fair trade) are tied to premium pricing. Kouhizadeh and Sarkis (2018) noted that while blockchain improves traceability, it also raises concerns regarding interoperability and data governance.

Blockchain reinforces assurance of provenance and boosts consumer confidence. However, the high costs associated with onboarding, requirements for digital identities for farmers, and a lack of interoperable standards hinder widespread adoption in Nigeria.

IoT and Digital Sensing for Post-Harvest and Logistics

IoT-enabled solutions are currently being evaluated to tackle the significant post-harvest losses in Nigeria. The FAO (2020) reported that temperature and humidity sensors implemented in pilot warehouses markedly decreased spoilage rates compared to traditional storage methods. RFID tracking systems in the grain and horticultural supply chains have enhanced adherence to HACCP-like food safety protocols (NBS, 2023). Cold chain monitoring has been associated with a decrease in spoilage incidents and improved grade realization, especially for perishable goods (Van der Burg, Bogaardt, & Wolfert, 2020). Furthermore, remote sensing technologies that forecast yields have been shown to improve procurement planning and increase transparency in contracts between producers and off-takers (World Bank, 2021). Implications: IoT solutions provide significant reductions in losses and bolster transparency in logistics. Nevertheless, issues such as high capital requirements, unreliable electricity supply, and limited maintenance capabilities remain major obstacles to expanding these solutions in rural Nigeria.

Cross-Cutting Constraints

Throughout these areas of innovation, recurring limitations consist of:

1. Gaps in infrastructure especially in electricity and mobile broadband.
2. Cost barriers for devices and data subscriptions.
3. Challenges related to digital literacy and language that marginalize certain farmer demographics.
4. Disjointed policies and ineffective extension systems.

5. Concerns regarding trust and data privacy, particularly due to Nigeria's history with unsuccessful agricultural subsidy initiatives (Adegbite & Akinbode, 2020; Adegbite & Machethe, 2020; Mol, 2015).

Collectively, these studies present a detailed empirical overview: digital innovations are contributing to observable enhancements in transparency, traceability, and efficiency; however, their adoption tends to be inconsistent and often depends on socio-economic, infrastructural, and institutional factors.

3. Methodology

This research adopts a qualitative mixed-method approach, integrating a desk review with primary data gathering through interviews and focus group discussions (FGDs). The desk review utilizes peer-reviewed articles, policy documents, case studies, and reports from organizations such as the Food and Agriculture Organisation (FAO), the World Bank, the International Fund for Agricultural Development (IFAD), and Nigerian government entities—the review focuses on practical applications of digital agriculture across Africa, particularly in rural Nigeria.

For primary data, semi-structured interviews were conducted with 40 smallholder farmers, 5 cooperative leaders, and 5 agricultural extension agents spanning four Nigerian states, representing the principal agro-ecological areas: Kano (North-West), Benue (North-Central), Ogun (South-West), and Ebonyi (South-East). These states were intentionally chosen to reflect diversity in farming methods, availability of digital infrastructure, and socio-economic conditions. A purposive sampling technique was employed to ensure diversity in gender, age, and farm scale.

Alongside interviews, four FGDs (one for each state) were conducted with groups of 8–10 participants, including farmers, cooperative leaders, and extension officers. The FGDs served as a venue for participants to collectively share their experiences, clarify meanings, and discuss the barriers and opportunities related to digital agriculture. This participatory method complemented individual interviews by capturing communal viewpoints and group dynamics.

The interview and FGD guides examined farmers' views, experiences, and obstacles regarding digital agriculture tools, such as mobile-based extension services, e-wallet programs, digital payment systems, and online market connections. Data from the desk review, interviews, and FGDs were analyzed thematically, facilitating the correlation between secondary data and the lived experiences of farmers.

This integrated approach offers a more profound, contextually aware comprehension of the challenges facing the adoption of digital technology in rural Nigeria, while also underscoring regional differences and the interplay between individual and communal perspectives in determining adoption obstacles.

4. Findings and Discussion

4.1 Socioeconomic Characteristics of Respondents

A total of 50 respondents participated in the primary data collection, consisting of 40 smallholder farmers, five cooperative leaders, and five agricultural extension officers across four Nigerian states (Kano, Benue, Ogun, and Ebonyi). Table 1 presents the demographic and socioeconomic characteristics of the respondents.

Table 1: Socioeconomic Characteristics of Respondents

Variable	Category	Frequency (n=50)	Percentage (%)
Gender	Male	32	64.0
	Female	18	36.0
Age Group (Years)	18–30	10	20.0
	31–45	22	44.0
	46–60	13	26.0
	61 and above	5	10.0
Educational Level	No formal education	11	22.0
	Primary education	9	18.0
	Secondary education	20	40.0
	Tertiary education	10	20.0
Farm Size (Hectares)	<1	14	28.0
	1–3	21	42.0
	4–6	10	20.0
	Above 6	5	10.0
Role in Agriculture	Smallholder farmers	40	80.0
	Cooperative leaders	5	10.0
	Extension officers	5	10.0

The table shows that most respondents were male (64%), within the productive age bracket of 31–45 years (44%), and had at least a secondary school education (40%). Farm sizes were predominantly small, with 70% cultivating three hectares or less. This reflects the general profile of Nigerian smallholder farmers (FAO, 2022).

4.2 Farmers' Access and Use of Digital Agriculture Tools

Respondents were asked about their awareness and use of digital agriculture tools, including mobile-based extension services, e-wallet subsidy programs, digital payments, and online market linkages. Table 2 summarises the responses.

Table 2: Access and Use of Digital Agriculture Tools

Digital Tool	Aware (%)	Users (%)	Key Barriers Reported
Mobile-based extension services	70	45	Poor network, limited skills
E-wallet subsidy programs	60	35	Irregular updates, corruption
Digital payment systems	75	50	Lack of smartphones, distrust
Online market platforms	40	20	Poor literacy, low connectivity

The results suggest that while the understanding of digital agriculture is relatively widespread (over 60% for most technologies), actual utilization is significantly lower because of both structural and social obstacles. This observation aligns with findings from Aker and Mbiti (2010) as well as recent evidence from Nigeria reported by Nwankwo et al. (2021), which underscore digital literacy and infrastructure as key factors influencing adoption.

4.3 Insights from Focus Group Discussions (FGDs)

The FGDs conducted in the four states yielded more in-depth qualitative perspectives:

- i. Regional differences: Farmers in Ogun and Ebonyi reported superior access to mobile networks and digital payment systems compared to those in Kano and Benue, where infrastructural deficiencies are more pronounced.
- ii. Trust issues: A number of farmers voiced doubts about e-wallet initiatives due to previous experiences with delays or misallocated subsidies.
- iii. Gender disparities: Women farmers, particularly in Kano and Benue, indicated lesser access to smartphones and opportunities for digital training, further entrenching existing inequalities.
- iv. Role of cooperatives: Leaders of cooperatives noted that jointly accessing digital tools (like bulk purchases of airtime/data for mobile advisory services) mitigated expenses and enhanced adoption rates.

4.4 Triangulated findings from the desk review, interviews, and focus group discussions

The insights gleaned from the desk review, interviews, and FGDs uncover a multifaceted interaction of structural, economic, and socio-cultural elements that hinder the adoption of digital agriculture in rural Nigeria. While farmers from all four studied states acknowledged the potential advantages of digital tools for enhancing productivity and market access, their experiences underscored ongoing challenges that reflect wider trends across Africa. The following discussion consolidates the key themes.

4.4.1 Limited Digital Infrastructure and Connectivity Gaps

Inadequate access to dependable internet and mobile network services emerged as the most reliable obstacle. Farmers in Ebonyi and Benue recounted instances of disruptions in network service during crucial farming times, restricting their access to up-to-date weather forecasts and mobile advisory resources. A farmer from Benue shared during an interview: “The application functions when the network is available, but during planting season, we frequently depend on traditional methods since there is no signal on the farm.” This observation corroborates findings from Aker et al. (2021), who noted that unreliable

connectivity in sub-Saharan Africa disproportionately impacts rural farmers when compared to their urban agribusiness counterparts.

4.4.2 Affordability of Digital Tools and Services

Even in instances where digital platforms are present, the issue of affordability continues to be a major barrier. Numerous farmers interviewed mentioned that the prices for smartphones, data packages, and mobile money transaction fees were “too costly for regular use.” In Kano, discussions in focus groups indicated that younger farmers were more inclined to possess smartphones, while older farmers often depended on shared devices or basic feature phones. This generational variation in affordability emphasizes the findings of Jack and Suri (2014) in Kenya, which showed that mobile money adoption was quickest among younger individuals and male farmers, while older and poorer demographics fell behind due to financial constraints.

4.4.3 Low Digital Literacy and Skills Gaps

Farmers in all states reported difficulties in using digital platforms, especially those demanding competency in English or advanced smartphone capabilities. A female farmer in Ogun expressed: “The extension officer demonstrated how to utilize the market application, but many of us cannot read quickly or comprehend English. Thus, we rely on middlemen.” This aligns with Chavula’s (2022) research in Malawi, which revealed that low levels of digital literacy severely restrict technology adoption despite the availability of these platforms. Extension officers interviewed similarly lamented that many farmers stepped away from mobile advisory services because they found them overly complex.

4.4.4 Trust Deficits and Cultural Preferences

Trust was highlighted as a significant issue during the focus group discussions, particularly in Kano and Ebonyi. Numerous farmers expressed a preference for in-person interactions with extension agents or input suppliers rather than using digital platforms, citing concerns about fraud or misinformation. Cooperative leaders also expressed doubt regarding e-wallet programs, with one individual stating, “Farmers want to see the fertiliser before they pay. They do not trust sending money online.” This illustrates the critical role of cultural and relational aspects in agricultural transactions, which are frequently neglected by digital tools (Birner et al., 2020).

4.4.5 Institutional and Policy Constraints

Although Nigeria has launched digital agriculture initiatives like the Growth Enhancement Support (GES) e-wallet program, interviews indicated that policies were implemented unevenly. Farmers in Benue and Ebonyi reported issues with the inconsistent delivery of subsidised inputs that were promised through digital channels. Extension officers observed a lack of coordination between federal and state programs, leading to gaps in service provision. This aligns with the findings of Adebayo and Ogundeji (2021) that fragmented policy environments are detrimental to the effectiveness of digital agricultural initiatives in Nigeria.

4.4.6 Gendered Barriers to Access

Focus groups revealed noticeable gender disparities, with women indicating limited access to smartphones, data, and digital training opportunities. A cooperative leader in Ogun remarked that “men take the phone to the farm, while women depend on them for information.” This mirrors broader trends observed in Africa, as GSMA (2020) reported that women in sub-

Saharan Africa are 20% less likely than men to utilize mobile internet, contributing to a gendered digital divide within agriculture.

4.5 Discussion: Reconciling Technology and Tradition

The results imply that digital agriculture in rural Nigeria is not merely about the availability of technology, but also about navigating established social, cultural, and economic realities. Farmers' reliance on traditional techniques, such as verbal exchanges of information and trust-based markets, often conflicts with the impersonal nature of digital platforms. Additionally, issues related to infrastructure, inconsistencies in policy, and affordability challenges hinder the scalability of digital innovations. Importantly, the study emphasizes that farmers are not passive recipients of technology; they actively evaluate risks, costs, and cultural norms when deciding on the adoption of digital tools.

The findings resonate with global literature that highlights the contextual aspects of digital adoption. As Donovan et al. (2021) suggest, digital agriculture is most successful when it enhances rather than supplants traditional systems. In Nigeria, this necessitates a blended approach that incorporates digital tools into existing farmer networks, provides culturally sensitive extension services, and reinforces policies that tackle affordability, infrastructure, and gender inclusion.

Recommendations

From the findings of this investigation, the following recommendations are made to enhance the adoption of digital agriculture among smallholder farmers in Nigeria:

1. **Enhance Digital Infrastructure:** Both government and private sector players should prioritize the expansion of cost-effective internet access and mobile coverage in rural areas to diminish technological exclusion.
2. **Boost Digital Literacy:** Tailored training programs should be offered through agricultural extension services and cooperatives to improve the digital skills of farmers, particularly focusing on women and older farmers.
3. **Increase Accessibility and Inclusivity:** Platforms and applications should be developed in local languages and designed to be user-friendly, accommodating various literacy levels. Special provisions should be made for vulnerable groups, including women and youth.
4. **Foster Public-Private Partnerships:** Collaboration between government, ICT companies, and farming organizations is essential for establishing sustainable digital platforms, subsidized smartphone access, and dependable digital payment systems.
5. **Encourage Cooperative-Based Strategies:** Strengthening farmer cooperatives and community organizations can promote peer learning, trust, and collective adoption of digital agricultural solutions.
6. **Policy Harmonisation and Incentives:** Nigerian agricultural policies should integrate digital innovation as a priority, offering incentives such as tax breaks for ICT-driven agribusinesses and ensuring the timely implementation of digital subsidy programs.

Conclusion

This research indicated that although digital agriculture holds significant promise for revolutionizing smallholder farming in Nigeria, numerous obstacles restrict its widespread

implementation. The results highlight that socioeconomic elements—such as education level, gender disparities, and the scale of farming—along with challenges related to infrastructure and institutions, are key factors influencing farmers' adoption behaviors. Variations among regions were noted, with farmers in states possessing better infrastructure (like Ogun and Benue) encountering fewer obstacles compared to those in Kano and Ebonyi.

The combination of desk reviews, interviews, and focus group discussions emphasizes the need to tailor digital agriculture initiatives to the specific circumstances faced by rural farmers. It will be essential to tackle the identified barriers—especially in terms of digital literacy, cost accessibility, and trust—to ensure that digital agriculture has a substantial positive impact on food security, rural livelihoods, and Nigeria's overarching sustainable development objectives.

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