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Digital Transformation of Agricultural Education in Nigeria: Challenges, Opportunities, and Policy Implications

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Abstract

The rapid advancement of digital technologies is reshaping agricultural systems globally and creating new expectations for Agricultural Education institutions. As agriculture increasingly adopts smart technologies such as precision agriculture, artificial intelligence, Geographic Information Systems (GIS), remote sensing, Internet of Things (IoT), and digital farm management systems, Agricultural Education programmes must transform to prepare graduates with relevant digital competencies. This paper examines the state of digital transformation of Agricultural Education in Nigeria by reviewing existing literature on emerging technologies, institutional readiness, challenges, opportunities, and policy implications. It was discovered from the reviews that digital transformation of Agricultural Education in Nigeria remains at an emerging stage, characterized by increasing adoption of digital learning platforms but limited integration of advanced smart agricultural technologies. Major challenges identified include inadequate digital infrastructure, insufficient funding, unreliable electricity supply, limited internet access, inadequate digital competence among educators, curriculum gaps, and weak policy implementation. Despite these challenges, significant opportunities exist through digital agriculture innovations, professional development programmes, public-private partnerships, curriculum modernization, and increased investment in technology-enabled learning environments. Consequently, it was recommended that the development of a coordinated national digital transformation strategy for Agricultural Education should be ensured to strengthened collaboration among stakeholders, and continuous investment in digital resources.

Keywords: Digital transformation; Agricultural Education; Smart agriculture; Digital competence; Agriculture 4.0; Educational technology; Nigeria.

1. Introduction

Agriculture remains a critical driver of economic growth, food security, employment generation, and rural livelihoods in Nigeria. Despite the sector's significant contribution to national development, agricultural productivity continues to face challenges associated with climate change, declining soil fertility, limited mechanization, inadequate extension services, and low adoption of emerging technologies. Globally, the Fourth Industrial Revolution has accelerated the integration of digital technologies into agriculture, resulting in the emergence of precision agriculture, smart farming, artificial intelligence (AI), Internet of Things (IoT), big data analytics, blockchain, unmanned aerial vehicles (drones), remote sensing, Geographic Information Systems (GIS), and digital farm management systems. These innovations are transforming agricultural production by improving efficiency, sustainability, resource-use optimization, and decision-making (, 2022; Klerkx et al., 2019; Ayim et al., 2020).

The transformation of agriculture has important implications for Agricultural Education. Educational institutions responsible for training agricultural professionals must equip learners with the digital competencies and practical skills required to function effectively within increasingly technology-driven agricultural systems. Consequently, Agricultural Education is gradually shifting from traditional instructional approaches toward digitally enhanced teaching, experiential learning, simulation-based instruction, virtual laboratories, precision agriculture training, and technology-supported field experiences (UNESCO, 2023; Bertoglio et al., 2021).

Digital transformation extends beyond the adoption of computers or internet facilities. It represents a comprehensive institutional process involving the integration of digital technologies into teaching, learning, research, administration, curriculum development, assessment, extension services, and stakeholder engagement. Successful digital transformation therefore requires supportive institutional leadership, adequate digital infrastructure, appropriate policies, sustainable funding, continuous professional development, and organizational readiness for technological change (Bond et al., 2024; OECD, 2023).

In Nigeria, successive reforms have emphasized the modernization of agriculture through innovation, mechanization, and digital technologies. National initiatives promoting digital education and agricultural transformation have encouraged tertiary institutions to strengthen ICT integration and enhance digital capacity among educators and students (Federal Ministry of Education, 2022; Federal Ministry of Agriculture and Food Security, 2023). Nevertheless, the implementation of digital transformation within Agricultural Education remains uneven across institutions. Many Colleges of Education, universities, and colleges of agriculture continue to experience inadequate ICT infrastructure, unstable electricity supply, poor internet connectivity, limited access to smart agricultural technologies, insufficient funding, weak institutional policies, and inadequate digital competence among academic staff (Nwosu & Ugwoke, 2021; Okeke & Nwankwo, 2023).

Empirical evidence from different regions of Nigeria further indicates that although lecturers increasingly utilize digital technologies for communication, online teaching, and research, the integration of advanced smart agricultural technologies into Agricultural Education remains limited because of infrastructural,

institutional, financial, and human capacity constraints (Mohammed et al., 2024; Akpomedaye et al., 2024). This situation raises concerns regarding the preparedness of graduates for contemporary agriculture, where digital technologies increasingly influence production, processing, marketing, extension, and agribusiness management.

Although several studies have examined ICT integration, digital literacy, and technology adoption in Nigerian education, relatively few have synthesized existing evidence on the broader digital transformation of Agricultural Education from institutional, technological, pedagogical, and policy perspectives. Addressing this gap is important because digital transformation requires coordinated reforms that extend beyond individual technology adoption to encompass governance, curriculum modernization, infrastructure development, staff capacity building, industry collaboration, and policy implementation.

This paper therefore reviews the current state of digital transformation in Agricultural Education in Nigeria by examining existing challenges, emerging opportunities, and policy implications. The paper aims to provide evidence-based recommendations that can guide policymakers, educational administrators, professional bodies, development partners, and researchers in strengthening Agricultural Education for sustainable agricultural development and national food security.

2. Conceptual and Theoretical Perspectives

Digital transformation in Agricultural Education refers to the systematic integration of digital technologies into teaching, learning, research, curriculum delivery, institutional administration, and community engagement to improve educational quality and prepare graduates for technology-driven agricultural systems. Unlike simple ICT adoption, digital transformation involves institutional change, pedagogical innovation, curriculum reform, and continuous capacity development. It requires investments in digital infrastructure, supportive leadership, staff development, and policies that encourage technology-enabled teaching and learning (Bond et al., 2024; OECD, 2023; UNESCO, 2023).

Within Agricultural Education, digital transformation is closely associated with the adoption of smart agricultural technologies. These include precision agriculture tools, Geographic Information Systems (GIS), Global Positioning Systems (GPS), drones, remote sensing technologies, Internet of Things (IoT) devices, artificial intelligence applications, mobile agricultural applications, and digital farm management systems. These technologies are increasingly being used to improve agricultural productivity, environmental sustainability, resource-use efficiency, and data-driven decision-making (, 2022; Klerkx et al., 2019). Consequently, Agricultural Education institutions are expected to expose learners to these technologies to ensure that graduates possess competencies aligned with the evolving demands of modern agriculture.

An important component of digital transformation is the digital competence of educators. Digital competence encompasses the knowledge, skills, attitudes, and confidence required to effectively use digital technologies for teaching, assessment, communication, research, collaboration, and lifelong professional learning (Redecker, 2017; Falloon, 2020). For Agricultural Education

lecturers, digital competence extends beyond basic computer literacy to include the ability to integrate smart agricultural technologies into classroom instruction, practical field demonstrations, laboratory activities, and student projects. The effectiveness of digital transformation therefore depends not only on the availability of technological resources but also on educators' capacity to use them meaningfully within pedagogical contexts.

This review is informed by the Diffusion of Innovation Theory and the Technology Acceptance Model (TAM). The Diffusion of Innovation Theory, proposed by (2003), explains how innovations are adopted and spread within organizations and social systems. The theory suggests that factors such as perceived advantage, compatibility, complexity, trialability, and observability influence the adoption of innovations. In Agricultural Education, the theory helps explain institutional differences in the adoption of digital technologies and highlights the importance of organizational readiness, leadership support, and professional development.

The Technology Acceptance Model developed by (1989) complements this perspective by emphasizing that technology adoption is influenced by users' perceptions of usefulness and ease of use. Within Agricultural Education, lecturers are more likely to integrate digital technologies into teaching when they perceive such technologies as improving instructional effectiveness and when they possess adequate digital competence to use them confidently. Together, these theoretical perspectives provide a useful framework for understanding the technological, institutional, and human factors that shape digital transformation in Agricultural Education in Nigeria.

3. Digital Transformation of Agricultural Education in Nigeria

The digital transformation of Agricultural Education in Nigeria has gained increasing attention in response to the rapid evolution of digital agriculture and the growing demand for graduates equipped with twenty-first-century competencies. Government initiatives promoting digital literacy, ICT integration, and agricultural modernization have encouraged tertiary institutions to incorporate digital technologies into teaching, research, and extension activities (Federal Ministry of Education, 2022; Federal Ministry of Agriculture and Food Security, 2023). These efforts align with global calls for educational systems to prepare learners for digitally enabled agricultural value chains and climate-smart agriculture (, 2022; UNESCO, 2023).

In recent years, Nigerian universities and Colleges of Education have increasingly adopted learning management systems, virtual classrooms, digital libraries, online assessment platforms, and video conferencing technologies, particularly following the COVID-19 pandemic. Although these developments have improved access to digital learning, the integration of discipline-specific smart agricultural technologies into Agricultural Education remains limited. Advanced technologies such as precision agriculture tools, Geographic Information Systems (GIS), Global Positioning Systems (GPS), drones, remote sensing technologies, Internet of Things (IoT) devices, and digital farm management software are still unavailable or underutilized in many institutions (Mohammed et al., 2024; Okeke & Nwankwo, 2023).

The pace of digital transformation also varies considerably across institutions. While some universities have established digital innovation centres, smart laboratories, and partnerships with

technology companies, many Colleges of Education continue to struggle with inadequate ICT infrastructure, unreliable electricity supply, poor internet connectivity, limited funding, and insufficient technical support. These institutional disparities contribute to unequal learning opportunities and limit students' exposure to modern agricultural technologies required in contemporary agricultural practice (Nwosu & Ugwoke, 2021; Akpomedaye et al., 2024).

The preparedness of academic staff remains another critical determinant of successful digital transformation. Studies conducted in Nigeria indicate that many Agricultural Education lecturers possess basic digital skills but require additional training in the application of specialized smart agricultural technologies for teaching, research, and practical field instruction (Ogunlade & Adebayo, 2022; Mohammed et al., 2024). Continuous professional development is therefore essential to enable educators to integrate emerging technologies into pedagogical practice and improve students' digital competence.

Beyond teaching and learning, digital transformation presents opportunities to strengthen agricultural research and extension services. Digital data collection tools, mobile-based advisory platforms, geospatial technologies, artificial intelligence-assisted analytics, and online collaborative research platforms have expanded opportunities for knowledge generation and dissemination. Stronger collaboration among higher education institutions, agricultural research institutes, extension agencies, technology companies, and development partners can accelerate innovation and facilitate the transfer of digital agricultural technologies to farming communities (FAO, 2022; World Bank, 2023).

Despite the progress recorded, the overall level of digital transformation in Agricultural Education in Nigeria remains at a developmental stage. Achieving meaningful transformation requires coordinated investment in infrastructure, curriculum modernization, institutional leadership, staff capacity development, sustainable funding, and supportive national policies. Without these complementary reforms, the capacity of Agricultural Education institutions to produce graduates capable of driving Nigeria's digital agricultural transformation may remain constrained.

4. Challenges to Digital Transformation of Agricultural Education in Nigeria

With the ever increasing recognition of the importance of digital technologies in education and agriculture, the digital transformation of Agricultural Education in Nigeria continues to face significant structural, institutional, and human capacity challenges. These barriers limit the effective integration of digital technologies into teaching, learning, research, and community engagement.

One of the most persistent challenges is inadequate digital infrastructure. Many Colleges of Education and other tertiary institutions operate with insufficient computer laboratories, limited broadband connectivity, outdated ICT facilities, and inadequate access to smart agricultural technologies such as Geographic Information Systems (GIS), drones, remote sensing equipment, precision agriculture tools, and digital farm management software. These infrastructural deficiencies reduce opportunities for practical

learning and hinder the acquisition of industry-relevant digital competencies (, 2022; World Bank, 2023).

Inadequate and inconsistent funding also remains a major obstacle. The acquisition, maintenance, and upgrading of digital infrastructure require substantial financial investment, yet many educational institutions operate under limited budgets. Consequently, priority is often given to basic institutional needs at the expense of investments in emerging educational technologies. This situation slows curriculum modernization and limits students' exposure to contemporary digital agricultural practices (Federal Ministry of Education, 2022; OECD, 2023).

Another critical challenge relates to the digital competence of academic staff. Although many lecturers possess general ICT skills, relatively few have received specialized training in smart agricultural technologies or digital pedagogies that support technology-enhanced teaching. The absence of continuous professional development programmes limits lecturers' confidence and ability to integrate emerging technologies into classroom instruction, laboratory activities, and field-based learning experiences (Falloon, 2020; Mohammed et al., 2024).

Policy implementation gaps further constrain digital transformation efforts. Nigeria has introduced several policies promoting digital education, innovation, and agricultural modernization; however, implementation has often been inconsistent because of inadequate funding, weak institutional coordination, limited monitoring mechanisms, and insufficient stakeholder collaboration. As a result, policy objectives have not always translated into sustainable institutional practices (Federal Ministry of Agriculture and Food Security, 2023; UNESCO, 2023).

Curriculum limitations also present significant challenges. In many Agricultural Education programmes, curricula continue to emphasize conventional agricultural practices with limited integration of precision agriculture, agricultural data analytics, artificial intelligence applications, Internet of Things (IoT), climate-smart agriculture, and other emerging digital innovations. Consequently, graduates may possess strong theoretical knowledge but insufficient practical experience with technologies increasingly demanded by employers and the agricultural industry (Klerkx et al., 2019; Ayim et al., 2020).

The digital divide between institutions and geographical regions further complicates digital transformation. Institutions located in urban centres generally enjoy better internet connectivity, electricity supply, access to technology partners, and digital infrastructure than those in rural or underserved areas. This disparity contributes to unequal educational opportunities and widens differences in students' exposure to digital agricultural technologies.

Finally, resistance to organizational change remains an important but often overlooked barrier. Successful digital transformation requires institutional leadership, supportive organizational culture, and willingness among educators to adopt new instructional approaches. Resistance arising from limited technological confidence, increased workload, or uncertainty regarding the benefits of digital innovation can slow the adoption of technology-enhanced teaching practices. Addressing these behavioural and organizational factors is therefore as important as improving infrastructure and funding.

Taken together, these challenges demonstrate that digital transformation in Agricultural Education is a multidimensional process requiring coordinated reforms at institutional, national, and policy levels. Sustainable progress will depend on integrating investments in infrastructure, human capacity development, curriculum modernization, leadership, and governance rather than addressing these issues in isolation.

5. Opportunities for Digital Transformation of Agricultural Education in Nigeria

Despite the challenges confronting digital transformation in Agricultural Education, significant opportunities exist for repositioning the sector to meet the demands of modern agriculture and the digital economy. Harnessing these opportunities will enhance teaching quality, strengthen research capacity, improve students' employability, and support sustainable agricultural development.

One major opportunity lies in the increasing availability of smart agricultural technologies. Precision agriculture, Geographic Information Systems (GIS), Global Positioning Systems (GPS), drones, remote sensing technologies, Internet of Things (IoT) devices, artificial intelligence (AI), and digital farm management systems are transforming agricultural production globally. Integrating these technologies into Agricultural Education curricula will enable students to acquire practical competencies that align with contemporary agricultural practices and labour market expectations (, 2022; UNESCO, 2023).

The rapid expansion of digital learning platforms also provides opportunities to improve instructional delivery. Learning Management Systems (LMS), virtual classrooms, digital libraries, simulation software, and open educational resources can enhance access to quality learning materials, encourage collaborative learning, and support flexible teaching approaches. These technologies are particularly valuable for extending learning beyond the traditional classroom and strengthening students' digital literacy (Bond et al., 2024).

Another important opportunity is the growing emphasis on capacity building for educators. Continuous professional development programmes focusing on digital pedagogy, smart agricultural technologies, and technology-enhanced teaching can significantly improve lecturers' confidence and competence. Such initiatives will facilitate the effective integration of digital tools into classroom instruction, practical demonstrations, research, and extension activities (Falloon, 2020; Redecker, 2017).

Partnerships among higher education institutions, agricultural research institutes, technology companies, development agencies, and the private sector offer additional opportunities for digital transformation. Collaborative initiatives can support curriculum development, technology transfer, staff training, research funding, internship programmes, and access to modern agricultural technologies. These partnerships will strengthen the relevance of Agricultural Education while promoting innovation and entrepreneurship among students (World Bank, 2023; FAO, 2022).

Nigeria's expanding digital economy and increasing government commitment to agricultural modernization also provide a

favourable environment for digital transformation. National initiatives promoting digital literacy, innovation, broadband expansion, and agricultural technology adoption create opportunities for educational institutions to modernize their programmes and align them with national development priorities (Federal Ministry of Education, 2022; Federal Ministry of Agriculture and Food Security, 2023).

Furthermore, digital transformation can strengthen agricultural research and extension by improving data collection, analysis, knowledge dissemination, and collaboration among researchers, educators, extension personnel, and farmers. Mobile advisory platforms, digital extension services, geospatial technologies, and online research networks can accelerate the dissemination of innovations and contribute to improved agricultural productivity and food security.

To maximize these opportunities, educational institutions must adopt strategic and coordinated approaches that integrate technological investment, curriculum reform, staff development, institutional leadership, and stakeholder collaboration. Such efforts will position Agricultural Education as a catalyst for developing the skilled workforce required to drive Nigeria's transition towards digitally enabled and sustainable agricultural systems.

6. Policy Implications

The findings synthesized in this review have significant implications for educational policy, institutional governance, curriculum development, and agricultural workforce development in Nigeria. Achieving meaningful digital transformation in Agricultural Education requires coordinated action among government agencies, regulatory bodies, educational institutions, development partners, and the private sector.

First, there is a need for national policies that prioritize digital transformation as a core component of Agricultural Education. The Federal Ministry of Education, in collaboration with the Federal Ministry of Agriculture and Food Security, should develop and implement a national framework for digital transformation in Agricultural Education. Such a framework should provide clear standards for digital infrastructure, curriculum integration, staff development, and institutional monitoring to ensure consistent implementation across tertiary institutions.

Second, regulatory agencies such as the National Commission for Colleges of Education (NCCE) and the National Universities Commission (NUC) should review existing Agricultural Education curricula to incorporate emerging digital agriculture competencies. Curriculum reforms should emphasize practical training in Geographic Information Systems (GIS), precision agriculture, remote sensing, drone technology, Internet of Things (IoT), agricultural data analytics, and digital farm management systems to better align graduate competencies with industry needs.

Third, sustained investment in digital infrastructure is essential. Governments and institutional administrators should improve broadband connectivity, electricity supply, smart classrooms, digital laboratories, and access to modern agricultural technologies. Such investments will provide enabling environments for effective teaching, learning, research, and innovation while reducing disparities among institutions.

The review also highlights the importance of continuous professional development for academic staff. Policies should

support regular training, certification programmes, industry attachments, and collaborative research that strengthen lecturers' competencies in digital pedagogy and smart agricultural technologies. Building educators' digital competence is fundamental to the successful integration of technology into Agricultural Education.

Furthermore, stronger collaboration between tertiary institutions, agricultural research institutes, technology companies, extension agencies, and development partners should be encouraged. Public-private partnerships can facilitate technology transfer, curriculum enrichment, research funding, student internships, and innovation hubs that expose learners to contemporary agricultural technologies and enhance graduate employability.

Finally, institutional leaders should establish mechanisms for monitoring and evaluating digital transformation initiatives. Regular assessment of infrastructure, staff competencies, technology utilization, and student learning outcomes will enable evidence-based decision-making and ensure that investments in digital transformation produce measurable improvements in educational quality and agricultural innovation.

Implementing these policy measures will strengthen Agricultural Education institutions, improve the digital readiness of graduates, and contribute to Nigeria's broader goals of agricultural modernization, food security, youth employment, and sustainable national development.

7. Conclusion

Digital transformation represents a major opportunity for repositioning Agricultural Education in Nigeria to meet the demands of contemporary agriculture and the evolving digital economy. This review has demonstrated that the integration of digital technologies into Agricultural Education extends beyond the adoption of ICT tools; it requires comprehensive institutional transformation involving curriculum reform, digital competence development, infrastructure improvement, supportive policies, and strategic partnerships.

Although Nigerian educational institutions have made progress in adopting digital learning platforms and ICT-based instructional approaches, the integration of advanced smart agricultural technologies remains limited. Challenges including inadequate infrastructure, insufficient funding, weak policy implementation, limited digital competence among educators, curriculum gaps, and unequal access to technology continue to constrain the pace of transformation.

However, emerging opportunities in digital agriculture, including precision farming, artificial intelligence, Internet of Things, geospatial technologies, mobile learning, and digital extension platforms, provide pathways for strengthening Agricultural Education and preparing graduates for technology-driven agricultural systems. These opportunities can only be fully realized through coordinated actions involving government agencies, regulatory bodies, educational institutions, technology providers, and development partners.

The future of Agricultural Education in Nigeria depends on the ability of institutions to transition from conventional approaches toward digitally enabled, innovative, and industry-responsive learning systems. Investment in educator capacity development, smart agricultural infrastructure, curriculum modernization, and

evidence-based policy implementation will be critical for achieving sustainable digital transformation.

Ultimately, digital transformation should be viewed not merely as a technological upgrade but as a strategic educational reform that can enhance agricultural innovation, improve graduate employability, strengthen research capacity, and contribute to Nigeria's goals of food security and sustainable development.

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