CLIMATE SMART AGRIBUSINESS FINANCING (CSAF) FORESTRY AND WASTE MANAGEMENT

GLOBAL ISSUES & LOCAL PERSPECTIVES

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Preface

This book adopts an exegetical approach as well as a pedagogic model, making it attractive agriculture and environmental economics teachers, professional practitioners and scholars. It is eschews pedantry and lays bars the issues in such clarity that conduces to learning. The book elaborates on contemporaneous **Climate Smart Agribusiness Financing (CSAF) Forestry and Waste Management** issues of global significance and at the same time, is mindful of local or national perspectives making it appealing both to international and national interests. The book explores the ways in which **Climate Smart Agribusiness Financing (CSAF) Forestry and Waste Management** issues are and should be presented to increase the public's stock of knowledge, increase awareness about burning issues and empower the scholars and public to engage in the participatory dialogue **Climate Smart Agribusiness Financing (CSAF) Forestry and Waste Management** necessary in policy making process that will stimulate increase in food production and environmental sustainability. **Climate Smart Agribusiness Financing (CSAF) Forestry and Waste Management :** *Global Issues & Local Perspectives* is organized in two parts. Part One deals with The Concept of **Climate Smart Agribusiness Financing (CSAF)**, Part Two is concerned with The Concept of **Forestry and Waste Management**

Eteyen Nyong; August 202

Chapter Ten

ICTs and Digital Technologies in Agricultural Extension in Nigeria

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Introduction

Agricultural extension has traditionally served as a vital mechanism for transferring knowledge, innovations, and technologies from research institutions to farmers. However, the rapid advancement of Information and Communication Technologies (ICTs) has significantly transformed extension delivery systems worldwide. In the 21st century, characterized by globalization, climate change, and increasing food demand, conventional extension approaches alone are no longer sufficient to meet the diverse and dynamic needs of farmers. Although Agricultural extension remains a cornerstone for rural development, technology dissemination, and productivity enhancement. In Nigeria, agriculture contributes significantly to national development, accounting for about 23% of GDP, yet productivity remains suboptimal due to information gaps and weak extension systems (Salahudeen, Mukhtar, Abubakar, & Salawu, 2024). Traditional extension approaches which largely dependent on face-to-face interaction have proven inadequate in reaching the vast and dispersed farming population.

Globally and within Sub-Saharan Africa, ICT deployment has been empirically linked to improved agricultural performance, value chain efficiency, and knowledge transfer. According to Oyelami, Sofoluwe, Ajeigbe (2022), The emergence of Information and Communication Technologies (ICTs) and digital innovations have redefined extension delivery by enabling real-time, scalable, and cost-effective dissemination of agricultural information. ICTs and digital technologies have emerged as powerful tools for enhancing the efficiency, research and effectiveness of agricultural extension services. These technologies facilitate real-time communication, improve access to agricultural information, and support data-driven decision-making. In developing countries such as Nigeria, ICT has enabled extension services by increasingly recognizing and critically improving agricultural productivity, rural livelihoods, and food security

This chapter examines the role, applications, benefits, challenges, and future prospects of ICTs and digital technologies in agricultural extension, with particular emphasis on Nigeria

Conceptual Frame

Information and Communication Technologies (ICTs)

Information and Communication Technologies (ICTs) refer to a broad range of electronic tools, systems, and resources used to collect, process, store, and transmit information and to facilitate communication between individuals or groups. Iin other words it refers to a broad range of technologies used to collect, process, store, and disseminate information. These include radio, television, mobile phones, computers, the internet, and satellite systems. Simply put, ICTs are technologies that help people access information and communicate with others, especially through digital or electronic means. ICTs combine two main elements, (1) Information Technology (IT) which deals with data processing, storage, and management, examples: computers, databases, software; and Communication Technology (CT) that enables the transmission and exchange of information, examples: telephones, internet, radio networks. The functions of ICTs include information storage (e.g., databases), Information processing (e.g., software applications), Information transmission (e.g., internet, mobile networks) and Communication (e.g., calls, messaging, video conferencing), In agricultural extension, ICTs are used to share farming information and innovations, provide weather forecasts and market prices, and connect farmers with extension agents and buyers

In academic literature, Information and Communication Technologies (ICTs) have been widely defined as follows: ICTs refer to “the diverse set of technological tools and resources used to communicate, create, disseminate, store, and manage information” (United Nations Development Programme, 2001). Similarly, ICTs are defined as “technologies that facilitate communication and the processing and transmission of information by electronic means, including computers, telecommunications, and digital media” (World Bank, 2017). From an agricultural perspective, ICTs encompass “hardware, software, networks, and media for the collection, storage, processing, transmission, and presentation of information in support of agricultural development and extension services” (Food and Agriculture Organization, 2019). Synthesizing from the preceding definitions, ICTs can be conceptualized as: An integrated system of digital and communication technologies including hardware, software, and network infrastructure used to generate, process, store, and exchange information, thereby facilitating knowledge dissemination, decision-making, and interactive communication across sectors such as agricultural extension.

Digital Technologies

Digital technologies are advanced ICT tools that rely on digital systems for data processing and communication. Examples include mobile applications, artificial intelligence (AI), big data analytics, and the Internet of Things (IoT). From scholarly perspective, Digital Technology is a core concept within ICT discourse and is defined in academic literature as follows: (1) Digital technology refers to “electronic tools, systems, devices, and resources that generate, store, or

process data in digital form, typically using binary code (0s and 1s)" (World Bank, 2016). Similarly, it encompasses "technologies that enable the encoding, transmission, and manipulation of information in digital formats, including computers, mobile devices, the internet, and software applications" (Organisation for Economic Co-operation and Development, 2015).

From a development perspective, Digital technologies are "tools that leverage digitized data and connectivity to enhance communication, efficiency, innovation, and service delivery across sectors" (Food and Agriculture Organization, 2019). Drawing from these perspectives, digital technology can be defined asa broad category of electronic technologies that utilize digital (binary) data to create, process, store, and transmit information, enabling automation, connectivity, and intelligent decision-making in various sectors, including agriculture. In agricultural extension, digital technologies include tools such as mobile applications, remote sensing systems, artificial intelligence, and online advisory platforms that enhance real-time information delivery and farmer engagement. Agricultural extension, in this context, evolves into digital extension systems, where information flows are multidirectional linking farmers, researchers, markets, and policymakers in real time.

Agricultural Extension

Agricultural extension as a concept has been variously conceived. It has been viewed is a system of non-formal education that disseminates knowledge, innovations, and skills to farmers to improve agricultural productivity and livelihoods. Scholarly, it is defined in diverse perspectives. by several scholars and institutions: Agricultural extension is "a service or system that assists farmers through educational procedures in improving farming methods and techniques, increasing production efficiency and income, and enhancing their standards of living" (Food and Agriculture Organization, 2010). Similarly, it is defined as "the application of scientific research and knowledge to agricultural practices through farmer education and advisory services" (World Bank, 2012). From a broader developmental perspective, Agricultural extension is "a participatory process of knowledge exchange that empowers farmers to identify problems, access innovations, and improve livelihoods within a dynamic agricultural system" (United Nations Development Programme, 2005). Drawing from these perspectives, agricultural extension can be conceptualized as: A systematic, non-formal educational process and institutional service that facilitates the dissemination of agricultural knowledge, innovations, and skills to farmers through interactive communication, with the aim of improving productivity, income, and rural livelihoods.

There are some classical and widely cited scholarly definitions of Agricultural Extension from key authorities. Leagans (1961) viewed Agricultural extension as "the application of scientific research and new knowledge to agricultural practices through farmer education." Here Leagans emphasized that: Extension is a process of helping people learn to help themselves by applying improved practices in agriculture and rural life. Kelsey and Hearne (1963) conceive Agricultural extension is "a system of out-of-school education for rural people through which

they are taught improved farming methods and techniques, aiming at better living." van den Ban and Hawkins (1996) defined Agricultural extension is "a conscious use of communication of information to help people form sound opinions and make good decisions." This definition highlights communication and decision-making as core components. Roling (1988) sees Extension is "a professional communication intervention deployed by an institution to induce change in voluntary behavior with a presumed public or collective utility." Swanson (2008) views Agricultural extension is "a series of embedded communicative interventions designed to develop and/or induce innovations which supposedly help to resolve problematic situations. "From these classical perspectives, agricultural extension can be seen as: A participatory, educational, and communication-driven process through which scientific knowledge and innovations are disseminated to farmers, enabling them to improve agricultural practices, make informed decisions, and enhance their livelihoods. Based on these Classical conceptions, Leagans emphasized education and self-help; Kelsey and Hearne: Focused on rural development and improved living; Van den Ban and Hawkins highlighted communication and decision-making, Roling viewed extension as behavioral change intervention while Swanson inked extension to innovation systems.

The key elements of Agricultural Extension are(i) Education- focus on learning rather than mere information transfer; (ii)Communication- two-way interaction between farmers and experts.; (iii) Innovation diffusion -transfer of new technologies and practices; and (iv)Capacity building: Empowering farmers to make informed decision. Contextually, modern agricultural extension goes beyond traditional advisory services to include participatory approaches, market linkage support, and digital extension systems, especially with the integration of ICTs.

Relevance of Diffusion of innovations theory to ICTs in agricultural extension in Nigeria.

The Diffusion of Innovations Theory developed by Everett M. Rogers provides a robust analytical lens for understanding how ICT-based innovations are introduced, communicated, and adopted among farmers in Nigeria. In the context of agricultural extension, ICT tools—such as mobile phones, radio programs, and digital platforms—are treated as innovations, while farmers represent the social system through which diffusion occurs.

ICTs as Innovations in Nigerian Agricultural Extension

In Nigeria, ICTs (e.g., mobile advisory services, digital marketplaces, and social media platforms) are relatively new approaches compared to traditional extension methods. Their adoption depends on how farmers perceive their usefulness and relevance. Studies among maize farmers in Kaduna State show that farmers who perceived mobile phone–based advisory services as useful and compatible with their farming practices were significantly more likely to adopt them. This aligns with Rogers' attributes of relative advantage and compatibility as key drivers of adoption.

Communication Channels and ICT Diffusion

Rogers emphasized that communication channels influence how quickly innovations spread. In Nigeria, ICTs themselves have become powerful communication channels. Traditionally, radio, and extension agents comes to mind. While contemporarily, mobile phones, internet, WhatsApp groups apply. In many rural communities in Nigeria, farmers receive agricultural tips through radio programmes and subsequently discuss and validate the information via WhatsApp groups. This hybrid communication system accelerates diffusion by combining mass media and interpersonal channels.

Adoption Process in Nigerian Context

farmers in Nigeria typically move through rogers' five stages of adoption. knowledge: awareness through radio or extension agents; persuasion: discussions with peers or observation of early adopters; decision: trial use of ICT tools (e.g., mobile apps); implementation: regular use for farming decisions; and confirmation: continued use after observing benefits. Some cassava farmers in in Nigeria initially became aware of ICT-based advisory services through extension campaigns. Adoption increased after they observed yield improvements among early users, demonstrating the importance of observability (FAO, 2019).

Adopter Categories in Nigerian Agriculture

The diffusion pattern of ICTs among Nigerian farmers reflects Rogers' adopter categories: innovators: educated, urban-linked farmers using smartphones and apps; early adopters: progressive farmers and cooperative leaders; early majority: farmers adopting after seeing proven benefits; and late majority & laggards: rural farmers with limited education and access. Research Younger, educated farmers are more likely to adopt ICT tools early, while older farmers relied on traditional extension methods, illustrating socio-economic influences on adoption categories.

Attributes of ICT Innovations in Nigeria

The adoption of ICTs in agricultural extension is strongly influenced by Rogers' five attributes: relative advantage: access to timely market prices and weather updates; compatibility: alignment with local farming practices; complexity: ease of using mobile phones vs. complex apps; trialability: ability to test services (e.g., free SMS alerts); and observability: visible improvements in yield and income. Mobile-based market information systems in Nigeria have been widely adopted because they provide immediate financial benefits, making their relative advantage highly visible.

Role of Extension Agents as Change Agents

In DIT framework, extension agents act as change agents who facilitate diffusion by Creating awareness of ICT tools, demonstrating their use, and providing technical support. Programmes supported by Nigerian agricultural development projects have trained extension agents to use mobile devices for data collection and farmer advisory services, significantly improving outreach and efficiency.

Social Systems and Peer Influence

The Nigerian rural setting is characterized by strong social networks, including farmer cooperatives and community groups. These networks enhance diffusion through peer learning. Farmers' cooperatives in Nigeria often adopt ICT tools collectively. Once cooperative leaders adopt a technology, other members tend to follow, demonstrating the role of social influence in diffusion.

Barriers to Diffusion

Despite the relevance of the theory, several factors slow down ICT diffusion in Nigeria, limited infrastructure (electricity, internet), low digital literacy, high cost of devices, and cultural resistance. These barriers affect the rate of adoption, a key concern in Rogers' model.

ICTs and Digital Technologies and agricultural extension in Nigeria

Agricultural extension is undergoing a digital transformation driven by advances in Information and Communication Technologies (ICTs). Emerging digital technologies are making extension services more efficient, personalized, data-driven, and accessible. These innovations enable extension agents to provide timely advisory services, improve farmer decision-making, and promote sustainable agricultural practices. Artificial intelligence (AI), big data analytics, and the Internet of Things (IoT) are some of the contemporary Digitals that find applications in Agricultural Extension

Digital technologies are advanced ICT tools that rely on digital systems for data processing and communication. Examples include mobile applications, artificial intelligence (AI), big data analytics, and the Internet of Things (IoT) (Food and Agriculture Organization., 2022).

Mobile App Applications in Agricultural Extension

Mobile applications (Mobile Apps) have become an essential tool in modern agricultural extension. They enable extension agents, farmers, researchers, agribusinesses, and policymakers to communicate efficiently, access real-time information, and improve agricultural productivity. The widespread availability of smartphones and mobile internet has transformed the way agricultural knowledge is generated, shared, and applied. Agricultural extension traditionally relied on face-to-face interactions, demonstrations, and printed materials. Today, mobile applications complement these methods by providing timely, location-specific, and interactive agricultural advisory services.

A mobile application is a software programme designed to run on smartphones, tablets, and other mobile devices. Agricultural mobile applications are specifically developed to provide information and services related to crop production, livestock management, weather

forecasting, pest and disease control, market information, agricultural finance, and extension communication.

Roles of Mobile Applications in Agricultural Extension

Information Dissemination

Mobile applications provide farmers with instant access to improved crop varieties, livestock management practices, fertilizer recommendations, soil management, irrigation techniques and harvesting methods. Unlike traditional extension, information can be updated immediately.

Weather Information

Farmers receive Daily weather forecasts, Rainfall predictions**,** Temperature alerts**,** Wind speed information**,** Flood warnings and Drought alerts among others**.** This helps farmers make informed planting and harvesting decisions.

Pest and Disease Diagnosis

Many agricultural apps use image recognition and artificial intelligence to identify Crop diseases, Insect pests, Nutrient deficiencies and Weed infestations. Some applications recommend appropriate control measures.

Market Information

Farmers can access Current commodity prices, Market demand, Buyers' contacts, Price trends and Nearby markets. This reduces exploitation by middlemen.

Advisory Services

Agricultural extension agents can send recommendations**, r**espond to farmers' questions**,** share videos**,** conduct virtual training and organize webinars**.** Communication becomes faster and cheaper.

Farm Record Keeping

Applications help farmers maintain records of farm expenses, income input, purchases, labour costs, yield records, and livestock production. This improves farm management decisions.

Precision Agriculture

Some mobile applications integrate with GPS, drones, sensors and satellite imagery. This enables site-specific fertilizer application, soil monitoring, crop monitoring and yield estimation

Financial Inclusion

Farmers can use mobile applications to access loans, purchase insurance, save money, make digital payments and also receive subsidies

Training and Capacity Building

Mobile Apps provide interactive lessons, demonstration videos, audio tutorials, farmer discussion forums and e-learning modules. this encourages learning as a continuous process.

Farmer-to-Farmer Learning

Some Agricultural Mobile Apps contain social networking features allowing farmers to share experiences, ask questions, upload photos, discuss production and challenges as well as learn best agricultural practices

Agricultural Mobile Application

Some widely known agricultural mobile applications as enumerated by Qiang, et al (2012) include: Hello Tractor- Tractor hiring and mechanization services; Plantix -Crop disease diagnosis using AI; FarmCrowdy- Agribusiness support and farmer services in Nigeria; Digital Green- Farmer education through videos; iCow -Livestock management; e-Soko- Market information services; and RiceAdvice - Fertilizer recommendations for rice farmers

Artificial Intelligence (AI) and Machine Learning

Artificial Intelligence enables agricultural extension systems to analyze large volumes of agricultural data and provide intelligent recommendations. It is applied in

- Pest and disease diagnosis through image recognition.
- Personalized crop management recommendations.
- Yield prediction models.
- Smart fertilizer recommendations.
- Weather-based advisory services.

It is faster decision-making, increases accuracy reduces production risks and improves extension efficiency.

Internet of Things (IoT)

IoT connects farm devices and sensors to the internet, allowing real-time monitoring of farm conditions. It is applied in agricultural extension in the following areas: soil moisture monitoring, automated irrigation systems, livestock health monitoring, greenhouse climate control, water quality monitoring, and crop growth monitoring. IoT aids efficient resource utilization, reduced labour requirements, improved productivity and early detection of production problems.

Remote Sensing Technology

Satellite imagery and aerial photography provide valuable agricultural information over large geographical areas. It can be applied in crop health monitoring, drought assessment, flood monitoring, vegetation mapping, pest outbreak surveillance, and land-use planning. It is beneficial where large-scale monitoring, timely intervention and reduced field inspection costs are priotized.

Geographic Information Systems (GIS)

GIS integrates spatial and geographic information for agricultural planning and extension. It finds application in soil fertility mapping, farm mapping, precision fertilizer application., climate risk mapping, agricultural zoning and site-specific extension recommendations. It is beneficial when improved planning, better resource allocation and enhanced decision-making. are required.

Precision Agriculture

Precision agriculture uses digital technologies to manage farm operations based on location-specific information. It is useful in variable-rate fertilizer application, precision irrigation, GPS-guided machinery, yield mapping., precision pesticide application. It is advantageous as it uses leads to increased efficiency, lowered production costs, and reduced environmental pollution.

Drone (Unmanned Aerial Vehicle) Technology

drones provide aerial data for farm monitoring and crop management. it is used for crop surveillance, disease detection, fertilizer spraying, pesticide application, and field mapping as well as crop damage assessment. It aids rapid field assessment, labour savings, improved precision. and reduces operational costs.

Big Data Analytics

Big data combines information from weather stations, satellites, markets, sensors, and farm records. it finds application in production forecasting market trend analysis. climate prediction., farm performance analysis and risk assessment. It enhances evidence-based decision-making improved productivity and better planning.

Social Media Platforms

Extension organizations increasingly use social media to reach farmers. The platform can be used for knowledge sharing, farmer discussion groups, live demonstrations, video tutorials, extension announcements. Popular platforms used in agricultural extension include WhatsApp, Facebook, YouTube, Telegram, and X (formerly Twitter). Social Media Platforms aids interactive learning. rapid information dissemination, and peer-to-peer knowledge exchange.

Cloud Computing

Cloud technology allows agricultural information to be stored and accessed remotely. it is useful as farmer databases, in farm record management., online extension services., knowledge repositories and as digital learning platforms. Cloud Computing enables easy data access, secure information storage and improves collaboration.

. **Blockchain Technology**

Blockchain provides secure and transparent digital record systems. It is useful in agricultural product traceability, food safety monitoring, smart contracts, supply chain management, and digital certification. This is because it enhances transparency, reduced fraud an improves consumer confidence.

Digital Advisory Platforms

This is integrated digital platforms combine multiple extension services into one system. It is useful in the following areas: crop calendars, weather information, market intelligence, expert consultation and e-learning. It gives a One-stop information access, Improved farmer engagement, and better extension coordination.

E-Learning and Virtual Training Platforms

Digital learning platforms provide continuous education for farmers and extension personnel. Applications in this regard are in the area of online courses, webinars, virtual field demonstrations, digital farmer schools, interactive learning modules. E-learning and virtual training platforms is very beneficial to agricultural extension due to its potentiality in continuous capacity building, flexible learning and reduced training costs.

Decision Support Systems (DSS)

Decision support systems combine scientific data and expert knowledge to guide agricultural decisions. It is applicable in the area of crop selection, fertilizer recommendations, disease forecasting, irrigation scheduling, and farm planning.The benefits derived from it benefits include better farm management, reduced uncertainty and increased productivity.

Robotics and Agricultural Automation

Robotics is increasingly being used to automate repetitive agricultural operations. This is applicable in automated harvesting, robotic weeding, precision spraying, livestock feeding, and greenhouse automation among others. It is labour saving, efficient and improves precision

Importance of ICTS and Digital Technologies in Agricultural Extension in Nigeria

Improved access to timely and accurate agricultural information

Emerging digital technologies are transforming agriculture by making information more accessible, timely, and accurate. Through Mobile Apps & SMS Services farmers can receive instant updates on weather forecasts, pest outbreaks, and market prices directly on their phones, even in rural areas. Satellite Imaging & Drones provide real-time data on soil health, crop growth, and water usage, helping farmers make timely and precise decisions. IoT Sensors & Smart Devices fields monitor soil moisture, temperature, and nutrient levels, sending timely and accurate data to farmers for better resource management. Big Data & AI Analytics using advanced algorithms analyze large datasets to predict yields, detect diseases early, and recommend best farming practices. Through Online Platforms & social media farmers can access expert advice, training videos, and peer-to-peer knowledge sharing instantly, bridging the gap between research institutions and rural communities. In short, these technologies reduce delays, improve accuracy, and empower farmers with actionable insights, leading to higher productivity and resilience.

Increased extension coverage, especially in remote areas.

Emerging digital technologies are expanding agricultural extension coverage, especially in remote areas, in several powerful ways. Using Mobile Phones & Apps, farmers in rural areas can receive advice, training, and alerts directly on their phones, bypassing the need for physical visits from extension officers. Interactive radio programs combined with SMS or WhatsApp allow farmers to ask questions and get expert responses, reaching communities that traditional extension services struggle to cover. Digital platforms provide training videos, manuals, and expert forums accessible anytime, reducing dependence on limited extension staff. Through Drones & Remote Sensing, extension agents can monitor large areas quickly and share findings with farmers, improving coverage without needing to travel extensively. Social Media & Messaging Groups such as WhatsApp, Facebook, and community groups connect farmers with extension officers and peers, creating networks that spread knowledge faster and wider. Contemporary Digital Technologies break down geographic barriers, reduce costs, and allow extension services to reach more farmers with timely, practical advice.

Promotion of climate-smart agriculture

Emerging digital technologies support climate-smart agriculture (CSA**)** by helping farmers adapt to climate change, reduce greenhouse gas emissions, and increase agricultural productivity in a sustainable manner. Mobile applications, satellite systems, and weather platforms provide accurate forecasts, enabling farmers to make informed decisions on planting, irrigation, fertilizer application, and harvesting. Technologies such as GPS, drones, sensors, and Geographic Information Systems (GIS) allow farmers to apply water, fertilizers, and pesticides only where needed, reducing waste, production costs, and environmental pollution. Digital technologies detect and communicate early warnings about droughts, floods, pest outbreaks, and crop diseases, allowing farmers to take preventive measures and minimize losses. Internet of Things (IoT) sensors monitor soil moisture and automatically regulate irrigation, improving water-use efficiency and conserving scarce water resources.

AI analyzes weather, soil, and crop data to recommend climate-resilient farming practices, suitable crop varieties, and optimal planting dates.

Satellite imagery and drones monitor crop health, soil conditions, and vegetation changes, enabling timely interventions and better management of natural resources. Social media, mobile apps, and online extension platforms disseminate information on climate-resilient farming practices, conservation agriculture, agroforestry, and sustainable land management to farmers. Emerging digital technologies promote climate-smart agriculture by providing farmers with timely information, data-driven decision support, precision resource management, and rapid access to climate adaptation strategies. These technologies improve productivity, enhance resilience to climate change, conserve natural resources, and contribute to more sustainable agricultural systems.

Enhancement of productivity and farm profitability

Emerging digital technologies enhance farm productivity and profitability in several key ways. Drones, GPS, and sensors allow farmers to apply water, fertilizer, and pesticides only where needed, reducing waste and boosting yields. IoT-enabled irrigation ensures crops get the right amount of water, improving growth while lowering costs. Predictive models help farmers plan planting and harvesting times, detect diseases early, and optimize resource use, leading to higher efficiency. Mobile apps connect farmers directly to buyers, reducing middlemen and increasing profit margins. Blockchain and digital tracking improve trust and efficiency in transactions, ensuring farmers get fair prices. Generally, these technologies reduce input costs, increase yields, and open better market opportunities—directly translating into higher productivity and profitability for farmers.

Reduction in production risks through early warning systems

Emerging digital technologies reduce production risks through early warning systems by providing farmers with timely alerts and actionable insights. They act as an early shield, helping farmers anticipate threats, minimize losses, and secure more stable harvests. Mobile apps and satellite data deliver accurate forecasts of rainfall, drought, or storms, helping farmers prepare and protect crops. AI-powered platforms analyze field data and send alerts about potential outbreaks, allowing farmers to act before damage spreads. These technologies detect stress in crops early (e.g., water shortage or disease symptoms), enabling preventive measures. Field sensors track soil moisture, temperature, and humidity, warning farmers of conditions that could harm crops. SMS, WhatsApp, and online platforms quickly spread alerts from extension services to even the most remote farmers.

Supporting of evidence-based policy formulation

Emerging digital technologies strengthen evidence-based policy formulation by providing accurate, timely, and comprehensive data, improving analysis and forecasting, and enabling policymakers to design, implement, and evaluate agricultural policies that are more effective, transparent, and responsive to farmers' needs. The digital technologies support evidence-based

policy formulation by generating, analyzing, and sharing accurate, real-time agricultural data that policymakers can use to make informed decisions. Mobile devices, digital surveys, and IoT sensors collect timely data on crop production, weather conditions, pest outbreaks, and farmer needs, providing reliable evidence for policy decisions.

Advanced analytics process large volumes of agricultural data to identify trends, predict future challenges, and evaluate the effectiveness of existing policies. GIS and satellite technologies map land use, soil conditions, crop performance, and environmental changes, helping governments plan interventions based on accurate spatial information. AI models analyze complex datasets to forecast food production, climate risks, and disease outbreaks, enabling proactive and data-driven policymaking. Online dashboards and management information systems track the implementation and outcomes of agricultural programmes, allowing policymakers to assess performance and make necessary adjustments. Cloud-based platforms and digital databases facilitate collaboration among government agencies, researchers, extension services, and development partners by providing access to up-to-date information.

Strengthening of farmer–extension agent communication

Emerging digital technologies improve communication between farmers and extension agents by making interactions faster, more frequent, and more accessible, regardless of distance. Platforms such as WhatsApp, Telegram, and Facebook enable extension agents to share advisory messages, answer farmers' questions, and create discussion groups for continuous interaction. Farmers receive timely information on weather forecasts, pest outbreaks, market prices, and recommended farming practices through text or voice messages. Technologies such as Zoom and Google Meet allow extension agents to conduct remote training, demonstrations, and consultations, reducing the need for physical meetings.

Agricultural apps enable farmers to submit photos of crop diseases or pests, receive expert recommendations, and access extension services at any time. AI-powered chatbots provide instant responses to common farming questions and complement the work of extension agents by offering 24-hour support. Farmers and extension agents can exchange photos, videos, voice notes, and documents, making it easier to diagnose problems and explain recommended practices. Putting it succinctly, emerging digital technologies strengthen farmer–extension agent communication by enabling real-time, two-way information exchange, improving access to expert advice, reducing communication delays, and fostering continuous learning and collaboration, ultimately enhancing agricultural productivity and decision-making.

Encouragement of youth participation through technology-driven agriculture

Emerging digital technologies encourage youth participation in agriculture by making farming more modern, attractive, and rewarding. Technologies like drones, sensors, and AI-driven apps appeal to tech-savvy youth, turning agriculture into a high-tech profession rather than traditional manual labor. Youth can share innovations, access training videos, and connect with global agricultural communities, making farming more engaging and collaborative. Opportunities to build apps, create digital marketplaces, or develop smart solutions attract

young entrepreneurs into agriculture. Digital courses and virtual workshops provide skills in modern farming techniques, empowering youth to adopt and scale new practice. Mobile money and e-commerce platforms allow young farmers to sell produce directly and access credit, making farming more profitable and appealing. Digital technologies transform agriculture into a knowledge-driven, innovative, and profitable sector, motivating youth to see farming as a career of opportunity rather than necessity.

Improvement in sustainability through efficient resource use

Emerging digital technologies enhance agricultural sustainability by helping farmers use resources more efficiently, reducing waste while maintaining or increasing productivity. GPS, drones, and sensors enable farmers to apply fertilizers, pesticides, and water only where and when needed, minimizing waste and environmental pollution. IoT-based soil moisture sensors monitor water requirements in real time, ensuring crops receive the right amount of water and preventing over-irrigation. AI analyzes data on soil, weather, and crop conditions to recommend optimal planting times, input use, and crop management practices, improving resource efficiency. Satellite imagery and drones identify areas affected by nutrient deficiencies, pests, or water stress, allowing farmers to target interventions instead of treating entire fields.

Mobile apps and farm management software help farmers monitor input use, track production costs, and make informed decisions that optimize the use of land, labour, and capital. Accurate weather forecasts help farmers schedule planting, irrigation, fertilizer application, and harvesting at the most appropriate times, reducing unnecessary resource use and crop losses. Summarily, emerging digital technologies improve sustainability by optimizing the use of water, fertilizers, pesticides, energy, and labour, reducing environmental impacts, lowering production costs, conserving natural resources, and promoting long-term agricultural productivity.

Challenges of ICTS and Digital Technologies in Agricultural Extension in Nigeria

ICTS and Digital Technologies have transformed agricultural extension by enabling rapid communication, timely dissemination of information, and improved farmer–extension agent interactions. However, their adoption and effectiveness, especially in developing countries such as Nigeria, are constrained by several challenges.

Poor Network Connectivity: Many rural farming communities have inadequate mobile network coverage, resulting in unreliable internet access. This limits farmers' ability to receive real-time advisory services, weather forecasts, pest alerts, and market information.

High Cost of Smartphones and Data: Although smartphone ownership is increasing, many smallholder farmers cannot afford smartphones, mobile data subscriptions, or regular device maintenance. This financial barrier restricts access to mobile-based extension services.

Low Digital Literacy: A significant proportion of farmers, particularly elderly and less-educated farmers, lack the digital skills required to download, install, navigate, and effectively use agricultural mobile applications.

Limited Literacy and Language Barriers: Many agricultural applications are developed in English or other international languages. Farmers who are unable to read these languages experience difficulty understanding the content. Additionally, low general literacy levels further hinder adoption.

Inadequate Electricity Supply: Frequent power outages and the absence of reliable electricity in rural areas make it difficult for farmers to charge mobile devices regularly, thereby limiting continuous access to mobile applications.

Lack of Localized Content: Many mobile applications provide generalized agricultural recommendations that may not reflect local climatic conditions, soil characteristics, indigenous farming practices, or local pest and disease situations.

Poor Quality or Outdated Information: Some agricultural applications are not regularly updated with current recommendations, market prices, weather information, or emerging disease outbreaks, reducing their usefulness and credibility.

Limited Awareness: Many farmers are unaware of the existence of agricultural mobile applications or the benefits they offer. Weak promotional campaigns and limited extension outreach contribute to low awareness.

Resistance to Technology Adoption: Some farmers prefer traditional face-to-face interactions with extension agents and may distrust recommendations delivered through digital platforms due to unfamiliarity or perceived complexity.

Inadequate ICT Infrastructure: Limited internet infrastructure, poor broadband penetration, and insufficient telecommunications investment in rural areas reduce the effectiveness of mobile-based extension systems.

Privacy and Data Security Concerns: Farmers may be reluctant to share personal or farm-related information due to concerns about misuse of their data, unauthorized access, or cyber fraud.

Limited Technical Support: Users often lack access to technical assistance when they experience application errors, login problems, or software updates, leading to frustration and eventual abandonment.

Poor Integration with Conventional Extension Services: In many countries, mobile applications operate independently of existing agricultural extension systems. Weak coordination between digital platforms and extension officers limits the effectiveness of advisory services.

Gender Digital Divide: Women farmers often have less access to smartphones, internet services, digital education, and financial resources than men, reducing their participation in mobile-based agricultural extension.

Inadequate Government Support and Policy: Weak policies, insufficient funding, and limited public investment in digital agriculture hinder the development, maintenance, and scaling of agricultural mobile applications.

Lack of User-Centered Design: Some applications are designed without involving farmers during development. Consequently, the interfaces may be difficult to navigate or fail to address farmers' actual information needs.

Compatibility and Device Limitations: Some applications require newer smartphone operating systems or large storage space, making them inaccessible to farmers using older or low-cost devices.

Sustainability Challenges: Many agricultural mobile applications depend on donor funding or short-term projects. When funding ends, application maintenance, updates, and technical support often cease

Implications of ICTS and Digital Technologies in Agricultural Extension Practice in Nigeria

Emerging digital technologies are transforming agricultural extension by changing how extension services are planned, delivered, monitored, and evaluated. Their adoption has far-reaching implications for farmers, extension agents, policymakers, and the agricultural sector.

Increased Efficiency and Productivity

Digital technologies enable extension agents to reach many more farmers in less time. Mobile applications, digital advisory platforms, and automated communication systems reduce travel time and administrative tasks, allowing extension personnel to focus on technical support and problem-solving.

Wider Outreach and Inclusiveness

Digital platforms overcome geographical barriers by delivering agricultural information to farmers in remote and underserved communities. This increases access to extension services, although efforts are needed to ensure women, youth, and marginalized farmers are not excluded due to limited access to digital tools.

Real-Time Information Delivery

Farmers can receive instant updates on weather forecasts, pest outbreaks, market prices, and improved farming practices. This enables timely decision-making, reduces production risks, and improves farm productivity.

Shift from Traditional to Digital Extension

The role of extension agents is evolving from being the primary source of information to becoming facilitators, knowledge brokers, and digital advisors who help farmers interpret and apply information from multiple digital sources.

Personalized Advisory Services

Technologies such as Artificial Intelligence (AI), Geographic Information Systems (GIS), remote sensing, and Internet of Things (IoT) devices provide location-specific recommendations tailored to individual farms, improving the relevance and effectiveness of extension advice.

Improved Monitoring, Evaluation, and Decision-Making

Digital data collection tools and management information systems enable continuous monitoring of extension programmes. Policymakers and organizations can assess programme performance, identify gaps, and allocate resources more effectively.

Promotion of Climate-Smart Agriculture

Digital technologies support sustainable agricultural practices through precision farming, weather forecasting, smart irrigation, and early warning systems, helping farmers adapt to climate variability while conserving natural resources.

Enhanced Farmer Participation and Knowledge Sharing

Social media platforms, online discussion forums, and messaging applications encourage two-way communication between farmers and extension agents. Farmers can share experiences, ask questions, and learn from one another, creating collaborative learning networks.

Capacity Building Requirements

The successful integration of digital technologies requires extension agents and farmers to develop digital literacy and technical skills. Continuous training and professional development become essential components of effective extension systems.

Challenges of the Digital Divide

Not all farmers have access to smartphones, reliable internet, electricity, or digital skills. Without deliberate interventions, digital extension may widen inequalities between well-connected farmers and those in resource-poor rural communities.

Policy and Institutional Implications

Governments and institutions must invest in rural digital infrastructure, develop supportive ICT policies, strengthen cybersecurity, promote data privacy, and foster partnerships with the private sector and research institutions to ensure sustainable digital extension services.

Cost Effectiveness

Although the initial investment in digital infrastructure and training may be high, digital technologies reduce long-term operational costs by minimizing travel expenses, paperwork, and repetitive extension activities while increasing service coverage.

Strategies for Effective Adoption of ICTS and Digital Technologies in Agricultural Extension in Nigeria

The successful adoption of ICTS and Digital Technologies in agricultural extension in Nigeria requires coordinated efforts from governments, extension organizations, technology developers, telecommunication providers, research institutions, and farmers. The following strategies as adapted from Food and Agriculture Organization. (2022) can enhance the effective use and sustainability of mobile applications in agricultural extension.

Improved Rural ICT Infrastructure

Governments and telecommunication companies should expand mobile network coverage and broadband internet services to rural farming communities. Reliable connectivity enables farmers to access real-time agricultural information, weather forecasts, and market updates

Enhanced Digital Literacy among Farmers

Extension agencies should organize regular training programmes to improve farmers' digital skills. Training should cover smartphone operation, downloading, installing agricultural applications, accessing extension information and using multimedia features such as videos, voice messages, and images among others.

Development of User-Friendly Applications

Mobile applications should be designed with simple navigation, clear icons, and intuitive interfaces that can easily be understood by farmers with varying educational backgrounds.

Provision of Content in Local Languages

Applications should support indigenous languages and include voice-based features to accommodate farmers with limited literacy. Audio instructions, illustrations, and videos improve accessibility.

Localization of agricultural information

Extension content should be tailored to local conditions, including climate, soil characteristics, cropping systems, pest and disease prevalence, and indigenous farming practices. This will increase farmers' confidence and improve adoption.

Integrating mobile applications with conventional extension

Mobile applications should complement—not replace—face-to-face extension services. Extension agents can use applications during farm visits to demonstrate improved technologies, monitor farm performance, provide personalized recommendations, and collect field data.

Strengthening capacity of extension personnel

Extension officers should receive continuous training on digital agriculture tools so they can effectively guide farmers in using mobile applications and interpreting digital information.

Ensuring affordable access to smartphones and internet

Governments and private-sector partners can subsidize smartphones for smallholder farmers, offer discounted mobile data plans, promote affordable digital devices and support farmer cooperatives in acquiring ICT resources.

Provision of reliable electricity supply

Improving rural electrification and promoting solar-powered charging stations will ensure that farmers can consistently power their mobile devices.

Promoting awareness and sensitization

Extension organizations should conduct awareness campaigns through radio programmes, community meetings, farmer field schools, demonstration farms, farmer cooperatives, and social media platforms. These activities increase awareness of the benefits and availability of agricultural mobile applications.

Encouraging participatory application development

Farmers, extension agents, researchers, and software developers should collaborate throughout the design process. User feedback helps ensure applications address real agricultural problems and remain practical.

Ensuring regular content updates

Agricultural information should be updated frequently to include weather forecasts, pest and disease outbreaks, current market prices, government agricultural policies. and improved farming technologies. Timely updates maintain the relevance and credibility of extension services.

Strengthening data privacy and cybersecurity

Developers should incorporate strong security measures to protect farmers' personal and farm data. Clear privacy policies enhance users' trust and willingness to use digital platforms.

Fostering public–private partnerships

Collaboration among governments, universities, agribusiness firms, telecommunication companies, NGOs, and international development organizations can support application development, infrastructure expansion, farmer training, and long-term sustainability.

Promoting gender-inclusive digital extension

Special interventions should ensure that women farmers have equal access to smartphones. internet services., digital literacy training, financial support, and agricultural advisory services. Gender-inclusive approaches improve agricultural productivity and rural livelihoods.

Establishment of supportive policies and institutional frameworks

Governments should formulate policies that promote digital agriculture, support ICT investment in agriculture, encourage innovation, protect digital users and provide sustainable funding for agricultural extension technologies.

Monitoring and evaluating application performance

Regular assessment should measure adoption rates; user satisfaction, agricultural productivity, extension effectiveness, and challenges encountered by users. Evaluation findings should inform continuous improvement of mobile applications.

Promoting Offline functionality

Applications should allow users to download essential information for offline access. Synchronization can occur automatically once internet connectivity becomes available, making the applications more useful in areas with poor network coverage.

Integrating emerging technologies

Developers should incorporate technologies such as Artificial Intelligence (AI) for personalized recommendations; Geographic Information Systems (GIS) for location-specific advisories; Remote sensing for crop and weather monitoring; Internet of Things (IoT) devices for farm monitoring and Machine learning for pest and disease prediction. These innovations enhance the accuracy, relevance, and responsiveness of extension services

Strengthen farmer organizations

Farmer cooperatives and producer groups can serve as channels for training members, sharing digital experiences; purchasing devices collectively, disseminating extension messages, and providing peer support.

Conclusion

Emerging digital trends are reshaping agricultural extension by making advisory services more responsive, precise, and accessible. Technologies such as artificial intelligence, IoT, drones, GIS, remote sensing, mobile applications, social media, blockchain, and cloud computing enable extension systems to provide timely, location-specific, and data-driven support to farmers. To fully realize these benefits, governments, research institutions, extension agencies, private-sector organizations, and development partners must invest in digital infrastructure, strengthen digital literacy, promote inclusive access, and create supportive policies. Such efforts will accelerate agricultural innovation, improve food security, and contribute to sustainable rural development.

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