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Adoption of E-extension System for Effective Delivery of Climate-Smart Agricultural Practices in Nigeria

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Abstract: In the face of escalating climate change challenges, the agricultural sector plays a pivotal role in ensuring food security and sustainable development. This paper delves into the imperative adoption of e-Extension systems to enhance the delivery of climate-smart agriculture practices in Nigeria. The current state of climate-smart agriculture in Nigeria underscores the need for an integrated e-Extension framework. The study delves into the potential benefits of employing digital platforms, mobile applications, and web-based systems in disseminating climate-resilient agricultural practices. Emphasis is placed on the efficiency, scalability, and accessibility of e-Extension systems, which can bridge information gaps, promote sustainable farming methods, and empower farmers to adapt to evolving climate conditions. Furthermore, the article discusses the challenges and opportunities associated with the adoption of e-Extension systems in the Nigerian agricultural landscape. In conclusion, this advocates for the strategic integration of e-Extension systems as a catalyst for the widespread adoption of climate-smart agricultural practices in Nigeria. The synthesis of technology and agriculture is envisioned to empower farmers, improve productivity, and contribute to the nation's resilience in the face of climate variability.

Keywords: Agricultural extension, e-Extension systems, climate-smart agriculture, agriculture, Nigeria.

INTRODUCTION

Agriculture plays an important role in the Nigerian economy as it employs a significant portion of the population and contributes to the country's food security (Jung, 2023). However, climate change poses a major challenge to agricultural productivity as rising temperatures, erratic rainfall patterns and extreme weather events become more common. To meet this challenge, adopting climate-smart agricultural practices is crucial. Equally important is the effective implementation of these practices for farmers across the country (Mpala & Simatele, 2024). One solution that has enormous potential in Nigeria is the use of e-Extension systems. The traditional extension system in Nigeria faces several limitations that hinder the successful implementation and dissemination of climate-smart agricultural practices (Izuogu, *et al.*, 2021). Inadequate extension workers, limited resources and the inability to reach remote areas are common problems in the current system. As a result, smallholder farmers, who are particularly vulnerable to the impacts of climate change, often lack access to the necessary information and technologies to improve their agricultural practices (Ogundeji, 2022; Agwu, *et al.*, 2023).

The introduction of an e-Extension system can address these challenges and bridge the knowledge gap between extension services and Nigerian farmers (Olagunju, *et al.*, 2021). An e-Extension system uses digital technologies such as cell phones, the Internet and other electronic devices to deliver agricultural information and services directly to farmers. This digital platform provides farmers with a more accessible and efficient way to access timely and relevant information about climate-smart practices, thereby increasing their productivity and resilience to climate change (Hamma & Idrisa, 2022). By leveraging the widespread use of mobile phones in Nigeria, an e-Extension system can reach a larger audience, including smallholder farmers in remote areas (Ezeh, *et al.*, 2023). Farmers can receive information in their local language, making it even more accessible and understandable. The system can provide timely weather forecasts, warnings of pest and disease outbreaks, and advice on appropriate agricultural practices based on climate forecasts (Agyekum, *et al.*, 2022). In addition, farmers can receive advice on sustainable land management techniques, water conservation strategies and improved crop varieties suitable for their specific pre-ecological zones (Mcharo & Maghenda, 2021).

The benefits of an e-Extension system goes beyond knowledge dissemination. It enables real-time communication between farmers and agricultural experts, enabling personalized advice and troubleshooting (Singh, *et al.*, 2023). This interactive platform enables farmers to make informed decisions and take appropriate actions in their agricultural practices. In addition, the system can facilitate the exchange of best practices between farmers and promote peer-to-peer learning and collaboration (van Ewijk, *et al.*, 2024). Another benefit of adopting an e-Extension

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system is that it improves data collection and analysis. Monitoring farmers' activities and results through the digital platform can generate valuable data that will help policymakers and researchers evaluate the effectiveness of climate-smart agricultural practices and make evidence-based decisions (Sennuga, *et al.,* 2023). This data-driven approach enables targeted interventions and resource allocation, ensuring agricultural investments achieve the desired impact (Liang & Shah, 2023).

However, despite the potential benefits, the adoption of e-Extension systems in Nigeria faces challenges that need to be addressed. Limited internet connectivity, particularly in rural areas, is a significant barrier. To overcome this, partnerships with telecommunications companies and the government are critical to expand internet access and coverage in remote regions (Nebedum & Chukwu, 2023). Furthermore, building digital skills among farmers and extension workers is crucial to ensure they can effectively use the e-Extension system and maximize its benefits (Gow, *et al.,* 2023). An e-extension system holds promise for improving the implementation of climate-smart agricultural practices in Nigeria. By leveraging digital technologies, this system can overcome the limitations of the traditional extension approach, provide farmers with timely and relevant information, promote knowledge sharing, and improve data-driven decision-making (Olagunju, *et al.,* 2021; Hamma & Idrisa, 2022). However, to fully realize the potential of e-extension systems, investments in infrastructure, digital competence and effective partnerships are necessary (Gow, *et al.,* 2023). With a comprehensive and well-designed e-Extension system, Nigeria can improve its agricultural resilience, mitigate the impacts of climate change and achieve sustainable food production for the country's growing population (Izuogu, *et al.,* 2021).

Challenges Facing Agricultural Extension System in Nigeria

Agricultural extension services play a crucial role in disseminating information, knowledge and skills to farmers. However, agricultural extension in Nigeria faces significant challenges that hinder the effective promotion of climate-smart agricultural practices. One of the major challenges of agricultural extension in Nigeria is the lack of awareness and knowledge about climate-smart practices among extension workers (Ekpa, *et al.,* 2021). Many extension workers have a limited understanding of climate change and its impact on agriculture. This lack of awareness affects their ability to effectively communicate and promote climate-smart practices to farmers (Olorunfemi, *et al.,* 2021). Another major challenge is the limited funds and resources allocated to agricultural extension programmes in Nigeria. Insufficient financial support limits the ability of extension workers to reach large numbers of farmers and provide them with the necessary tools and resources to implement climate-smart practices (Antwi-Agyei & Stringer, 2021).

Furthermore, the lack of training and capacity building opportunities for extension workers further exacerbates the problem (Maulu, *et al.,* 2021). Limited access to technology and information also represents a significant barrier to the dissemination of climate-smart agricultural practices. Many farmers, particularly in rural areas, have limited access to modern technologies such as weather forecasting tools, precision farming techniques and climate information services (Balasundram, *et al.,* 2023). This lack of access affects their ability to make informed decisions and effectively implement climate-smart practices. Furthermore, inadequate training and capacity building opportunities for extension workers hinder their effectiveness in promoting these practices (Antwi-Agyei & Stringer, 2021). The lack of necessary training and knowledge among extension workers poses a major challenge. Many extension workers have a limited understanding of climate change and its impacts on agriculture (Ifeanyi-obi & Ekere, 2021). This lack of awareness affects their ability to effectively communicate and promote climate-smart practices to farmers.

Furthermore, the inadequate capacity building programmes for extension workers limit their ability to provide up-to-date information and technical assistance to farmers (Ogunniyi, *et al.,* 2020). Continuous training and capacity building are essential to ensure that extension workers have the necessary skills and knowledge to effectively promote climate-smart practices and address the specific challenges faced by farmers in different regions of Nigeria (Suvedi, *et al.,* 2023). Addressing the training and capacity building needs of agricultural extension workers is crucial

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to increase their effectiveness in disseminating climate-smart agricultural practices. By providing comprehensive training programmes, workshops, and access to relevant information and resources, extension workers can better serve farmers and promote sustainable agricultural practices (Antwi-Agyei & Stringer, 2021).

In addition to the challenges faced by extension workers, there are also policy and institutional barriers that hinder the effective implementation of climate-smart agricultural practices in Nigeria (Wakweya, 2023). The lack of a supportive policy framework for climate-smart agriculture and the lack of clear policies and guidelines makes it difficult to integrate climate-smart practices into existing agricultural policies and programmes (Okoronkwo, *et al.,* 2024). There is a need for policymakers to prioritize climate-smart agriculture and develop comprehensive policies that incentivize and support farmers to adopt these practices. Institutional barriers, such as weak coordination between government agencies and stakeholders, also hinder the implementation of climate-smart agricultural practices. There is a need for better collaboration and coordination between relevant ministries, research institutions, extension agencies and farmers' organizations to ensure effective dissemination and adoption of climate-smart practices (Wakweya, 2023).

Finally, the lack of institutional capacity and resources for monitoring and evaluation further undermines the effectiveness of climate-smart agricultural programmes (Antwi-Agyei, *et al.*, 2021). Robust monitoring and evaluation systems are essential to track the progress and impact of these programmes and make informed decisions for future interventions (Pearce-Higgins, *et al.*, 2022).

Potential for Adoption of e-Extension System for Climate-Smart Agricultural Practices

Over the years, various initiatives have been implemented to promote climate-smart agricultural practices in Nigeria. These include the introduction of agroecological practices, sustainable land management techniques and the use of climate-resilient crop varieties (Oyetunde-Usman, & Shee, 2023). However, there remains a need for more targeted interventions to help farmers adapt to the changing climate and improve their productivity. The potential for adopting e-Extension systems for climate-smart agricultural practices is immense and can revolutionize the way farmers access information and resources (Alhassan & Haruna, 2024). These systems provide farmers with real-time access to weather forecasts, pest control strategies, soil health tips and other important information to adapt to changing climate conditions. By leveraging digital technologies, e-extension systems can reach a broader audience and provide personalized recommendations based on specific needs and locations (Biradar, *et al.*, 2023).

The introduction of e-extension systems has the potential to revolutionize climate-smart agricultural practices in Nigeria. By bridging the information gap and providing farmers with real-time advice and insights, these systems can improve productivity, sustainability and resilience in the face of climate change (Savari, *et al.*, 2023). With access to weather forecasts, farmers can plan their activities more effectively, thereby optimizing planting and harvesting schedules. By receiving alerts of pest and disease outbreaks, farmers can take timely measures to curb crop losses (Abiri, *et al.*, 2023). In addition, e-Extension systems can promote the use of climate-resilient crop varieties and cultivation techniques and enable farmers to adapt to changing climatic conditions (Oyetunde-Usman & Shee, 2023). By adopting e-Extension systems, Nigeria can unlock its agricultural potential and contribute to food security, rural development and environmental sustainability.

The impact of e-Extension systems on climate-smart agricultural practices has been profound, with positive outcomes for farmers, the environment and the economy (Tadesse & Ahmed, 2023). Farmers who have adopted these systems report increased crop yields, reduced losses to pests and diseases, and improved resilience to climate change (Heeb, *et al.*, 2019). By obtaining timely information about weather conditions, farming practices and market prices, farmers can make informed decisions to optimize their agricultural activities and improve their livelihoods (Andati, *et al.*, 2023). The environment has also benefited from the adoption of e-Extension systems as farmers are encouraged to adopt sustainable practices that reduce greenhouse gas emissions, conserve water resources and protect biodiversity (Nwokolo, *et al.*, 2023). By promoting climate-smart agriculture, e-Extension systems

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help mitigate the impacts of climate change and strengthen the resilience of agricultural systems. Furthermore, the adoption of digital technologies in agriculture has resulted in greater efficiency, lower input costs and improved profitability for farmers, thereby contributing to economic growth and poverty reduction (Balasundram, *et al.*, 2023).

By adopting climate-smart practices such as conservation agriculture, agroforestry and precision agriculture, farmers can reduce greenhouse gas emissions, conserve water resources and improve soil health (Ndung'u, *et al.*, 2023). These practices contribute to climate change mitigation and adaptation efforts, ultimately leading to more resilient and sustainable agricultural systems (Malhi, *et al.*, 2021). One of the key technologies needed to promote climate-smart agriculture in Nigeria is e-Extension systems. These systems use digital platforms such as mobile phones, tablets and computers to provide agricultural information and services to farmers (Okediran, *et al.*, 2018; Hamma & Idrisa, 2022). E-extension systems have the potential to reach large numbers of farmers, provide timely and relevant information, facilitate knowledge sharing and collaboration among stakeholders (Relebohile & Keregero, 2019; Biradar, *et al.*, 2023).

Despite these positive impacts, there are challenges and limitations associated with the introduction of e-Extension systems for climate-smart agriculture (Wakweya, 2023). Limited access to digital technologies, farmers' lack of technical skills, and inadequate infrastructure are some of the barriers that hinder the widespread adoption of these systems (Izuogu, *et al.*, 2023). Governments, development partners and other stakeholders must address these challenges by investing in capacity building, expanding connectivity and creating enabling policy environments to support the expansion of e-Extension systems (Biradar, *et al.*, 2023). Overall, the adoption of e-extension systems for climate-smart agriculture in Nigeria holds great potential to strengthen farmers' resilience, improve their productivity and contribute to sustainable development (Ifeanyi-Obi, *et al.*, 2022). To realize this potential, it is important to address the challenges and concerns associated with the adoption of e-Extension systems and ensure that the technology is accessible, affordable and user-friendly for all farmers.

Success Stories from Other Countries

In recent years, the adoption of e-Extension systems for climate-smart agricultural practices has gained momentum in various countries around the world. These systems use digital technologies to provide farmers with real-time information, data and resources to optimize their agricultural activities and adapt to changing climate conditions. Using mobile phones, internet platforms and other digital tools, farmers can access important information on weather conditions, crop management, pest control and soil health, among other things. Several success stories can be identified that reflect the potential for adopting an e-Extension system for climate-smart agricultural practices: examples include: iCow, M-Farm and M-Shamba in Kenya; Kisan Suvidha app, mKisan portal and mobile app, Krishi Vigyan Kendras (KVKs) and Kisan call centers in India; e-Granary Platform, M-Omulimisa and MUIIS (Market-led User Owned ICT4Ag Enabled Information Services) in Uganda; PalayCheck, Rice Crop Manager (RCM) mobile app and AgriDoc mobile app in the Philippines; AgroAPI, Agromet Sugarcane App and InfoAgro in Brazil; E-Agriculture Senegal Platform in Senegal; and Krishi Gobeshona Foundation (KGF) in Bangladesh.

ICow and M-Farm is a mobile phone-based platform that provides farmers with personalized SMS messages and has been successfully used to disseminate information about climate-smart agricultural practices in Kenya (Krell, *et al.*, 2021). Through the platforms, farmers receive timely weather updates, soil conservation tips and guidance on crop management practices adapted to changing climate conditions, as well as market information. This has led to higher yields and improved farmer resilience (Kropff, *et al.*, 2023). Additionally, M-Shamba is a mobile agricultural extension service that provides farmers with information on climate-smart practices, market prices and pest control. Farmers subscribe to the service and receive personalized advice based on their location and crop preferences. M-Shamba has helped improve crop yields and the resilience of smallholder farmers in Kenya to climate change (Emeana, *et al.*, 2020).

The Kisan Suvidha app provides farmers with access to personalized information on weather forecasts, market prices and best agricultural

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practices (Kumar, 2023). The app also includes pest and disease control and soil health monitoring features, promoting climate-smart agriculture across the country. The adoption of such digital tools has enabled Indian farmers to make informed decisions, optimize resource utilization and adapt to changing climatic conditions (Kumar, *et al.*, 2021). The mKisan portal and mobile app have been used to provide agricultural extension services to farmers across the country via SMS and voice messages. The mKisan platform provides farmers with personalized advice on crop management, weather forecasts, market prices and government programmes directly on their mobile phones and has been widely adopted by farmers across India (Javeed, *et al.*, 2020). The system also provides information on climate-smart agricultural practices tailored to local conditions, helping farmers adapt to changing climatic conditions and improve their yields.

Additionally, Krishi Vigyan Kendras (KVKs) or Agricultural Science Centers across India. These centers use e-Extension services to disseminate information about climate-smart agricultural practices to farmers. Various mobile apps, websites and online platforms are used to provide information on weather forecasts, crop recommendations, market prices and best agricultural practices (Sivakumar, *et al.*, 2022). In addition, Kisan call centers provide agricultural extension services over the phone. Farmers can call for advice on climate-smart practices, crop management, pest control and more. These centers have been very successful in reaching remote areas and have contributed significantly to the dissemination of agricultural information (Subramanian, 2021).

A notable e-Extension service initiative for farmers is the e-Granary platform in Uganda, which delivers agricultural information to farmers' mobile phones via SMS and voice messages. Through e-Granary, farmers receive tips on climate-smart practices such as conservation agriculture and drought-resistant crop varieties that help them mitigate the effects of climate change and improve their livelihoods (Moitui, 2019). The use of mobile phone-based platforms such as "M-Omulimisa" has enabled farmers to access timely information on weather forecasts, farming practices and market trends, contributing to improved agricultural productivity and resilience (Ajambo, *et al.*, 2023). MUIIS (Market-led, User-owned ICT4Ag-enabled Information Services) is a project in Uganda that uses ICT (Information and Communications Technology) to provide agricultural extension services to smallholder farmers. Through mobile phones and other digital channels, farmers receive personalized weather forecasts, agronomic advice, and market information to support their decision-making process (Vandreck & Asigma, 2019). MUIIS has demonstrated positive impacts on crop yields, income generation and climate resilience among participating farmers.

The Philippine Rice Research Institute (PhilRice) has developed the mobile app "PalayCheck" to help rice farmers adopt climate-smart practices for sustainable rice production. PalayCheck provides recommendations on crop management, water-saving techniques and pest control strategies tailored to local agro-climatic conditions. Through the widespread adoption of PalayCheck, Filipino rice farmers have improved their resilience to climate change, reduced input costs and increased yields, contributing to food security and rural development (Elmer, *et al.*, 2022). Rice Crop Manager (RCM) is another mobile app designed to help rice farmers make informed decisions about farming practices. It provides personalized fertilizer application, pest control and water management recommendations based on real-time weather data and field observations. By following the recommendations of the RCM app, Filipino rice farmers were able to optimize their yields while minimizing the environmental impact of their agricultural activities (Manalo IV, *et al.*, 2022). Additionally, the AgriDoc mobile app was launched to provide farmers with access to agricultural experts, weather forecasts, pest and disease management information, and market prices (Phanith, *et al.*, 2023).

AgroAPI, launched by Brazil, is an open access platform that provides farmers and extension workers with real-time agricultural data and decision support tools. It provides information on weather patterns, soil moisture levels and plant growth stages, enabling users to make data-driven decisions for climate-smart agriculture. The use of digital technologies such as AgroAPI has increased the productivity of Brazilian farmers while minimizing environmental impact and adapting to climate variability (Sine, *et al.*, 2015).

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Another notable e-Extension tool is the Agromet Sugarcane app, which provides sugarcane farmers with real-time weather information, crop-specific advisories and pest control recommendations. By adopting these climate-smart practices, Brazilian farmers have been able to mitigate the impacts of climate change on their crops and improve their overall resilience (Dhanya, *et al.*, 2022). Finally, "InfoAgro" was launched, an online platform developed by the Brazilian Agricultural Research Corporation (Embrapa) to provide advisory services to farmers. The platform offers a wide range of resources, including articles, videos and interactive tools, on topics such as sustainable agriculture, soil conservation and climate-smart practices. It has managed to reach a large number of farmers and promote the adoption of environmentally friendly farming techniques (Bolfe, *et al.*, 2023).

In Senegal, the "e-Agriculture Senega Platform" was launched to give farmers access to extension services and market information via mobile phones and the Internet. The platform offers training modules on climate-smart agricultural practices, including soil conservation, water management and agroforestry techniques (Nantongo, *et al.*, 2022). By adopting these practices, Senegalese farmers were able to improve their resilience to climate change and achieve sustainable agricultural development (Ariom, *et al.*, 2022).

Launched by Krishi Gobeshona Foundation (KGF), "Krishi Batayan" in Bangladesh is an e-Extension platform to disseminate agricultural information and advice to farmers across the country. The platform uses various digital channels, including mobile apps, websites and social media, to provide content on climate-smart practices, crop management and market information. Krishi Batayan has been instrumental in providing farmers with knowledge and skills to adapt to climate change and improve their livelihoods (Huber & Davis, 2017).

Implications for Nigeria

Success examples from various countries provide Nigeria with valuable lessons and prove that digital technology can harness the power of e-Extension to benefit agricultural communities (Relebohile & Keregero, 2019). The integration of digital technology will play a very important role in bridging knowledge gaps, suggesting that a significant number of farmers can be reached even with very few extension staff (Olagunju, *et al.*, 2021).

The adoption of e-extension systems in Nigeria holds enormous potential to transform the agricultural sector. By harnessing the power of digital technology, Nigerian farmers can overcome challenges related to access to information, limited extension services and inadequate infrastructure (Mohammed, *et al.*, 2021). An e-Extension system can provide Nigerian farmers with local weather forecasts, pest and disease management strategies, soil health recommendations and market information. This information can enable farmers to make data-driven decisions, optimize resource allocation, and mitigate climate risks (Charalampoulos & Droulia, 2024). Additionally, e-Extension systems can facilitate knowledge sharing and peer-to-peer learning between farmers. By connecting farmers within and between regions, these systems promote collaboration and the exchange of best practices. This collective learning approach can accelerate the adoption of climate-smart agricultural practices and promote sustainable rural development (Hamma & Idrisa, 2022). An e-Extension is a term that describes the use of ICT to expand agricultural knowledge and services to farmers and other stakeholders in the agricultural sector. It uses various ICT tools, including mobile phones, the internet, social media and other digital platforms, to provide timely and relevant information to farmers, advisors, researchers and policy makers (Biradar, *et al.*, 2023).

A recently completed study by Hamma and Idrisa (2022) and Etuk, *et al.*, (2023) revealed that great potential does exist for the adoption of the e-Extension system in Nigeria. The study established that agricultural extension professionals in the country see the potential for the utilization of digital tools to transform them from mere agents of extension into knowledge workers, engaged in bottom-up, demand-driven, pluralistic approaches to technology generation, assessment, refinement, and transfer. The ICT deployment for agriculture extension services was embraced with testimonies of success from other countries in the areas of delivery cost-effectiveness, easy and timely access as well as undiluted information to farmers (Relebohile & Keregero, 2019). Nigeria's agricultural extension professionals understand the country's ability and use of digital technology and

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welcome its introduction as well as implementation. Therefore, a useful starting point may be to sensitize them to begin using selected ICT applications to electronically distribute extension messages to farmers most especially climate-smart agricultural practices.

CONCLUSION AND RECOMMENDATIONS

The paper concludes that the adoption of e-Extension systems for climate-smart agricultural practices in Nigeria holds immense promise. By leveraging digital technologies, these systems can bridge the information gap, empower farmers, and enhance agricultural productivity, sustainability, and resilience. However, the successful implementation of e-Extension systems requires addressing challenges related to digital infrastructure, content localization, and farmer capacity building. With the right strategies and collaborations in place, Nigeria can harness the potential of e-Extension systems to transform its agricultural sector and ensure a more resilient and sustainable future.

To successfully implement e-Extension systems in Nigeria, several recommendations should be considered. Firstly, there is a need for public-private partnerships to leverage existing digital infrastructure and resources. Collaboration among government agencies, telecommunications companies, and agricultural stakeholders can help overcome infrastructure challenges and ensure widespread access to e-Extension services. Secondly, content development should prioritize localization and context-specificity. Working closely with agricultural experts and extension officers, e-Extension systems should provide information that is tailored to Nigeria's diverse agroecological zones, farming systems, and cultural practices. This will ensure that farmers receive relevant and actionable advice.

Furthermore, training and capacity-building programmes should be developed to enhance digital literacy among farmers. By providing workshops, demonstrations, and user-friendly interfaces, e-Extension systems can empower farmers to navigate digital platforms and make informed decisions based on the information provided.

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