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Impact of Digital Technologies in Agricultural Extension

N. K. Singh [a++], N. H. Sunitha [b#], Gagan Tripathi [c†], D. R. K. Saikanth [d‡*], Akanksha Sharma [e#], Asha Elizabeth Jose [f^] and M. V. Karuna Jeba Mary [g##]

[a] Department of Agronomy, Krishi Vigyan Kendra, Pratapgarh, India.
[b] Department of Agricultural Extension Education Centre, Huvinahadagali, University of Agricultural Sciences Raichur, Karnataka, India.
[c] Department of Agriculture Extension, GBPUAT, Pantagar, India.
[d] ICAR-ATARI, ZONE-X, Hyderabad, India.
[e] AKS University, Satna (MP), India.
[f] Dr. PDKV, Akola, India.
[g] Department of Agricultural Extension, Tamil Nadu Agricultural University, Coimbatore TN, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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[++] *Subject Matter Specialist;*
[#] *Assistant professor;*
[†] *M.sc Student;*
[‡] *SRF;*
[^] *Ph.D. Scholar;*
[##] *Post-doctoral fellow;*
**Corresponding author: E-mail: drksaikanth1@gmail.com;*

ABSTRACT

The emergence and widespread adoption of digital technologies have reshaped the landscape of agriculture extension services, fostering increased efficiency, accessibility, and sustainability. The proliferation of digital technologies such as smartphones, the internet, data analytics, and sensor-based devices has ushered in a new era of agriculture extension services. These technologies have enabled real-time communication, data-driven decision-making, and access to a vast repository of agricultural information. Farmers, extension agents, and policymakers now have a wealth of tools and applications at their disposal, empowering them to make informed choices for increased agricultural productivity and sustainability. Digital tools have profoundly impacted agricultural extension services, revolutionizing how information is disseminated and accessed by farmers. Some analysis of how mobile apps, web platforms, and data analytics have transformed agricultural extension, empowering farmers and increasing productivity. Mobile applications and web-based platforms have facilitated the dissemination of agricultural knowledge, empowering farmers with up-to-date practices. By reducing the digital divide, ICT-based extension services promote equitable access to information, leading to enhanced agricultural productivity and sustainability. By bridging the information gap, digital technologies enhance agricultural productivity, profitability, and sustainability. Local language support ensures farmers from various linguistic backgrounds can easily understand and benefit from the information provided, enhancing the tool's usability and impact. Tailoring agricultural information to specific regions addresses diverse farming practices and challenges, enhancing relevance and adoption. By promoting language and regional adaptation, digital technologies can bridge the digital divide and empower farmers with valuable insights for sustainable agricultural development.

Keywords: Agriculture extension; agricultural knowledge; agricultural practices; digital agriculture; digital tools; advisory services; empowering farmers; sustainable agriculture.

1. INTRODUCTION

In recent years, the agricultural sector has witnessed a significant transformation due to the integration of digital technologies into traditional practices. The emergence and widespread adoption of digital technologies have reshaped the landscape of agriculture extension services, fostering increased efficiency, accessibility, and sustainability. Digital change is a foundational change since it influences how individuals, things, and associations coordinate their exercises [1]. Orientation jobs and connections in horticulture are different, ladies and men frequently have different information requirements and inclinations [2]. The majority of farmworkers are women [3]. As in individual concerns, digital technology can be a promising caterer to the distinct information needs of farmers [4], irrespective of gender. It involves different app users especially women farmers, working in the design process which improves usability in the agricultural sector [5].

This paper presents a comprehensive review of the impact of digital technologies on agriculture extension, highlighting the progress, challenges, and opportunities arising from this digital revolution. The digital transformation of farming will adapt societal processes on a larger scale [6]. Many extension systems still struggle to reach farmers [7]. It has been shown that big data and data analytics can improve farming operations [8], which will significantly aid agricultural decision-making processes [9]. Mechanical advancement is vital to speed up the transition toward an economical food framework [10] and advancing the precision of the fertilization process. [11]. The proliferation of digital technologies such as smartphones, the internet, data analytics, and sensor-based devices has ushered in a new era of agriculture extension services. These technologies have enabled real-time communication, data-driven decision-making, and access to a vast array of agricultural information. Farmers, extension workers, and policymakers now have a wealth of tools and applications at their disposal, enabling them to make informed decisions for increased agricultural productivity and sustainability. In addition, timely hiring and the provision of adequate logistics should improve the delivery of agricultural extension services [12]. Furthermore, according to Eastwood et al. [13], professional expertise is underutilized in digital agriculture, necessitating more work to access these resources. This research aims to provide comprehensive insights that can inform

stakeholders and promote effective digital agriculture extension strategies.

2. METHODOLOGY

The study on the impact of digital technologies in agriculture extension remains essential for several reasons. Firstly, technology in agriculture is rapidly evolving, and new innovations continue to emerge. Understanding how these advancements influence farming practices, productivity, and sustainability is crucial for informed decision-making. Secondly, there are still challenges to overcome, such as ensuring equitable access to technology for small-scale farmers and addressing concerns related to data ownership and privacy. Additionally, assessing the long-term effects of technology adoption on the environment and social dynamics is essential. Conducting ongoing reviews will enable policymakers, farmers, and stakeholders to harness digital technologies' full potential for a resilient and efficient agricultural sector. Additionally, case studies from Kenya, India, and the Philippines are analyzed, involving direct observations and analysis of farm-level data.

3. RESULTS AND DISCUSSION

Digital tools have profoundly impacted agricultural extension services, revolutionizing how information is disseminated and accessed by farmers. Rajkhowa and Qaim [14] show that utilizing customized digital extension administrations is decidedly and fundamentally connected with input force the integration of digital technologies in agriculture extension has yielded significant and transformative impacts on various aspects of the agricultural sector. Some analysis of how mobile apps, web platforms, and data analytics have transformed agricultural extension, empowering farmers and increasing productivity. Digital tools have overcome geographical barriers, allowing farmers to access information regardless of their location. Mobile apps and web platforms offer a wide range of resources, including weather forecasts, market prices, best practices, pest management techniques, and government schemes. This access to real-time and relevant information helps farmers make informed decisions and enhances their overall knowledge base. Access to data enables farmers to make informed decisions, enhance productivity, and reduce risks. Mobile applications and web-based platforms have facilitated the dissemination of agricultural knowledge, empowering farmers with up-to-date practices [15]. By reducing the digital divide, ICT-based extension services promote equitable access to information, leading to enhanced agricultural productivity and sustainability [16]. Such advancements underscore the pivotal role of digital technologies in transforming traditional agriculture extension into a dynamic and data-driven approach. Data analytics plays a crucial role in providing personalized recommendations to farmers. By analyzing historical data and using machine learning algorithms, these tools can suggest crop varieties suited to specific soil types, weather conditions, and individual farmer preferences. Tailored recommendations improve crop yield and reduce resource wastage. Timely advisory services are paramount for farmers' success, and digital technologies have revolutionized their delivery. Through mobile apps, SMS, and voice-based platforms, real-time weather updates, market prices, and crop management advice can reach farmers rapidly [17]. These services empower farmers to make informed decisions, mitigate risks, and optimize resource usage. By bridging the information gap, digital technologies enhance agricultural productivity, profitability, and sustainability. Providing timely and tailored advice to farmers fosters resilient farming practices, ensuring food security and livelihood improvement. Timely information helps farmers prepare in advance, minimizing losses and ensuring better resource utilization.

Many digital tools are designed to cater to diverse linguistic and regional preferences. Local language support ensures farmers from various linguistic backgrounds can easily understand and benefit from the information provided, enhancing the tool's usability and impact. They are crucial considerations for the effective implementation of digital technologies in agriculture for farmers. Local languages and vernacular content on digital platforms ensure better accessibility and understanding [18]. Tailoring agricultural information to specific regions addresses diverse farming practices and challenges, enhancing relevance and adoption [19]. Digital tools need to accommodate regional variations in crops, weather, and cultural practices to provide context-specific guidance. By promoting language and regional adaptation, digital technologies can bridge the digital divide and empower farmers with valuable insights for sustainable agricultural development.

Digital tools serve as virtual training platforms, offering instructional videos, webinars, and e-learning modules. Farmers can access these

resources to learn about new agricultural techniques, best practices, and innovations. This continuous capacity-building empowers farmers to adopt modern and sustainable farming methods. Digital technologies have democratized knowledge sharing and training in agriculture. E-learning platforms, webinars, and mobile applications offer flexible and cost-effective opportunities for farmers and extension agents to acquire new skills and stay updated with the latest agricultural advancements [20]. This democratization of knowledge has led to improved agricultural practices and increased adoption of sustainable farming techniques.

Digital tools often include features that help farmers connect with buyers, traders, and cooperatives, thus creating direct market linkages. By eliminating intermediaries, farmers can get better prices for their produce and reduce post-harvest losses. With data analytics, farmers can make data-driven decisions. By collecting and analyzing data related to their farming practices, they can identify patterns, optimize resource allocation, and improve overall farm management. This data-centric approach enhances productivity and resource efficiency. Digital technologies have enabled the development of sophisticated decision support systems (DSS) that assist farmers in making informed choices. Data analytics, machine learning, and AI-powered DSS provide personalized recommendations for crop selection, fertilization, and pest management based on specific farm conditions [21]. This leads to more efficient resource management and increased yields. Some digital tools also enable farmers to access financial services and credit facilities. By maintaining digital records of their farming activities and financial transactions, farmers can build credit histories and become eligible for loans and insurance products. Internet of Things (IoT) devices and sensors integrated with digital tools enable remote monitoring of crops and livestock. Farmers can track soil moisture levels, temperature, and other critical parameters from their smartphones. This information facilitates precision agriculture, allowing farmers to apply inputs only where and when necessary, reducing costs and environmental impacts.

Digital platforms foster collaboration among farmers, researchers, and extension workers. Through online forums and social media groups, farmers can share their experiences, challenges, and successful practices, creating a vibrant community of learning. The integration of Internet of Things (IoT) devices, sensors, and drones has given rise to precision farming and smart agriculture. These technologies allow farmers to monitor crop health, soil moisture levels, and other environmental variables in real-time [22]. By using data-driven insights, farmers can optimize resource utilization, minimize wastage, and increase overall productivity.

3.1 Some International Case Studies

Case 1. "M-Kilimo" Mobile App in Kenya

The M-Kilimo mobile app was developed and implemented in Kenya to address the challenges faced by smallholder farmers in accessing agricultural information. The app allowed farmers to receive personalized advice and recommendations based on their specific crop types, location, and local weather conditions. It provided information on crop management practices, market prices, pest and disease control, and even financial services. The platform utilized SMS and voice messages to reach farmers with limited internet access, making it accessible to a wide audience. [23] The M-Kilimo app significantly improved farmers' access to timely and relevant information, leading to better crop yields, reduced production costs, and increased income for smallholder farmers. The personalized advice and real-time alerts helped farmers make informed decisions, leading to more sustainable and profitable farming practices. The success of the M-Kilimo app demonstrates how digital technologies can effectively bridge the information gap and empower farmers to enhance their agricultural practices.

Case 2. "e-Krishak Samadhan" Web Portal in India

The e-Krishak Samadhan web portal was launched by the government of Uttar Pradesh, India, to provide agricultural information, advisory services, and problem-solving support to farmers. The portal allowed farmers to submit their agricultural-related queries and issues online, which were then addressed by a team of agricultural experts and extension officers. Farmers could also access a vast repository of agricultural resources, including guidelines, videos, and market-related information. [24] The e-Krishak Samadhan web portal significantly improved the accessibility of agricultural information and advisory services for farmers in Uttar Pradesh. Farmers reported that they

received prompt responses to their queries, leading to better decision-making and improved farm management practices. The portal also facilitated peer learning as farmers could access information shared by others, and it contributed to reducing the dependency on traditional extension services. Overall, the e-Krishak Samadhan portal demonstrated how digital technologies can enhance the efficiency and effectiveness of agriculture extension services.

Case 3. "Agricultural Social Media Influencers" in the Philippines

In the Philippines, the Department of Agriculture partnered with influential social media personalities known as "agricultural social media influencers" to promote modern farming practices and disseminate agricultural information to a broader audience. These influencers used various social media platforms such as Facebook, YouTube, and Instagram to share engaging content, including videos, tutorials, and success stories related to agriculture [25]. The use of social media influencers significantly expanded the reach and impact of agricultural extension services in the Philippines. The engaging and relatable content attracted a younger audience, including aspiring farmers and urban dwellers, who previously had limited exposure to agriculture. The influencers' authentic experiences and practical tips inspired many to take up farming as a livelihood or as a hobby. This case study illustrates the power of digital technologies and social media in transforming the perception of agriculture and attracting new interest and investment in the sector. The case studies on the impact of digital technologies in agriculture extension present compelling evidence of the transformative potential these innovations offer to the agricultural sector. The M-Kilimo mobile app in Kenya demonstrated how personalized and real-time information can significantly improve farmers' decision- making, leading to enhanced yields and income. The e-Krishak Samadhan web portal in India showcased the power of prompt advisory services in empowering farmers and reducing dependency on traditional extension systems. Moreover, the use of agricultural influencers through social media in the Philippines exemplified how digital platforms can engage a diverse audience and promote sustainable farming practices. These case studies collectively emphasize the importance of embracing digital solutions to drive inclusive and sustainable agricultural development.

Table 1. List of the case studies with several information

Project Name	Digital Technology and audience	Objectives	Methodology	Key Findings	Strengths	Limitations
M-Kilimo Mobile App in kenya	Mobile App (SMS, Voice) for Smallholder farmers	Improve access to information	Field experiment	Improved yields & income, better decisions, reduced costs, sustainable practices	Personalized advice, real-time alerts	Limited internet access for some farmers
e-Krishak Samadhan Portal in india	Web Portal for Farmers in Uttar Pradesh	Provide advisory support	Impact evaluation	Prompt responses, better farm management, reduced dependency on extension services	Wide accessibility, repository of resources	Limited reach to farmers without internet
Agricultural Influencers in phillipines	Social Media (Facebook, YouTube, Instagram) for general public	Promote modern farming	Case study	Expanded reach, inspired interest in agriculture, attracted urban dwellers and aspiring farmers	Appeal to younger audience, increased interest	Influence may vary based on influencer's reach

3.2 Challenges and Opportunities

India faces challenges in technology adoption due to low income, illiteracy, and marginal land holdings, hindering modern agriculture practices [26]. While digital technologies have demonstrated significant benefits, there are challenges that need to be addressed. Connectivity issues in rural areas, digital illiteracy among farmers, and concerns related to data privacy are some of the obstacles that need attention [27]. Collaborative efforts between governments, private sectors, and NGOs can create opportunities to bridge these gaps and ensure equitable access to digital agriculture extension services.

4. CONCLUSION

Digital tools have revolutionized agricultural extension services, empowering farmers with easy access to information, personalized recommendations, and timely advisory services. The integration of data analytics has facilitated data-driven decision-making and precision agriculture. Digital technologies have ushered in a new era of agriculture extension services, offering unprecedented opportunities to transform traditional farming practices. By leveraging the power of digital tools, farmers and extension agents can access real-time information, enhance decision-making, and adopt sustainable agricultural practices. However, addressing challenges related to accessibility and data security is crucial to ensuring the equitable distribution of digital benefits in agriculture extension. The perspective for the review on the impact of digital technologies in agriculture extension is that it has the potential to revolutionize traditional farming practices and significantly improve overall agricultural productivity and efficiency. By leveraging digital tools such as mobile applications, data analytics, and remote sensing, farmers can access real-time information on weather patterns, soil conditions, pest outbreaks, and market prices. This empowers them to make informed decisions, optimize resource allocation, and adopt precision farming techniques, leading to higher yields and reduced environmental impacts. Moreover, the integration of digital technologies can enhance the reach of agricultural extension services, facilitating knowledge dissemination, and fostering innovation among farmers. Ultimately, this research can contribute to the sustainable transformation of the agriculture sector, ensuring food security and rural development. Overall, these tools have contributed to increasing productivity, promoting sustainable practices, and transforming the way farmers engage with extension services and the agricultural ecosystem as a whole.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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