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**Original article****Revolutionizing Agricultural Extension Services: AI-Powered Automation and Customization****Varsha, S. C.<sup>1</sup>, Amrutha Basavaraju<sup>1</sup>, Virupakshi Aski<sup>2</sup>, Harsha, C.<sup>2</sup> and Pooja, V.<sup>1</sup>**<sup>1</sup>Department of Agricultural Extension, UAS, GKVK, Bengaluru<sup>2</sup>Department of Agricultural Extension, KSNUAHS, Shivamogga\*Corresponding author: [scvarsha97@gmail.com](mailto:scvarsha97@gmail.com)

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**ABSTRACT**

Agricultural extension services play a pivotal role in empowering farmers by disseminating knowledge and fostering sustainable practices. Artificial Intelligence (AI) is transforming extension services by enhancing efficiency, accuracy, and scalability in agricultural advisory systems. Automation in agriculture and in its allied sector, is rapidly growing field of interest worldwide. However, traditional extension models face challenges such as scalability, timeliness, and customization to diverse farming needs. This paper explores the transformative potential of artificial intelligence (AI) in automating and customizing agricultural extension services. Leveraging AI-driven tools such as chatbots, decision support systems, expert systems, helplines, remote sensing analytics, predictive modelling, and precision farming solutions, is advancing precision agriculture, boosting supply chain transparency, and improving resource management. AI also plays a crucial role in providing early warnings for pest outbreaks and climate-related risks, promoting sustainability and resilience in farming systems, and aiding farmers in adapting to environmental changes. Although challenges such as cost, limited data access, and low digital literacy persist, AI-driven solutions, supported by focused training programs and public-private partnerships, are making these technologies accessible to underserved and smallholder farmers. Furthermore, these innovative approaches enhance efficiency, outreach, and farmer-centric solutions by enhancing market connections by offering price insights, improving access to buyers, and reducing dependence on intermediaries. This paper highlights the examples of different AI-based platforms that are involved in extension services to the farmers, focusing on their role in improving productivity, decision-making, and sustainability in agriculture, further, assist in providing personalized advice, monitoring crop health, and enhancing resource management for farmers. The paper underscore AI's capability to bridge gaps in traditional extension services, making them more adaptive, data-driven, and inclusive, while enabling better decision-making and enhancing farmers' resilience to climate change and market fluctuations. This work aims to serve as a comprehensive guide for policymakers, researchers, and practitioners in advancing the integration of AI in agricultural extension.

**Keywords:** Extension services, Artificial Intelligence, Automation, Agriculture

## **INTRODUCTION**

Agricultural extension services play a crucial role in enhancing agricultural productivity and improving the livelihoods of farmers. These services bridge the gap between research institutions and farmers by providing them with the latest information, technologies, and practices. Extension agents educate farmers about better farming techniques, pest management, soil health, and climate-smart practices, helping them adopt more sustainable and efficient methods. This support not only boosts crop yields and farm income but also promotes food security and rural development. By empowering farmers with knowledge, agricultural extension services contribute to overall economic growth and the resilience of farming communities.

The goal of agricultural extension is to close the knowledge gap that currently exists between farmers and scientists by providing farmers with information, technology, and innovations. In addition, agricultural extension also plays a major role in successful implementation of programmes related to agriculture and rural development. Despite these huge responsibilities there are many problems faced by extension that limit its capability and performance acts as hindrance in achieving its objectives (Singh and Mishra, 2024).

The present paper was conceptualized to explore the AI in agricultural extension services and to analyse the opportunities and challenges of AI based technologies in agricultural extension services.

## **METHODOLOGY**

The present paper reviews the data derived from the existing literature, articles, research papers etc. on the aspects of revolutionizing the agricultural extension services with the AI powered automation and customization.

## **RESULTS AND DISCUSSION**

Agricultural extension plays a crucial role in rural development, acting as a catalyst for social and economic transformation while establishing a foundation for future growth (Chintakindi *et al.*, 2024). Artificial Intelligence (AI) is making substantial progress in the realm of agricultural extension, reshaping the dissemination of information, decision-making processes, and the advancement of farming techniques (Jayasingh *et al.*, 2024).

Addressing the evolving and increasing challenges in agriculture requires a broader scope for extension services with diverse goals. These services are essential for advancing rural communities and play a vital role in agricultural research and development strategies. They enable the effective transfer of critical information and the practical implementation of knowledge within the agriculture sector. Without practical application, agricultural research risks becoming purely theoretical; therefore, it is essential to provide farmers with solutions through effective extension approaches. Agricultural research institutions should prioritize the development of practical technologies, while extension services should emphasize their adoption and integration by farmers (Chintakindi *et al.*, 2024).

## **Challenges in traditional models of agricultural extension services**

**Limited Access to Updated Information:** Extension agents may lack resources or training to provide the latest agricultural knowledge and technologies. Farmers often receive outdated or non-specific advice due to limited access to updated data.

**Geographical Barriers:** Farmers in remote or marginalized areas often have limited access to extension services.

**Lack of Timely Recommendations:** Delays in delivering critical information, such as pest alerts or weather updates, can reduce productivity.

**Resource and Funding Constraints:** Traditional extension services often depend on government or donor funding, which can be inconsistent or inadequate.

**Overburdened Extension Agents:** High farmer-to-agent ratios limit personalized attention to individual needs.

**Lack of Inclusivity:** Limited focus on diverse farming communities, leading to a one-size-fits-all approach that may not meet the needs of all farmers.

**Limited Capacity of Extension Agents:** Extension agents may be overburdened, lacking the necessary skills or numbers to adequately serve large farming populations.

These challenges call for a more modern, participatory approach to agricultural extension.

## **Role of AI in Addressing these Challenges**

Artificial Intelligence offers transformative potential to overcome these limitations:

**Automation:** AI-powered tools like chatbots and virtual assistants handle repetitive tasks, such as answering frequently asked questions or providing weather updates, allowing human extension workers to focus on complex issues.

**Customization:** AI analyzes large datasets, including soil health, weather patterns, and crop conditions, to generate tailored advice for individual farmers.

**Scalability:** AI systems can process and deliver information to thousands of farmers simultaneously, bridging the gap between limited extension workers and large farming communities.

**Timely Interventions:** AI's predictive models can anticipate pest outbreaks, weather changes, and market trends, enabling proactive decision-making.

**Enhanced Communication:** Multilingual AI tools ensure farmers receive information in their preferred language, increasing accessibility and understanding.

By integrating AI into agricultural extension services, these systems can evolve into more efficient, adaptive, and farmer-centric platforms, ultimately driving sustainable agricultural development.

## **Opportunities of using AI-based digital technologies for agricultural extension Services**

There are several strategic opportunities for improving knowledge transmission and promoting sustainable farming practices in agricultural extension such as, digital solutions, public-

private partnerships (PPP), integrating local knowledge, community-based approaches and monitoring & evaluation (Chintakindi *et al.*, 2024).

Deji *et al.* (2024) in their study on opportunities and challenges associated with AI based digital technologies usage for agricultural extension services in Nigeria showed that majority (97.70 %) indicated provision of real-time insights by using AI-based technologies in agricultural extension services. Further, 75.60 per cent of the respondents indicates that the provision of reliable farm data was an opportunity and 67.20 per cent perceived that AI-based digital technologies also help in the proper identification and treatment of farm diseases. Few more opportunities like reliable problem identification and treatment, improved farmers and household livelihood and reduced vulnerability were found in the study.

Mobile technology has emerged as a highly dynamic tool for agricultural extension in India. With over a billion mobile phone users nationwide, it presents a unique opportunity to connect directly with farmers. Tools such as voice messages, SMS advisories, and mobile applications have become widespread, offering farmers timely updates on weather forecasts, pest warnings, and market trends. (Ex: Kisan Call Centers). In addition to mobile technologies, internet-based solutions have broadened the reach of agricultural extension by enabling e-learning, online advisory services, and access to digital databases. Platforms like Agropedia, developed by IIT Kanpur with support from the Indian Council of Agricultural Research (ICAR), provide a comprehensive digital space for sharing and accessing agriculture-related knowledge. Furthermore, Remote sensing technologies and drones are increasingly being used for precision farming. Advanced technologies provide detailed insights into crop health, soil conditions, and water requirements. Drones, in particular, offer an aerial perspective, allowing for efficient monitoring of extensive farmland. These tools are invaluable in addressing challenges brought about by unpredictable weather and climate change (Manobharathi, 2024).

GIS technology has played a pivotal role in mapping agricultural landscapes and analyzing soil data, enabling informed decision-making for crop planning and land management (Mitran *et al.*, 2021).

The major advantages of using AI in extension services are target audience, seamless connectivity, real time, data updation by the ways of information support from the institutional stakeholders and response of farmers in the form of feedback and experiences in the AI systems and efficiency (Jayasingh *et al.*, 2024).

### **Challenges associated with the used of AI-based Extension services**

Deji *et al.* (2024) showed that the majority (94.70 %) of the respondents indicated a lengthy technology adoption process as the prime challenge of using AI-based digital technologies for agricultural extension and advisory services. Followed by the majority (70.20 %) of the respondents revealed that lack of higher technical skills, privacy and security threat (65.50 %) and inadequate involvement of farmers, and other stakeholders' capacity building in the technology development (60.30 %).

Artificial Intelligence (AI) has significant potential in agriculture but faces challenges like the lack of robust data, adaptability to changing external factors, and high costs. Current AI applications

focus more on products like seeds and pesticides rather than field-level solutions due to data limitations and infrastructure immaturity. For effective adoption, AI systems must be affordable, robust, and capable of real-time decision-making. Open-source platforms and mobile integration can enhance accessibility, enabling efficient pest detection and pesticide use, reducing environmental impact and costs (Agarwal and Agarwal, 2021).

The major disadvantages of using AI in extension services are costly installation of internet services, farmer's unfavourable attitude and lack of digital education (Jayasingh *et al.*, 2024).

Despite its success, integrating technology into India's agricultural extension encounters several challenges. Key obstacles include the digital divide, varying literacy levels among farmers, and resistance to adopting new technologies (Manobharathi, 2024).

The labor-intensive nature of agricultural extension services makes widespread use of robotics unlikely. Furthermore, the reliability of robots in these settings is questionable due to limitations in handling diverse tasks, frequent maintenance needs, and reliance on power sources, especially in rural or remote areas (Sravani *et al.*, 2024).

### **Different AI platforms that are involved in extension services to the farmers**

Several AI platforms are actively contributing to agricultural extension services by providing farmers with actionable insights, improving productivity, and enabling informed decision-making.

M-velanmai, an innovative mobile-based advisory service launched through a public-private partnership led by Tamil Nadu Agricultural University with an aim to provide in-time tailored information to the farmers as sought by them on a range of agricultural topics through their mobile phones. Plantix app This application offers immediate, personalized information to individual farmers based on their specific crops. Early warning system for pest management. These are some of the platforms where agricultural extension services have AI technologies (Jayasingh *et al.*, 2024).

Raman *et al.* (2024) gave some examples of chatbots and LLMs used for Agricultural Extension Advisory Services (AEAS) in India, like, Krishi Sakhi, AgroStar, Farmer CHAT, to address the needs of farmers on the frontlines of climate change and water security. Ama Krush for farmers, user-centric artificial intelligence systems that deliver information to citizens are emerging as critical modalities for solving information asymmetry in governance., Digital Green, Fasal Salh (IFFCO), which provides personalized agricultural advice. Krishi Sakhi is an initiative by the Government of India that focuses on providing agricultural information and guidance to farmers, especially women (Patel and Sethi, 2021). Agro Star, an agritech platform in India, provides Agri Chat Bot services Javaid *et al.* (2023).

### **CONCLUSION**

AI-powered automation and customization have the potential to greatly improve agricultural extension services. By using AI, extension services can move beyond one-size-fits-all advice to provide farmers with personalized, real-time recommendations tailored to their specific needs. This can help farmers make better decisions, manage resources more efficiently, and increase productivity, leading to more sustainable farming practices.

To fully realize these benefits, it is essential for governments, researchers, and technology providers to work together. This collaboration will ensure that AI tools are accessible, easy to use, and adapted to the unique challenges farmers face. With the right support and training, AI can help transform agricultural extension services, making them more efficient, effective, and beneficial to farmers around the world.

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