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Extension 5.0: How AI is Transforming Farmer Advisory Services

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Agricultural extension is undergoing a fundamental transformation as artificial intelligence (AI), digital platforms, big data, remote sensing, and conversational technologies reshape the way agricultural knowledge reaches farmers. Traditional extension systems have played a crucial role in disseminating scientific information, but they often face challenges related to limited personnel, delayed communication, inadequate localization, and difficulty in reaching geographically dispersed farming communities. The emerging concept of **Extension 5.0** represents a more intelligent, participatory, personalized, and human-centred approach to agricultural advisory services. In this model, AI does not simply replace extension personnel; instead, it strengthens their capacity by processing large volumes of agricultural information and delivering timely, context-specific recommendations. AI-powered chatbots, machine learning models, computer vision, satellite imagery, Internet of Things (IoT) sensors, and generative AI are increasingly being integrated into advisory systems. Farmers can now receive weather-based recommendations, pest alerts, nutrient management guidance, crop disease diagnosis, and market information through smartphones, voice interfaces, and local-language platforms. Recent developments in India, including AI-enabled pest surveillance, Kisan e-Mitra, digital agricultural infrastructure, and hyper-local climate advisories, demonstrate the growing institutional importance of intelligent extension systems. International initiatives such as Farmer.Chat and Ethiopia's digital fertilizer advisory systems further illustrate the potential of AI to improve advisory reach and personalization. However, technological sophistication alone cannot guarantee successful extension. Data quality, local relevance, digital literacy, gender inclusion, algorithmic bias, and the risk of inaccurate AI-generated recommendations remain important concerns. Extension 5.0 must therefore combine artificial intelligence with human expertise, farmer knowledge, and strong institutional validation. The future of agricultural extension lies not in replacing human interaction but in creating an effective partnership between farmers, extension professionals, scientific institutions, and intelligent technologies.

Keywords: Artificial intelligence, agricultural extension, Extension 5.0, digital agriculture, farmer advisory services,

Introduction

Agriculture is becoming increasingly knowledge-intensive. Farmers today must make decisions in an environment characterized by climate variability, emerging pests and diseases, fluctuating input prices, changing markets, and increasing pressure to produce more sustainably. A decision regarding sowing, irrigation, fertilizer application, or pest management that is appropriate in one location may be unsuitable in another. Consequently,

farmers require information that is not only scientifically correct but also **timely, location-specific, understandable, and actionable**.

Agricultural extension has traditionally served as the bridge between scientific research and farming communities. Extension professionals, researchers, demonstrations, farmer meetings, radio programmes, printed materials, and field visits have historically been the primary channels for transferring agricultural knowledge. Although these approaches remain important, conventional extension systems often struggle to maintain an effective farmer-to-extension-worker ratio, particularly in regions dominated by small and marginal farmers. The rapid expansion of digital technologies has created new possibilities. Mobile phones, social media, satellite data, weather services, sensors, and digital platforms have already expanded the reach of agricultural information. Artificial intelligence is now taking this transformation further by enabling advisory systems to interpret complex datasets and generate increasingly personalized recommendations.

This evolution can be understood as a progression from **information dissemination to intelligent decision support**. Extension 5.0 represents the next stage of this transition. While earlier digital extension systems primarily focused on distributing information, Extension 5.0 emphasizes interaction, personalization, prediction, automation, and continuous learning. Importantly, Extension 5.0 should not be interpreted as "AI replacing extension workers." Agriculture is highly context-dependent, and farmers often require trust, field observation, social interaction, and practical interpretation. Instead, AI can function as an intelligent assistant that enables extension professionals to serve larger populations more effectively while allowing farmers to access information whenever required. Recent developments indicate that this transition is already underway. India's Digital Agriculture Mission has created an expanding digital foundation, while AI-based systems are being used for pest surveillance, farmer queries, crop monitoring, and localized weather advisories. Government reporting in early 2026 indicated that the Kisan e-Mitra chatbot had answered more than 9.3 million farmer queries, while AI-supported pest surveillance and monsoon advisory systems were being expanded across agricultural regions (PIB, 2026).

Understanding Extension 5.0

Extension 5.0 can be described as a **human-centred, AI-enabled agricultural advisory ecosystem** in which digital intelligence works alongside farmers, scientists, extension personnel, and local institutions. The fundamental difference lies in the nature of communication. Traditional extension has often followed a largely linear model:

Research institution → Extension worker → Farmer

Extension 5.0 moves toward a more interactive system:

Farmer ↔ AI platform ↔ Extension worker ↔ Scientific database ↔ Research institution

In this system, information flows in multiple directions. Farmers can ask questions, upload photographs, report pest outbreaks, and provide feedback. AI systems can analyse these inputs, identify patterns, and generate preliminary recommendations. Extension professionals and scientists can then validate complex cases and use farmer-generated data to improve future advisories.

Table 1. Evolution of Agricultural Extension Toward Extension 5.0

Extension Stage	Dominant Approach	Nature of Communication	Role of Technology
Traditional Extension	Field visits and demonstrations	Mostly one-way	Limited
Extension 2.0	Mass media and broadcast communication	One-to-many	Radio and television
Extension 3.0	ICT-enabled advisory	Interactive	Mobile phones and internet

Extension Stage	Dominant Approach	Nature of Communication	Role of Technology
Extension 4.0	Digital and precision agriculture	Data-driven	IoT, GIS, drones and sensors
Extension 5.0	**AI-enabled, human-centred advisory**	**Personalized and continuous**	**AI, generative AI, analytics and intelligent platforms**

The most important characteristic of Extension 5.0 is therefore **contextual intelligence**. Rather than providing every farmer with the same general recommendation, the system aims to consider crop, location, weather, season, soil conditions, and, increasingly, farm-specific circumstances.

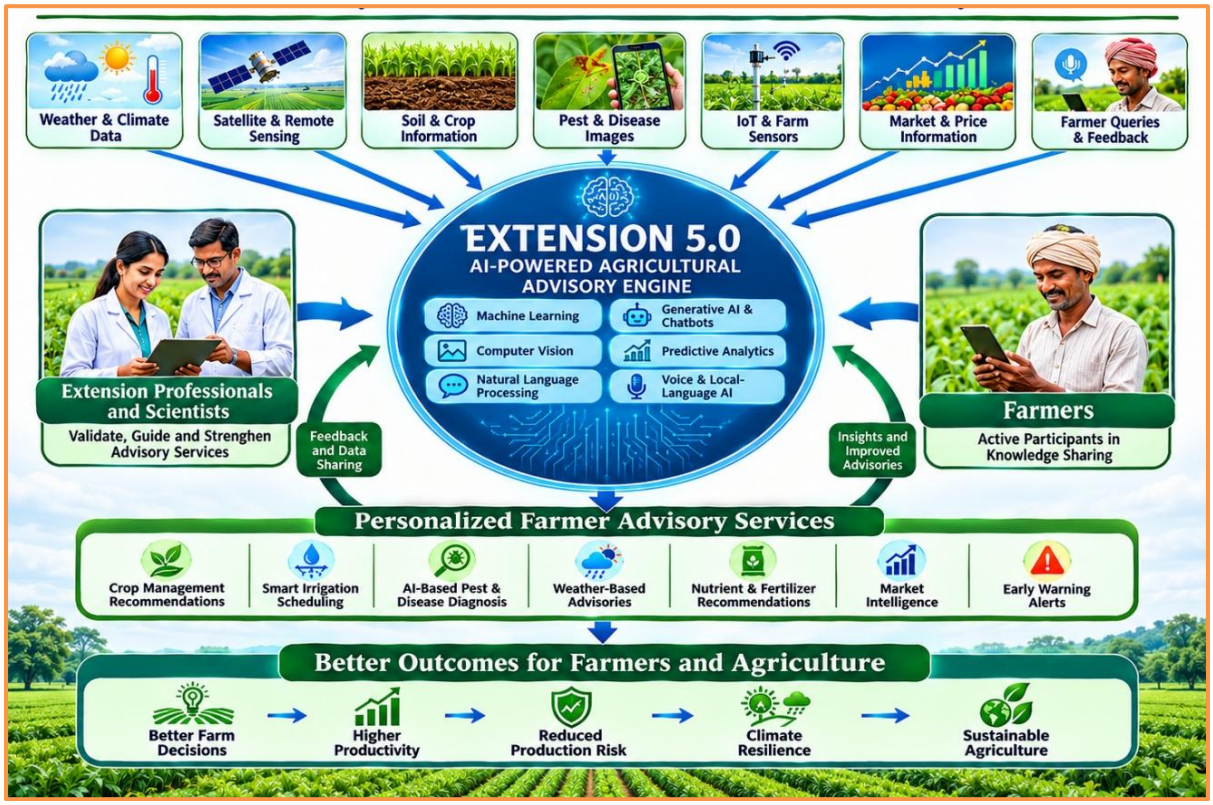

Figure 1. Conceptual framework of Extension 5.0

Recent Advancements in AI-Based Farmer Advisory Services

1. Generative AI and Agricultural Chatbots

Generative AI has introduced a new form of farmer interaction. Instead of navigating complicated applications or searching through technical documents, farmers can ask questions in natural language.

A farmer may ask:

"My tomato leaves are curling after rainfall. What should I do?"

An AI-enabled system can potentially combine information about the crop, weather conditions, likely pest or disease problems, and locally validated agricultural knowledge to generate a useful response. One prominent example is **Farmer.Chat**, developed by Digital Green with AI technologies to support agricultural advisory services. Research published by Microsoft describes the platform as a generative AI-based advisory system designed to provide personalized and contextually relevant information to smallholder farmers. By 2024, deployments across multiple countries had demonstrated its capacity to answer large numbers of agricultural queries at scale (Singh et al., 2024).

Digital Green has also emphasized multilingual and localized advisory delivery, recognizing that farmers often prefer communication through local languages and voice-based interaction rather than complex written interfaces.

2. AI-Powered Pest and Disease Diagnosis

Crop pests and diseases represent one of the most time-sensitive challenges in agriculture. Traditional diagnosis may require a farmer to visit an extension office or wait for a field expert. AI-based computer vision systems can potentially shorten this process. Using smartphone images, machine learning algorithms can identify visual symptoms associated with diseases, nutrient deficiencies, or pest damage. The system can then provide preliminary management guidance or escalate uncertain cases to an agricultural expert. India has increasingly incorporated AI into pest surveillance. The National Pest Surveillance System has been developed to support monitoring across numerous crops and pest types and to provide more timely information to extension personnel (PIB, 2026).

The real value of such systems lies in **early detection**. When farmers and extension workers report symptoms digitally, outbreaks can potentially be identified before they spread across wider geographical areas.

3. Hyper-Local Weather and Climate Advisories

Climate uncertainty has increased the importance of weather-responsive agriculture. Generic weather forecasts are often insufficient for farm-level decisions. Farmers need to know how changing weather conditions should influence irrigation, sowing, fertilizer application, harvesting, and pest management. AI can analyse historical climate records, real-time weather observations, satellite information, and predictive models to generate more localized recommendations. In India, AI-supported initiatives are being developed to strengthen context-specific agrometeorological advisory services. A 2025 initiative involving ICRISAT and Indian research and technical institutions focused specifically on AI-powered, context-specific climate advisory services for climate-resilient agriculture.

The goal is to move from simply telling farmers **what the weather will be** to explaining **what the farmer should do because of the expected weather**.

4. AI, Satellite Data and Remote Sensing

Satellite imagery is increasingly becoming an important source of agricultural intelligence. AI can analyse large volumes of remote-sensing data to identify field boundaries, crop conditions, vegetation patterns, and changes occurring over time. These capabilities have important implications for extension. Instead of waiting for farmers to report every problem, extension systems may increasingly identify risk areas proactively. Recent AI developments have demonstrated how agricultural monitoring models originally developed for applications including Indian agriculture can support field mapping, crop monitoring, credit assessment, and broader agricultural information systems.

This creates the possibility of **proactive extension**, where advisories are triggered by detected risks rather than being delivered only after farmers request help.

5. Voice-Based and Local-Language Advisory

For many farming communities, text-heavy digital platforms are not the ideal solution. Farmers may prefer to speak rather than type, particularly when interacting in regional languages and dialects. AI-based speech recognition and text-to-speech technologies can make agricultural advisory systems more inclusive. A farmer can speak a question in a familiar language, while the AI system processes the request and delivers an audio response. This is particularly significant in countries such as India, where agricultural communities communicate in numerous languages and dialects. AI systems capable of supporting voice and multilingual interaction can reduce linguistic barriers and improve accessibility.

Case Studies: AI in Agricultural Advisory Services

Case Study 1: Kisan e-Mitra and AI-Enabled Agricultural Services in India

India has rapidly expanded its digital agricultural infrastructure. AI is increasingly being integrated into farmer-facing platforms, pest surveillance, crop insurance, and weather-based advisory systems. According to official government information published in 2026, the **Kisan e-Mitra chatbot** had responded to more than 9.3 million queries by December 2025 and was handling thousands of daily farmer interactions across 11 regional languages. AI-based pest surveillance was also supporting extension personnel with real-time advisory

information (PIB, 2026). The significance of this development lies in scale. A conventional extension worker can interact with only a limited number of farmers each day. Digital conversational systems can respond continuously, while complex cases can be referred to human experts.

Case Study 2: Farmer.Chat and Smallholder Farmers

Farmer.Chat represents an important example of how generative AI can be adapted for agricultural extension. The platform has been developed to support natural-language interaction and context-sensitive advisory delivery. Unlike conventional agricultural applications that require users to select options from predefined menus, generative AI systems allow farmers to ask questions more freely. The system can process information from agricultural knowledge sources and generate conversational responses. Research on Farmer.Chat reported engagement with more than 15,000 farmers and responses to hundreds of thousands of agricultural queries during its early scaling phase, highlighting the potential for AI to expand advisory access beyond the physical limitations of conventional extension systems (Singh et al., 2024).

Case Study 3: Ethiopia's AI-Enabled Fertilizer Advisory

A particularly important example of Extension 5.0 is Ethiopia's development of a national digital fertilizer and agronomy advisory system. The Harmonized Fertilizer and Agronomy Solutions (HaFAS) system integrates soil, climate, and agronomic information to generate site-specific recommendations. According to CGIAR reporting, the system reached approximately 49,000 farmers during 2025 and was supported by thousands of on-farm trials across major crops. Reported results included substantial yield improvements and reductions in input costs.

The case demonstrates an important principle: AI is most effective when it is built on **validated agronomic data, field experimentation, institutional support, and continuous feedback from farmers and extension systems**.

Table 2. Selected Examples of AI-Enabled Agricultural Advisory Systems

Initiative	Technology/Application	Primary Advisory Function	Key Significance
Kisan e-Mitra, India	AI chatbot	Farmer query resolution	Large-scale multilingual access
National Pest Surveillance, India	AI and analytics	Pest monitoring and alerts	Early warning support
Farmer.Chat	Generative AI	Personalized agricultural advice	Conversational advisory
HaFAS, Ethiopia	AI and decision support	Fertilizer and agronomy recommendations	Site-specific guidance
AI Climate Advisory Initiatives	AI and climate analytics	Weather-responsive decisions	Climate resilience

Benefits of Extension 5.0

The adoption of AI can potentially transform agricultural advisory services in several ways.

1. **Personalization**
2. Recommendations can be adapted according to location, crop, season, weather, and farm conditions.
3. **24/7 Accessibility**
4. Unlike traditional office-based advisory systems, AI platforms can provide basic support at any time.
5. **Scalability**
6. A single intelligent system can support a very large number of farmers simultaneously.

7. **Early Warning**
8. AI can analyse data to identify emerging pest, disease, or climate risks.
9. **Reduced Information Gaps**
10. Digital systems can connect remote farmers with scientific information more rapidly.
11. **Support for Extension Personnel**
12. AI can reduce repetitive workloads and allow extension workers to focus on complex, field-based, and relationship-oriented activities.

The economic potential is also considerable. FAO has highlighted that AI-supported digital advisory systems could substantially reduce the cost of delivering agricultural information when appropriately developed and scaled.

Challenges and Concerns

Despite its potential, Extension 5.0 is not without limitations. The first major concern is **accuracy**. Generative AI systems can sometimes produce responses that sound convincing but are scientifically incomplete, overly general, or unsuitable for local farming conditions. Research and expert discussions have therefore emphasized the importance of grounding AI systems in reliable agricultural knowledge and involving human experts in advisory validation. The second challenge is the **digital divide**. Farmers without smartphones, reliable internet, electricity, or digital skills may remain excluded. Third, agricultural data must be treated responsibly. Questions related to farmer privacy, data ownership, commercial use of farm information, and algorithmic transparency require clear governance. Finally, AI cannot fully replace human extension. Agricultural innovation depends heavily on trust, demonstrations, farmer-to-farmer learning, and local relationships. Evidence from Bihar, India, suggests that digital communication tools can efficiently support agricultural information sharing but should complement rather than replace face-to-face interaction and field-based extension.

Table 3. Key Opportunities and Challenges of Extension 5.0

Opportunities	Challenges
Personalized advisory services	AI-generated inaccuracies
Rapid dissemination of information	Limited digital infrastructure
Early pest and climate warnings	Data quality limitations
Multilingual communication	Language and cultural contextualization
Support for extension workers	Digital literacy gaps
Lower advisory delivery costs	Privacy and data governance
Large-scale farmer outreach	Risk of excluding marginalized groups

The Future: Human Intelligence + Artificial Intelligence

The most successful Extension 5.0 systems will likely be **hybrid systems**. AI will manage speed, scale, pattern recognition, and data processing, while humans will provide scientific judgement, ethical oversight, empathy, local understanding, and practical validation. The future extension professional may therefore work very differently. Instead of spending substantial time repeatedly answering basic questions, extension personnel may use AI-generated dashboards to identify high-risk villages, emerging pest outbreaks, or farmers requiring specialized assistance. Similarly, farmers may increasingly use voice-enabled AI assistants for routine questions while continuing to depend on demonstrations, field visits, progressive farmers, scientists, and local extension workers for complex decisions.

The extension system of the future should therefore follow a simple principle:

AI should augment agricultural intelligence—not replace agricultural relationships.

Conclusion

Extension 5.0 represents a significant transformation in the philosophy and practice of agricultural advisory services. Artificial intelligence is enabling extension systems to become more responsive, personalized, predictive, and scalable. AI-powered chatbots, computer

vision, remote sensing, weather analytics, multilingual voice interfaces, and machine learning are gradually changing how agricultural knowledge is generated, interpreted, and delivered. The examples emerging from India and other countries demonstrate that intelligent advisory systems are no longer a distant possibility. They are increasingly becoming part of mainstream agricultural development. However, technology alone cannot solve the challenges of agricultural extension. The true success of Extension 5.0 will depend on the quality of agricultural data, scientific validation, institutional coordination, farmer participation, and digital inclusion. AI recommendations must be locally relevant, understandable, affordable, and trustworthy. The future is therefore not a choice between traditional extension and artificial intelligence. It is the creation of a stronger, integrated system in which AI provides speed and intelligence, extension professionals provide expertise and trust, and farmers remain active participants in the knowledge process. If developed responsibly, Extension 5.0 could help transform agricultural advisory services from a system that merely delivers information into one that continuously supports better decisions, stronger resilience, and more sustainable farming.

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