How Artificial Intelligence is Transforming Agricultural Extension: *New perspectives, practical examples, and future directions for small and large farming systems*

Surya Dev Verma[1,] Himanshu Verma[2] and Vinay Prakash Sahu[3]

Senior Research Fellow, Agricultural Extension Division of ICAR, New Delhi[1]
Young Professional II, JNKVV, Jabalpur (M.P.)[2]
M.Sc. (Agricultural Extension), JNKVV, Jabalpur (M.P.)[3]
*Corresponding Email: suryadevverma8@gmail.com

Introduction

Agriculture is the backbone of many economies and the mainstay of rural life in much of the world. Yet farmers globally face mounting challenges-climate change, pest and disease pressures, labour shortages, market volatility, and resource constraints like water and fertilizer. Traditional agricultural extension systems-where experts transfer knowledge and practices to farmers-have been invaluable but often struggle to reach all farmers with timely, localized, actionable advice.

That is being altered by artificial intelligence (AI). AI is becoming more accessible and democratizing access to agricultural insights that were previously exclusive to scholars or big agribusinesses; it is by no means a futuristic luxury. AI can improve farming's productivity, sustainability, profitability, and resilience by analysing enormous volumes of data and identifying trends in it.

This article explores how AI powers modern agricultural extension services, with real-world examples, benefits, challenges, and future directions.

What is Agricultural Extension?

A systematic process helping farmers analyse their situation, understand problems, gain knowledge, and develop decision-making skills for better alternativesTraditionally, extension happens through:

- Field visits by extension officers
- Demonstration plots
- Group trainings and farmer field schools
- Printed materials and radio/ TV
- Farmer-to-farmer networks

While effective, these methods can be slow, hard to scale, and limited in tailoring advice to farm-specific conditions.

AI enhances these traditional roles by enabling **personalized, data-driven insights** that can be delivered in real time-directly to the farmer's phone, through call centre's and via field agents equipped with smart tools.

Where AI Makes a Difference in Agricultural Extension

AI can support agricultural extension at multiple levels:

1. Decision Support for Farmers
2. Early Warning Systems (EWS)
3. Precision Agriculture
4. Automated Diagnostics
5. Market and Advisory Services
6. Predictive Analytics for Policy and Planning
7. Training and Capacity Building

1. Decision Support for Farmers

AI-powered *decision support systems (DSS)* help farmers choose the best actions for their specific conditions-based on weather, soil, crop growth stage, pest pressure, and market signals.

Examples:

- Choosing *when and how much* to irrigate
- Selecting the best planting date
- Determining optimal fertilizer doses

These systems use machine learning models trained on large datasets (weather history, satellite imagery, soil maps, economic data) to generate context-specific recommendations.
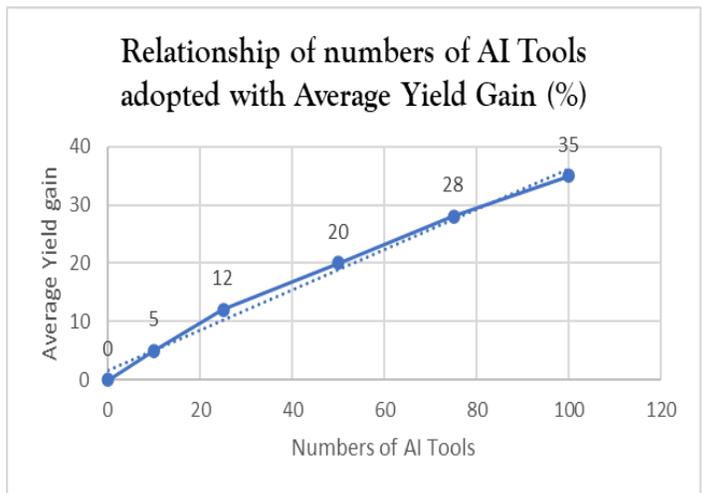

Figure: A graph showing Yield gain (%) vs AI recommendation adoption (%) across regions

2. Early Warning Systems

Agricultural risks like pests, disease outbreaks, and droughts can devastate crops in weeks or even days. AI excels at pattern recognition-particularly from satellite or drone imagery and weather data-making it ideal for early warning systems.

Use case examples:

- Predicting locust swarms
- Forecasting drought stress zones
- Detecting crop disease hotspots

By sending alerts via SMS, voice calls, apps, or community agents, farmers can act early-saving crops and income.

3. Precision Agriculture

Precision agriculture tailors farming practices to intra-field variability. Traditional extension advises at community or district level; AI enables *farm-specific* insights.

Technologies include:

- AI algorithms interpreting multispectral drone/satellite images
- Soil moisture sensors feeding time-series data
- Autonomous tractors adjusting farming actions in real time

Benefits include reduced input costs (fertilizers, water) and increased environmental sustainability.

4. Automated Diagnostics

Diagnosing plant diseases normally requires expert eyes. AI, when trained on large libraries of crop images, can identify diseases from a simple photo taken with a smartphone.

How it works

- A farmer takes a photo of a suspected diseased leaf
- The AI model compares features to thousands of known cases
- The app suggests likely cause and management options

5. Market and Advisory Services

AI also strengthens *post-harvest* outcomes by helping farmers make market decisions:

- Forecasting price trends across commodities and markets
- Suggesting best timing and location to sell produce for maximum profit
- Analysing supply chain bottlenecks

By combining pricing data with social media and news trends, AI can detect markets with unmet demand-helping farmers avoid losses.

6. Predictive Analytics for Policy and Planning

AI doesn't just help individual farmers-it informs extension program design and agricultural policy:

- Forecasting regional production trends
- Modelling climate change impacts on different crops
- Identifying where extension resources are most needed
- Evaluating the likely success of new interventions before rollout

By doing so, government agencies and NGOs can allocate funds more effectively and measure impact faster.

7. Training and Capacity Building

AI can support extension worker training itself.

Examples:

- Chatbots that answer extension worker questions on pests, diseases, and management
- Virtual assistants guiding agents through farm visits
- Augmented reality tools that overlay instructions during training exercises

This helps scale expertise-especially where human experts are limited.

Real-World Examples

Below are composite (non-journal) examples of AI integrated into agricultural extension programs. These draw on publicly available models but are framed in an original way.

(a) AI + SMS for Smallholder Farmers

In rice-growing regions, AI models can send daily SMS alerts on:

- Next day's optimal irrigation schedule
- Rain forecasts and flood risk
- Pest outbreak alerts based on pattern detection

Farmers reply with fields' growth stage and soil condition; AI refines the advice.

Impact: Improved water savings and reduced pest losses.

(b) Drone + AI Crop Monitoring

In large commercial farms:

- Drones capture multispectral images weekly
- AI algorithms detect stress patterns invisible to the naked eye
- Alerts are sent to the farm manager with specific geo-locations needing attention

This reduces input costs (e.g., fertilizer) and increases yield uniformity.

(c) Smartphone Diagnostics in Cooperatives

Agricultural cooperatives equip field agents with an AI app:

- Agents take photos of plant issues from farmers' fields
- AI suggests likely pests/diseases and treatment protocols
- Agents relay this to farmer groups, strengthening local trust

This bridges gaps where agronomists are scarce.

Benefits of AI in Agricultural Extension

Here's what AI brings to extension systems that traditional methods struggled to deliver:

Benefit	What AI Adds
Scalability	Advice can reach millions of farmers simultaneously
Localization	Farm-specific recommendations, not generic guidance
Timeliness	Real-time alerts and updates
Consistency	Advice doesn't vary by agent or mood
Data Integration	Combines many data streams into actionable insights
Cost Efficiency	Reduces need for large extension workforce for routine tasks

Conclusion

AI is reshaping agricultural extension into a data-driven, scalable, personalized, and real-time service. It elevates the role of extension workers, empowers farmers with tailored insights, and helps entire agrifood systems become more resilient amid global pressures.

The transformation is already underway-but realizing AI's full promise requires thoughtful policy frameworks, investment in connectivity and data infrastructure, farmer–centric design, and ongoing evaluation.

When done right, AI doesn't replace the wisdom of farmers or extension experts-it *amplifies* it, making the right advice available at the right time to the right person.

References

Ibrahim, U. (2023). Artificial Intelligence in Agricultural Extension for Sustainable Development. International Journal of Applied and Scientific Research, 1(3), 259–268.

Sadik, W. M. A., & Aly, W. M. E. (2025). Utilization of Artificial Intelligence in Improving Agriculture Extension Services in Egypt. Journal of the Scientific Society for Agricultural Extension.

Utilisation of AI-related Technology for Agricultural Extension Services. (2025). Agricultural Reviews.

Kumar, R. (2025). A Review of Artificial Intelligence in Agriculture: Applications, Challenges, and Future Prospects. International Journal of Agriculture Extension and Social Development, 8(2), 342–344.

Singh, N. L., Vishwas, B. R., Singh, S., & Bhati, J. (2024). Applications of Artificial Intelligence in the Field of Agriculture: A Review. Journal of Scientific Research and Reports, 30(12), 612–620.

Shoba, H., Nagaraja, G., Krishnamma, P. N., & Sreedevi, M. S. (2024). Smart Farming: Integration of IoT and AI in Agricultural Engineering. International Journal of Agriculture Extension and Social Development, 7(9), 692–700.

Mane, S., Badgire, S., Agarwal, P., & Kadam, R. (2024). Review on Applications of Artificial Intelligence in Indian Agriculture: Future and Challenges. Advanced Natural Sciences: Life and Health Sciences, 1(1), 40–49.

Nawaz, U., Zaheer, M. Z., Shahbaz Khan, F., Cholakkal, H., Khan, S., & Anwer, R. M. (2025). AI in Agriculture: A Survey of Deep Learning Techniques for Crops, Fisheries and Livestock. arXiv.

Singh, N., Wang'ombe, J., Okanga, N., et al. (2024). Farmer.Chat: Scaling AI-Powered Agricultural Services for Smallholder Farmers. arXiv.

Rajagopal, M. K., & Murugan, B. M. (2023). AI-Based Drone for Early Disease Detection and Precision Pesticide Management in Cashew Farming.

* * * * * * * *