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ARTIFICIAL INTELLIGENCE: A NEW HORIZON IN AGRICULTURE

Smart technologies for productive, climate-resilient and farmer-centric agriculture

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Abstract

Artificial Intelligence (AI) is creating new opportunities to improve agricultural decision-making by analysing information from weather services, soil tests, satellite imagery, sensors, field photographs and markets. Its applications include precision farming, crop-health monitoring, pest surveillance, irrigation scheduling, weather-informed crop planning and post-harvest quality assessment. India's digital agriculture initiatives including Kisan e-Mitra, the National Pest Surveillance System (NPSS) and the Digital Agriculture Mission illustrate the growing role of technology in agricultural services. These developments are especially relevant to rainfed and semi-arid regions, where the timing and distribution of rainfall strongly influence crop establishment and productivity. Yet AI is not a stand-alone solution: reliable data, local validation, affordability, farmer training and responsible data governance are essential. This article reviews key applications and Indian initiatives and discusses how AI can be integrated with agricultural research and extension to support sustainable, climate-resilient farming.

Keywords: Artificial intelligence, Agriculture 4.0, precision agriculture, digital agriculture, climate resilience, agricultural extension.

Introduction

Agriculture must increase and stabilise production while conserving soil, water and biodiversity. Indian farmers manage a range of interconnected risks: uncertain rainfall, rising input costs, pests and diseases, fragmented holdings, price fluctuations and uneven access to timely technical advice. Addressing these challenges requires more than new machinery or improved varieties; it also requires better decisions about when, where and how to use available resources.

Artificial Intelligence refers to computational methods that identify patterns in data, interpret images, generate predictions and support decisions. In agriculture, AI can combine information from satellites, weather forecasts, soil sensors, field observations and historical records to provide timely, location-specific insights. When linked with the Internet of Things (IoT), drones, mobile applications and digital advisory services, AI becomes part of the wider transition commonly described as Agriculture 4.0.

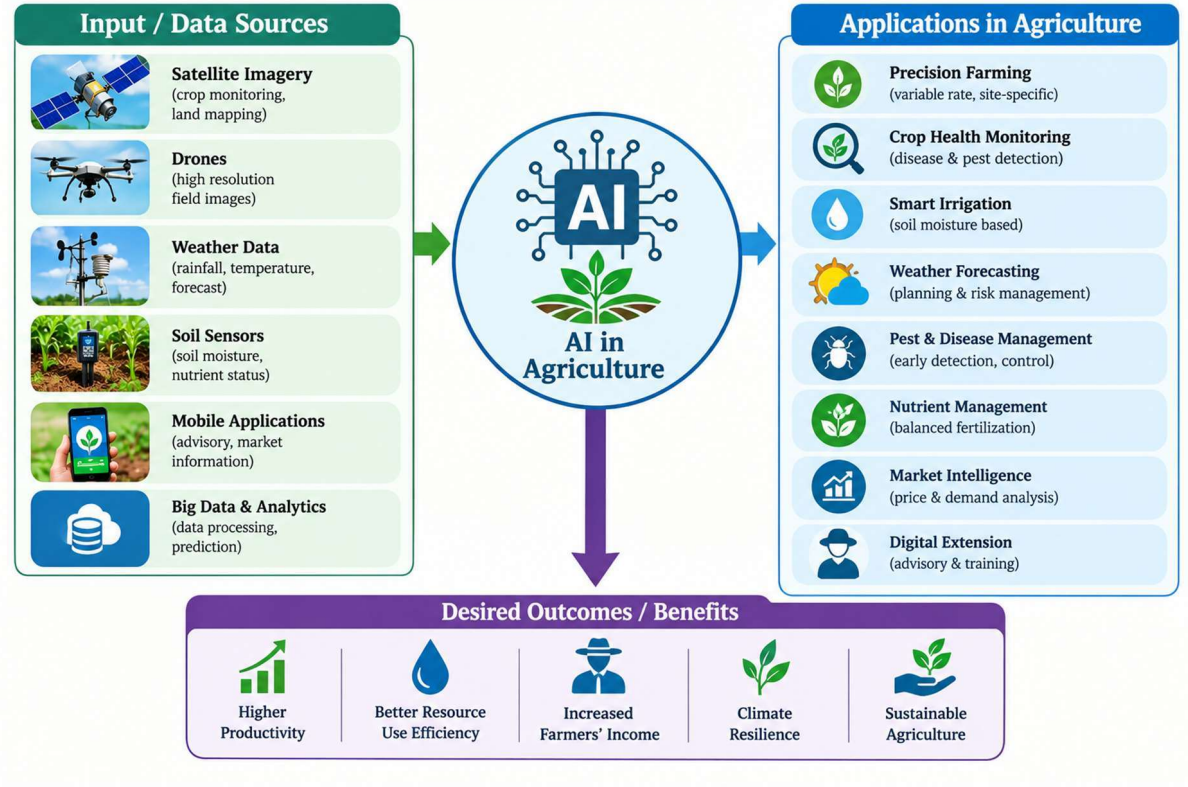


Fig.1. Artificial Intelligence in Agriculture: Key Inputs, Applications and Benefits

From Data to Decisions: How AI Can Support Farming

An AI-enabled agricultural service typically follows a cycle: collecting data, analysing patterns, generating an advisory, implementing a suitable field action and using feedback to improve the service. Data may include rainfall forecasts, soil characteristics, crop-stage observations, photographs of pests, satellite-derived crop indicators and market information. The quality and relevance of the recommendation depend on the accuracy of these inputs and on whether the model has been tested in the target region.

A model developed for one crop, soil or climatic region may not perform equally well elsewhere. Therefore, local calibration, independent field validation and clear communication of uncertainty are essential before recommendations are widely promoted.

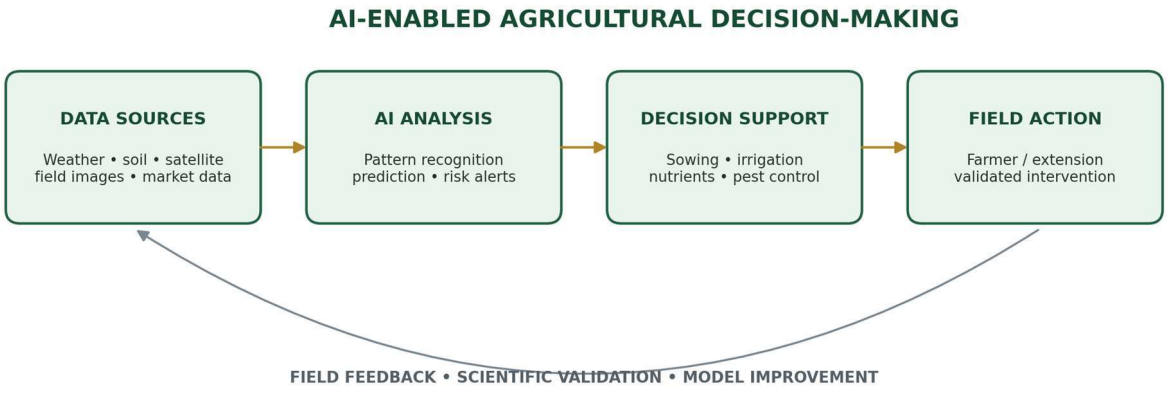


Figure 2. Conceptual framework for AI-enabled agricultural decision-making. The cycle requires field feedback and scientific validation.

Major Applications of AI in Agriculture

1. Precision agriculture and site-specific input management

Fields often show spatial variation in soil texture, fertility, water-holding capacity and crop growth. AI can analyse satellite or drone imagery alongside soil-test and yield data to identify zones with different management needs. Where suitable equipment and reliable data are available, these insights may support variable-rate application of fertilizers, targeted scouting and more efficient input use. Benefits should be assessed through field comparisons, including input costs, yield and profitability.

2. Crop-health monitoring and pest management

AI-based image-recognition tools can help screen photographs of leaves, stems, fruits or insects for symptoms associated with pests, diseases and nutrient disorders. Satellite and drone observations can flag patches of abnormal crop growth for closer inspection. Such tools can help extension workers prioritise visits and may support early intervention, but an image-based result should not automatically be treated as a confirmed diagnosis. Field verification, pest thresholds and integrated pest-management principles remain necessary.

3. Weather-informed crop planning

Rainfall timing and distribution influence sowing, crop establishment, fertilizer response and harvesting. AI-based analysis can combine weather forecasts, historical records and crop-stage information to provide decision support for sowing windows, irrigation planning and risk alerts. Forecasts are probabilistic, however, and should be presented with uncertainty rather than as guarantees. Farmers should use them alongside local observations and advisories from competent agricultural and meteorological agencies.

4. Irrigation and soil-moisture management

Sensor-based systems can combine soil-moisture readings, weather conditions and crop water requirements to guide irrigation scheduling. In rainfed regions, data-driven advisories may also help plan moisture-conservation operations and make better use of limited supplemental irrigation. AI can complement established practices such as in-situ moisture conservation, suitable land configuration, mulching and efficient irrigation; it cannot replace sound soil and water management or create water where supplies are inadequate.

5. Post-harvest management and markets

Machine vision can support grading of produce by size, colour and visible defects, while data analytics can assist inventory management, demand estimation and transport planning. Market information tools may help farmers and Farmer Producer Organisations compare prices and identify potential selling opportunities. Outcomes still depend on transparent information, functioning markets, storage, transport and farmers' bargaining capacity.

Table 1. Agricultural applications of AI and their potential contribution

Application	AI-enabled approach	Potential contribution
Crop planning	Weather, soil and crop-history analysis	Better-informed sowing and crop choices
Crop monitoring	Satellite/drone image analysis	Early flagging of crop stress
Pest surveillance	Image recognition and risk alerts	Timely field scouting and targeted response
Irrigation	Soil moisture + weather + crop stage	Improved irrigation scheduling
Nutrient management	Soil-test and crop-requirement analysis	More balanced input decisions
Post-harvest	Machine vision and quality classification	Consistent grading and handling
Extension	Voice-based multilingual services	Wider access to information

*Source: Compiled from Government of India publications and the August 2025 *Kurukshetra* issue on Agritech.*

Indian Initiatives: Moving Digital Agriculture into Practice

Kisan e-Mitra is a voice-based AI chatbot developed to answer farmers queries related to the PM-KISAN scheme and other government services. In a Press Information Bureau release dated 22 July 2025, the Ministry of Agriculture and Farmers' Welfare reported that it supported 11 regional languages, handled more than 20,000 queries daily and had answered over 95

lakh queries. These figures are a dated official snapshot, not a permanent or current total.

The National Pest Surveillance System (NPSS), launched on 15 August 2024, uses AI and machine learning to support pest and crop-health surveillance. A PIB release dated 1 April 2025 reported that the platform was being used by more than 10,000 extension workers and supported 61 crops and over 400 pests at that time. These dated figures illustrate the scale of the programme as reported in 2025.

The Digital Agriculture Mission, approved in September 2024 with a total outlay of ₹2,817 crore, aims to strengthen digital public infrastructure for agriculture, including AgriStack and the Krishi Decision Support System. Such infrastructure can help connect agricultural datasets and improve the delivery of digital services. The usefulness of these initiatives ultimately depends on data quality, interoperability, safeguards for farmers and the ability to convert digital outputs into actionable field advice.

Opportunities for Rainfed and Semi-Arid Agriculture in Rajasthan

AI has particular relevance to rainfed and semi-arid agricultural systems of Rajasthan, where rainfall variability, limited water availability and soil-moisture stress can influence crop establishment and yield. In districts such as Bhilwara and surrounding areas, locally validated advisory systems could combine rainfall forecasts, soil characteristics, crop-stage information and field observations.

For *kharif* crops, weather-informed advisories may help farmers assess sowing opportunities and plan early-season operations. Soil-moisture observations and crop-stage information may support decisions about conservation practices or limited supplemental irrigation. Image-based crop monitoring may help extension personnel identify suspicious patches and prioritise field visits. These services should be designed for local languages and the realities of smallholder farming.

AI could also support comparisons among alternative cropping systems by organising information on crop water requirements, soil suitability, expected returns and local markets. For example, choices within maize-based systems should be assessed through locally relevant field trials and economic analysis rather than generic recommendations. Agricultural universities, research stations, Krishi Vigyan Kendras and extension agencies can play a key role in building datasets, validating outputs and training farmers.

Limitations, Ethics and the Way Forward

The adoption of AI faces several constraints. Incomplete or biased datasets can reduce reliability, while weak connectivity, device costs and limited digital literacy may exclude farmers who could benefit from advisory services. Models can also fail when transferred to a different region or crop without validation. Data ownership, privacy, consent and accountability must be addressed transparently. In addition, an AI-generated recommendation should not be followed blindly where it conflicts with field conditions or established safety guidance.

1. **Scientific validation:** test tools through replicated trials, multi-location demonstrations and independent performance assessment.
2. **Local relevance:** develop datasets for regional crops, soils, climates and languages, and update them as conditions change.
3. **Affordable access:** explore shared services through FPOs, cooperatives, custom-hiring centres and extension institutions.
4. **Capacity building:** train farmers and extension personnel to interpret advisories and understand uncertainty.
5. **Measurable outcomes:** assess yield, net returns, input use, water-use efficiency, farmer satisfaction and unintended effects.

The most effective approach is a partnership among farmers, scientists, extension workers, public agencies and technology developers. AI systems should be evaluated not only by technical accuracy but also by whether they deliver practical, affordable and equitable benefits in the field.

Conclusion

Artificial Intelligence is opening a new horizon for agriculture through precision management, crop-health monitoring, pest surveillance, weather-informed planning, irrigation support and improved post-harvest operations. Indian initiatives such as Kisan e-Mitra, NPSS and the Digital Agriculture Mission demonstrate the growing integration of digital technologies into agricultural services. For Rajasthan's rainfed farming systems, AI can help organise complex information and support better-informed decisions on sowing, moisture conservation, crop diversification and resource use. Yet technology alone cannot ensure sustainability. Reliable data, local validation, farmer participation, affordability and responsible governance are indispensable. The real promise of AI is not simply to automate farm operations,

but to empower farmers and agricultural institutions with timely, credible and actionable information.

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