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Role of AI and Smart Farming in Enhancing Pulse Production

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Pulses such as chickpea, pigeon pea, green gram, black gram and lentil are important for food security, soil fertility and sustainable agriculture. However, their productivity is often limited by rainfed cultivation, erratic rainfall, moisture stress, nutrient deficiencies, pests and diseases. Artificial Intelligence (AI) and smart farming technologies, including machine learning, IoT sensors, drones, satellite remote sensing, GIS and mobile-based advisory systems, can support precision sowing, nutrient and water management, early pest and disease detection, crop monitoring and yield prediction. In pulses, these technologies are particularly useful for improving resource-use efficiency, managing climate-related risks and supporting biological nitrogen fixation. Despite challenges such as high technology costs, limited digital infrastructure and low digital literacy, AI-driven smart farming can help make pulse production more productive, resilient and sustainable.

Keywords: Artificial intelligence, Precision agriculture, Internet of Things (IoT), Machine learning, Digital agriculture

Introduction

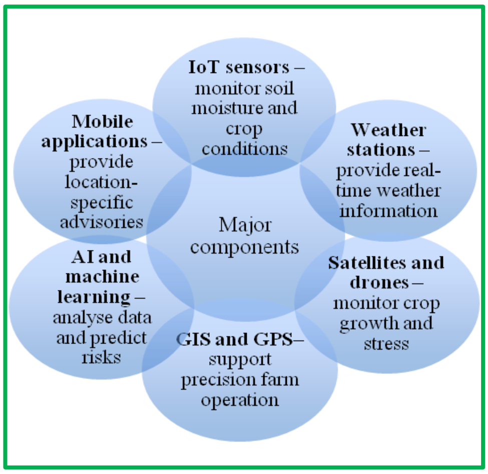
Pulses are an important part of sustainable agriculture because they provide nutritious plant protein, improve soil fertility and support diversified cropping systems. Through biological nitrogen fixation, pulse crops enrich the soil and reduce dependence on synthetic nitrogen fertilizers, while also benefiting succeeding crops. India has the largest area under pulse cultivation but productivity remains below the global average due to rainfed farming, irregular rainfall, nutrient deficiencies, pest and disease attacks, limited mechanization and low adoption of modern technologies. Climate variability has further increased these challenges through rising temperatures, prolonged dry spells and unpredictable rainfall. In this context, Artificial Intelligence (AI) and smart farming offer practical solutions for improving pulse production. AI can analyse information from weather stations, soil sensors, satellites, and drones to provide timely, field-specific recommendations. These technologies can improve irrigation, nutrient management, pest and disease detection, and yield prediction, making pulse farming more productive, resource-efficient, climate-resilient, and sustainable (Wolfert *et al*., 2017).

Importance in pulse production

Pulses play an important role in sustainable agriculture by supporting food security, nutrition, and soil health. Crops such as chickpea, pigeon pea, green gram, black gram, and lentil are rich sources of plant protein and improve soil fertility through biological nitrogen fixation. Their association with *Rhizobium* bacteria helps convert atmospheric nitrogen into forms that plants can use, reducing the need for external nitrogen fertilizers. Pulses are also valuable in crop rotations, particularly in cereal-based systems. Including pulses can improve soil structure and organic matter, support beneficial soil microorganisms, and help break pest and disease cycles. They also provide an important source of income for small and marginal farmers, especially in rainfed areas. However, pulse production is often affected by irregular rainfall, insect pests, diseases, nutrient deficiencies, and unstable market prices. These challenges can reduce yield and increase production risks. In this context, Artificial Intelligence (AI) and smart farming technologies can help farmers make timely decisions by providing field-specific information on weather, nutrients, pests, diseases, and crop management. Thus, AI can make pulse production more productive, efficient, and climate-resilient and has the potential to bridge this information gap by converting complex datasets into practical advisories that farmers can easily understand and implement.

Role of AI and Smart Farming

Artificial Intelligence (AI) and smart farming are transforming pulse production through data-driven and precise crop management. AI analyses information from sensors, drones, satellites, weather stations, and mobile applications to monitor soil moisture, crop growth, nutrients, pests, and diseases. This information helps provide timely recommendations for irrigation, nutrient management, pest and disease control, and harvesting. By matching crop management with field conditions, these technologies can improve pulse productivity, resource-use efficiency and sustainability.



Applications of AI and Smart Farming in pulse production

1. Precision sowing and crop establishment: Successful pulse production begins with timely sowing and proper crop establishment. AI-based decision support systems analyze historical weather data, rainfall forecasts, soil characteristics and climatic conditions to recommend the optimum sowing window for crops such as chickpea, green gram, black gram, pigeon pea and lentil. GPS-enabled precision seed drills ensure uniform seed depth and spacing, resulting in better germination, synchronized flowering and improved crop stand (Shamshiri *et al*., 2018).

Major tools used: GPS-enabled seed drills**,** Automatic Weather Stations (AWS)**,** Machine learning weather models**,** GIS-based field mapping

Benefits: Optimum sowing time**,** uniform crop establishment and better plant population**,** reduced risk of drought-related crop failure.

2. Smart Nutrient Management: Pulse crops require balanced nutrition, particularly phosphorus, sulfur, zinc, molybdenum, and boron, for effective nodulation and biological nitrogen fixation. AI integrates information from soil testing laboratories, nutrient sensors, crop growth data, and remote sensing to recommend field-specific fertilizer doses. Variable-rate fertilizer application improves nutrient-use efficiency while reducing fertilizer wastage. Integration of nano fertilizers and biofertilizers with AI-based nutrient recommendations further enhances fertilizer efficiency.

Major tools used: Portable soil nutrient sensors**,** Variable Rate Technology (VRT)**,** Digital soil maps**,** AI-based nutrient recommendation software

Benefits: Balanced fertilizer application**,** Improved nutrient-use efficiency**,** Enhanced nodulation**,** Reduced fertilizer cost

3. Smart Irrigation Management: Although pulse crops require less water than cereals, moisture stress during flowering and pod filling significantly reduces yield. IoT-based soil moisture sensors continuously monitor water availability in the root zone. AI combines this information with weather forecasts and evapotranspiration data to recommend irrigation only when required.

Major tools used: IoT soil moisture sensors**,** Smart irrigation controllers**,** Mobile irrigation advisory applications

Benefits: Water conservation**,** reduced energy consumption**,** higher water-use efficiency

4. Pest and disease monitoring: Major insect pests of pulses include gram pod borer (*Helicoverpa armigera*), aphids, whiteflies, and pod bugs. Common diseases include Yellow Mosaic Virus (YMV), Fusarium wilt, powdery mildew and anthracnose. Deep learning algorithms analyze leaf images captured by smartphones or drones to identify diseases at an early stage. AI also combines weather data and historical disease records to predict disease outbreaks before symptoms become severe (Kamilaris & Prenafeta-Boldú, 2018).
Major tools used: Smartphones with AI diagnostic apps, Drone-mounted RGB and Thermal cameras, Machine learning disease prediction models
Benefits: Early disease diagnosis, reduced pesticide use, lower yield losses and timely crop protection
5. Drone-based crop monitoring: Agricultural drones equipped with multispectral and thermal cameras provide detailed information on crop health. They can identify nutrient deficiencies, water stress, weed infestation, insect damage and poor crop establishment several days before symptoms become visible to farmers. Drone-based precision spraying also minimizes pesticide wastage and environmental pollution (FAO, 2025).
Major tools used: DJI Agras T40, DJI Phantom 4 Multispectral, NDVI image analysis software
Benefits: Rapid field scouting, precision spraying, reduced labour requirement, improved crop health monitoring.
6. Remote sensing and satellite monitoring: Satellite-based remote sensing provides continuous monitoring of pulse-growing regions. Artificial Intelligence processes satellite imagery to estimate crop biomass, vegetation indices (NDVI), drought severity, nutrient deficiency and crop acreage. These technologies assist both farmers and policymakers in monitoring crop performance and planning agricultural interventions (Wolfert *et al*., 2017).
Major tools used: Sentinel-2, Landsat-8 satellites, Google Earth Engine, GIS software (ArcGIS, QGIS)
Benefits: Large-area crop monitoring, drought assessment, yield estimation
7. Yield prediction and harvest planning: AI models integrate weather data, crop growth information, soil fertility, and satellite observations to predict yield before harvest. Accurate forecasts help farmers arrange harvesting machinery, labour, storage facilities and marketing strategies (Mohammed *et al*., 2025).
Major tools used: Machine learning algorithms, Cloud computing platforms, Satellite imagery
Benefits: Better harvest planning and improved market decisions, reduced post-harvest losses, higher profitability.

Challenges in adoption

Several challenges limit the widespread adoption of AI in pulse farming.

- High cost of drones, sensors, and precision equipment.
- Limited internet connectivity in rural areas.
- Low digital literacy among farmers.
- Insufficient availability of quality agricultural datasets.
- Small and fragmented landholdings.
- Concerns regarding ownership and privacy of farm data.

Future prospects

The future of pulse farming will increasingly depend on intelligent digital technologies. Advances in AI, robotics, satellite monitoring and IoT are expected to improve precision farming and support climate-resilient agriculture. Emerging technologies such as autonomous farm machinery, AI-assisted crop breeding, etc will further strengthen decision-making and enhance farm productivity. As these technologies become more affordable and user-friendly, their adoption among smallholder farmers is expected to increase significantly, contributing to improved food security, environmental sustainability and rural livelihoods.

Conclusion

Artificial Intelligence and smart farming are revolutionizing pulse production by enabling precise, data-driven crop management. Through real-time monitoring, predictive analytics, remote sensing, drones and IoT-based technologies, AI helps farmers optimize resource use, improve productivity and reduce environmental impacts. Although challenges such as affordability, digital literacy and infrastructure remain, supportive government policies and continued technological innovations are expected to accelerate adoption. By integrating scientific intelligence with farmers' traditional knowledge, AI has the potential to transform pulse cultivation into a more productive, profitable and sustainable agricultural enterprise.

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