Indian Farming 75 (01): 82-85; January 2025

Use of next-gen technologies in rainfed agriculture

Artificial Intelligence, Machine Learning and Drones

N. Ravi Kumar*, R. Nagarjuna Kumar, N. Showri Raju, G. Ravindra Chary and Vinod Kumar Singh

ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, Telangana 500 059

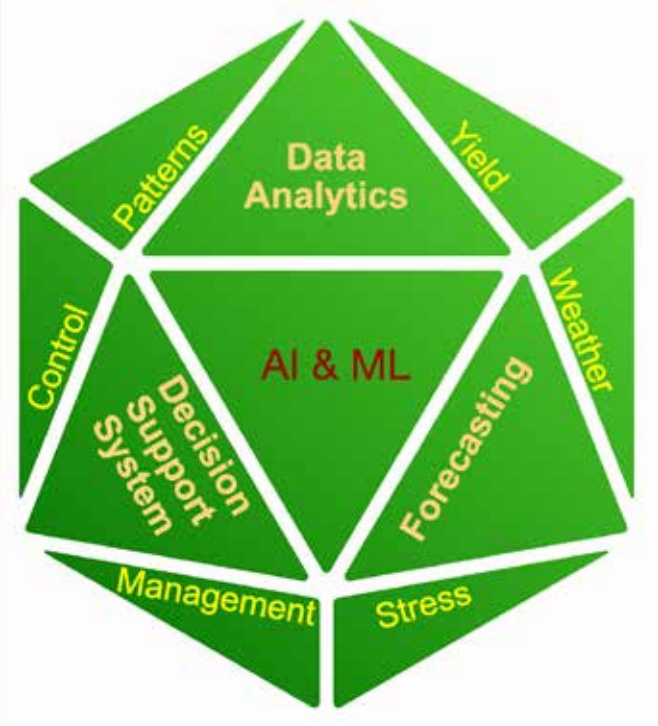
The adoption of next-generation technologies such as artificial intelligence (AI), machine learning (ML), and drones is transforming rainfed agriculture, which faces challenges like water scarcity, climate variability, and soil degradation. AI enhances decision-making through precise weather forecasting, crop health monitoring, and decision support systems. ML contributes by analyzing data for yield prediction, optimizing soil and water management, and developing climate-resilient crop strategies. Drones play a pivotal role in aerial surveillance, precision application of resources, and rapid damage assessment. The integration of these technologies leads to better resource efficiency, increased resilience, and enhanced productivity. However, challenges such as high costs, the need for technical training, and reliable infrastructure must be addressed for widespread adoption. However, these technologies have the potential to make rainfed agriculture more sustainable and profitable.

Keywords: Artificial intelligence, Drones, Machine learning, Next-gen technologies, Rainfed agriculture

RAINFED agriculture solely depends on rainfall and provides livelihood to the small and marginal farmers in the country. Rainfall is highly unreliable, both in time and space, with strong risks of dry spells at critical growth stages even during good rainfall years. Next-generation technologies in agriculture are transforming traditional farming methods to boost efficiency, productivity, and sustainability. The use of next-generation technologies such as artificial intelligence (AI), machine learning (ML), drones and Internet of Things (IoTs) has been revolutionising agriculture. These technologies help farmers overcome challenges related to unpredictable weather, resource limitations, and productivity issues.

Artificial intelligence (AI) and Machine learning (ML)

Artificial intelligence and Machine learning (AI & ML) become a transformative tool in rainfed agriculture. It has significant potential to enhance income by reducing losses. It is helping to improve decision-making, optimise resource-use, and manage risks associated with the variability of rainfall. Rainfed farming relies entirely on natural precipitation, often faces challenges related to unpredictable weather, climate change, and limited access to irrigation. AI&ML can mitigate these challenges by harnessing data to provide actionable insights. These tools broadly helps in data analytics (DA), forecasting and decision support system (DSS).



Functions of AI and ML

AI and ML Functions

Data analytics: AI& ML algorithms can analyse large dataset on weather, soil health, and crop conditions to predict weather patterns, droughts, and optimal planting time. This helps farmers make informed decisions on crop selection and timing for planting and harvesting.

Forecasting: By integrating multiple datasets, AI & ML can forecast potential crop yields, enabling farmers to better plan for harvests and market strategies. Developed algorithms can predict soil moisture content and water availability based on historical and real-time data, helping farmers optimize the use of rainwater and reduce wastage. These models can analyse images and data to detect early signs of crop diseases and pest infestations, allowing for timely intervention and reducing potential losses.

Decision support systems: These platforms offer real-time decision support for crop management, suggesting practices like fertilisation schedules and pest control based on the collected data.

Application in rainfed agriculture

***Crop monitoring and health assessment*:** Using AI & ML combined with remote sensing technologies, such as satellite imagery and drone-based sensors, farmers can monitor the health of their soil and crops. Algorithms analyze these data such as moisture content, pH levels, and nutrient composition to detect early signs of nutrient deficiencies, pest infestations, or diseases. Image recognition algorithms, such as convolutional neural networks (CNNs), are particularly effective in analysing images from drones or smartphones to detect anomalies in crops. Additionally, models that use weather and environmental data can predict the likelihood of pest outbreaks, enabling farmers to take preventive measures before significant damage occurs. By training these models on large data sets, farmers can receive recommendations on which crops are best suited for their land, how to optimise fertilisation, and when to irrigate, even in the absence of irrigation infrastructure. This information allows for timely interventions to maintain crop health

***Yield prediction*:** These models use a combination of remote sensing data, weather forecasts, past yield data, and even socio-economic factors to predict yields with high accuracy. This allows farmers and agribusinesses to plan better, manage resources, and minimise risks associated with poor yields. By running different scenarios through these models, farmers can predict the impact of variables like unexpected droughts or flooding, which aids in strategic planning and insurance claims.

***Supply chain optimization*:** It can also analyse market trends, demand forecasts, and logistical data to streamline the transport of crops. This minimises delays and reduces costs by suggesting the most efficient routes and storage practices to keep products fresh. It assists in tracking produce from the farm to the consumer, ensuring transparency and food safety. This builds trust with consumers and helps in recalling batches in case of contamination.

***Climate change adaptation*:** AI&ML-powered advanced models, such as recurrent neural networks (RNNs) and long short-term memory (LSTM) networks, can analyse patterns in rainfall, temperature, and humidity to predict future weather over days, weeks, or even seasonal conditions and provides more accurate and longer-term predictions. Farmers can use this information to adjust planting schedules, protect crops from predicted severe weather, and plan harvests to avoid damage from unexpected storms.

***Advisory services and decision support systems*:** AI&ML driven platforms and mobile apps can turn data into actionable intelligence and provide farmers with personalised advice on when to plant, what crop varieties to choose, and how to manage pests and diseases through Decision support systems (DSS). These systems consider real-time data inputs such as local weather forecasts, soil health, and crop growth stages to give tailored advice on planting, fertilisation, and pest control.

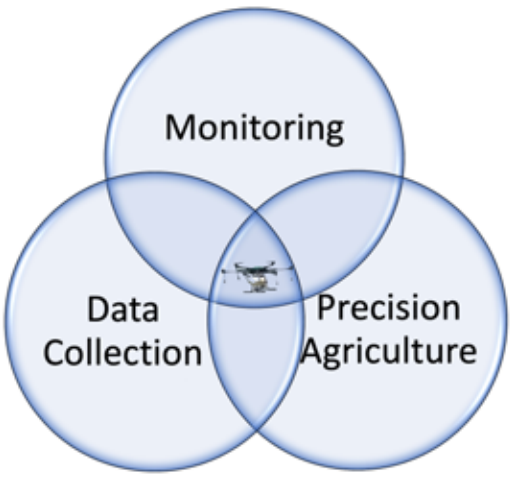
Drones in rainfed agriculture

Drones have become a valuable machine in rainfed agriculture, providing farmers with new capabilities to monitor, manage, and optimise their practices. Their ability to collect real-time, high-resolution data over large areas can help farmers overcome challenges related to the reliance on natural rainfall, limited resources, and climate variability.

***Aerial monitoring and mapping*:** Drones equipped with multispectral and thermal cameras can capture detailed images of farmland, which help assess crop health, detect stress areas, and monitor growth patterns.

***Precision agriculture*:** Drones can be used to apply fertilizers, pesticides, and even seed dispersal in a targeted manner. This ensures that only specific areas of the field receive treatment, optimising input usage and minimising costs.

***Data collection*:** Drones provide valuable data for ML and AI algorithms by surveying large tracts of farmland quickly and efficiently. This data includes information on crop vigour, soil quality, and potential problem areas.



Functions of drone in agriculture

Application of drones in rainfed agriculture

Crop spraying and fertilizer application: Drones can deliver pesticides, herbicides, and fertilizers evenly across crops, reducing waste and ensuring even coverage. Once the pest attack is identified, farmers can implement targeted pest control measures, which are more efficient and environmentally friendly than blanket treatments. They use less product compared to traditional methods, cutting down on costs. Faster than manual labor or ground-based machinery, which helps farmers cover large areas quickly. Reduces human exposure to potentially harmful chemicals.

Planting and seeding: Advanced drones equipped with seed-dispersing technology can perform aerial seeding, making it possible to plant crops quickly and efficiently over large areas. This is particularly useful in rainfed agriculture for timely planting coinciding with rainfall.

Mapping and field surveying: Drones can create high-resolution maps of farms which can be used to track changes in crop growth over time and make informed decisions about crop management besides regular crop health monitoring and pest detection to enable timely interventions. Drones can also be used for estimating yield and assessing crop maturity to plan harvesting schedules besides identifying areas that need soil treatment or remediation for future planting.

Spray agricultural drones are part of a broader category of agricultural Unmanned Arial Vehicles (UAVs) that integrate advanced technology such as Global Positioning System (GPS), sensors, and AI to enhance productivity and sustainability in farming. They are designed to be user-friendly, often equipped with software that allows for easy programming and operation by farmers.

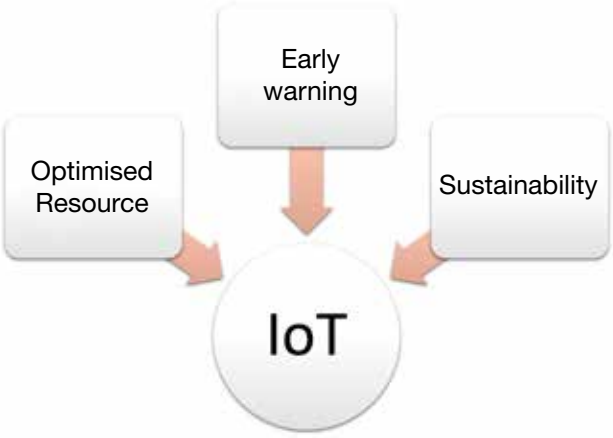
Drones are transforming rainfed agriculture by providing high-resolution, real-time data that enhances decision-making and resource management. While there are challenges to overcome, such as costs and technical training, the benefits of adopting drone technology in rainfed farming are substantial, making it a valuable investment for the future of agriculture.

IoT (Internet of Things) and Smart farming

The Internet of Things (IoT) is playing a significant role in transforming rainfed agriculture by providing real-time data collection, remote monitoring, and automated decision-making tools. This technology helps farmers address the inherent challenges of rainfed production systems. By integrating IoT, farmers can optimize resource-use, increase productivity, and manage risk more effectively. Applications of IoT in rainfed agriculture are described below.

***Soil moisture and nutrient monitoring*:** IoT-based soil sensors can measure key properties such as moisture levels, temperature, pH, and nutrient content. These sensors provide continuous data that helps farmers understand when their soil has enough moisture to support crop growth or if it requires conservation measures like mulching. Nutrient sensors inform farmers about the nutrient status of the soil, allowing them to adjust fertilization plans accordingly and avoid nutrient deficiencies or overuse.

Weather monitoring: IoT weather stations equipped with sensors for temperature, humidity, rainfall, and wind speed help farmers access hyper-local weather information in real-time. Accurate weather data is crucial in rainfed agriculture for planning sowing, harvesting, and field operations. This allows farmers to align agricultural practices with current and forecasted weather conditions, reducing the risk of crop failure.



Functions of Internet of Things (IoT)

Smart irrigation systems: **S**mart irrigation systems using IoT can provide supplementary irrigation during dry spells. These systems rely on soil moisture data and weather forecasts to determine when and how much water to apply, optimizing water-use and ensuring crops have enough moisture to thrive. Integrating IoT sensors with AI systems further enhances this capability by providing real-time feedback on soil and environmental conditions.

Crop monitoring and health analysis: IoT devices, such as drones and remote sensors, can be deployed to monitor crop health through imaging and data collection. These devices can detect signs of disease, pest infestation, or water stress, which may not be visible from the ground. Coupled with machine learning algorithms, IoT devices can identify patterns and send alerts to farmers, enabling them to take timely action to protect their crops.

Data-driven decision support: The data collected by IoT sensors is often fed into decision support systems (DSS), which provide farmers with actionable insights. For instance, these systems can recommend the best times for planting and harvesting based on current and predicted weather patterns, soil moisture, and crop growth stages. Farmers can access this information via mobile apps or web platforms, facilitating real-time decision-making.

Technological components of IoT: IoT components are soil moisture, temperature, humidity sensors, nutrient and pest detection sensors; devices that measure rainfall, wind speed, temperature, and other climate parameters; Wi-Fi, LoRaWAN, cellular networks, and satellite communications that facilitate data transfer.

Challenges and considerations

Data accessibility is the major concern and obtaining **r**eliable data on weather, soil, and crops may be difficult in remote areas. Ensuring that data collected

Benefits of next generation technologies in agriculture

- ***Enhanced decision-making***: AI&ML provides farmers with data-driven insights with precise strategies that improve crop and livestock management.
- ***Reduced environmental impact***: By optimizing the use of resources like water, fertilizers, and pesticides, AI&ML helps reduce pollution and promotes sustainability.
- ***Increased productivity***: Automating labour-intensive tasks and applying targeted approaches boost overall productivity and yield.
- ***Real-time data collection***: Drones can quickly cover large areas, providing real-time insights into the state of crops and soil.
- ***Cost efficiency***: Reduces the need for extensive manual labour and allows for targeted interventions that save resources.
- ***Improved decision-making***: High-quality data from drones helps farmers make informed decisions about planting, irrigation, and pest management.
- ***Early warning systems***: Timely alerts for adverse weather conditions, pest infestations, or water stress, enable farmers to take preventive measures.
- ***Higher yields***: By optimizing planting times and monitoring crop health, farmers can improve yields and reduce losses.
- ***Sustainability***: Encourages environmentally friendly practices by minimizing the overuse of water, fertilizers, and pesticides.

by IoT devices is secure and used ethically is an ongoing concern. AI&ML solutions require large, high-quality datasets for training. In regions where data collection is sparse, these models may underperform or fail to provide accurate recommendations. Reliable predictions depend on the quality and quantity of data, which can be sparse in remote areas.

Smallholder farmers in rainfed regions may face difficulties accessing these advanced technologies due to costs and lack of infrastructure. Implementing AI&ML tools requires robust internet connectivity and reliable power sources, which may not be readily available in all farming areas. Many small farmers may find it difficult to afford advanced AI tools or the connectivity needed for real-time data analysis. IoT technology and its installation can be expensive, making it difficult for small farmers to adopt. Reliable internet connectivity is crucial for IoT to function effectively, but this can be a challenge in rural and remote areas.

Farmers may be hesitant to adopt new technologies due to a lack of training, understanding, or concerns about the initial cost of investment. Farmers need adequate training and support to effective use of AI based systems, IoT devices and drones. Agricultural extensionists should also be trained to use AI-powered tools.

Future of next generation technologies in rainfed agriculture

Next generation technologies continue to evolve and seamless integration of AI & ML, IoT devices and drones will lead to more predictive systems that help farmers make informed decisions with even greater accuracy. Additionally, advancements in cost-effective IoT solutions and better connectivity options will likely increase adoption among smallholder farmers. The future of AI&ML in agriculture may see deeper integration with IoT, blockchain for supply chain transparency, and augmented reality (AR) for training and operational guidance. These technologies can play a larger role in shaping sustainable agricultural policies by providing data that supports eco-friendly practices and sustainable resource management. Machine learning models may evolve to provide customised recommendations tailored specifically to individual farms, taking into account unique conditions and farmer preferences.

SUMMARY

Next-gen technologies like AI, ML, and drones are revolutionizing rainfed agriculture by addressing challenges such as water scarcity and climate unpredictability. AI aids in weather forecasting, crop monitoring, and decision-making. ML supports data-driven yield prediction, soil and water management, and development of climate-resilient crops. Drones provide aerial surveillance, precision resource application, and damage assessments. These technologies improve efficiency, resilience, and productivity but face hurdles like high costs, training needs, and infrastructure requirements. Despite challenges, their adoption promises significant advancements in sustainability and productivity for rainfed farming.

*Corresponding author email: ravi.nakka@icar.gov.in