

FROM SKY TO SOIL: HOW DRONES AND WEATHER FORECASTING ARE TRANSFORMING INDIAN AGRICULTURE

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ABSTRACT



Indian agriculture is entering a technological era where drones, satellites, artificial intelligence (AI), remote sensing, and advanced weather forecasting support precision farming. Drones detect crop stress, pests, diseases, weeds, and nutrient deficiencies while enabling targeted input application. AI-driven, localized weather forecasts help farmers make informed decisions about sowing, irrigation, fertilization, spraying, and harvesting. Integrating drone observations with weather intelligence can improve resource-use efficiency and strengthen climate resilience. However, affordability, technical training, connectivity, regulation, and data management remain key challenges for widespread adoption.

KEYWORDS: Agricultural drones, artificial intelligence, climate-smart agriculture, crop monitoring, precision agriculture, remote sensing, weather forecasting

INTRODUCTION

Agriculture has always depended on the sky. Farmers watch clouds, temperature, rainfall and winds before deciding when to sow, irrigate, spray or harvest. Today, technology is making this traditional relationship between weather and farming far more precise.

A new agricultural ecosystem is emerging in India in which drones provide a bird's-eye view of the crop while weather forecasting provides a forward-looking view of the atmosphere. When these two sources of information are combined with satellite data, sensors, AI and farm-level observations, agriculture can become more predictive rather than reactive.

India is already moving in this direction. The Government of India is using drones, satellites, remote sensing, GIS, AI and IoT for technology-driven crop monitoring. The FASAL system, for example, uses satellite and agro-meteorological information for pre-harvest crop forecasting.

DRONES: THE FARMER'S EYE IN THE SKY

An agricultural drone is much more than a flying camera. Equipped with RGB, multispectral, thermal or other sensors, it can collect detailed information about crop and soil conditions. A drone flying over a field can reveal differences that may not be visible from the ground. Healthy plants reflect light differently from stressed plants. By analysing these differences, vegetation indices such as NDVI can help identify areas affected by water stress, nutrient deficiency or poor growth. Recent research shows that UAV-based remote sensing combined with machine learning and deep learning is becoming increasingly important for crop monitoring and disease detection. UAV imagery can provide high spatial and temporal resolution, allowing farmers and agricultural experts to examine specific portions of a field rather than treating the entire field uniformly.

FROM DETECTION TO ACTION

The real value of drones begins when information is converted into action.

For example, suppose a drone identifies a patch of crop showing signs of disease. Instead of spraying the entire field, farmers may be able to target the affected area. Similarly, drone-based mapping can identify areas requiring additional irrigation or nutrient management.

Drones can also be used for spraying fertilizers, pesticides and other agricultural inputs. India's Ministry of Agriculture has developed operational guidelines and schemes to promote agricultural drone use, including assistance for kisan drones and custom hiring centres.

The Government's Namo Drone Didi initiative is another important development. Under the programme, women Self-Help Groups are being supported to provide drone-based agricultural services to farmers. The scheme aims to create a new rural service model in which farmers can hire drone services rather than having to purchase expensive equipment themselves.

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WEATHER FORECASTING: FROM “WHAT HAPPENED?” TO “WHAT WILL HAPPEN?”

Knowing the present condition of a crop is only half the solution. Farmers also need to know what is likely to happen during the next few days. Rainfall, temperature, humidity, wind speed and solar radiation strongly influence crop growth and agricultural operations. A pesticide application immediately before heavy rain may be ineffective. Irrigating just before significant rainfall can waste water. Similarly, high winds can make drone spraying unsafe or reduce application efficiency. This is why weather forecasting is becoming an essential component of precision agriculture. The India Meteorological Department (IMD) has a long history of providing weather information for agriculture through its agricultural meteorology services. Today, these services include crop-specific advisories, weather forecasts and farmer-oriented dissemination systems. IMD's Gramin Krishi Mausam Sewa has been delivering agrometeorological advisories through multiple channels, including mobile-based services. In 2026, India introduced advanced AI-enabled forecasting products designed to provide more localized weather information. These developments include high-resolution rainfall forecasting and localized monsoon forecasting systems.

WHEN THE DRONE MEETS THE FORECAST?

The real revolution will come from integrating drone data with weather forecasts. Imagine a farmer growing cotton. A drone survey identifies early signs of water stress in one section of the field. The weather forecast predicts little rainfall during the next five days. The farmer can therefore prioritize irrigation in the affected area. Now consider another situation. A drone detects conditions associated with a potential pest or disease problem, while the weather forecast predicts high humidity and rainfall. Such weather conditions may increase the risk of disease development. An agricultural advisory system could alert the farmer to monitor the crop more closely and recommend an appropriate management strategy.

This creates a simple technological chain:

Drone observation → Weather forecast → AI analysis → Farm advisory → Farmer action

Such integration could make agricultural decisions timelier and more site-specific.

WEATHER FORECASTING AND CROP YIELD PREDICTION

Weather data are also becoming increasingly useful for estimating crop yields. Recent research published in MAUSAM has demonstrated the application of statistical, neural-network and hybrid models for weather-based crop yield forecasting. Such models can use rainfall, temperature and other weather variables to estimate yields before harvest, supporting agricultural planning and decision-making. Research in Gujarat has also explored the integration of meteorological information and machine learning for sugarcane yield prediction, showing the growing importance of combining weather science with AI in crop forecasting.

In the future, yield prediction systems may combine three major data streams:

1. *Weather data* – rainfall, temperature, humidity and wind.
2. *Remote sensing data* – satellite and drone observations.
3. *Field data* – soil moisture, crop stage, pest incidence and farmer observations.

The result could be a continuously updated digital picture of the farm.

BENEFITS FOR INDIAN FARMERS

The integration of drones and weather forecasting can offer several benefits:

1. *Better input management:* Fertilizers, pesticides and irrigation can be applied according to crop and field requirements.
2. *Early detection:* Drone imagery can identify crop stress, weeds, pests and diseases before they become widespread. Recent reviews highlight the growing use of UAVs and AI for targeted disease, weed and pest management.
3. *Water conservation:* Combining crop-stress information with rainfall forecasts can improve irrigation decisions.
4. *Reduced labour requirements:* Drone spraying can reduce the need for manual operations, particularly in large or difficult-to-access fields.

5. *Climate resilience*: Localized weather information can help farmers adjust sowing, irrigation and crop-protection decisions according to expected weather.
6. *Better decision-making*: Instead of relying only on visual observations or generalized forecasts, farmers can receive field-specific information.

CHALLENGES ON THE ROAD AHEAD

Technology alone cannot transform agriculture. Several challenges need attention.

The initial cost of drones, sensors, software and trained operators can be high. Small and marginal farmers may therefore benefit more from custom hiring centres, cooperatives and drone service providers than from individual ownership.

Training is equally important. A drone may collect thousands of images, but these images are useful only when correctly interpreted. Farmers and extension workers need training in understanding maps, crop indices and advisories.

Weather itself can also restrict drone operations. Strong winds, rain and poor visibility can interfere with flights and affect image quality and spraying performance.

Data privacy, cybersecurity, regulatory compliance, battery limitations and connectivity are additional concerns. Research on Indian agricultural drones has also identified cost, training, infrastructure and regulatory barriers as important issues for large-scale adoption.

THE FUTURE: SMART FIELDS, NOT JUST SMART MACHINES

The next step is not simply to put more drones in the sky. The objective should be to build an intelligent agricultural decision-support system. In the future, a farmer may receive a simple message such as:

“Rain is unlikely for the next five days. Drone imagery indicates moderate water stress in the eastern part of your field. Irrigate the affected area and avoid unnecessary irrigation elsewhere.”

Such a system would combine the expertise of meteorologists, agronomists, remote-sensing scientists, drone operators and AI developers. India is already developing this ecosystem. ICAR's precision-agriculture initiatives involve sensors, remote sensing from ground, drone and satellite platforms, AI and ICT for crop and soil monitoring. The integration of technology is therefore moving agriculture from uniform management to site-specific management, and from reaction to prediction.

CONCLUSION

The future of Indian agriculture will increasingly depend on the intelligent use of information. Drones can tell us what is happening in the field, while weather forecasting can tell us what may happen next. When these two technologies are connected through AI, remote sensing, sensors and agricultural expertise, farmers can make faster and more precise decisions. The transformation is not about replacing farmers with machines. It is about giving farmers better information at the right time. From the sky to the soil, the emerging message is clear that the farm of the future will not simply be mechanized—it will be informed, connected and climate-smart.

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