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Drone Technology in Indian Agriculture: Scientific Applications for Precision Farming and Sustainable Crop Management

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INTRODUCTION

Agriculture is the backbone of the Indian economy, contributing significantly to national food security, employment, and rural livelihoods. India is one of the world's largest agricultural producers, with approximately 54.8% of its total land area under agriculture and allied activities. The sector supports nearly 45% of the country's workforce and contributes about 18% of India's Gross Value Added (GVA). However, Indian agriculture faces several challenges, including climate variability, declining natural resources, labour shortages, increasing production costs, and frequent outbreaks of pests and diseases. These challenges necessitate the adoption of modern technologies that enhance productivity while conserving natural resources.

Recognising the transformative potential of drones, the Government of India introduced the Drone Rules, 2021, which simplified regulations governing drone registration and operations. These reforms, along with the Digital Sky platform, have significantly accelerated the adoption of drones across sectors, particularly agriculture. As of early 2026, India has developed a robust drone ecosystem comprising more than 38,500 registered drones, 39,890 DGCA-certified remote pilots, and 244 approved Remote Pilot Training Organisations (RPTOs).

Importance of Drone Technology in Indian Agriculture

India has more than 86% small and marginal farmers, many of whom operate fragmented landholdings. Rising labour costs, a shortage of skilled farm workers, and increasing pressure on water and fertiliser resources have highlighted the need for mechanisation and digital agriculture.

Drone technology offers several advantages over conventional farming practices: Rapid field scouting over large areas, early detection of crop stress, reduced labour dependency, accurate application of pesticides and fertilisers, lower operational costs, reduced human exposure to hazardous pesticides and improved environmental sustainability. Drones are particularly useful in difficult terrain, waterlogged paddy fields, cotton-growing regions, orchards, tea plantations, vineyards, sugarcane fields, and hilly areas where manual spraying is challenging.

Applications of Drone Technology in Precision Agriculture

1. Crop Monitoring and Field Surveillance

Crop monitoring is one of the most valuable applications of agricultural drones. Regular aerial surveys provide real-time information on crop growth and field conditions that cannot be easily observed from the ground. High-resolution drone imagery helps identify: uneven crop emergence, poor germination, nutrient deficiencies, water stress, weed infestation, lodging in cereals, storm or hail damage and crop maturity.

2. Precision Spraying of Crop Protection Chemicals

Conventional pesticide spraying often results in uneven coverage, excessive chemical use, spray drift, and increased health risks for farm workers. Drone-based spraying addresses these limitations through automated flight paths, controlled nozzle systems, and precise droplet application.

The major advantages of drone spraying include: Uniform spray coverage, targeted application, reduced pesticide wastage, lower labour

requirements, reduced crop damage, faster field operations and improved operator safety. Drone spraying is increasingly adopted in paddy, Cotton, Soybean, Maize, Sugarcane, Oilseed crops, Tea plantations, Coffee plantations, Fruit orchards and Vegetable cultivation.

3. Nutrient Management and Crop Health Assessment

Balanced nutrient management is essential for achieving higher crop productivity. Nutrient deficiencies often remain undetected until visible symptoms develop, by which time irreversible yield losses may have occurred.

Multispectral cameras mounted on drones detect subtle changes in leaf reflectance associated with nutrient deficiencies, enabling early diagnosis of deficiencies in nitrogen, Phosphorus, Potassium, Sulphur, Zinc and Iron. The resulting nutrient maps enable site-specific fertiliser application, improving fertiliser-use efficiency, reducing input costs, and minimising nutrient losses to the environment.

4. Water and Irrigation Management

Efficient water management has become a priority due to declining groundwater resources and erratic rainfall patterns. Thermal cameras mounted on drones detect differences in canopy temperature, helping identify: Water-stressed crops, Over-irrigated zones, Irrigation leakage, Blocked irrigation channels, Poor drainage and Waterlogging.

5. Pest and Disease Detection

Timely identification of pests and diseases is critical for minimising crop losses and reducing unnecessary pesticide applications. Traditional field scouting is

labour-intensive and often detects problems only after significant damage has occurred. Agricultural drones equipped with multispectral, hyperspectral, and thermal sensors can detect subtle physiological changes in plants before visible symptoms appear.

Drone imagery helps identify: Early insect infestations, fungal, bacterial, and viral diseases, chlorosis and nutrient stress, localised pest hotspots, crop lodging and storm damage

6. Yield Estimation and Crop Insurance

Reliable estimation of crop yield before harvest is essential for farm planning, marketing, crop insurance, and policy decisions. Drone-generated high-resolution imagery can estimate plant population, canopy cover, biomass, and crop vigour, which are closely related to final yield.

Table: Recent Facts and Applications of Drone Technology in Indian Agriculture

Parameter	Latest Status/Fact	Significance
Women SHGs targeted under Namu Drone Didi Scheme	15,000 SHGs	Expands drone-based custom hiring services across rural India.
Total scheme outlay	₹1,261 crore	Supports drone procurement, pilot training and entrepreneurship.
Drones already distributed to SHGs	1,094 drones (including 500 under Namu Drone Didi)	Accelerates adoption of precision agriculture technologies.
Drones approved under SMAM (2023–25)	2,122 drones	Promotes access through farmers and Custom Hiring Centres (CHCs).
Area covered under ICAR drone demonstrations	41,010 ha	Demonstrates the effectiveness of drones in precision farming.
Farmers benefited from ICAR demonstrations	4.52 lakh farmers	Enhances awareness and technology adoption nationwide.
Typical drone spraying capacity	~1 acre in 7–8 minutes	Saves labour, time and operational costs compared with manual spraying.

Source: Ministry of Agriculture & Farmers Welfare, Government of India; Press Information Bureau (2025–2026).

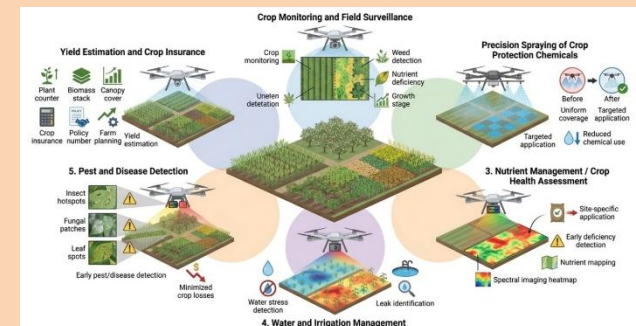


Figure: Applications of Drone Technology in Precision Agriculture

Government Initiatives Promoting Agricultural Drones

1. Drone Rules, 2021

The Drone Rules, 2021, significantly simplified drone regulations by reducing licensing requirements, simplifying approvals, and introducing the Digital Sky Platform for online registration and permissions. These reforms have accelerated drone manufacturing, training, and commercial operations across India.

2. Sub-Mission on Agricultural Mechanisation (SMAM)

Under the Sub-Mission on Agricultural Mechanisation (SMAM), financial assistance is available for the demonstration and promotion of agricultural drones. Support is provided to: Farmer Producer Organisations (FPOs), Custom Hiring Centres (CHCs), Krishi Vigyan Kendras (KVKs), ICAR institutes and state Agricultural Universities. The programme aims to encourage precision application of pesticides, fertilisers, and nano-fertilisers while making drone services accessible to small and marginal farmers.

3. Namo Drone Didi Scheme

The Namo Drone Didi Scheme is one of India's most significant initiatives to integrate drone technology into agriculture while promoting rural women's entrepreneurship. Approved as a Central Sector Scheme with an outlay of ₹1,261 crore, it aims to provide 15,000 drones to selected Women Self-Help Groups (SHGs) from 2023–24 to 2025–26. Selected SHGs receive Central Financial Assistance of 80% of the drone package cost, up to ₹8 lakh, along with pilot training and technical support.

Benefits of Drone Technology

The adoption of drones provides significant agronomic, economic, environmental, and social benefits.

1. Agronomic Benefits

Early detection of crop stress, improved pest and disease management, better nutrient-use efficiency, uniform spray application and improved crop productivity.

2. Economic Benefits

Reduced expenditure on pesticides, fertilisers, and water, lower labour costs, faster completion of field operations and higher profitability through efficient input use.

3. Environmental Benefits

Reduced pesticide drift, lower chemical residues, efficient water use, reduced greenhouse gas emissions through optimised field operations and promotion of sustainable resource management.

4. Occupational Health Benefits

Drone spraying minimises direct exposure of farmers and farm workers to hazardous pesticides, thereby reducing health risks associated with manual spraying.

Challenges in Adoption

High initial investment for drone procurement, limited awareness among farmers regarding precision agriculture, requirement for trained and DGCA-certified drone pilots, limited battery endurance for large farms, operational constraints during high winds, rainfall, or adverse weather, need for reliable maintenance and after-sales support in rural areas and limited availability of drone service providers in remote regions.

These challenges can be addressed through continued government support, capacity-building programmes, research, and expansion of custom hiring services.

CONCLUSION

Drone technology is transforming Indian agriculture by enabling data-driven, precise, and sustainable farm management. Through high-resolution crop monitoring, precision spraying, nutrient management, irrigation assessment, pest surveillance, and yield estimation, drones help farmers improve productivity while reducing production costs and conserving natural resources.

Government initiatives such as the Drone Rules, 2021, the Sub-Mission on Agricultural Mechanisation (SMAM), and the Namo Drone Didi Scheme have accelerated the adoption of agricultural drones and created new opportunities for technology-driven rural development. Although challenges related to affordability, technical expertise, and infrastructure remain, continuous advancements in digital agriculture and supportive policy interventions are expected to make drones an integral component of India's future farming systems.