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Original article

Application of Drones in Modern Agriculture

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ABSTRACT

The article is about the trending drones in agricultural sector from its various types to numerous applications. The article discusses the development of drones in Indian farm sector and various support schemes pertaining drones. Also, the limitations on wide adoption of drones were discussed. Thus the article provides a recent updates on drones in Indian agriculture on recent trends moving towards smart farming era.

Keywords: *Unmanned Aerial Vehicles; Precision agriculture; Drone spraying; Smart agriculture.*

INTRODUCTION

Drones or Unmanned Aerial Vehicles (UAVs) are revolutionizing agriculture by enhancing precision, efficiency, and labour savings across farming operations. These aerial systems enable targeted interventions in fields, informed by high-resolution imaging and spatial data, allowing for optimized input use and improved crop management. In addition to reducing the physical burden of traditional farm labour, drones facilitate real-time monitoring of crop growth, nutrient status, and field conditions, supporting timely and data-driven decision-making. Their integration with geospatial technologies and autonomous systems enhances the effectiveness of mechanized operations, from land preparation to harvesting, while enabling productivity assessment and yield estimation. By combining high-throughput sensing, automation, and site-specific management, drones provide a sustainable and technologically advanced approach that improves resource efficiency, crop performance, and overall farm management, particularly in challenging and labour-intensive ecosystems.

Drones

A drone is an Unmanned Aerial Vehicle (UAV) meaning it can fly without a human pilot onboard. Instead, it is controlled either remotely by a human operator using a controller or autonomously using onboard computers and sensors. Based on flight, it may be classified as Rotor craft/fixed wing/hybrid VTOL. Based on power, it may be battery, petrol, tethered, fuel cell or solar powered. Different categories of drones include nano (upto 250 grams), micro (0.25 to 2 kg), small (2 to 25 kg), medium (25 to 150 kg) or large (150 to 500 kg).

'DRONES' are Dynamic Rotor Operated Navigation Equipments applied in various sectors including defence, surveying, agriculture, logistics, photography, videography etc. Some of the latest thrust areas of drone developments include

- Beyond Visual Line of Sight (BVLOS) operations
- Drone systems: Anti-drone systems and Swarm technology
- Renewable energy applications: Solar and Fuel cell powered drones
- Communications: 5G/6G and satellite communications
- Battery technology: Increased endurance, energy density, life cycles and charging infrastructure

Agricultural drones were predominantly engaged in crop spraying (developed in 1980's), but recent research and developments had produced enormous farm based application for the drones apart from spraying. In recent years, drone sales in India have doubled, Government of India is encouraging drone usage in agriculture through its schemes like Production-Linked Incentive (PLI) Scheme for Drones in 2021, Namo Drone Didi, Certification Scheme for Unmanned Aircraft Systems, Agricultural Drone subsidies.

Agriculture sector uses rotorcraft of small category (25 kg in which 10 kg payload) for spraying purpose in general. Fixed wing drones may be used in surveillance purposes, as those type of drones require run-way for take-off. Other rotor crafted drones were applied on various other agricultural applications. Agricultural operations include a sequence from tillage to post harvest of crops in most cases. In this chapter, various applications of drones in each operation is discussed.

Land survey

Land surveying is often a tedious and time-consuming task, especially in unplanned or irregular land areas covered with a large number of trees, shrubs, and other vegetation. Traditional ground-based surveying requires extensive manoeuvring, making the process slow and labor-intensive. Drones equipped with spatial information systems offer an efficient solution by completing surveys through aerial navigation without the need for ground movement.

In India, the Survey of Villages Abadi and Mapping with Improvised Technology in Village Areas (SVAMITVA) scheme, launched in 2021 by the Government of India, has significantly accelerated the process of land mapping. By 2025, the programme has successfully surveyed remarkable portion of land, contributing to accurate property records and streamlined land management.

Drone based area measurement provides a rapid solution to estimate seed/fertilizer/other input requirements instantly.

Tillage

Unmanned tractors, though not yet fully commercialized, represent a key component of Agriculture 5.0, where automation and data-driven decision-making dominate farm operations. To support such autonomous tillage machinery, drones play an essential role in boundary demarcation, path planning, and field navigation using RTK-GPS and geospatial data. In addition, 3D tillage mapping and monitoring using UAV-based imaging, followed by 3D surface modelling, allows for precise assessment of soil disturbance patterns and tool performance, thereby improving the quality and efficiency of tillage operations.

Sowing and planting

Drone-based centrifugal seed broadcasting systems, including commercially available models and the TNAU-developed prototype, are actively being researched for broadcasting a variety of seeds such as paddy, pelleted millets and green manure crops. Direct paddy seed broadcasting has significant potential to be replaced by drone-based broadcasting after proper calibration and rate optimization, ensuring uniform seed distribution and minimal wastage.

Research conducted abroad has demonstrated the successful use of drone-based seedling dispersion, which shows drone's entry in mechanized nursery transplanting. Similarly, drone-assisted line sowing of seeds is under active trials, with successful and commercially viable results expected in the near future. Furthermore, drones have shown great potential on field marking for sapling placement in orchard establishment, enabling precise spacing, rapid layout planning and generating baseline geospatial data for future orchard management.

Fig.1 Drone based paddy seeding at Trichy district (TN)

Crop monitoring

Imaging drones equipped with spectral (multispectral or hyperspectral) cameras enable precise mapping of fields by capturing spatially referenced spectral data, which can be used to assess crop nutrition and monitor weed infestations (Arasan *et al.*, 2025). Additionally, drone-based imaging facilitates the identification and mapping of irrigation requirements and pest infestations, supporting informed and timely management decisions.

Fig.2 Multispectral imaging drone (DJI Phantom 4)

Fertilizer application

Drone-based centrifugal seed broadcasting systems, including both commercially available models and the TNAU-developed prototype (Patent no. 561875, IN), have been successfully demonstrated for granular urea broadcasting in rice cultivation. It is notable that the wetland ecosystem is one of the most labour-intensive areas of agriculture, where fertilizer application is particularly strenuous due to the need to carry large quantities of fertilizer while walking through moist, marshy or puddled fields.

Variable rate fertilizer application is a site-specific nutrient management strategy designed to optimize fertilizer use by addressing spatial variability in crop nutrient deficiencies (Patle et al., 2023; Sivasubramaniam *et al.,* 2025) gaining momentum in India (Rathinavel *et al.,* 2025). Drone-based variable rate fertilizer application technology, whether applying granular or liquid fertilizers, offers a faster, more efficient and less labour-intensive solution. Institutions such as TNAU - Coimbatore have been actively developing (Design No. 427801-001, IN) and validating these technologies to improve nitrogen use efficiency and reduce drudgery in wetland rice ecosystems.

Plant protection

Drone based crop spraying through battery operated rotor craft is common as discussed earlier and numerous research outcomes were found (Borikar *et al*., 2022; Yallappa *et al.,* 2024). Petrol engine operated drone sprayers (Rajesh *et al.,* 2024) are also available for remote field coverage lacking battery charging facilities. 10 kg payload drones are commonly now available at hiring to farmers at various parts of the country. Also, 12 kg, 16 kg payload drones are commercially available with higher endurance. Government is involved actively in developing Standard Operating Procedures (SOP) for the drone spraying (drone flying speed, height of drone above the crop canopy, nozzle, swath characteristics, surrounding temperature, humidity and wind speed) in agriculture through various state agricultural universities and central institutes. Also, for some of the major crops like rice, maize, cotton, groundnut etc., SOPs were issues.

Fig.3 Drone spraying in paddy field at Trichy district (TN)

Fig.4 Engine drone spraying at Coimbatore (TN)

Drone based bird scarers are a recent innovation developed to mitigate yield losses caused by bird damage in field crops. TNAU has designed (Design no. 385070-001, IN) a dual motor bird scarer drone recently.

Special applications

Drone-based pollination (Hiraguri *et al*., 2023), particularly in greenhouses, is being researched to enhance crop production under controlled environmental conditions. Drone based delivery of input and produces are helpful in reducing unnecessary manual/machine movements inside the field as well as timely supply.

Harvesting

Fruit-picking drones are tethered, powered UAVs designed to identify and harvest mature fruits efficiently. Drone-based yield monitoring for field crops enables the estimation of crop productivity by capturing high-resolution images and analyzing spatial variations in plant growth and biomass.

Limitations

Requirement of Trained Pilots: The operation of agricultural drones requires trained and certified remote pilots. Most agricultural UAVs fall under the *small category* (up to 25 kg), which mandates a

Small Class Remote Pilot Certification as per DGCA norms. This creates a dependency on skilled manpower, and the shortage of trained operators in rural areas often restricts large-scale adoption.

Thefts/scams: Agricultural thefts are common, and modern gadgets such as UAVs are more vulnerable due to their high value and resale potential (Rathinavel *et al.,* 2024). Many farmers are unfamiliar with drone construction, functioning, and maintenance, making them susceptible to scams involving spare parts, billing frauds, or unauthorized service providers.

High Initial Investment: Although the cost of UAVs has significantly reduced in recent years, the price of even a small-class agricultural drone remains high for small and marginal farmers. In addition to the purchase cost, expenses on batteries, payloads (like sprayers or sensors), software licenses, insurance, and maintenance further increase the overall financial burden.

Dependence on Imported Components: A large proportion of critical drone components such as flight controllers, sensors, GPS modules etc., are imported. This not only affects the cost and availability but also poses data security risks, as sensitive agricultural data (like crop patterns, pest and disease status, or soil quality) could be vulnerable to foreign access. Promoting indigenous manufacturing under the *"Make in India"* initiative is vital to reduce dependency and ensure data sovereignty.

Weather and Environmental Factors: UAV operations are affected by wind speed, rain, temperature, and humidity (Yallappa *et al*., 2024). In monsoon or high-temperature conditions, flight stability and battery performance are reduced, leading to inconsistent data acquisition or spraying efficiency.

CONCLUSION

Drones have emerged as a transformative technology in modern agriculture, offering rapid, precise, and labour-efficient solutions across the entire crop production cycle. From land surveying and sowing to nutrient management, crop monitoring, and plant protection, UAVs enhance decision-making through spatial data and reduce drudgery, especially in labour-intensive systems like wetland rice. Government initiatives and technological advancements in batteries, sensors, communications, and automation further accelerate their adoption. Although challenges remain—such as high investment costs, the need for trained pilots, dependence on imported components, and weather limitations—ongoing research and indigenous development are steadily addressing these gaps. With continued innovation, drones are set to play a central role in Agriculture 5.0, enabling smarter, more sustainable, and data-driven farming.

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