

APPLICATION OF DRONE TECHNOLOGY IN PLANT PROTECTION

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ABSTRACT



Unmanned aerial vehicles (UAVs), commonly known as drones, are transforming precision plant protection through early crop-stress detection, pest surveillance, and targeted pesticide application. Equipped with RGB, multispectral, and thermal sensors, drones facilitate crop monitoring, mapping, and precision spraying. Multirotor, fixed-wing, single-rotor, and hybrid vertical take-off and landing (VTOL) platforms serve diverse agricultural needs. Emerging applications include sterile insect technique (SIT), pheromone deployment, and targeted release of beneficial organisms. Despite challenges related to cost, payload, battery life, weather, and regulations, advances in artificial intelligence and autonomous navigation enhance sustainable plant protection.

KEYWORDS: Disease detection, Integrated pest management, Plant protection, Precision agriculture, Remote sensing, Unmanned aerial vehicle

INTRODUCTION

A drone, or unmanned aerial vehicle (UAV), is an aerial platform that operates without a human pilot on board. It may be remotely controlled or programmed to fly autonomously and uses aerodynamic forces to remain airborne. Although UAVs were initially developed largely for military and surveillance purposes, they are now used in many civilian fields, including agriculture, environmental monitoring, traffic observation, and weather-related applications. In crop production, drones can collect field-level information and support timely, targeted plant-protection decisions.

The development of agricultural drone technology has progressed alongside improvements in navigation, imaging, sensors, and data processing. Early UAV development during the 1910s–1930s was closely associated with military aviation. In the 1980s, Japan introduced the Yamaha R-50 for agricultural pesticide spraying, including in rice fields. During the 1990s and 2000s, GPS and remote-sensing

technologies expanded the potential for crop monitoring and mapping. In the 2010s, commercial platforms became more accessible for spraying and precision-agriculture applications. During the 2020s, AI-enabled systems increasingly supported crop-health assessment, disease surveillance, yield estimation, and automated farm operations. In India, government initiatives such as the Sub-Mission on Agricultural Mechanization (SMAM) have supported the promotion of agricultural mechanization, including drone applications.

TYPES OF UAVS USED IN PLANT PROTECTION

1. *Multirotor UAVs*

Multirotor UAVs use several rotors to generate lift and are generally manoeuvrable and comparatively straightforward to operate. They are useful for close-range observation, photography, crop scouting, and field inspection. Their ability to hover and fly at low speeds makes them suitable for detailed monitoring and targeted operations, particularly in small or fragmented fields (Fig. 1).



Fig. 1. Multirotor UAV (Yinka-Banjo and Ajayi, 2029)

2. *Fixed-Wing UAVs*

Fixed-wing UAVs have an aircraft-like structure and can cover relatively large areas efficiently. They are useful for field mapping, crop surveillance, and monitoring extensive agricultural landscapes. Compared with multirotor platforms, they generally require more space or a suitable arrangement for take-off and landing and are less suited to hovering over a specific point (Fig. 2).



Fig. 2. Fixed wing multirotor UAV (Yinka-Banjo and Ajayi, 2029)

3. *Single-Rotor UAVs*

Single-rotor UAVs resemble helicopters and use one main rotor to generate lift. Depending on their design, they may offer greater payload capacity or flight endurance than small multirotor platforms. Potential agricultural applications include carrying specialized sensors, LiDAR-based surveying, and collecting data over larger areas (Fig. 3).



Fig. 3. Single-rotor UAV (Yinka-Banjo and Ajayi, 2029)

4. *Fixed-Wing–Multirotor Hybrid UAVs*

Hybrid UAVs combine the vertical take-off and landing (VTOL) capability of multirotor systems with the forward-flight efficiency of fixed-wing aircraft. This combination can allow operation from constrained launch areas while supporting longer-distance monitoring and mapping. Such platforms may be useful where both access flexibility and broad-area coverage are required (Fig. 4).



Fig. 4. Fixed-wing multirotor hybrid UAV (Yinka-Banjo and Ajayi, 2029)

APPLICATIONS OF DRONES IN PLANT PROTECTION

1. *Disease Detection and Crop-Stress Monitoring*

Drones can survey crop fields using high-resolution RGB, multispectral, and thermal cameras. These sensors record changes in colour, spectral reflectance, and canopy temperature that may be associated with disease or other forms of crop stress. For example, reductions in chlorophyll content or changes in canopy temperature may indicate that plants are under stress. Such observations can help identify areas

that require closer field inspection and may, under suitable conditions, reveal stress before symptoms become obvious to the naked eye. However, remote-sensing indicators are not always disease-specific; nutrient deficiencies, water stress, and other factors can produce similar signals, so field validation is important.

The Normalized Difference Vegetation Index (NDVI) is one commonly used indicator of vegetation condition. It is calculated from near-infrared (NIR) and red reflectance as follows:

$$\text{NDVI} = (\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$$

where NIR is the near-infrared light reflected by vegetation and Red is the red light reflected by vegetation. Healthy vegetation typically absorbs much of the red light used in photosynthesis and reflects more near-infrared radiation. Stress can alter this pattern and reduce NDVI values. Images captured by a drone can be processed to produce spatial maps of vegetation condition, helping identify areas for targeted scouting and management. NDVI should be interpreted alongside field observations and other relevant information rather than treated as a definitive diagnosis of a particular disease.

2. Precision Pesticide Application

Agricultural drones can apply pesticides using programmed flight paths, spray nozzles, and flow-control systems. When combined with field scouting, mapping, or sensor-based detection, they can direct applications towards identified infestation zones rather than treating the entire field uniformly. This site-specific approach may reduce unnecessary chemical use, save time, and improve the timeliness of plant-protection operations. Application performance depends on factors such as droplet size, flight height, speed, wind, canopy structure, formulation, and equipment calibration.

Key potential advantages include:

- Reduced time and labour requirements for spraying.
- More controlled application when the equipment is correctly calibrated.
- Reduced direct exposure of operators to spray mixtures.
- Access to some difficult, uneven, muddy, or waterlogged field areas.
- Potential reduction in pesticide wastage through targeted application.

3. Drone-Assisted Sterile Insect Technique and Mating Disruption

The sterile insect technique (SIT) is a species-specific pest-management approach in which sterile insects—typically males—are released into a target population. When sterile males mate with wild

females, viable offspring are not produced, which can reduce pest populations over time when releases are sufficiently frequent and well coordinated. Drones may help distribute sterile insects across orchards or other target areas. Their use can improve the logistics of releases, although success depends on the target species, release timing, insect handling, and an appropriate area-wide management programme.

Drones may also be used to distribute pheromones for mating disruption. These pheromones interfere with the ability of male insects to locate females, reducing successful mating. The source text reports that, in early 2018, approximately 20,000 sterile codling moth males (*Cydia pomonella*) were released by drone in apple orchards in Central Hawke's Bay, New Zealand. This example should be checked against the original source before publication.

4. Precision Release of Natural Enemies

Drones can support biological control by releasing beneficial organisms, including parasitoids and predators, into crop fields. These natural enemies can suppress pests such as aphids, borers, and caterpillars, thereby complementing other integrated pest management (IPM) practices. GPS-guided routes and field maps can help direct releases towards selected areas, while suitable release devices can improve the distribution of beneficial organisms.

One potential application is the distribution of *Trichogramma* parasitoid eggs to help manage lepidopteran pests, including the maize stem borer (*Chilo partellus*) and rice stem borer (*Chilo suppressalis*). The suitability of a drone-based release depends on the organism, release formulation, crop structure, weather, and the need to maintain the viability and effective distribution of the biological control agent.

Potential benefits of drone-assisted biological control include:

- Reduced reliance on chemical insecticides when integrated into an effective IPM programme.
- Faster distribution over large or difficult-to-access fields.
- More targeted placement of beneficial organisms.
- Potential savings in labour and time.

5. Insect Pest Detection and Surveillance

Drones can strengthen insect-pest surveillance by providing repeated, georeferenced observations of crop condition and field-level damage. Their applications include the following:

- a. *Early detection of crop stress*: RGB, multispectral, and thermal imagery can reveal changes such as discolouration, leaf curling, or canopy-temperature differences that may be associated with pest

injury. These signals can guide field inspection, although direct confirmation is often needed to distinguish pest damage from other causes of stress.

- b. *Monitoring pest populations and damage:* High-resolution images may help identify visible pest colonies, damaged plants, feeding marks, holes, webbing, or wilting. Image-analysis tools, including AI-based approaches, may assist in estimating pest abundance or tracking damage patterns where image quality and validation are adequate.
- c. *Pheromone-trap surveillance:* Drone imagery may be used to inspect pheromone traps and, where image resolution permits, support the counting of captured insects. Repeated observations can help identify changes in pest activity and inform the timing of field scouting or control.
- d. *Hotspot mapping and targeted management:* Combining drone observations with GPS and geographic information system (GIS) tools can produce maps of suspected pest hotspots. These maps help direct ground surveys and, where justified, site-specific interventions. Targeted spraying should follow confirmation of the pest problem and consideration of economic thresholds, beneficial organisms, and applicable label directions.
- e. *Surveillance across large areas:* Drones can survey orchards and field crops such as rice, cotton, and maize more rapidly than many manual scouting methods. Repeated flights can provide a record of crop condition over time and help identify where additional inspection is needed.

ADVANTAGES OF AGRICULTURAL DRONES

- **Time efficiency:** Drones can collect field imagery and survey large areas in less time than many ground-based monitoring methods.
- **Labour savings:** They can reduce the manual effort required for some monitoring, mapping, and spraying tasks.
- **Precision management:** Georeferenced data can help target pesticides or other interventions to areas where they are needed.
- **Earlier identification of problems:** Remote sensing can highlight crop-stress patterns and guide timely field inspection.
- **Improved crop monitoring:** Repeated flights provide spatial information that supports field-level decision-making.
- **Access to challenging terrain:** Drones may be useful in muddy, uneven, waterlogged, or otherwise difficult-to-access fields.

- **Potential reduction in chemical overuse:** Targeted application may reduce unnecessary pesticide use when supported by reliable diagnosis and appropriate calibration.
- **Support for digital agriculture:** Integration with GPS, sensors, GIS, and AI-based image analysis can improve the use of crop-monitoring information.

LIMITATIONS AND CHALLENGES

- **High initial cost:** Drones, sensors, spraying systems, and data-processing tools may be expensive, particularly for small-scale farmers.
- **Training and technical skills:** Operators need appropriate training in flight planning, equipment handling, data interpretation, and safe application practices.
- **Limited battery endurance:** Flight duration is constrained by battery capacity, payload, and operating conditions; recharging or battery replacement may interrupt work.
- **Weather sensitivity:** Wind, rain, and extreme temperatures can affect flight safety, image quality, and spray deposition.
- **Maintenance and software:** Equipment upkeep, repairs, calibration, and software updates add to operating costs.
- **Regulatory requirements:** Drone operations and agricultural spraying must comply with applicable aviation, pesticide-use, and other relevant rules.
- **Payload constraints:** Smaller platforms have limited capacity for spray mixtures, sensors, and other equipment, which may restrict operational coverage.

FUTURE PROSPECTS

Further progress in artificial intelligence, machine learning, sensor miniaturization, autonomous navigation, and data integration is likely to expand the role of drones in plant protection. Automated image analysis may help identify crop-stress patterns and prioritise scouting, while improved navigation and coordinated or swarm operations could increase monitoring efficiency. Advances in batteries, payload design, and spray-control systems may also improve operational performance. For these technologies to deliver reliable benefits, their use should be supported by field validation, operator training, economic assessment, and compliance with relevant regulations. Shared-service models, custom-hiring centres, and suitable support programmes may help make drone services more accessible to farmers.

CONCLUSION

Drone technology is creating new opportunities for plant protection through crop-stress monitoring, pest and disease surveillance, precision pesticide application, and the targeted release of sterile insects and natural enemies. Sensors, NDVI-based mapping, GPS, GIS, and AI-assisted image analysis can support more timely and site-specific decisions, potentially reducing labour demands and unnecessary chemical applications. Nevertheless, drones do not replace field scouting or expert diagnosis, and their effectiveness depends on suitable equipment, validated data, correct operation, and integration with broader integrated pest management practices. High costs, limited battery life and payload, weather constraints, technical requirements, and regulation remain important barriers. Training, supportive policies, and accessible service models will be important for wider adoption. Used appropriately, drones can contribute to more efficient and sustainable plant protection.

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