AgriScope
Monthly e-Magazine on Agriculture and Interdisciplinary Sciences
Visit at us: www.agriscope.in
Email at us: agri4scope@gmail.com

What Drones Are Teaching Us About Insect Pests in Crop Fields

Kamal Yadav*, Ajay Kumar Yadav, Tejpal Yadav, Landge Amol Dadasaheb

Research Scholar, Department of Entomology, School of Agricultural Sciences (SAS), Nagaland University, Nagaland, India.

*Corresponding Author Mail ID: - kamalyadav9292@gmail.com

Article ID: 21008

Abstract

Drones are reshaping pest detection and management by offering rapid, high-resolution imaging, multispectral and thermal sensing, automated trapping and precision spraying. These tools reveal pest hotspots, early damage and microclimate conditions driving outbreaks. With machine learning and cloud analytics, drone imagery becomes actionable risk maps that guide targeted interventions. This review summarises advances in platforms, sensors, data processing, and practical applications in surveillance and control, including developments in India. It also highlights the benefits, limitations, and priorities for scaling drone-enabled pest management in smallholder and commercial systems, showing that drones accelerate detection, support site-specific control, and integrate well with precision agriculture.

Introduction

Agricultural pest management has long depended on field scouting and reactive spraying, which often miss early and patchy infestations and limit subfield prioritization. Unmanned aerial vehicles (UAVs), commonly referred to as drones, now provide fast, repeatable and high-resolution coverage of large areas at far lower cost than manned aircraft or intensive ground surveys (Alsadik *et al.,* 2024; Guebsi *et al.,* 2024).

Equipped with RGB, multispectral, hyperspectral and thermal sensors, drones can capture early stress signals and damage patterns associated with insect feeding or vector-borne diseases. Advances in machine learning and deep learning have enabled near-real-time conversion of UAV imagery into pest hotspot and risk maps (*Zhu et al., 2024*), supporting threshold-based and site-specific interventions rather than blanket pesticide applications. These advantages have been widely reported across diverse crops and pest systems (*Guebsi et al., 2024*).

Beyond detection, drones also support active pest control. Experimental and commercial trials demonstrate their ability to spray liquids or granules, deploy pheromone formulations and release biological control agents with high spatial precision (*Subramanian, 2021; Talaeizadeh et al., 2025*). In India, the development of standard operating procedures (SOPs) and regulatory guidelines has further supported the safe adoption of agricultural spraying drones.

Drone Platforms and Sensors for Pest Work

Agricultural pest management primarily employs two types of UAV platforms: multirotor drones and fixed-wing drones. Multirotor drones provide stable hovering, fine waypoint control and high positional accuracy, making them suitable for detailed imaging and targeted spraying. Fixed-wing drones, in contrast, offer longer endurance and are better suited for surveying large agricultural landscapes (*Guebsi et al., 2024*).

RGB Cameras

High-resolution RGB imagery is widely used for visual scouting, damage assessment and the generation of orthomosaics and three-dimensional canopy models. When combined with expert rules or convolutional neural networks, RGB imagery can detect defoliation, discolouration, and canopy gaps associated with insect pest damage (*Zhu et al., 2024*).

Multispectral Sensors

Multispectral sensors capture reflectance in visible and near-infrared bands, enabling the calculation of vegetation indices such as NDVI and red-edge indices. Pest feeding and early disease symptoms often produce characteristic spectral changes that can be detected before visible damage appears (*Alsadik et al., 2024*).

Thermal Cameras

Thermal sensors identify canopy temperature anomalies caused by altered transpiration and physiological stress due to insect or pathogen attack. When combined with multispectral data, thermal imaging helps distinguish pest-induced stress from water or nutrient stress (*Alsadik et al., 2024*).

Hyperspectral Sensors

Hyperspectral imaging provides fine spectral resolution, allowing detection of subtle biochemical changes associated with pest or pathogen infestation. Although UAV-mounted hyperspectral sensors remain costly and operationally complex, they are increasingly used in research for early pest detection (*Guebsi et al., 2024*).

Light Detection and Ranging (LiDAR)

LiDAR systems capture detailed information on canopy height and structure. Changes in canopy architecture caused by lodging, defoliation or heavy herbivory can enhance pest detection models when combined with optical data (*Guebsi et al., 2024*).

Onboard Traps, Collectors and Acoustic Sensors

Innovative UAV payloads such as automated insect traps, sticky cards and acoustic sensors enable direct insect sampling and wingbeat-based species identification. These tools complement remote sensing and are particularly useful in inaccessible or hazardous locations (*Subramanian, 2021*).

Spraying and Dispensing Systems

Agricultural spraying drones are equipped with tanks, pumps and atomizers that enable low-volume, controlled pesticide application. Reviews highlight their ability to improve deposition efficiency while reducing operator exposure, provided that droplet size, flight height and wind conditions are carefully managed (*Talaeizadeh et al., 2025*). UAVs are also being tested for deploying pheromone dispensers and emulsions for mating disruption (*Subramanian, 2021*).

Practical Applications in Pest Management

Early Detection and Hotspot Mapping

Drones can detect subtle canopy changes associated with early pest infestation, particularly for pests with aggregated or patchy distributions such as defoliators, borers and sap feeders. Hotspot maps derived from UAV imagery guide focused ground scouting and targeted treatments, reducing labour and chemical inputs (*Alsadik et al., 2024; Guebsi et al., 2024; Zhu et al., 2024*).

Targeted Pesticide Application and Volume Reduction

Once pest hotspots are identified, UAV sprayers can selectively treat affected areas rather than entire fields. Field demonstrations in India show that this approach can significantly reduce pesticide volume, application time and farmer exposure when SOPs are followed (*Talaeizadeh et al., 2025*).

Pheromone and Mating Disruption Delivery

Drones offer an efficient means of applying pheromone formulations in orchards and large fields, where manual placement is challenging. Studies indicate that UAV-based pheromone delivery can effectively disrupt mating while minimizing chemical use, making it particularly suitable for organic and low-input systems (*Subramanian, 2021*).

Biological Control Agent Release and Habitat Management

UAVs have been tested for releasing sterile insects, parasitoids and entomopathogenic fungi directly over pest-infested zones. Although still limited in scale, these trials demonstrate strong potential for enhancing biological control and supporting integrated pest management (IPM) programs (*Subramanian, 2021*).

Rapid Damage Assessment after Outbreaks

Following pest outbreaks, extreme weather events or invasions such as locusts and fall armyworm, drones enable rapid damage assessment and monitoring of control operations. Their effectiveness in fast-response surveys has been documented across regions (*Guebsi et al., 2024*).

Case Studies and Demonstrations

Drone-Enabled Monitoring of Defoliators

Field trials show that UAV imagery can reliably detect defoliation patterns caused by armyworms and other chewing pests. Rapid mapping supports spot treatments and reduces whole-field spraying, lowering chemical use and labour requirements (*Alsadik et al., 2024; Guebsi et al., 2024; Zhu et al., 2024*).

UAV-Based Pheromone Delivery in Speciality Crops

Research in speciality crops such as berries demonstrates that drones can successfully apply pheromone emulsions for mating disruption where ground methods are impractical. Results confirm UAVs as a viable complement to manual dispensers (*Subramanian, 2021*).

Limitations, Challenges and Risks

Sensor and Model Limitations

Some pests, particularly root feeders or early internal feeders, do not produce detectable canopy signatures. Separating pest-induced stress from nutrient or water stress requires multisensor data and extensive ground validation, and model transferability across regions remains a challenge (*Alsadik et al., 2024; Zhu et al., 2024*).

Operational Constraints

Battery life, payload capacity and weather conditions limit UAV operations, especially for spraying missions. Spray drift and off-target deposition remain concerns, making adherence to operational guidelines critical (*Talaeizadeh et al., 2025*).

Regulatory, Safety and Social Issues

Drone use is governed by aviation and agricultural regulations, and operations near populated areas raise safety and privacy concerns. High initial costs and training requirements pose barriers for smallholders, although the Indian government pilots and SOPs are improving adoption and confidence (*Subramanian, 2021*).

Ecological and Resistance Risks

Although targeted spraying reduces overall chemical use, improper application may still harm non-target organisms. Overreliance on drone-based chemical control without IPM integration could contribute to resistance development, emphasizing the need for monitoring and diversified control strategies (*Subramanian, 2021*).

Conclusion

Drones demonstrate that insect pest management can be more spatially precise, timely and data-driven than conventional approaches. By revealing hidden damage patterns and enabling targeted interventions such as spot spraying and aerial pheromone delivery, UAVs reduce chemical inputs and improve control efficiency. Continued investment in validated detection methods, operator training, regulatory clarity and service delivery models will be essential. When embedded within IPM and extension systems, drone technologies have strong potential to enhance sustainable pest management across both smallholder and commercial agriculture.

References

1. Alsadik, B., Ellsäßer, F. J., Awawdeh, M., Al-Rawabdeh, A., Almahasneh, L., Oude Elberink, S., Abuhamoor, D., & Al Asmar, Y. (2024). *Remote sensing technologies using UAVs for pest and disease monitoring: A review centered on date palm trees*. *Remote Sensing, 16*(23), 4371. https://doi.org/10.3390/rs16234371
2. Guebsi, R., Mami, S., & Chokmani, K. (2024). *Drones in precision agriculture: A comprehensive review of applications, technologies, and challenges*. *Drones, 8*(11), 686. https://doi.org/10.3390/drones8110686
3. Subramanian, K. S., Pazhanivelan, S., Srinivasan, G., Santhi, R., & Sathiah, N. (2021). *Drones in insect pest management*. *Frontiers in Agronomy, 3*, Article 640885. https://doi.org/10.3389/fagro.2021.640885
4. Talaeizadeh, A., Sharifi, I., Alasty, A., & Ghatrehsamani, S. (2025). *Agricultural spraying drones: A comprehensive review*. *Smart Agricultural Technology, 12*, Article 101519. https://doi.org/10.1016/j.atech.2025.101519
5. Zhu, H., Lin, C., Liu, G., Wang, D., Qin, S., Li, A., Xu, J.-L., & He, Y. (2024). *Intelligent agriculture: Deep learning in UAV-based remote sensing imagery for crop diseases and pests detection*. *Frontiers in Plant Science, 15*, 1435016. https://doi.org/10.3389/fpls.2024.1435016