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Agricultural drones in integrated farming system: A new horizon

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Abstract

Agricultural drones are redefining modern farming by integrating advanced aerial technologies with precision agriculture practices. As a pivotal component of integrated farming systems, drones also known as Unmanned Aerial Vehicles (UAVs) offer multifaceted applications across various stages of agricultural production. From land surveying and crop monitoring to targeted agrochemical spraying and real-time pest and disease detection, drones enhance efficiency, accuracy, and sustainability in farming operations. Recent advancements in sensor technology, artificial intelligence, and data analytics have enabled drones to detect crop stress, monitor livestock behaviour, and support decision-making processes with high-resolution spatial data. These technologies help optimize resource use, minimize environmental impacts, and reduce labour dependency. In livestock systems, drones enable remote tracking, welfare assessment, and pasture management. Moreover, drone-based spraying systems significantly reduce chemical drift and enhance operator safety. Despite numerous benefits, challenges such as high initial costs, regulatory hurdles, limited battery life, and the need for technical expertise hinder widespread adoption, particularly among smallholder farmers. However, with continued innovation and supportive policies, agricultural drones are poised to become essential tools for sustainable and climate-smart agriculture. This review highlights the current applications, benefits, challenges, and future prospects of drone technology within integrated farming systems, presenting it as a transformative tool for the next generation of agriculture.

Keywords: Agricultural drones, precision agriculture, integrated farming systems, crop monitoring, sustainable agriculture

1. Introduction

Integrated Farming Systems (IFS) represent a holistic approach to agriculture, combining crop cultivation with livestock, aquaculture, agroforestry, and other enterprises to optimize resource use and enhance farm sustainability. As the global demand for food increases amidst challenges like climate change, land degradation, and dwindling natural resources, IFS offers a resilient and efficient model for ensuring food security while maintaining environmental balance (Pretty *et al.*, 2012)^[19]. However, the success of IFS largely depends on timely decision-making, efficient monitoring, and precise management of diverse farming components. This is where digital innovations, particularly agricultural drones, are emerging as transformative tools.

Agricultural drones, or Unmanned Aerial Vehicles (UAVs), are becoming increasingly popular due to their ability to provide rapid, high-resolution data for farm management. Unlike traditional practices that rely on labour-intensive ground surveys or delayed satellite imagery, drones offer real-time, cost-effective aerial monitoring, making them ideal for dynamic farm environments. From field mapping and soil assessment to pest monitoring and chemical spraying, drones serve as multi-functional devices that enhance precision agriculture practices (Boursianis *et al.*, 2022)^[4].

The integration of drone technology into IFS marks a new horizon in agricultural innovation. Their utility spans across various farm operations conducting topographical surveys, identifying crop stress, delivering variable-rate agrochemicals, monitoring livestock, and even automating complex farm tasks. For instance, multispectral and thermal imaging sensors mounted on drones enable farmers to detect early signs of water stress or disease, which allows for targeted intervention, reducing input costs and environmental impact (Cancela, *et al.*, 2019)^[5]. Likewise, GPS-enabled drones facilitate precise field demarcation and planning, especially in diverse and

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spatially complex farming systems.

Despite these promising developments, the adoption of drones in integrated farming is still in its nascent stage in many regions, primarily due to high initial investment costs, lack of technical expertise, and regulatory constraints. Nonetheless, recent policy shifts and declining hardware costs are improving accessibility. As such, a systematic review of current drone applications in IFS is essential to understand their potential, limitations, and future prospects.

This paper aims to review and synthesize the existing literature on the role of agricultural drones in integrated farming systems, focusing on key aspects such as farm planning, crop health monitoring, agrochemical spraying, pest and disease control, livestock management, and precision farming. By highlighting technological capabilities, real-world applications, and research gaps, this review underscores how drones are reshaping modern agriculture toward greater efficiency, sustainability, and resilience.

2. Preparation for Crop Monitoring and Stress Detection

Effective crop monitoring and stress detection in farming begins with careful planning and system setup. Preparation involves the installation of appropriate IoT devices, such as multispectral cameras, thermal sensors, and soil moisture probes, which are essential for capturing real-time field data. Selecting suitable data collection intervals and defining stress indicators such as changes in leaf colour, temperature, or moisture levels is crucial for meaningful analysis. Additionally, geo-referencing and mapping of fields using GPS technology ensure spatial accuracy in monitoring. Before deploying machine learning algorithms, historical crop data, weather records, and previous stress patterns must be gathered and pre-processed. These datasets help train models to recognize anomalies and predict potential threats. Calibration of sensors and synchronization with cloud platforms is also necessary to facilitate seamless data flow. Overall, a well-prepared system sets the foundation for timely detection of crop stress, enabling proactive intervention and better crop health management.

3. Crop Monitoring and Stress Detection

Crop monitoring is a critical component of precision agriculture, and drones have emerged as a game-changing tool in this domain. Equipped with advanced sensors such as multispectral, hyperspectral, thermal, and near-infrared (NIR) cameras, agricultural drones enable farmers to remotely assess crop health, detect early signs of stress, and take timely action to mitigate potential losses. Unlike traditional scouting, which is time-consuming and limited in spatial coverage, drone-based remote sensing provides a bird's-eye view of the entire field, allowing for continuous, large-scale monitoring with high temporal and spatial resolution.

One of the most widely used analytical tools in drone-assisted crop monitoring is the Normalized Difference Vegetation Index (NDVI). NDVI is calculated using reflectance data from the red and NIR bands to evaluate photosynthetic activity in plants. High NDVI values indicate healthy, actively growing vegetation, while low values signal poor health due to stress factors such as nutrient deficiency, drought, disease, or pest attacks (Abbas *et al.*, 2023) ^[1]. These NDVI maps help farmers identify affected zones within the field, enabling them to implement site-specific management strategies, such as targeted fertilization, irrigation adjustments, or pest control interventions. Thermal imaging sensors on drones can detect variations in canopy temperature, a useful proxy for water stress. Plants

experiencing water shortage tend to have higher canopy temperatures due to reduced transpiration. Early detection of such stress allows for efficient water resource allocation, which is vital in regions facing water scarcity. Similarly, multispectral data can highlight chlorophyll content, plant vigor, and biomass accumulation, offering deeper insights into crop development and potential yield forecasting.

Another advantage of drone-enabled crop monitoring is its ability to track the spread of diseases and pest infestations. By identifying unusual patterns or color changes in the crop canopy, drones can alert farmers to the onset of problems before they become visible to the naked eye. This early detection facilitates timely remedial actions and reduces the need for blanket chemical treatments, aligning with environmentally sustainable practices.

4. Drone-Assisted Spraying of Agrochemicals

Drone-assisted spraying of agrochemicals has rapidly evolved into a transformative practice in modern agriculture. Unlike conventional spraying methods involving tractor-mounted boom sprayers or manual labor, drones offer precision, efficiency, and reduced environmental impact. Unmanned Aerial Vehicles (UAVs), fitted with atomizers or rotary nozzles and controlled via GPS-based software, enable targeted application of pesticides, herbicides, and fertilizers minimizing chemical drift, optimizing input use, and ensuring coverage uniformity across diverse terrains.

The primary advantage of drone-based spraying lies in precision targeting. Traditional methods often result in excessive application, runoff, and contamination of non-target areas such as water bodies or neighbouring ecosystems. In contrast, drones utilize pre-programmed flight paths and real-time field data (NDVI, thermal imaging) to selectively treat affected zones, drastically cutting down on chemical use. According to Huang *et al.* (2009) ^[13], drone spraying reduces pesticide use by up to 30% and water consumption by over 90%, compared to traditional sprayers.

Another major benefit is operator safety. Manual spraying exposes workers to hazardous chemicals, especially under windy or uneven field conditions. Drones mitigate this risk by enabling remote operation, thus aligning with occupational health and safety standards in agriculture (Wang *et al.*, 2021) ^[23]. Additionally, drone sprayers are ideal for hard-to-reach or steep terrains where ground equipment cannot easily maneuver, such as terraced hillsides in tea or grape plantations.

Drone models such as DJI Agras, XAG V40, and Krishi Rakshak are specifically designed for agricultural spraying. These drones typically feature payload capacities of 10–30 liters and come equipped with radar sensors for obstacle avoidance and terrain following. Autonomous flight systems allow drones to adapt their spraying intensity and height based on crop canopy density and wind conditions ensuring uniform deposition and minimizing off-target drift (Chen *et al.*, 2021) ^[7].

Integration with GIS and field mapping software further enhances precision. Using prescription maps, farmers can calibrate spray volumes based on vegetation indices or pest severity levels. Some advanced systems now employ AI algorithms to detect weeds and diseases mid-flight, adjusting their spraying protocols dynamically.

However, challenges remain in the widespread adoption of drone spraying. Regulatory restrictions regarding UAV operation, especially near populated or sensitive zones, remain a significant barrier in many countries. Battery limitations and payload capacity also restrict flight time and coverage area.

Nonetheless, with growing investment and research into drone technologies, hybrid power systems and swarm-based drone spraying are being explored to overcome these limitations (FAO, 2018)^[9].

Table 1: Performance Characteristics of Agricultural Drones

Drone Model	Payload Capacity (kg)	Flight Time (minutes)	Coverage Area per Flight (ha)	Sensor Types	Applications
DJI Agras MG-1	10	20-30	4-6	Multispectral, RGB, Thermal	Crop spraying, precision application
Parrot Anafi USA	0.5	32	1	Multispectral, RGB	Crop monitoring, pest detection
SenseFlyeBee SQ	1.5	55	120-150	Multispectral, RGB, LiDAR	Field surveying, crop health monitoring
Quantum Systems Trinity F90+	5	90	400	Multispectral, RGB, Thermal	Large-area mapping, field inspection
Delair UX11	1.3	100	100-200	RGB, LiDAR, Hyperspectral	High-resolution mapping, precision farming
AgEagle RX-60	1.5	30	2-4	Multispectral, RGB	Crop monitoring, irrigation management

5. Pest and Disease Management Using Drones

Drones are increasingly playing a pivotal role in pest and disease surveillance and management within Integrated Farming Systems (IFS). By combining real-time aerial monitoring with remote sensing technologies, Unmanned Aerial Vehicles (UAVs) enable early detection of pest infestations and disease outbreaks, which is crucial for timely intervention and sustainable crop protection.

One of the key innovations is the use of multispectral and hyperspectral sensors, which capture data beyond the visible spectrum. These sensors can detect subtle changes in plant physiology, such as variations in chlorophyll content or canopy temperature early indicators of biotic stress caused by pests or pathogens (Abd El-Ghany *et al.*, 2020)^[2]. Normalized Difference Vegetation Index (NDVI), Photochemical Reflectance Index (PRI), and Disease Water Stress Index (DWSI) maps are generated from drone-acquired images to identify hotspots of infestation or infection, enabling site-specific treatment.

Machine learning and artificial intelligence (AI) are being integrated with drone-collected imagery to automate pest and disease identification. Algorithms trained on large datasets can differentiate between pest damage, nutrient deficiency, and mechanical injury with high accuracy. For instance, Choi, Y. (2023)^[8] developed a convolutional neural network (CNN)-based drone system that could identify rice blast disease with over 95% accuracy in field conditions.

Drones also play a proactive role in monitoring pest migration and population dynamics. By flying predetermined routes at scheduled intervals, drones capture time-series data that help forecast pest outbreaks. This temporal analysis is valuable for decision-making in integrated pest management (IPM) programs. For example, detecting early symptoms of locust swarms or fall armyworm infestations can guide targeted pesticide application or bio-control interventions (FAO, 2020)^[10].

Moreover, drones can assist in biological control deployment. UAVs are being tested to release beneficial insects, such as *Trichogramma* spp., into infested areas. This approach offers an eco-friendly alternative to chemical pesticides and is particularly useful in inaccessible terrains. Martel *et al.*, (2021)^[18] demonstrated that drone-based parasitoid release in maize fields resulted in a significant reduction of stem borer populations. Integration with geographic information systems (GIS) enables farmers to correlate pest hotspots with landscape features such as water bodies, wind corridors, or crop rotation patterns. This

spatial insight is critical for understanding pest behavior and planning long-term control strategies.

Despite the promise, challenges persist in drone-based pest and disease management. Issues such as sensor calibration, flight time limitations, and variable lighting conditions can affect image quality and accuracy. Moreover, regulatory frameworks governing drone flights and data privacy are still evolving in many countries, impeding large-scale adoption.

Nonetheless, continuous advancements in sensor technology, AI integration, and regulatory support are rapidly improving the utility of drones in pest and disease control. As part of a broader digital agriculture framework, UAVs are becoming indispensable for ensuring crop health and resilience, particularly under the stress of climate change and increasing pest pressures.

6. Livestock Monitoring and Management Using Drones

The integration of drones into livestock management within Integrated Farming Systems (IFS) offers unprecedented opportunities for improving animal health, welfare, and productivity. Traditionally, managing large herds or flocks across expansive or difficult terrain has posed logistical challenges. With the advent of drone technology, farmers can now monitor, track, and manage livestock remotely with greater precision and efficiency.

Aerial Surveillance and Herd Monitoring

Drones equipped with high-resolution RGB and thermal cameras enable real-time surveillance of livestock, allowing for efficient tracking of animal movement, behavior, and location. In open grazing systems, drones can quickly identify stragglers or missing animals, reducing the time and labor required for manual checking. Thermal imaging is particularly useful in detecting livestock in dense vegetation or at night, enhancing security and reducing livestock losses due to theft or predators (Anderson & Gaston, 2013)^[3].

Health and Welfare Assessment

Thermal cameras mounted on drones can identify individuals with elevated body temperatures an early sign of illness or infection. This non-invasive method of health surveillance reduces stress on animals compared to physical handling. For example, studies by Chapa *et al.*, (2020)^[6] showed that UAV-based thermal imaging could detect mastitis in dairy cows by identifying abnormal temperature patterns in udders.

Pasture Assessment and Grazing Management

Drones also aid in assessing pasture conditions and planning rotational grazing. By generating Normalized Difference Vegetation Index (NDVI) maps, drones can help determine forage availability and quality. This allows farmers to adjust grazing intensity, ensuring optimal use of pasture resources and preventing overgrazing (Koh & Wich, 2012)^[15]. Drone data can also be used to monitor water points and shade availability, critical factors in animal welfare and heat stress mitigation.

Automated Behavior Monitoring

Advanced drone systems, combined with artificial intelligence, are now capable of analyzing livestock behavior patterns such as lying, walking, feeding, and aggressive interactions. This behavioral data is invaluable in early disease detection, estrus detection in breeding programs, and identifying welfare issues (Walter *et al.*, 2017)^[22]. Drone-based behavioral studies have shown high accuracy in detecting abnormal movement patterns associated with foot-and-mouth disease and lameness.

Emergency Response and Calving Surveillance

In remote or mountainous grazing areas, drones are a valuable tool for locating and assisting animals in distress. For instance, during extreme weather events or calving periods, drones can locate birthing animals, assess conditions, and guide human intervention when needed. This minimizes mortality rates and enhances reproductive efficiency.

Limitations and Future Outlook

While promising, challenges such as limited flight times, weather dependency, and data interpretation constraints persist. Furthermore, livestock may exhibit initial stress responses to drone noise or proximity, although habituation generally occurs over time. Regulatory limitations on UAV use over inhabited areas or near airports also need to be navigated.

As drone technology continues to advance with longer battery life, quieter rotors, and improved AI, its application in livestock management is expected to grow. Drones will increasingly serve as essential tools for real-time decision-making, contributing to sustainable and ethical livestock production.

7. Precision Agriculture and Data-Driven Decision-Making Using Drones

Precision agriculture represents a paradigm shift in farming, emphasizing the use of technology to observe, measure, and respond to inter- and intra-field variability in crops. Drones, or Unmanned Aerial Vehicles (UAVs), have emerged as one of the most powerful tools in this approach, offering rapid, high-resolution data collection that supports timely and site-specific decision-making. These advancements are part of a larger movement towards precision farming, where data and technology are used to optimize agricultural practices, improve yields, and reduce input costs (Sudha *et al.*, 2024)^[20]. Their integration into Integrated Farming Systems (IFS) aligns with sustainability goals, resource optimization, and improved productivity.

High-Resolution Data Acquisition

Drones equipped with RGB, multispectral, hyperspectral, and thermal cameras provide detailed data on plant health, soil conditions, and environmental stressors. Multispectral imagery enables the calculation of vegetation indices such as NDVI (Normalized Difference Vegetation Index), NDRE (Normalized Difference Red Edge), and GNDVI (Green NDVI), which are

essential for assessing plant vigor, chlorophyll content, and photosynthetic activity (Hunt *et al.*, 2005)^[14]. This data helps identify areas needing fertilizer, irrigation, or pest control, enabling precise input application.

Variable Rate Application (VRA)

By analyzing drone-derived maps, farmers can implement Variable Rate Application of inputs such as fertilizers, water, and pesticides. This technology helps apply inputs only where necessary, thereby reducing waste, input costs, and environmental contamination. For instance, drone surveys can reveal nutrient-deficient patches in a field, allowing automated ground-based equipment or UAV sprayers to apply site-specific doses (Tsouros *et al.*, 2019)^[21].

Decision Support Systems (DSS)

The integration of drone-collected data with Geographic Information Systems (GIS), Artificial Intelligence (AI), and cloud computing supports the development of advanced Decision Support Systems. These platforms can predict pest outbreaks, recommend irrigation schedules, or optimize planting patterns based on real-time weather and field data (Zhang *et al.*, 2017)^[24]. By automating data analysis and integrating it into daily farm operations, drones serve as the linchpin of smart farming.

Real-Time Monitoring and Alerts

Drones enable near-instantaneous surveillance, offering early warnings about crop anomalies such as pest infestations, fungal infections, or weed outbreaks. When integrated with IoT sensors on the ground, they can triangulate data for highly reliable alerts, improving the speed and effectiveness of responses (Boursianis *et al.*, 2022)^[4]. For example, combining drone data with in-field moisture sensors can trigger precision irrigation only where needed.

Economic and Environmental Benefits

Precision agriculture with drones reduces input costs, increases yields, and minimizes ecological footprints. It promotes sustainability by avoiding blanket pesticide or fertilizer applications. According to a 2021 study by FAO, farms that adopted drone-enabled precision agriculture reported reduction in chemical inputs and increase in yields (FAO, 2021)^[11].

Challenges and the Way Forward

Despite the benefits, the adoption of drone-based precision farming faces challenges such as high initial investment, the need for technical training, data privacy concerns, and regulatory hurdles. Additionally, integration into smallholder systems in developing regions remains limited due to economic and infrastructural constraints.

With ongoing advancements in automation, AI, and machine learning, drones will become even more capable of autonomous operation, analysis, and decision-making. These technologies, when made accessible and affordable, have the potential to revolutionize farming practices globally.

8. Challenges, Limitations, and Policy Implications in Drone-Based Agriculture

While agricultural drones offer immense potential for improving efficiency, sustainability, and productivity in Integrated Farming Systems (IFS), several challenges and limitations hinder their widespread adoption. Addressing these barriers is essential for enabling equitable access and maximizing their benefits in both developed and developing agricultural sectors.

Technical Limitations

One of the primary limitations is related to drone hardware and battery capacity. Most commercial drones used in agriculture have limited flight times, typically ranging from 20 to 40 minutes, which can restrict coverage in large farms. Payload capacity is also limited, especially in spraying drones, reducing the volume of agrochemicals that can be applied per flight (Gupta *et al.*, 2015)^[12]. Additionally, environmental factors like wind, rain, and electromagnetic interference can disrupt drone operations and data accuracy.

Data Management and Interpretation

Drones generate vast amounts of high-resolution imagery and sensor data. While this data is valuable, its management, storage, and interpretation require advanced computational tools and expertise. Many farmers, particularly smallholders, lack access to the software (e.g., GIS, AI-based decision support systems) and technical skills necessary to derive actionable insights from drone data (Kotronoulas *et al.*, 2023)^[16]. The absence of user-friendly platforms further complicates adoption.

Table 2: Summary of Limitations in Agricultural Drone Usage

Limitation	Description	Impact
Flight Time	Limited battery capacity restricts the operational time of drones	Reduces coverage area per flight, more frequent recharging needed
Payload Capacity	Limits the volume of agrochemicals or sensors that can be carried	Restricts the ability for large-scale pesticide application
Regulatory Restrictions	Limited airspace access, drone registration requirements	Increased operational costs and delays in deployment
Data Management	Large datasets require advanced software and interpretation skills	Increases data processing time and requires specialized training
Cost	High initial investment in hardware, sensors, and software	Economic barrier for smallholder farmers, especially in low-income countries

Economic Constraints

The initial cost of acquiring drones, sensors, and associated software is a major barrier. While prices have decreased in recent years, high-end agricultural drones still represent a significant investment, especially for small-scale farmers in low-income countries. The added cost of training, maintenance, insurance, and regulatory compliance can deter adoption. Although drone-as-a-service (DaaS) models are emerging, their availability remains limited in rural regions.

providers remain largely unresolved. This ambiguity can lead to reluctance in adopting drone-based technologies, especially when sensitive data is involved (Boursianis *et al.*, 2022)^[4].

Regulatory and Legal Challenges

Drone usage is tightly regulated in many countries due to safety, privacy, and airspace management concerns. Farmers must often acquire permits, licenses, and insurance to legally operate drones. Restrictions on altitude, proximity to populated areas, and no-fly zones may limit drone applications in certain locations. These regulations vary significantly across jurisdictions and are often poorly understood by farmers (Leenes *et al.*, 2017)^[17].

Policy Implications and Recommendations

To overcome these challenges, governments and agricultural organizations must formulate comprehensive policies that support drone adoption while addressing safety, affordability, and data governance. Recommendations include:

- Subsidies and credit schemes to support drone acquisition by smallholders.
- Public-private partnerships to develop and disseminate DaaS models.
- Training programs to build farmer capacity in drone operation and data interpretation.
- Harmonized regulatory frameworks that are transparent, farmer-friendly, and supportive of innovation.
- Investment in research and infrastructure to support integration with AI, IoT, and remote sensing systems.
- With supportive policies and adequate infrastructure, drones can play a transformative role in reshaping modern agriculture.

Privacy and Data Security

The use of drones for aerial surveillance raises ethical and legal concerns related to privacy and data ownership. Questions about who owns the collected data farmers, drone operators, or service

Table 3: Key Benefits of Drones in Integrated Farming Systems

Application	Benefit
Farm Survey & Land Use Planning	Accurate field mapping, terrain analysis
Crop Health Monitoring	Early detection of nutrient deficiency, pests, and disease
Pest and Disease Management	Targeted pesticide application
Livestock Monitoring	Real-time animal tracking and health monitoring
Precision Spraying	Reduced agrochemical use, better application efficiency
Data Integration for Decision Making	Improved data-driven farm management

9. Conclusion and Future Prospects

The integration of drone technology into Integrated Farming Systems (IFS) marks a transformative advancement in modern agriculture. Drones, equipped with multispectral sensors, GPS, thermal imaging, and precision spraying systems, are redefining how farmers manage land, crops, and livestock. From high-resolution field surveys and topographical mapping to real-time crop health monitoring, targeted agrochemical spraying, and pest detection, the applications of drones are both diverse and

impactful. As this review highlights, drones significantly enhance operational efficiency by reducing the time, labor, and resources required for critical agricultural tasks. Crop stress detection using vegetation indices like NDVI, along with site-specific pesticide application, supports sustainable practices by minimizing input overuse and environmental damage. Moreover, livestock management is benefitting from thermal surveillance and real-time location tracking, enabling better

animal welfare and farm security. In the broader scope of precision agriculture, drones contribute to increased yield, reduced waste, and informed decision-making—central to the goals of climate-smart and resource-efficient farming.

However, despite these advantages, several technical, economic, and policy barriers persist. Short drone flight durations, limited payload capacities, and high equipment and maintenance costs can restrict adoption, particularly among smallholder farmers. Furthermore, challenges related to data processing, privacy, and complex regulatory frameworks must be addressed for seamless integration. The lack of standardization and accessible training further complicates widespread adoption, especially in rural and resource-constrained settings.

Looking ahead, the future of agricultural drones is promising, with emerging technologies poised to enhance functionality and affordability. Integration with the Internet of Things (IoT), Artificial Intelligence (AI), and Machine Learning (ML) will automate data interpretation and enable predictive analytics for real-time decision support. Swarm drone technology, where multiple UAVs operate collaboratively, could significantly increase coverage for large-scale farming operations. Solar-powered and hybrid drones may overcome battery limitations, extending operational hours and reducing dependence on conventional energy sources.

Moreover, policy and institutional support will play a pivotal role in driving the future trajectory of drone use in agriculture. Governments must prioritize inclusive technology dissemination through subsidies, public-private partnerships, and farmer training initiatives. Open-access platforms for drone data analysis and regulatory harmonization across regions will foster greater trust and adoption.

In conclusion, agricultural drones represent a new horizon in IFS, offering scalable, sustainable, and data-driven solutions to the multifaceted challenges of 21st-century farming. By aligning technological innovation with farmer-centric policies and capacity-building measures, drones can unlock new frontiers in agricultural productivity, environmental stewardship, and rural resilience.

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