

Agricultural Drones: Transforming Farming Practices with Advanced Technology

Meet Fafolawala, Yash Mehta, Dr. Anish Vahora

Dept. of Electronics and Communication Birla Vishvakarma Mahavidyalaya Anand, India

DOI: <https://doi.org/10.51583/IJLTEMAS.2025.140400105>

Received: 30 April 2025; Accepted: 08 May 2025; Published: 18 May 2025

Abstract: The agricultural sector is experiencing a substantial transformation with the introduction of drone technology. Unmanned aerial vehicles (UAVs), commonly referred to as drones, are revolutionizing agricultural practices by enabling efficient data acquisition, crop surveillance, and resource allocation. This review paper aims to provide a comprehensive analysis of agricultural drone technology, examining their mechanisms, classifications, applications, the role of autonomous drones, and the algorithms governing their operations. The results highlight the potential of drones to enhance agricultural productivity, optimize resource utilization, and promote sustainable farming practices.

Keywords – Drones, Sensors, UAVs, precision agriculture, spraying

I. INTRODUCTION

Agriculture serves as the foundation of our nation's economy. The majority of food grains are transported from rural areas to urban centres. The agricultural sector faces numerous challenges, including increasing food demand due to population growth, climate change, and the necessity for sustainable practices. The United Nations projects that the global population will reach approximately 9.7 billion by 2050, necessitating a 70% increase in food production. Contemporary agricultural practices using traditional methods have become increasingly challenging. In this context, drone technology has emerged as a transformative force in agriculture. [1]

Drones enable farmers to collect data efficiently and accurately, facilitating informed decision-making that enhances productivity while minimizing environmental impact. Functioning as a form of remote sensing, drones provide valuable insights into crop health, soil conditions, and resource management.[2] This review examines various aspects of agricultural drones, including their underlying technology, functionalities, types, applications, and the algorithms that enhance their effectiveness.

DRONE TECHNOLOGY AND MECHANISM

The evolution of unmanned aerial vehicle (UAV) technology over the past decade has been significant, propelled by advancements in hardware, sensors, and

software. These developments have contributed to the increasing adoption of UAVs across diverse sectors, including agriculture.[3] Contemporary UAVs are equipped with sophisticated technologies that enhance their operational capabilities. They possess the capacity to function autonomously or be operated remotely, offering versatility in their application.

The integration of GPS, imaging sensors, and data processing software has rendered drones indispensable tools in contemporary agriculture.

Components of Drone Technology

Sensors: Agricultural drones come equipped with various sensors, such as RGB, multispectral, thermal cameras, LiDAR, and GPS modules, allowing them to collect a wealth of data.[1][4] **Software:** Specialized software, such as Pix4D and MATLAB, is used to analyze and interpret the raw data. The integration of machine learning and artificial intelligence algorithms further enhances the data analysis process.[4] **Frame:** Drones typically have lightweight frames made from materials like carbon fiber or plastic, ensuring both durability and reduced weight.[4] **Propellers:** Most agricultural drones utilize multiple rotors (e.g., quadcopters and hexacopters) for vertical take-off and landing, as well as hovering capabilities. The design and configuration of the propellers affect lift capacity and flight stability.[5] **Motors:** Brushless DC motors drive the propellers, providing efficient propulsion and control. The type and power of the motors determine the drone's overall performance, including speed and payload capacity.[5] **GPS Module:** GPS technology enables precise navigation, allowing drones to autonomously follow predetermined flight paths. Advanced GPS systems can achieve centimetre-level accuracy, essential for precision agriculture.[5] **RGB Cameras:** Capture high-resolution images for visual assessments of crops, helping detect health issues.[6][1] **Multispectral Cameras:** Analyze plant health and stress levels by capturing data across multiple wavelengths, identifying nutrient deficiencies and disease stress.[1][6] **LiDAR:** Measures distances and generates high-resolution 3D maps of the terrain, valuable for topographic assessments.[6] **Thermal Cameras:** Detect temperature variations to identify water stress in plants, optimizing irrigation practices. **Battery:** Most drones operate on rechargeable lithium-polymer batteries, with flight times ranging from 20 to 60 minutes, depending on weight and payload. Improvements in battery life and rapid recharge capabilities are crucial for efficient operations. [1][7]

Working Mechanism

Flight Control: Drones can be controlled either remotely by an operator or autonomously using onboard systems. Autonomous drones utilize GPS for navigation and can be programmed with specific flight paths, allowing for dynamic adjustments based on environmental factors.[8] **Data Collection:** Drones capture images and data regarding crops, soil conditions, and environmental factors during flight. This information can be used for real-time monitoring or stored for subsequent analysis.[8] **Data Processing:** The collected data is processed with specialized software to generate actionable insights. Farmers can visualize data through maps and reports, facilitating informed decision-making regarding crop performance and resource usage.[8]

TYPES OF AGRICULTURAL DRONES

There are various types of Agricultural Drones available, explained in the sub sections A through D.

Multi-Rotor

Multi-rotor drones are the simplest form of drones. They are equipped with multiple rotors, typically ranging from four to eight. Common configurations include quadcopters (four rotors), hexacopters (six rotors), and octocopters (eight rotors). These drones generally have lightweight frames made from materials like carbon fibre or plastic, enhancing their agility and durability. Multirotor drones have control over the positions from where they take photography, thereby achieving more accurate results. The downside of the multi-rotor is, less endurance and speed. Because of this, these types of drones are used for only some agricultural activities. [9]

Fixed-Wing

Fixed-wing Rotor drones use wing-like structure for their operation. The fixed wing rotor drones use plane-like wings, they require a runway or sufficient space for take-off and landing. Their aerodynamic structure enables them to cover longer distances at higher speeds, making them efficient for surveying extensive areas. Their structure comprises a rigid frame built with lightweight materials, and they incorporate GPS and provide autopilot systems. [9]

Single-Rotor Helicopter

A single Rotor helicopter drone has more advantages compared to other types of drones. For sustaining more endurance, it is fixed with the gas-controlled system. The Aerodynamic rules stress that, if any system is having larger rotor blades, then the spin will be less, and efficiency of the system will be more. Because of this, the single rotor helicopters are more efficient when compared with other kinds of drones. Since single rotor helicopters have long rotor blades, it is having more advantage in agricultural fields. [9]

Fixed-Wing Hybrid

Fixed-wing hybrid VTOL (Vertical Take-off and Landing) type of drones are a combination of the features of UAV (Unmanned Aerial Vehicle), and the ability to remain in one place that is hovering, and thereby retaining hybrid features. Because of this feature, this type of drones are able to take off from one place and are having ability to sustain over some area vertically. [9]

Table 1 Various Types Of Drones With Features And Price [9]

Types of Drones	Analysis	Purpose	Price
Multi-Rotor	Easy to control, Efficient VTOL leads to overflight VTOL, suitable for small areas, can function in restricted areas, limited flight time and payload capacity.	Used for aerial photography and video capture.	₹2.65L - ₹3.18L
Fixed-Wing	Long endurance, wide coverage, requires space for take-off, no VTOL, appropriate training is needed for operators. costly.	Ideal for mapping, channel monitoring, power inspections.	₹13.25L - ₹63.6L
Single-Rotor	Strong hover flight and VTOL, greater endurance, able to carry heavier payloads, costly.	Data transfer, LiDAR aerial scanning.	₹13.25L - ₹1.59 Cr
Fixed-Wing Hybrid	Combines VTOL with extended endurance, still under development.	Used for deliveries over specific areas.	₹13.1L- ₹1 Cr

ALGORITHM

For spray systems

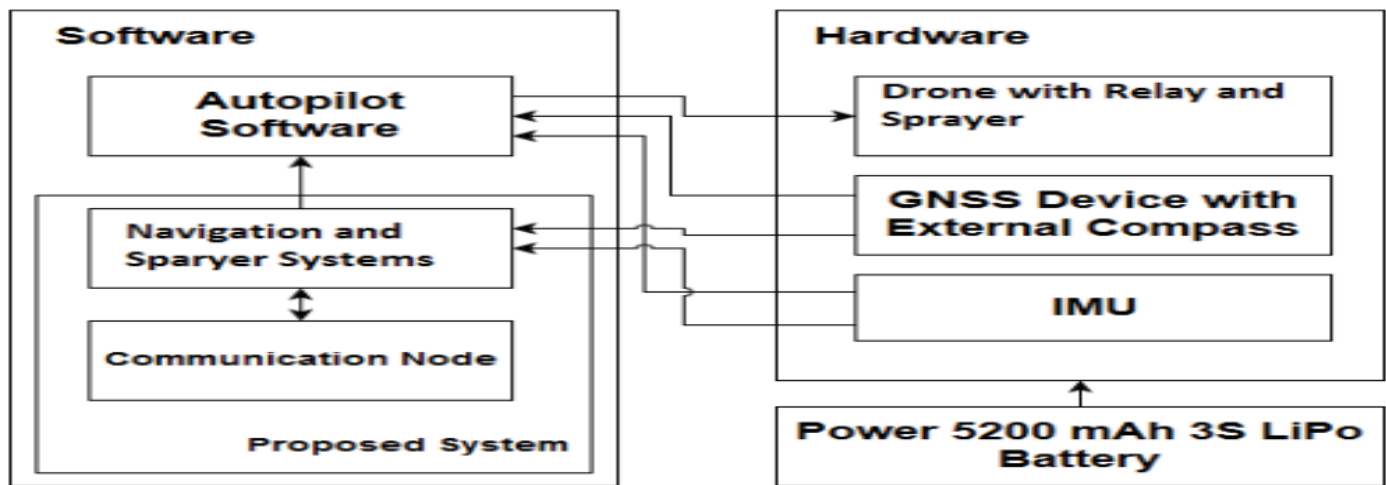


Figure 1 The system architecture of drone for sprayer pesticide

Software Component [10]

Autopilot Software: This software is crucial for the autonomous operation of the drone. It allows the drone to execute predefined missions without human intervention, such as flying over a field, maintaining altitude, and returning to a base station. The autopilot software communicates with the drone's hardware to control its movements, ensuring precise navigation and stability during flight.[10] **Navigation and Sprayer Systems:** These systems control both the movement of the drone and the spraying mechanism. The navigation system is responsible for guiding the drone over the agricultural area, calculating the optimal path for coverage while avoiding obstacles and minimizing overlap. The sprayer system ensures accurate and uniform application of fertilizers, pesticides, or water, based on the input from the autopilot software. These systems work together to maximize efficiency and precision.[10] **Communication Node:** This is responsible for exchanging data between the drone and a ground control station or remote operator. The node facilitates real-time communication, enabling remote control, monitoring, and adjustments during the drone's operation. It may also be used to receive flight commands or provide telemetry data like the drone's location, battery status, or environmental data. [10]

Hardware Component [10]

Drone with Relay and Sprayer: This is the physical drone equipped with a spraying mechanism. The relay ensures that commands from the software components are carried out by the drone. The sprayer, likely using a pump and nozzle system, is responsible for distributing the liquid onto crops. The hardware must be durable and lightweight to carry the payload of chemicals or water while maintaining flight stability.[10] **GNSS Device with External Compass:** The Global Navigation Satellite System (GNSS) device provides the drone with positioning information, allowing it to determine its precise location in real-time. This is essential for navigation and path planning, ensuring the drone covers the entire field accurately. The external compass works alongside the GNSS to provide directional orientation, helping the drone maintain a correct course, especially in areas with poor GPS signals or when precise directional control is required.[10] **IMU (Inertial Measurement Unit):** The IMU is a sensor that measures the drone's velocity, orientation, and gravitational forces using accelerometers and gyroscopes. It helps maintain the drone's stability during flight by continuously adjusting its position and orientation based on feedback from the environment. The IMU is critical for maintaining balance, particularly when flying over uneven terrain or in windy conditions.[10] **Power 5200 mAh 3S LiPo Battery:** This is the power source for the drone. A 3S LiPo battery consists of three cells, providing a nominal voltage of 11.1V. The 5200 mAh capacity determines how long the drone can operate before requiring a recharge. This battery is typically lightweight yet capable of delivering a high discharge rate, which is necessary for powering both the drone's motors and its onboard systems such as the sprayer and sensors.

Figure 2 illustrates the flow of operations for an autonomous pesticide-spraying drone system. The process starts with inputting the waypoints, which include coordinates, altitude, and speed for the drone to follow. After setting the current location as the starting point, the drone initiates take-off and flies toward the designated waypoints. The system checks if the drone has reached each waypoint and, upon arrival, activates the pesticide sprayer for 5 seconds before disabling it. This ensures a controlled and precise application of pesticides at each location.[11]

Once the drone reaches all programmed waypoints, it disables the sprayer and prepares to return to the starting point. The system confirms that all waypoints have been visited, after which the drone autonomously flies back to its initial location and lands,

completing the mission. This process automates pesticide application across a field, improving efficiency and ensuring optimal coverage, while minimizing human intervention. [11]

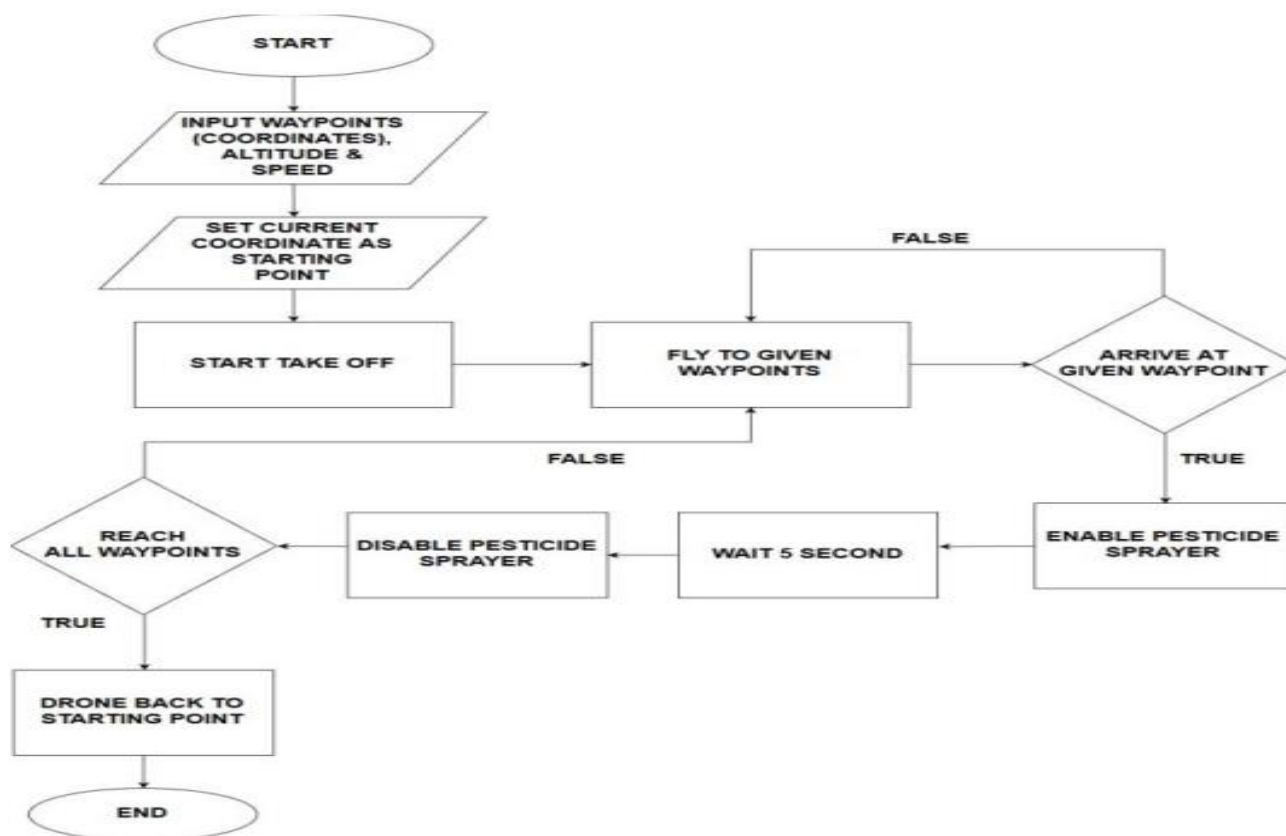


Figure 2 The flowchart of the drone for spray systems [10]

APPLICATION

The usage of drones in the agriculture sector is gaining popularity day by day because of its precession and speed of collecting the needed information.

Estimating soil condition

One of the major applications of drones are checking the condition of the soil. In the traditional approach of farming there are various steps involved in examining the soil, like visiting the ground manually with physical equipment and examining the prototype of soil for various factors, Where the drone consists of various sensors and well developed equipment for examining the soil accurately, and thereby giving correct reports.[2][12]

Fighting infections and pests

Another most important category of agriculture is the identification of infections and pests in the farming area. Agricultural drones can also help in identification of infections and pests, and the amount of inflammation can also be identified, and spraying suitable amounts of medicine on the crops which got infected, thereby reducing the human effort. [2][12]

Planting future crops

In agriculture, drones are not only used for providing the weather report or other activity reports but also physically capable to plant seeds in the soil. Recently some of the Drone manufacturing companies are experimenting over this activity, in view of providing smooth, fast and effective smart agriculture methods.[12]

Agriculture spraying

Using drones in agriculture suitable for smart farming, spraying techniques can be adopted. The sensors in the drones will collect the information from agricultural lands, and based on the necessity the fertilizers and pesticides will be sprayed on the required crops. The drones are also capable of identifying the crops which got infected, the amount of infection, and based on the amount of infection, the fertilizers will be sprayed on crops, and leaving the healthy crops without spraying the pesticides. [2][13]

Livestock monitoring

Drones are not only used in agriculture but also helpful in harvesting animals. Animals such as cows, sheep etc, if lost, then drones can be used to detect the location of these animals by using sensors and can collect the information of the location of the pet animals. Drones are also helpful in identifying wounded pet animals which are lost. [2][14]

Crop surveillance

In the process of agriculture, monitoring the health of the crops is a necessary activity. In this context, in the traditional approach, frequent visits will be given by the farmer's agricultural lands and monitors the status of the crops. But if the agricultural lands are huge, monitoring all the crops on daily basis is a very tough task for the farmers, in such cases drones are more capable of visiting all the lands and thereby monitors the crops and information can be maintained periodically. [15]

Table 2 Comparative Analysis of Drones on Best Practices [12]

Best Practices in Agriculture	Drone Types			
	Multi-Rotor	Fixed-Wing	Single-Rotor	Fixed Wing
Estimating soil condition	Good	Moderate	Good	Poor
Planting future crops	Good	Moderate	Good	Good
Fighting infections and pests	Good	Good	Moderate	Poor
Agriculture spraying	Bad	Moderate	Poor	Good
Crop surveillance	Good	Bad	Good	Poor
Livestock monitoring	Moderate	Moderate	Moderate	Good

ISSUES IN AGRICULTURAL DRONE AND ITS SOLUTION

Regularity Constraint

The regulations governing drone operations differ widely across regions, leading to confusion and inconsistent enforcement. Farmers often struggle to obtain necessary permits, navigate no-fly zones, and comply with safety regulations, which limits the effective use of drones in agriculture. Integration with Regulatory Frameworks: Advanced drone technology can incorporate real-time geofencing capabilities, allowing drones to automatically adhere to local regulations and avoid restricted areas. This technology can connect with national and regional databases to ensure compliance with current laws.[16][18]

Cost of Technology

The initial investment required for high-quality agricultural drones, including equipment and software, poses a significant barrier for small-scale farmers. Additional expenses for training, maintenance, and operation further complicate adoption. Shared Drone Services: Implementing cooperative models where farmers can share drone resources or hire drone services on a pay-per-use basis can lower individual costs while providing access to advanced technology.[16][18]

Data Privacy and Security

Collecting and managing sensitive data related to farming practices can raise concerns about data privacy and security. Farmers must be cautious about potential risks linked to data breaches or the misuse of information. Enhanced Data Encryption: Implementing robust encryption methods for data transmission and storage can safeguard sensitive agricultural data from unauthorized access.[17][19]

Maintenance and Repair Challenges

Maintaining and repairing drones can be demanding due to the technical expertise required and the availability of spare parts. This can lead to extended downtimes and reduced operational efficiency. Modular Design: Creating drones with modular components can simplify maintenance and repair processes, allowing farmers to easily replace damaged parts without needing specialized knowledge, thus reducing downtime. [17][19]

CONCLUSION

Modern farming is being revolutionized by agricultural drones, which offer solutions to pressing issues such as growing food demands, inefficient resource use, and climate fluctuations. These unmanned aerial vehicles facilitate precise soil evaluation, crop surveillance, pest control, and targeted spraying. Equipped with cutting-edge sensors, self-navigation capabilities, and machine

learning algorithms, drones boost farm productivity and environmental sustainability. Nevertheless, their widespread adoption faces obstacles, including steep prices, regulatory constraints, and complex upkeep requirements. To address these challenges, innovative approaches like drone-sharing services, geofencing for regulatory compliance, modular designs, and enhanced data security are being implemented. Anticipated advancements in artificial intelligence, battery technology, and drone autonomy promise to further enhance their efficiency and accessibility. As regulatory frameworks evolve, drones are expected to play a crucial role in ensuring global food security while promoting environmentally friendly farming methods. Achieving their full potential will require coordinated efforts among scientists, policymakers, and industry leaders.

REFERENCES

1. Designing a Model for Traffic Rule Violation at Railway Track Using Raspberry PI in Indian Context Anish Vahora, Bhargav Goradiya, Devansh Parikh, Akash Shah International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS)
2. Heartbeat Monitoring And Wireless Data Logging Using Arm Cortex A8 Anish Vahora¹, Ripal Patel², Bhargav Goradiya³, Arpan Desai International Journal on Recent and Innovation Trends in Computing and Communication
3. Kalaiselvi, P., Krishnaveni, A., Sapna, ., Singh, A., Chaurasia, J., Labanya, R., Krishnamoorthi, A., & Kumar, V. (2024). Harvesting Efficiency: The Rise of Drone Technology in Modern Agriculture. *Journal of Scientific Research and Reports*, 30(6), 191–207. <https://doi.org/10.9734/jsrr/2024/v30i62033>
4. Schirrmann, M. (2023). Advances in remote sensing technologies for assessing crop health (pp. 43–64). *burleigh dodds science*. <https://doi.org/10.19103/as.2022.0107.03>
5. Bharad, N. B., Vagadia, V. R., Dulawat, M. S., Khanpara, B. M., & Lakhani, A. L. (2024). A Comprehensive Review of Unmanned Aerial Vehicle (UAV) Sprayers Used in Modern Agriculture. *Journal of Scientific Research and Reports*, 30(10), 573–585. <https://doi.org/10.9734/jsrr/2024/v30i102483>
6. Asvadi, A., Nunes, U., Peixoto, P., & Girao, P. (2016, November 1). 3D object tracking using RGB and LIDAR data. <https://doi.org/10.1109/itsc.2016.7795718>
7. Huang, M.-Y. (2022). Development of adjustable landing struts for vertical take-off and landing vehicles. *Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering*, 237(4), 1574–1582. <https://doi.org/10.1177/09544089221119243>
8. Zovathi, O., Palffy, B., & Benedek, C. (2022). Real-time Vehicle Localization and Pose Tracking in High-Resolution 3D Maps. 1786–1790. <https://doi.org/10.23919/eusipco55093.2022.9909654>
9. Hashemi, S. R., Esmaeli, R., Aliniagerdroudbari, H., Alhadri, M., Alshammari, H., Mahajan, A., & Farhad, S. (2019, November 11). New Intelligent Battery Management System for Drones. <https://doi.org/10.1115/imece2019-10479>
10. Famili, A., Park, J.-M., Stavrou, A., & Wang, H. (2023). PILOT: High-Precision Indoor Localization for Autonomous Drones. *IEEE Transactions on Vehicular Technology*, 72(5), 6445–6459. <https://doi.org/10.1109/tvt.2022.3229628>
11. Dileep, M. R., Navaneeth, A. V., Danti, A., & Ullagaddi, S. (2020, November 26). A Study and Analysis on Various Types of Agricultural Drones and its Applications. <https://doi.org/10.1109/icrcicn50933.2020.9296195>
12. Budiharto, W., Chowanda, A., Suroso, J. S., Gunawan, A. A. S., & Irwansyah, E. (2019). A Review and Progress of Research on Autonomous Drone in Agriculture, Delivering Items and Geographical Information Systems (GIS). 2019. <https://doi.org/10.1109/wsce49000.2019.9041004>
13. Lan, C.-W., Shen, H.-J., Hsu, C.-F., Lin, H.-C., Chu, P.-J., & Wu, C.-J. (2020, November 4). Development of the Autonomous Battery Replacement System on the Unmanned Ground Vehicle for the Drone Endurance. <https://doi.org/10.1109/ifuzzy50310.2020.9297363>
14. Dutta, G., & Goswami, P. (2020). Application of drone in agriculture: A review. *International Journal of Chemical Studies*, 8(5), 181–187. <https://doi.org/10.22271/chemi.2020.v8.i5d.10529>
15. Katekar, V., & Cheruku, J. K. (2023). The Application of Drone Technology for Sustainable Agriculture in India. *Current Agriculture Research Journal*, 10(3), 352–365. <https://doi.org/10.12944/carj.10.3.19>
16. C, G., David, A., Saginala, M., & Gomathi Sankar, J. (2023). Application of Drone Technology in Agriculture (pp. 50–81). *igi global*. <https://doi.org/10.4018/978-1-6684-6413-7.ch004>
17. Sharma, S., Solanki, S., Aswal, K., Malhotra, I., & Thakur, E. (2021). Review On Application Of Drone Systems In Agriculture. 5, 40–45. <https://doi.org/10.1109/ispc53510.2021.9609383>
18. Sharma, M., & Hema, N. (2021, November 25). Comparison of Agricultural Drones and Challenges in Implementation: A Review. <https://doi.org/10.1109/icsc53193.2021.9673491>
19. Sindiramutty, S. R., Hussain, M., Murugesan, R. K., Manchuri, A. R., Tee, W. J., Jhanjhi, N. Z., Yun, K. J., Ashraf, H., & Tan, C. E. (2024). Data Security and Privacy Concerns in Drone Operations (pp. 236–290). *igi global*. <https://doi.org/10.4018/979-8-3693-0774-8.ch010>