iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IV **Month of publication:** April 2025

DOI: https://doi.org/10.22214/ijraset.2025.69150

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Drone Swarming for Precision Agriculture

Prathmesh Ashok Singh[1], Faiz Ahmed Qureshi[2], Zaid Arodiya[3]
Department of Mechanical and Mechatronics Engineering (Additive Manufacturing) Thakur College of Engineering and Technology, Mumbai, India

Abstract: ***Precision agriculture has emerged as a transformative approach in modern farming, leveraging advanced technologies to enhance efficiency and productivity. Among these innovations, Unmanned Aerial Vehicles (UAVs), commonly known as drones, have gained significant attention for their ability to streamline data gathering, crop monitoring, and on-the-spot decision-making. Outfitted with sophisticated sensors such as multispectral cameras, LiDAR, and thermal imagers, drones offer farmers a comprehensive aerial perspective of their fields. This capability allows for timely detection of crop health issues, nutrient imbalances, pest activity, and water stress. Access to such real-time insights empowers farmers to implement targeted interventions in irrigation, fertilization, and pest control—leading to better crop yields, reduced input costs, and more sustainable use of natural resources.***

Keywords: (Drone Swarming, UAV (Unmanned Aerial Vehicle, Precision Agriculture, Crop monitoring)

I. INTRODUCTION

With a growing global population and the mounting pressures of climate change, agriculture is under immense pressure to produce more food using fewer natural resources. This challenge has fueled the adoption of precision agriculture, a data-driven approach that is redefining how we manage and cultivate farmland. Central to this shift are drones—Unmanned Aerial Vehicles (UAVs)—which have rapidly evolved from niche tools into essential assets for modern farmers.

Drones are redefining the agricultural landscape by offering unparalleled access to real-time field intelligence, enabling greater accuracy, efficiency, and control in farming operations. No longer limited to hobbyists or military use, these advanced aerial platforms now play a pivotal role in automating data collection, analyzing crop conditions, and guiding critical farm decisions.

This paper explores the growing significance of drone technology in precision agriculture, examining its applications, advantages, and transformative impact. As we delve into this topic, we uncover how drones are reshaping farming practices—turning innovation into productivity and supporting a more sustainable, tech-enabled future for agriculture.

II. STRUCTURAL AND FUNCTIONAL ELEMENTS OF A DRONE

Unmanned Aerial Vehicles (UAVs), or drones, consist of various interconnected components designed to operate cohesively for efficient flight and task execution. While the specific configuration depends on the drone's purpose—be it agriculture, surveillance, or delivery—the following components form the fundamental structure and functionality of most UAVs:

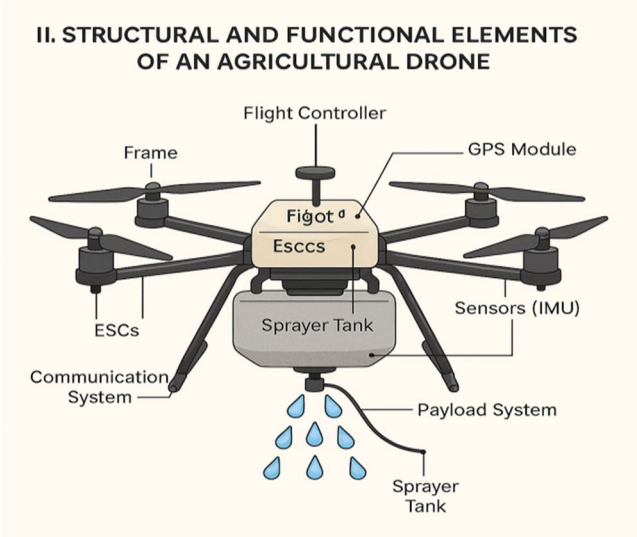


Fig 1.Agri-Drone: Key Structural Elements

©IJRASET: All Rights are Reserved

1) Frame: The frame serves as the central structure of the drone, holding all other components together. It is engineered from lightweight yet high-strength materials such as carbon fibre, aluminium alloys, or reinforced plastics. A well-designed frame ensures durability during flight while minimizing the overall weight for better efficiency.
2) Propellers: Propellers are responsible for generating thrust and lift. Their number and configuration determine the drone's stability and maneuverability. Common setups include quadcopters (4 propellers), hexacopters (6), and octocopters (8). Balanced and durable propellers are essential for smooth and vibration-free operation.
3) Motors: Brushless DC motors are typically used to drive the propellers. These motors convert electrical energy into mechanical rotation, directly influencing the lift, speed, and control of the drone. The number of motors corresponds to the number of propellers and impacts the drone's redundancy and power distribution.
4) Electronic Speed Controllers (ESCs): ESCs regulate the current flow to each motor, allowing for variable speeds and responsive maneuvering. They act as an interface between the flight controller and the motors, translating flight commands into precise motor outputs for stable and agile flight.
5) Flight Controller: Often termed the "brain" of the drone, the flight controller processes input from sensors and pilot commands. It continuously calculates and sends appropriate signals to the ESCs to maintain stability, control altitude, and manage autonomous or manual flight paths. Advanced flight controllers also support GPS integration, waypoint navigation, return-to-home functions, and obstacle avoidance.
6) Power Supply System: Drones typically use rechargeable lithium-polymer (Li-Po) batteries due to their high energy density and lightweight properties. The power system ensures uninterrupted energy flow to all electronic components. Battery management systems are integrated to monitor voltage, prevent overcharging, and maximize flight time.
7) GPS Module: The GPS unit allows for precise geolocation, autonomous navigation, and features like waypoint tracking, geofencing, and return-to-home. In agricultural drones, GPS is vital for maintaining consistent spraying routes and surveying specific coordinates.
8) Sensors (IMU, Gyroscope, Barometer, Compass):The Inertial Measurement Unit (IMU), which combines gyroscopes and accelerometers, detects orientation and motion. The barometer helps maintain altitude, while the compass ensures directional awareness. These sensors work together to stabilize the drone and respond to environmental changes.
9) Communication System: A robust communication system, including transmitters and receivers, enables real-time data exchange between the drone and the ground control station (GCS). In advanced drones, telemetry data such as altitude, battery level, and position are transmitted continuously to the operator.
10) Payload System: Depending on the drone's application, it may carry different payloads such as high-resolution cameras, multispectral sensors, thermal imaging devices, or sprayers. These are integrated with gimbals or mounts to stabilize the payload and ensure accurate performance during operations.
11) Ground Control Station (GCS): The GCS serves as the remote interface for piloting and monitoring the drone. It may be a handheld controller, a mobile device, or a laptop-based software system. Operators use it to set flight paths, control functions, and analyse data received from the drone.

By integrating these components effectively, drones are capable of executing complex tasks with precision, stability, and reliability, transforming various sectors—including agriculture—through smart automation and real-time data-driven insights.

III. REVOLUTIONIZING AGRICULTURE WITH DIGITAL AND DRONE TECHNOLOGIES

Modern agriculture is undergoing a significant transformation, driven by the urgent need to boost productivity and resource efficiency amid growing environmental and socio-economic challenges. Traditional farming methods—particularly in irrigation, pest control, and crop surveillance—are proving unsustainable in the long term. To overcome these limitations, the integration of advanced digital technologies has become essential.



Fig2 .Farmers with a drone in their agriculture field.

Technologies such as Artificial Intelligence (AI), Big Data, Geographic Information Systems (GIS), Global Positioning Systems (GPS), Internet of Things (IoT), satellite imaging, remote sensing, and cloud computing are playing a pivotal role in addressing the age-old inefficiencies of agriculture. Among these, drone technology—represented by Unmanned Aerial Vehicles (UAVs)—stands out as a highly versatile and impactful solution. Operable remotely or autonomously via programmed flight paths, drones are now widely applied in fields ranging from defence and disaster response to construction and mineral exploration—and increasingly, in agriculture.

During the COVID-19 pandemic, the relevance of drone applications in farming grew sharply due to a shortage of agricultural labour and the need for physical distancing. Studies conducted during the lockdown period highlighted the growing potential of drones for agricultural use, offering continuity in farming activities and supporting food security.

Post-pandemic, the adoption of digital tools in agriculture has only accelerated. Climate change and global uncertainties have further emphasized the need for resilient and tech-enabled farming systems. Emerging technologies not only offer solutions to persistent problems but also support the realization of global Sustainable Development Goals (SDGs).

To meet the goal of doubling farmers' incomes in India, the agricultural sector must embrace these cutting-edge innovations. Precision agriculture, powered by real-time data and automated systems like drones, can enhance productivity and ensure that farmers of all scales gain access to critical market and environmental information.

Drone technology, in particular, offers a powerful alternative to manual labour. It has emerged globally as one of the most effective tools for modernizing agriculture. In India, farmer acceptance is growing, driven by labour shortages and the rising need for accurate, data-driven farming practices. As a result, drones are becoming essential for ensuring food security and improving agricultural sustainability.

IV. TRANSFORMATIVE ROLES OF DRONES IN MODERN AGRICULTURE

Drones are rapidly gaining recognition across various sectors for their versatility and efficiency. Beyond their well-documented roles in wildlife protection, disaster response, and medical supply delivery in remote regions, drones have proven highly valuable in agriculture. Their integration into farming systems spans numerous applications—from crop cultivation to agroforestry—such as seed dispersal in difficult terrain, crop health monitoring, and soil and water management.

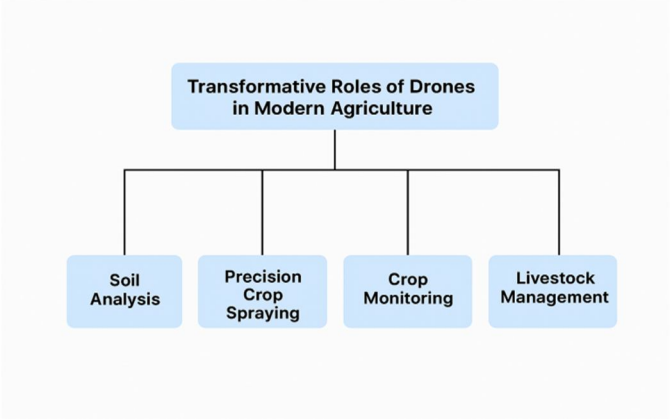


Fig 3.Transformative roles of drones in agriculture

As illustrated in Figure 2, drone technology serves multiple functions in agriculture. Below are some of the key applications where drones are making a significant impact:

A. Soil Analysis for Field Planning

Effective crop production begins with a thorough understanding of soil conditions. Factors like soil type, structure, and nutrient composition play a crucial role in determining suitable crops and optimal input strategies. Drones equipped with specialized sensors can collect valuable data for assessing soil quality, moisture levels, and nutrient presence, both before and after crop planting.

This aerial insight aids in precision decision-making, helping farmers tailor their crop choices, irrigation plans, and fertilizer usage to specific field conditions. Reports from organizations like the FAO have emphasized how drone-based soil analysis is improving pre-cultivation planning, ensuring that every hectare of land is utilized more efficiently and sustainably.

B. Precision Crop Spraying

Crop losses due to pests, weeds, and plant diseases account for nearly 20–30% of total agricultural output in India. The Food and Agriculture Organization (FAO) estimates that without crop protection technologies, up to 50% of agricultural yields could be lost. Traditional pesticide application methods are not only labour-intensive but also pose significant health risks to farmers through prolonged exposure to toxic chemicals, which can affect the skin, eyes, and respiratory system.

Statistics reveal a concerning impact: between 2013 and 2018, pesticide exposure was linked to the deaths of 183 farmers in Maharashtra and over 440 fatalities nationwide. It is estimated that around 60,000 farmers may have died over the years due to such hazardous practices.

Drone technology presents a safer and more efficient alternative. When integrated with Artificial Intelligence (AI), Machine Learning (ML), and analytical tools such as the Normalized Difference Vegetation Index (NDVI), drones provide real-time insights into plant health, soil conditions, and yield forecasts. High-resolution cameras and multispectral sensors allow drones to identify specific areas in need of treatment and perform site-specific spraying with remarkable precision.

This targeted approach not only minimizes chemical use but also enhances efficiency. Studies have shown that drones can complete spraying operations up to five times faster than traditional manual methods, significantly saving time and operational costs. Furthermore, optimized, map-based application techniques have demonstrated up to 20% reductions in nitrogen fertilizer use—supporting both economic and environmental sustainability.

C. Crop Monitoring

Crop monitoring remains a significant concern not only for farmers but also for various stakeholders across the agricultural value chain. The increasing unpredictability of weather patterns has intensified this challenge, leading to a higher risk of crop failure and increased costs for maintenance and recovery. Regular monitoring is crucial for identifying issues such as pest infestations, disease outbreaks, and environmental stress before they escalate. Drones offer a practical solution by capturing multispectral, geospatial, and temporal data at scheduled intervals, allowing for systematic observation of crop development and overall field health.

Unlike manual scouting, which is time-consuming and often limited in scope, drones provide a broader and more detailed view of the entire farmland. With advanced data analytics, farmers can uncover early signs of crop stress or damage that may not be immediately visible on the ground. This enables timely interventions, potentially saving significant portions of the yield.

Equipped with multispectral cameras, drones can capture high-resolution images of the crops during a single flight. These images are then analyzed to detect irregularities, such as pest-affected zones. Once problem areas are identified, drones can utilize GPS coordinates to conduct targeted spraying, applying the exact amount of pesticides or nutrients required—thereby improving precision, reducing waste, and minimizing environmental impact.

V. GOVERNMENT INITIATIVES DRIVING DRONE INTEGRATION IN INDIAN AGRICULTURE

The Indian government has launched several initiatives to integrate drone technology into agriculture, aiming to enhance productivity and support farmers.

A. Namo Drone Didi Scheme

Launched in November 2023, the Namo Drone Didi Scheme is a central sector initiative designed to empower women-led Self-Help Groups (SHGs) by providing them with drones for agricultural services. With an allocation of ₹1,261 crore, the scheme plans to equip 15,000 selected women SHGs between 2024-25 and 2025-26. These drones will be used for rental services to farmers, particularly for the application of liquid fertilizers and pesticides, thereby generating additional income for the SHGs and promoting sustainable farming practices.



Fig4. Namo Drone Didi – Promoting Drone Use by Rural Women

B. Boosting Farm Tech with Drone Support

Under the Sub-Mission on Agricultural Mechanization, financial assistance is provided to promote the use of Kisan Drones. This includes support for demonstrations on farmers' fields, individual drone purchases, and the establishment of Custom Hiring Centres (CHCs) offering drone services. Such measures aim to make drone technology more accessible to farmers, facilitating precision agriculture and efficient resource management.

C. Drone Shakti Scheme

Announced in the Union Budget 2022, the Drone Shakti Scheme focuses on empowering start-ups and promoting the Drone-as-a-Service (DrAAS) model. This initiative encourages the development and application of drone technology across various sectors, including agriculture, by supporting drone start-ups and facilitating the adoption of drones for tasks such as precision farming and crop monitoring.

D. Incentives for Drone Manufacturing

To boost domestic drone manufacturing, the government introduced the Production-Linked Incentive Scheme in 2021, allocating ₹120 crore to promote the production of drones and related components. This initiative aligns with the Atmanirbhar Bharat vision, aiming to position India as a global hub for drone production and reduce dependency on imports.

E. State-Level Initiatives

Several state governments are also exploring the use of drone technology in agriculture. For instance, Maharashtra is utilizing agricultural projects and schemes to integrate drones into farming practices, while Tamil Nadu is collaborating with academic institutions to develop drone applications for crop monitoring and pesticide spraying. These state-level efforts complement national initiatives, fostering a conducive environment for the adoption of drone technology in agriculture.

Through these initiatives, the Indian government aims to modernize agriculture, enhance productivity, and support farmers by integrating advanced drone technology into traditional farming practices.

VI. CHALLENGES IN ADOPTING DRONE TECHNOLOGY IN INDIAN AGRICULTURE

Despite the promising potential of drones in transforming agriculture, several practical challenges continue to hinder their widespread adoption across rural India. For drone technology to be integrated effectively into farming, the following barriers must be addressed:

1) Limited Internet Connectivity: Many rural areas still face poor internet access, which is a major hurdle since drones rely on stable network connections for GPS, data transmission, and remote operations.

2) Weather Sensitivity: Drones perform best in calm weather. Adverse conditions like strong winds, rain, or extreme heat can interfere with drone stability, accuracy, and flight safety, making them unreliable during unpredictable weather spells.

3) Lack of Technical Knowledge: Operating drones requires specialized skills, including understanding flight dynamics, maintenance, and data interpretation. Many farmers are not yet trained or equipped to handle such advanced tools.

4) Unclear Regulatory Framework: Although drone usage is permitted in India under DGCA guidelines, uncertainties remain—especially for agricultural spraying. Clearly defined standards for permissible agrochemicals and flight safety are still evolving.

5) High Initial Investment: The cost of purchasing drones, training operators, and maintenance is relatively high. For small and marginal farmers, these expenses are often unaffordable without government or institutional support.

6) Short Flight Duration: Current agri-drones typically have limited battery life, operating for only 20–60 minutes per charge. This restricts the coverage area per flight and increases operational costs due to frequent charging or battery swaps.

7) Shortage of Trained Pilots: There is a notable scarcity of trained drone operators, particularly in rural and semi-urban areas. Even when drones are available, the lack of skilled manpower to operate and maintain them is a bottleneck.

8) Economic Viability for Small Farmers: In India, most farmers own small or fragmented plots. Investing in or renting drone services might not be cost-effective at an individual level unless made accessible via cooperatives or SHG models.

9) Safety and Legal Restrictions: Public drone operations require government approvals due to concerns over national security, privacy, and misuse. These safety and legal roadblocks discourage open deployment.

10) Heavy Dependence on Imports: India still depends largely on imported components for drones. Limited domestic production, inadequate funding for drone start-ups, and slow R&D progress affect self-reliance and affordability.

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

VII. CONCLUSION

Agriculture is undergoing a transformative shift to meet the rising food demands of a growing population, ensure farmer welfare, and adapt to global uncertainties. Among the emerging innovations, drone technology stands out as a game-changer due to its versatile applications. By providing real-time, accurate data from above, drones significantly reduce human errors and inefficiencies common in traditional farming practices.

Often referred to as the "eye in the sky," drones combine advanced software, sensors, and imaging tools to offer precise insights into crop health, soil conditions, and irrigation needs. They assist farmers not only in making informed decisions but also in automating labour-intensive tasks—saving time, effort, and resources.

Despite their potential, the large-scale use of drones in Indian farming is still limited due to factors like high costs, unclear regulations, and a lack of technical know-how among users. Addressing these barriers is crucial for harnessing the full potential of drone technology. With the right support and policies, drones can revolutionize Indian farming, making it more efficient, sustainable, and beneficial for millions of farmers across the country.

VIII. ACKNOWLEDGEMENT

We would like to express our sincere gratitude to all those who supported and guided us throughout the course of this research. First and foremost, we thank our project supervisor and faculty from the Department of Mechanical & Mechatronics Engineering, Thakur College of Engineering and Technology, for their invaluable insights, continuous encouragement, and technical expertise.

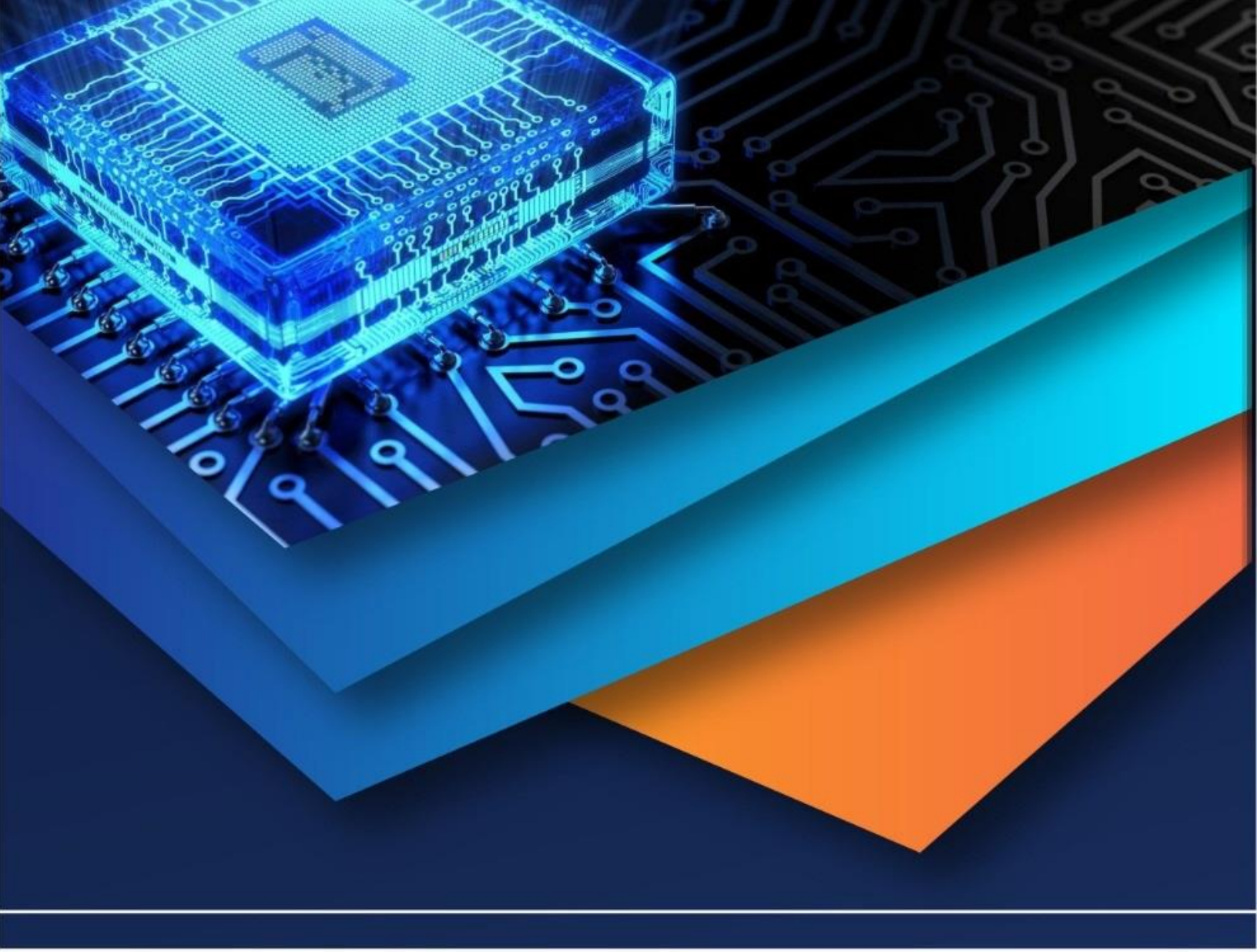
We are also grateful to the staff and peers who contributed to the brainstorming sessions and provided feedback that greatly enhanced the quality of this work. A special thanks to the institutions and online platforms that offered open resources and data, enabling us to explore the current advancements in drone technology and its applications in agriculture.

Lastly, we extend our heartfelt appreciation to our families and friends for their constant motivation, patience, and moral support throughout this project.

REFERENCES

[1] Food and Agriculture Organization of the United Nations. (2021). E-agriculture in action: Drones for agriculture. FAO & ITU. Retrieved from http://www.fao.org/3/ca1465en/CA1465EN.pdf
[2] Ministry of Agriculture and Farmers Welfare. (2022). Policy for the Promotion of Drone Technology in Agriculture. Government of India.
[3] Press Information Bureau. (2022). Union Budget 2022-23 Highlights. Government of India. Retrieved from https://pib.gov.in
[4] Indian Council of Agricultural Research (ICAR). (2023). ICAR Guidelines for Use of Drones in Agriculture. Retrieved from https://icar.org.in
[5] World Economic Forum. (2021). Using Drones to Modernize Agriculture in India. Retrieved from https://www.weforum.org
[6] Meena, H. R., & Singh, A. (2022). Drone technology and its application in Indian agriculture. Agricultural Reviews, 43(1), 14-22. https://doi.org/10.18805/ag.R-2267
[7] Department of Agriculture, Tamil Nadu. (2022). Drone Initiatives in Crop Monitoring and Spraying. Retrieved from https://www.tnagriculture.in
[8] Directorate of Plant Protection, Quarantine & Storage (DPPQS). (2020). Use of drones for locust control operations in India. Ministry of Agriculture, Government of India.

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)