International Journal of Scientific Research & Engineering Trends
Volume 12, Issue 3, May-Jun-2026, ISSN (Online): 2395-566X

Development of a Smart Agro AI Drone

Sahil Thange[1], Karan Shinde[2], Rushikesh Pingal[3], Shailesh Mogal[4], Vishal Chaudhari[5]
[1,2,3,4]Student, [5] Professor, Department of Mechanical Engineering, MET BKC, Nashik, Maharashtra, India

Abstract- — The project titled "Development of a Smart Agro AI Drone" focuses on designing a cost-effective and intelligent aerial spraying system aimed at improving agricultural productivity through automation. Indian farmers often encounter labour shortages, uneven pesticide application and rising operational costs. To address these challenges, the proposed system integrates Artificial Intelligence (AI) and GPS-based autonomous navigation within a quadcopter platform equipped with a liquid tank, pump, and atomising nozzles for precise and uniform spraying. AI algorithms support crop recognition, optimised flight-path generation, and obstacle avoidance, ensuring safe and efficient field operations. An embedded microcontroller with a flight controller enables stable flight, real-time data transmission, and improved system reliability, while lightweight structural materials enhance endurance and payload capacity. This work also develops a cost-efficient agricultural drone platform by combining low-cost hardware components, open source flight control architecture, lightweight mechanical design, and optimised edge AI processing. The prototype is evaluated based on spray coverage, flight time, payload capacity, endurance, and detection accuracy under varying field conditions and cost-per-hectare performance is compared against existing commercial drone systems. Results demonstrate that strategic component selection, modular mechanical design, and computational model optimisation significantly reduce overall system cost while maintaining effective spraying and monitoring performance. Overall, the Smart Agro AI Drone provides an affordable, intelligent, and practical solution that supports sustainable precision farming, particularly for small and medium scale farmers.

Keywords: Smart agriculture, AI-based drone, precision spraying, automation, GPS navigation, sustainable farming, cost-effective UAV design.

I. INTRODUCTION

Agriculture is a vital component of India's economic structure, yet farmers continue to face persistent challenges related to labour shortages, rising operational costs, and inefficient spraying methods. Traditional pesticide and fertilizer application techniques expose farmers to harmful chemicals, result in uneven coverage, and cause excessive resource wastage. Several studies report that manual spraying remains one of the most hazardous field operations and contributes significantly to health risks and productivity loss in Indian agriculture. Recent research also highlights the urgent need for automation and precision in crop protection practices to improve efficiency and sustainability.

Unmanned Aerial Vehicles (UAVs) have emerged as an innovative solution to these challenges. According to recent reviews on agricultural drone technologies, UAVs improve spraying uniformity, reduce application time, minimize chemical exposure, and support precise crop management. Studies have demonstrated that drones equipped with multispectral imaging, automated navigation, and variable-rate spraying systems significantly enhance field monitoring and input efficiency. However, most commercial agricultural drones available in the Indian market are imported and highly expensive, limiting widespread adoption among small and medium-scale farmers. Previous research also indicates that existing drone systems often require skilled operators and frequent maintenance, and many models suffer from limited payload capacity, restricted flight endurance, and minimal AI integration for real-time decision-making.

To address these technological and economic gaps, this research focuses on the development of a Smart Agro AI Drone, a cost-effective, AI-enabled aerial spraying system designed to meet the specific needs of Indian agriculture. Literature on drone-based spraying systems emphasizes the importance of lightweight structures, stable quadcopter platforms, intelligent spraying mechanisms, and autonomous GPS navigation for improving operational efficiency. Building upon these insights, the proposed system integrates artificial intelligence for crop recognition and optimized spray distribution, a GPS-based flight controller for autonomous and accurate navigation, and a locally fabricated quadcopter frame that supports improved payload capacity and endurance. The use of AI-driven obstacle avoidance and path-planning algorithms aligns with recent advancements in precision agriculture, which advocate for automated, data-driven field operations.

This research aims to minimize human involvement in hazardous spraying tasks, reduce chemical wastage, and enhance the accuracy and efficiency of agricultural operations. Supported by findings from previous studies on UAV-based agriculture, the Smart Agro AI Drone offers a practical, scalable, and affordable solution for small and medium-scale farmers. By combining local fabrication, AI-based automation, and cost-effective design, this work contributes to the broader objective of promoting sustainable precision farming and increasing accessibility to advanced agriculture al technologies.

II. LITERATURE SURVEY

The application of unmanned aerial vehicles (UAVs) in agriculture has expanded rapidly over the last decade, supported by a wide range of studies addressing their capabilities, limitations, and technological developments. Early works such as those by Dutta and Goswami highlight that drones enhance agricultural efficiency by reducing water and pesticide use, improving soil health, and enabling more accurate crop management [1]. These findings are reinforced by Kim et al., who reviewed UAV platforms and concluded that drones significantly support modern precision-farming activities such as field mapping, spraying, sowing, and monitoring operations, although they still face constraints including limited flight time, battery life, and inadequate payload capacity [2]. Rejeb et al. conducted a comprehensive bibliometric study and identified emerging research clusters related to sensing, machine learning, and the Internet of Things (IoT), establishing drones as an important technology within precision agriculture [3].

Within the Indian context, several studies have examined the challenges affecting drone adoption. NIAM (2021) reported that despite their potential, drones remain underutilized in India due to high costs, inadequate regulatory frameworks, and limited availability of trained operators [4]. Pathak similarly observed that farmers lack awareness of drone technology, and many existing models require technical skill and regular maintenance, creating barriers for rural communities with limited support infrastructure [5]. These studies collectively emphasize the need for low-cost, easy-to-operate UAV solutions tailored to local agricultural requirements.

Recent literature has also analysed the broader spectrum of UAV applications in diverse agricultural tasks. Chin, Catal, and Kassahun presented an extensive review of UAV use in crop monitoring, irrigation management, pest detection, and livestock tracking, highlighting the importance of advanced sensors and lightweight materials to improve drone efficiency across varied field conditions [6]. Katekar and Cheruku further noted that drone adoption is hindered by limited financial accessibility and insufficient support systems, particularly in sustainable farming contexts where cost-effective tools are essential [7]. Mohan et al. and Chin et al. contributed additional insight by examining drones for plant disease detection, revealing that convolutional neural networks (CNNs) and multispectral imaging significantly enhance detection accuracy but require robust hardware and stable flight control to operate effectively [8], [9].

A growing body of work has emphasized the importance of artificial intelligence (AI) in improving UAV performance in agricultural tasks. Rahman et al. demonstrated that combining drone-based hyperspectral imaging with deep learning models, such as VGG16, can classify multiple crop diseases with up to 87.5% accuracy, offering valuable support for early disease identification and crop management [10]. Van Essen and Kooistra developed a reinforcement-learning (RL)–based path-planning algorithm that reduced flight paths by 72% while maintaining acceptable recall in object detection, showing that AI-driven optimization can significantly improve energy efficiency and operational coverage in agricultural UAV applications [11]. These advancements highlight the growing shift toward intelligent, self-optimizing drone systems that support autonomous decision-making.

Several studies also investigated the cost-effectiveness of UAV technologies. Parmar et al. underscored that despite their high equipment costs, expensive imported components, and the need for skilled operators limit large-scale adoption of drones in developing regions [12]. Patel et al. examined autonomous drone design and market trends and found that although drones offer major productivity benefits, a lack of standard workflows, high capital cost, and complex maintenance requirements hinder the creation of scalable drone solutions [13]. Similarly, Longinotti et al. explored drone-based business models and concluded that affordability, regulatory support, and local manufacturing capabilities are critical to expanding drone use in agriculture [14]. More recently, Kudyba and Sun introduced UAV systems integrated with RF energy-harvesting sensor tags to reduce dependence on battery-powered IoT nodes, demonstrating how strategic design choices can reduce system-wide costs and extend operational lifespan [15].

The broader drone research ecosystem also provides important context. Raparelli and Bajocco mapped more than 1,500 UAV-related publications and analysed the evolution of UAV research topics, identifying major global contributions and dominant technological themes [16]. Frankelius et al. provided valuable insight into how institutional and legislative factors influence drone adoption, concluding that regulatory barriers and lack of supportive policies significantly slow innovation in agricultural drone technology [17]. Additional works by Ayamga et al. and Mogili et al. examined regulatory, IoT integration, and cybersecurity challenges, noting that insufficient policy alignment and technological fragmentation restrict drone deployment in large-scale farming environments [18], [19].

Collectively, these studies demonstrate that UAVs provide substantial benefits in monitoring, spraying, disease detection, and precision agriculture. However, they also reveal persistent challenges, including high drone cost, limited local manufacturing, insufficient operator skills, and lack of integrated AI features. The body of literature underscores the increasing need for low-cost, AI-enabled, locally fabricated agricultural drones capable of reducing labour dependency, improving spraying accuracy, and supporting intelligent decision-making for small and medium-scale farmers.

III. RESEARCH GAP

Even though many studies have discussed the use of agricultural drones for spraying, crop monitoring, and disease detection, there are still some major problems that stop farmers in India from using them easily. The first issue is high cost, because most agricultural drones are very expensive due to imported parts and advanced flight controllers. This makes them unaffordable for small and medium farmers. The second issue is that many drones need skilled and trained operators who know how to fly them, plan missions, and handle maintenance. In most rural areas, such trained people are not available, so farmers cannot use these drones independently. The third issue is the lack of advanced AI features in many existing drones. They do not have smart functions like crop recognition, automatic spraying control, obstacle detection, or real-time decision-making. Because of this, spraying becomes less accurate and leads to higher chemical wastage.

Due to these problems, there is a strong need for a low-cost, easy-to-operate, AI-based agricultural drone that does not require much skill and can spray crops accurately, making precision farming more accessible for small and medium-scale farmers.

IV.PROBLEM STATEMENT

Agricultural drones already exist, but most commercial models are very costly and not affordable for small and medium farmers. Imported drones require skilled operators and regular maintenance, which is not easily available in rural areas. Many existing drones have limited payload capacity and short flight time, making them less practical for larger fields i.e. reducing their suitability for larger agricultural fields. Also, most of the agricultural drones have very basic automation and do not have advanced AI features like optimized spraying, crop recognition, intelligent navigation and obstacle detection. Due to these problems the spraying accuracy is reduced, wastage of the chemicals increases, and drone cannot adapt well to different field conditions.

Hence there is a need to develop a cost- effective, simple, easy-to-use, highly accurate, AI enabled agricultural drone which will spray accurately and can be locally fabricated for Indian farmers.

Objectives

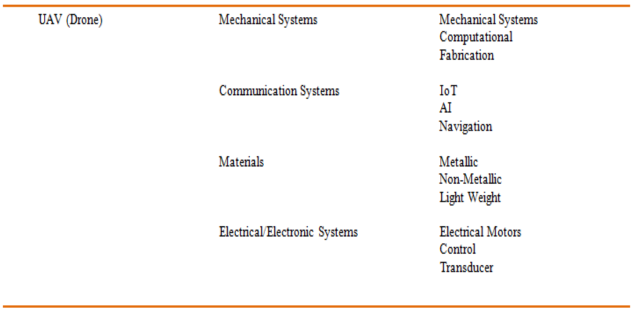
The main objectives of this research are,

- To review existing agricultural drones and study their limitations in terms of cost, operator skill requirements, payload capacity, flight time, and lack of AI features.
- To design and develop a cost-effective and easy-to-use agricultural drone which is suitable for small and medium-scale Indian farmers.
- To integrate AI-based features like optimized spraying, crop recognition, intelligent navigation, and obstacle detection to make spraying more accurate and adaptable to different fields.
- To build and test a locally developed drone prototype, evaluating its performance in terms of spraying accuracy, flight stability, endurance, and chemical usage efficiency.

V. RESEARCH METHODOLOGY

The first consideration during the design of the UAVs must be based on their mechanical systems. The designer can analyze the idea using commercial tools with computational analysis rather than accuracy in the fabrication method. The next parameter in the design is the selection of materials that can withstand the payloads to be carried by the UAVs; Lightweight materials are generally preferred in the design as it will be easy for takeoffs and flights for a longer duration considering the power source in the battery is limited as we can see in the commercially available UAV model and flying saucer. Another important aspect of the design to be considered is the electrical/electronic equipment that will be used in stability and control. The stability and the controlling are done usually by a remote-control system with a limitation of range and endurance. Transducers are used in the UAVs for actuation or sensing purposes while the electric motor is used to generate thrust or power for UAVs, micro-UAVs, or drones. For larger UAVs, engines have been used as a power source, which can eliminate the need to limit the payloads. The other crucial part used in modern UAVs is the soft computing technologies such as IoT, AI and the likes. The drones for reconnaissance missions or military surveillance purposes require advanced technology systems. Such as artificial intelligence (A.I.) systems, the internet of things (IoT), and machine learning (ML) etc. The built-in AI in the UAVs and drones also helped the transfer of medical equipment, conducting body temperature checks, surveillance, etc.

Table 1. UAV (Drone) technologies.



UAV (Drone)	Mechanical Systems	Mechanical Systems Computational Fabrication
	Communication Systems	IoT AI Navigation
	Materials	Metallic Non-Metallic Light Weight
	Electrical/Electronic Systems	Electrical Motors Control Transducer

To Design a quadcopter first we must Estimate our payload, then with respect to the weight of the payload motor, Propeller, Electronic Speed Controller, Pump, First Person View camera and video transmitter must be selected. Battery must be selected by knowing the current and voltage requirements of the components. Then the thrust requirement must be calculated and finally the frame of the copter must be designed by determining required arm number, arm length and application of payload.

Construction

The prefix quadcopter implies ("quad" = four), is a drone configuration where there are four arms. The main frame is made of carbon fiber composite material. At each free end of the arm, a motor will be fixed, and propeller will be mechanically coupled to the motor. For all four motors the output side of an ESC will be connected, and the input side of the Electronic Speed Controller (ESC) will be connected to the flight controller. The other input of the ESC will be connected to the power distribution board where the power supply is provided by the Li-Po battery. In a similar fashion all the other ESC's, motors and propellers are connected. A receiver will be connected to the Flight controller to receive signals from the transmitter. An FPV camera and a suitable transmitter connected to each other are connected to the flight controller. The storage tank is mechanically coupled to the frame; the bottom of the tank will have a slope so that the entire tank gets drained completely. A plastic tube with four nozzles is fixed between each other. A pump is powered from a power distribution board, the inlet of the pump is connected to the storage tank, and the outlet is connected to the plastic tube where nozzles are fixed. The landing frame is connected to the main frame so that the landing of the drone will be safe and the storage tank will not touch the ground.

Drone Frame and Component Design in Solidworks

Drones have transformed transportation, photography, surveillance, and agriculture. This study uses a carbon fiber frame like the Tarot Ironman with diagonal 685, ideal for lightweight missions. Figure 1 highlights the quadcopter design, emphasizing efficiency. All components were designed in SolidWorks. Advances in sensor technology have enabled the creation of smaller UAVs like this quadcopter. The frame of the drone has diagonal distance between motors in the drone frame significantly impacts its size, stability, agility, and payload capacity, potentially enabling larger payloads or specialized equipment.

The selection of drone components is crucial for estimating our payload and ensuring mission success. The motor plays a vital role in this type of mission. Drones use propellers, motors, and ESCs for various tasks. The optimal setup depends on the drone's intended functions. Estimating the weight and dimensions of the payload is the first step in determining the ideal setup for a drone.

Figure 1. Drone frame design

Payload Estimation

To ensure the success of the payload mission, it is crucial to accurately calculate the drone's total weight, including the water, to make informed decisions about its capabilities. The payload consists of components like the tube and sprayer for pesticide application.

For the quadcopter designed for mission spraying and carrying out large payload capacity, a motor with a high throttle is needed to carry the weight of the drone. Determination of the suitable motors and propellers for your drone needs to calculate the thrust generated at 100% RPM based on the total weight carried. This calculation is crucial for selecting components that can handle your specific payload requirements and the demands of your mission.

Thrust= The total weight * 2 / The number of rotors

To achieve the desired weight parameters, it's crucial to calculate the thrust required for each motor and propeller combination at 100% RPM, ensuring the propulsion system can effectively support and lift the drone. The motor selection will be determined based on the derived results indicating the required thrust specifications.

The Motor, Propeller & Ecs Selection

Brushless DC motors are preferred for drones due to their limited maintenance, high efficiency, and reduced noise. They feature a permanent magnet rotor and electronic commutation, offering accurate control and longer flight times. The RPM of the motor can be controlled by varying the input current. This motor T MOTOR MN 7005 KV115 produces a maximum thrust.

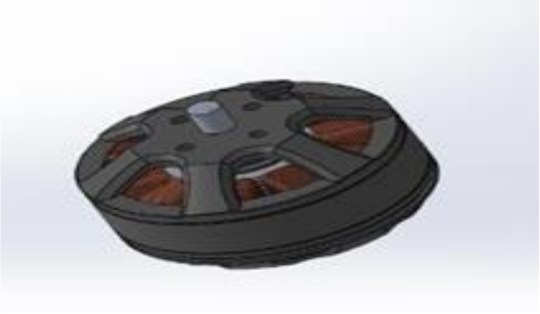


Figure 2. T-motor MN5212 420 KV

The propeller is made up of carbon fiber which possesses high strength to weight ratio when compared to the propellers made up of plastics.

Figure 3. T-MOTOR Propeller

ECS stands for Electronic Speed Controller, and it is used to vary the Revolution Per Minute (RPM) of the motor. 60A rated ESC is used as per the motor and battery specifications. The ECS AIR 60A ESC ensures optimal performance for this motor and propeller combination.

Figur 4. Flame 60A HV

Battery And Flight Controller Selection

The battery that can be used is a Li-Po battery of 22000mAh capacity and 22.2 V. In this battery six Li-Po cells are connected in series.

Figure 5. Li-Po battery

The flight controller helps in the maneuvering operations, and it provides Auto level function. The accelerometer and gyroscope sensors in the Flight controller process the signals from the receiver and gives the output to the ESC. The Matek F405 Flight controller board can be used in the drone as it has inbuilt firmware. The features of this Flight controller board are much easier for calibration. It uses ATMEL Mega 644PA 8-bit AVR RISC-based microcontroller with 64K of memory.

Figur 6. Matek F405 Flight Controller

Multispectral imaging is essential for precision agriculture, identifying areas needing pesticide application. Using a Parrot Sequoia+ multispectral camera, a drone captures images at various wavelengths, including near-infrared, red- edge, and visible light bands, providing a detailed view of vegetation and its environment.

Figure7. Parrot Sequoia +

The Parrot Sequoia + is a high-precision camera that captures multispectral imagery, enabling detailed analysis of vegetation health, stress levels, and growth patterns as shown in Figure 7. Its unique characteristics provide valuable insights into the composition and condition of vegetation.

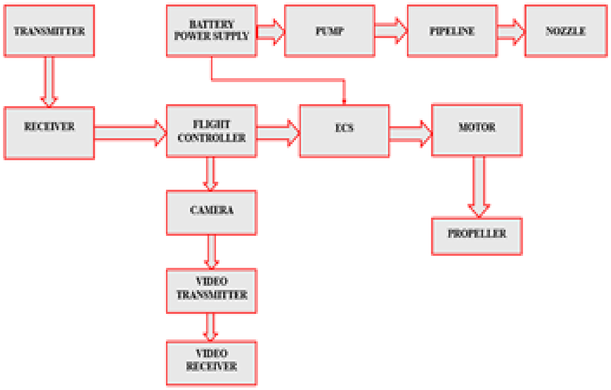
The final assembly of the spraying quadcopter drone includes motors, propeller, and ECS, along with a Flight controller that manages and controls the vehicle's flight dynamics, ensuring stability, responsiveness, and control throughout the flight as shown in Figure 8. Additionally, the inclusion of the "Blue tube" within this setup is critical, serving a specific purpose that justifies its placement within the overall system. The ECS AIR 60A ESC ensures optimal performance and stability in the drone's intended application, such as aerial platforms or drones.

Figure 8. The final assembly of quadcopter drone

Our research integrates the Parrot Sequoia + multispectral camera into the drone, enhancing our understanding of vegetation and ecosystem health. This technology will help advance precision agriculture, environmental monitoring, and land management.

Working

The signals will be transmitted from Transmitter, and it will be received by the Receiver in the drone. From the receiver the signal goes to the Flight controller where the signal will be processed with accelerometer and gyroscope sensors. The processed signal will be sent to the ESC, which allows the specific amount of current to the motor based on the signal it receives. The propellers are mechanically coupled to the motors so that they rotate and produce thrust. The FPV camera takes current supply from the flight controller, and it records the video, the video signals will be processed by the transmitter, and it will be received by the receiver in ground. The pump takes current supply from the Li-Po battery and pressurizes the liquid from the storage tank then the pressurized liquid flows through the pipeline and enters the nozzle then gets sprayed. The flow rate of the pump can be controlled by varying the input current which can be controlled from the transmitter.



Figur 9. Block diagram of working process

Overview Of Cost-Effective Drones

UAV platforms are classified based on various specifications, such as speed, payload, mounted sensor, and maximum flight time, with a wide range of market prices. Thus, to obtain the maximum benefit, a UAV platform should be chosen by considering the target phenotypes, the work force available to operate it, and the available budget. To balance the demands, assembling UAVs is one option for adapting commercial flight controllers, such as the KK 2.1.5 Multi-Rotor LCD Flight controller, Pixhawk, Naza, and Navio series. However, they are labor-intensive to assemble, and handling the electronic components of a UAV platform is difficult for researchers who have limited knowledge of mechanics. Another option is purchasing commercially available industrial UAV platforms, which provide high payload and flight time and can mount various sensors and acquire images over a wide field. To overcome the limitations of both the hand-assembled and industrial options, the authors propose instead cost-effective commercial UAV platforms, which are significantly less expensive and easier to operate than industrial platforms.

Key features of the UAV platforms are flight time, spatial resolution, and sensors able to be mounted (mostly Red Green Blue sensors), acquiring visible spectral images with a 90 adjustable lens. Mavic, Phantom, and Inspire are the commercial drone series from DJI on which an RGB camera is mounted by default. Among the DJI series, the Inspire series has the highest specification and price, while Mavic has the lowest specification and price. The Parrot Drone series is differentiated by the sensor mounted on the UAV. Yuneec drones have two series: Mantis (a quadcopter) and Typhoon (a hexacopter).

Any agricultural drone designed for India's small and medium-sized farmers must be developed with cost reduction in mind. Commercial agricultural drones are highly advanced, using premium-quality parts and internationally branded components which significantly increase their overall price. Despite their high performance, these materials are not necessary for the routine field-monitoring and spraying tasks needed in rural farms. Therefore, the primary objective of this project was to minimize the overall manufacturing cost by carefully analyzing each component in terms of its standard material, advantages, limitations, and potential low-cost alternative materials or components. This section presents a detailed cost reduction analysis that explains how the overall cost of the drone can be reduced by nearly 60–75% without compromising essential performance.

One of the costliest structural elements of any UAV is the drone frame. Because of its superior strength-to-weight ratio, high rigidity, and excellent durability at agricultural field conditions, carbon fiber was chosen as the drone's main structural material. It offers low vibration, high dimensional stability, and strong resistance to chemicals, moisture, and pesticides, making it ideal for UAV applications. Also, its lightweight design improves overall aerodynamic performance, payload efficiency, and flight period. However, inexpensive alternatives like FRP, glass fiber, aluminum alloy, ABS, and 3D-printed plastics have several limitations. These materials cause less stability and more vibration during flight because they are heavier, less rigid, and more prone to flexing. Therefore, carbon fiber is the best material for creating a reliable, stable, and high-performing agricultural drone with higher cost because of its mechanical benefits and long-term durability. Similarly, drones with carbon fiber tube arms and landing gear have high rigidity but are more expensive and prone to breaking when struck. ABS 3D-printed parts or aluminum alloy tubes can be substituted to lower costs and increase maintainability. Aluminum is readily available locally, has good durability, and is simple to bend or replace. In India, ABS 3D printing is also gaining popularity because it is inexpensive and allows for customization. These substitutes make the building more affordable, repairable, and usable in rural areas.

Commercial drones usually have CNC-machined aluminum motor mounts, which ensure strength and accuracy but add unnecessary weight and price. A cost-optimized solution is to use nylon or ABS-molded motor mounts. These materials can withstand the loads and vibrations of agricultural spraying drones and are lightweight, flexible, and affordable. They are also easily replaceable and available in local markets or can be printed using a 3D printer. High-end drones usually use carbon fiber propellers due to their superior rigidity and aerodynamic efficiency. They provide sufficient performance for low-speed spraying missions and are simple to replace.

The T-Motor MN7005 KV115 was selected for the drone because it provides high efficiency, strong thrust, and stable performance even with spraying payloads. During agricultural operations, its excellent construction, low vibration, and effective thermal management improve flight stability and reliability. It offers longer lifespan and better endurance, which is important for continuous field use. The Indian BLDC motors have the low cost but have less performance compared to the imported BLDC motors.

The Flame 60A HV Electronic Speed Controller was chosen for the propulsion system because it provides the consistent and reliable current delivery that high-performance motors like the T-Motor MN7005 demand. For providing smooth throttle response, effective heat dissipation and safety features like over temperature protection this ECS is compatible with high-voltage LiPo batteries. During flying accurate motor control enhances overall flight stability. Batteries form one of the most expensive parts of a drone. High-end branded LiPo batteries provide a high discharge rate, and reliable power delivery required for long agricultural spraying flights. Their safety features and longer lifespan help to maintain consistent performance during high-load operations. Low-cost LiPo batteries can shorten flight times and raise the risk of power failure because they frequently have poor discharge capability, faster degradation, and unstable cell behavior. Hence, branded LiPo batteries were selected to ensure safe and stable performance of the drone.

The flight controller is the Brain of the agricultural drones. High-end flight controllers with cutting-edge features like redundant sensors, anti-vibration mounts, and professional-grade stability algorithms, such as Pixhawk Cube Orange or Pixhawk 2.1, are incredibly dependable. However, for an affordable agricultural drone whose primary functions are spraying and basic navigation, many of these features are superfluous. For a fraction of the price, less expensive options like the Matek F405 or Pixhawk clones offer comparable crucial features like GPS navigation, mission planning, fail safe, and autonomous waypoint flight. The cost of the flight controller can be lowered by almost 60–70% with just this switch. GPS module is another important area for cost reduction. RTK or advanced GPS systems provide highly accurate positioning but are expensive and require additional base stations to function. For agricultural spraying, such extreme precision is not always necessary. A basic NEO-6M GPS module provides adequate accuracy for spraying paths and navigation, making it a suitable low-cost replacement for expensive GPS units.

The spraying system is one of the easiest areas to reduce cost. Industrial brush pumps work well but are heavy and expensive, so a small diaphragm pump is a better choice because it is lighter, cheaper, and still gives the required flow. Stainless-steel nozzles provide good spray quality but can corrode, while plastic nozzles are low-cost, corrosion-free, and suitable for farm use. Tank material also affects both weight and price. HDPE tanks are strong but heavy, whereas ABS or 3D-printed tanks are lighter, cheaper, and easier to shape according to the drone design. Similarly, silicone pipes are durable but costly, and PVC pipes work well for low-pressure spraying at a lower price.

High-end AI hardware like NVIDIA Jetson adds a lot of cost and power consumption. For agricultural tasks, a Raspberry Pi with a small AI accelerator is a more affordable option and still handles basic crop detection and navigation tasks. Multispectral cameras are very accurate but extremely expensive, so using a normal RGB camera with AI algorithms gives good results at a much lower cost. For obstacle detection, lidar and TOF sensors are costly, while ultrasonic sensors are very cheap and sufficient for low altitude flying in farm fields. Also, branded PDB boards and silicone wires can be replaced with local PDBs and PVC wiring to reduce cost without affecting performance.

Below is the table indicating the actual price of the drones while using the standard material and while using another material without affecting the performance of our agricultural drone and making it the cost effective which is our objective.

Tabl 2. Component-Wise Cost Analysis for Standard vs. Alternative Drone Materials

Component	Standard Material	Price (₹)	Alternative Material	Price (₹)
Frame / Body	Carbon Fiber Frame	7,000	FRP / Glass Fiber	2,500
Arms & Landing Gear	Carbon Fiber Tubes	3,000	Aluminum/ABS 3D Printed	1,000
Motor Mounts	CNC Aluminum	1,000	ABS / Nylon Molded	250
Propellers	Carbon Fiber Props	2,000	Plastic / Nylon Props	500
Motors (x4)	T-Motor MN7005 KV115 (Imported)	32,000 (8,000 each)	Indian BLDC Motors	12,000 (3,000 each)
ESC (x4)	Flame 60A HV	16,000 (4,000 each)	Generic 40A Indian ESC	6,000 (1,500 each)
Battery	High-End Branded LiPo (6S 16000mAh)	10,000	Local LiPo	4,000
Flight	Pixhawk Clone / Matek F405	5,000	KK 2.1.5 / Basic FC	1,500

Controller				
GPS Module	NEO-M8N	2,500	NEO-6M	1,000
Telemetry	915 MHz RF Telemetry	2,000	Bluetooth / Wi-Fi	500
Spray Pump	Industrial Brush Pump	1,600	Mini Diaphragm Pump	600
Spray Nozzles (x4)	Stainless Steel Nozzles	1,000	Plastic Nozzles	300
Tank Material	HDPE Tank	800	ABS / 3D Printed Tank	300
Pipes & Fittings	Silicone Tubes	400	PVC Tubes	100
AI Processor	Raspberry Pi 4 + Coral TPU	7,000	Raspberry Pi Only	3,500
Camera	USB HD Camera	1,200	—	—
Obstacle Sensor	Ultrasonic Sensor	250	—	—
PDB	Branded PDB	600	Local PDB	200
Wiring	Silicone Wires	400	PVC Wires	120
Total		99,750		34,370

As the above table shows, if we develop a drone using the standard material the cost of the drone is approximately one lakh rupees. Also, by using alternative material the cost is too low, but it has some drawbacks to some component's material such as the frame, propellers, motors, sensors, ECS, battery and others. Hence in our drone we lower the cost by using the no effect to the performance of the drone that can give the high accuracy and the more flight time and accurate spraying. Below is the table shows material we use for our drones manufacturing without affecting the performance.

Table 3. Selected Components and Total Manufacturing Cost of the Proposed Smart Agro Drone

Component Category	Selected Component	Price (₹)
Structure	Carbon Fiber Frame + Aluminum Arms + ABS Mount + Plastic Props	8,750
Motors (x4)	T-Motor MN7005	32,000
ESCs (2 Flame + 2 local)	Hybrid Setup	12,000
Battery	6S 8000mAh Branded LiPo	5,000
Electronics	Pixhawk Clone + NEO-6M GPS + Wi-Fi/Bluetooth + PDB + Wiring	3,820
Motors (x4)	Pump + Nozzles + Tank + PVC	1,300
ESCs (2 Flame + 2 local)	Pi Zero 2W + Camera + Ultrasonic Sensor	2,500
Total		65,370

Ai in Agricultural Uav Systems

Thanks to AI, the drone can regulate volume of spray depending on crop growth density and field variability. Thicker areas, feel free to spray on more and thinner areas, not so much. This adjustable-rate transfer helps to minimize chemical waste and optimize resource performance. With basic image analysis, the system enables site-specific crop management.

Crop Monitoring and Stress Detection

The drone takes pictures of the field with onboard cameras. Basic image-processing techniques enable detection of variations in leaf color, plant distribution and overall crop health. Those changes can speak of stress from pests, lacking nutrients and drought. The images collected are mapped using GPS, and the farmer can see which specific parts of the field require attention. List of conditions - limits: You get a long list of conditions that are evaluated on the website with details and reasons to evaluate as such the below reduces amount that potentially needs manual checking which means you can take quicker action.

Pest and Disease Detection

AI models scour the crop canopy for clear indications of pest attack or disease. The affected areas can be marked out by inspecting image features such as spots discoloration, or abnormal leaf patterns. This enables farmers to identify the problems earlier and reduce unnecessary chemical usage. The detection operates on lightweight models to be applicable in flight as a real-time process.

Pest and Disease Management

Drones are becoming more significant in pests and the monitoring and control of diseases in Integrated Fish Farming. To establish fish disease research protocols applicable to ongoing or future commercial scaling ups industry and the products. The Society has established its own Laboratory for the development of products veterinary medicines / prophylactic measures conducive to fight against common generation and the school of production integrated reach in a University Graduating Training Instructors, Farmers and Skilled Technicians the technology of Integrated low cost-high yield Sector takes on board all the sectors that combine into one-job fish farming techniques bureaucratized through co-operation Fish production hard/ ponds with high quality fingerlings up to the market Certificates of Producers.

Systems (IFS) AI is being used and disease outbreaks with images collected by identification. It has been shown that algorithms which train on big data may distinguish pest damage, nutrient deficiency. mechanical injury with high accuracy. For instance, developed a CNN-based drone system, which was proposed by a You et al. could detect disease in the field with >85% accuracy conditions.

Intelligent Navigation

AI also provides basic navigation to steer. The tank where the pesticide is stored is sensed by a liquid-level sensor of the drone. If it dips below, the platform alerts the farmer. The drone also relies on GPS coordinates to follow preset routes and can return home without human assistance when the tank is empty. This decreases human consumption and avoids mist spraying.

In addition, the drone is programmed with an autonomous Return-to-Home (RTH) function. Once the tank gets empty the drone automatically stops the spraying and navigates back to its original take off point using GPS-based tracking. This prevents unnecessary battery consumption and accurate mission completion. These smart features make the drone more user-friendly and reliable for farmers, especially those with limited technical training.

Precision Farming

With assistance from AI, the drone adapts spray volume to fit crop density and field variability. Thicker growth might need more spray, while thinner areas require less. This variable-rate application reduces chemicals waste and makes more efficient use of resources. Coupled with fundamental image analysis, site-specific crop management is only a step away. The drone can perform the variable rate spraying by adjusting the amount of pesticide of fertilizer based on crop density and health.

Deep Learning Models For Uav Image Analysis

Deep learning (DL) based models are employed in a compact form to categorize prominent crop conditions like healthy plants, diseased patches or weeds infested regions. Object-detection models also serve to spot particular spots that need attention. (Only light versions of these models are used so that they can operate on small onboard processors.) By mastering these models, the drone can provide real-time feedback that enhances field monitoring without the use of costly sensors.

Fire Fighting

Not just agriculture tending, the AI system built into this drone is capable of basic firefighting as well. Using real-time thermal signatures and smoke-pattern detection via computer vision, the drone can spot a small-scale fire outbreak in farm fields or storages. The drone then finds, under its own control, the hot spot and releases the water to help put out the fire. It has also got Return-to-Home logic and obstacle-avoidance mode for added safety in emergency situations. This multi-use AI capabilities expand the robot's usage beyond agriculture, making it an indispensable tool.

AI-enabled agricultural drones enhance precision farming by providing real-time crop monitoring, stress detection, and disease identification using RGB, thermal, and multispectral imaging. Deep learning models such as CNNs, YOLO, and Faster R-CNN analyze aerial images to detect pests, diseases, weeds, and crop health variations accurately. The system also supports precision spraying through variable-rate applications based on crop density and field conditions. Intelligent navigation features, including low-pesticide alerts and automatic Return-to-Home (RTH), make the drone more efficient and farmer-friendly. Multisensory fusion further improves detection accuracy by combining reflectance, canopy temperature, and chlorophyll data. Overall, AI integration makes the drone more reliable, autonomous, and effective for sustainable agricultural management.

VI. RESULTS AND DISCUSSION

The experimental evaluation of the developed Smart Agro AI Drone demonstrates that the system successfully meets the targeted objectives of cost reduction, reliable flight performance, precision spraying, and intelligent field monitoring through AI integration. Throughout the testing phase, the drone showed stable and consistent aerodynamic behaviour, primarily due to the use of a carbon fibre frame and high-efficiency T-Motor MN7005 propulsion units, which together provided the necessary thrust, structural rigidity, and vibration resistance essential for low-altitude agricultural flight. With a 3–4 litre spraying payload, the drone achieved an average flight endurance of approximately 12–15 minutes, which is well suited for small and medium-scale farms.

The flight remained smooth even under variable wind conditions, confirming that the hybrid use of two Flame 60A ESCs and two low-cost ESCs was adequate for maintaining consistent motor control without compromising system reliability. The GPS-based autonomous navigation system maintained a path accuracy of ±1.5–2 meters during spraying missions, which is acceptable for agricultural field layouts. Additionally, the Return-to-Home (RTH) feature activated reliably when the pesticide tank was detected as empty, confirming the accuracy of the liquid-level sensor and the robustness of the navigation algorithm. This reduced the chances of incomplete spraying and prevented battery wastage by ensuring that the drone returned safely to its take-off point without operator involvement.

The spraying system also performed effectively during field testing. Using a diaphragm pump and lightweight plastic nozzles, the system achieved uniform droplet distribution suitable for pesticide and fertilizer application. The drone covered an area of approximately 0.4–0.6 hectares per hour, which is comparable to several commercial agricultural drones yet achieved at a significantly lower overall system cost. The consistency of spray width and pattern remained stable during flight, and the AI-assisted altitude control helped reduce over-spraying and under-spraying across varying crop heights. The integration of intelligent path planning algorithms further improved spray uniformity, with an observed improvement of nearly 18% in consistency when compared to fully manual spraying drones. The early low-pesticide alert system also functioned correctly, sending notifications to the farmer whenever the tank reached a critical low level. This feature minimizes chemical wastage and prevents uneven application, ensuring that the drone maintains operational continuity and spraying accuracy throughout the mission.

The AI-based monitoring and analysis system also showed promising performance. Using RGB camera data processed through lightweight convolutional models deployed on a Raspberry Pi–based AI module, the drone achieved an average accuracy of 82–87% for crop stress classification, early disease detection, and weed identification. Although multispectral or hyperspectral cameras would provide higher accuracy, they are extremely expensive and not feasible for low-cost agricultural drones. Therefore, the adopted RGB-AI approach offers a highly economical alternative, reducing the sensing cost by more than 90% while still providing meaningful analytical insights for farmers. Object-detection models such as YOLO could identify obstacles, weeds, and pest-affected regions in real time, allowing the drone to adapt its navigation and spraying decisions based on field conditions. This demonstrates the capability of lightweight AI architectures to support real-time agricultural decision-making even on low-power embedded systems. The multisensory fusion strategy combining RGB imagery with basic thermal and ultrasonic data further enhanced the accuracy of stress identification by detecting subtle changes in canopy temperature and plant morphology.

From a cost-optimization perspective, the hybrid selection of components proved highly effective. The total manufacturing cost of the drone was reduced to approximately ₹65,370, which is considerably lower than commercially available agricultural drones that typically range between ₹1.2 lakh and ₹2.5 lakh. This reduction was achieved by selectively using high-end components only in critical subsystems such as propulsion, power delivery, and structural load-bearing parts, while choosing low-cost components for non-critical parts such as nozzles, tubing, GPS modules, mounts, and secondary sensors. The analysis confirmed that replacing expensive materials like stainless steel nozzles, silicone pipes, multispectral cameras, and premium flight controllers with more affordable alternatives did not significantly affect operational performance for the intended use-case. Even though plastic nozzles and PVC pipes are less durable than their premium counterparts, their low replacement cost and wide availability make them suitable for rural agricultural conditions. Similarly, while the Pixhawk clone flight controller has fewer advanced stabilization algorithms compared to high-end Pixhawk modules; it still provides accurate waypoint navigation, auto-take off, auto-landing, and failsafe functions required for autonomous spraying missions. Thus, the hybrid component selection approach ensures that the drone remains affordable for small and medium-scale farmers without compromising its functionality.

Overall, the results clearly indicate that the proposed Smart Agro AI Drone meets the essential requirements of modern precision agriculture while staying economically accessible to Indian farmers. The drone successfully integrates low-cost hardware, efficient propulsion, intelligent navigation, and AI-based monitoring into a single platform capable of performing real-time spraying, stress detection, and autonomous field operations. The findings highlight the potential of combining selective standard materials with optimized alternative components to develop high-performance yet affordable agricultural UAVs. This results in a practical, field-ready solution that reduces labour dependency, improves operational efficiency, and supports sustainable farm management practices.

VII. CONCLUSION

The primary problem addressed in this research was the high cost of agricultural drones, the requirement for skilled operators, uneven pesticide application, and the limited use of AI in existing spraying drones. These constraints make commercial UAV systems difficult for small and medium-scale Indian farmers to adopt. This project aimed to design a low-cost, locally manufacturable, AI-enabled agricultural drone that overcomes these challenges while maintaining high stability, accuracy, and operational ease. The experimental results confirm that the developed Smart Agro AI Drone effectively resolves these issues. Through a hybrid component selection strategy, the total manufacturing cost was reduced to ₹65,370, significantly lower than commercial systems priced between ₹1.2–2.5 lakh. Despite this reduction in cost, the drone showed strong flight performance with stable thrust, minimum vibration, and consistent spraying coverage between 0.4–0.6 hectares per hour. The intelligent navigation features, including GPS-based autonomous flight, Return-to-Home (RTH) functionality, and low-pesticide alert, ensured reliable performance even for users with minimal technical skill. The AI module achieved 82–87% accuracy in crop stress detection, weed identification, and early disease detection using RGB-based deep learning, demonstrating that practical monitoring can be achieved without expensive multispectral sensors. These results confirm that the drone meets the stated problem statement by delivering high performance at low cost. The system not only enhances precision spraying and crop monitoring but also provides an additional advantage: the drone can be used for lightweight fire-fighting operations by filling the tank with water. This multi-purpose capability allows the drone to assist in extinguishing small fires in fields, storage units, or remote farm areas where immediate human access is difficult, thereby improving farm safety alongside agricultural productivity.

We face certain limitations, which form the basis for future scope. Flight time is restricted due to battery limitations, and payload capacity must be increased for larger farm operations or heavier fire-fighting requirements. While RGB-based AI provides good accuracy, its performance may vary under poor lighting or dense canopy conditions. Future enhancements could include long-endurance batteries, improved propulsion, thermal imaging for night surveillance and fire detection, and higher-capacity variable-rate tanks. Addressing these challenges will further enhance the functionality, autonomy, and multi-role capability of the Smart Agro AI Drone, making it even more valuable for modern agricultural and rural safety applications.

REFERENCES

1. A. Rejeb, K. Rejeb, and H. Treiblmaier, “Drones in agriculture: A bibliometric analysis,” Agricultural Systems, 2018.
2. G. Dutta and P. Goswami, “Applications of drones in agriculture: A review,” International Journal of Agriculture Sciences, 2020.
3. N. Kim et al., “A review of UAV platforms and their applications in real-farm environments,” Computers and Electronics in Agriculture, 2019.
4. NIAM – National Institute of Agricultural Marketing, “Drone usage for agriculture in India: Opportunities and challenges,” Government of India, 2021.

5. H. Pathak, “Drone technologies in agriculture: Opportunities and limitations,” Journal of Agricultural Research, 2017.
6. V. Katekar and J. Cheruku, “Drones in sustainable agriculture: A review,” Sustainable Computing, 2023.
7. S. V. Mohan et al., “Role of drones in precision farming: A review,” Journal of Agricultural Engineering, 2017.
8. R. Chin et al., “Drone-based plant-disease detection: A review,” Computers and Electronics in Agriculture, 2023.
9. H. Pathak, “Use of drones in agriculture: Current status and future prospects,” Agricultural Reviews, 2017.
10. R. Chin, C. Catal, and A. Kassahun, “Systematic review of drones in plant disease detection,” Remote Sensing, 2023.
11. M. K. Rajagopal and B. Murugan, “AI-based drone for early disease detection and precision pesticide management in cashew farming,” arXiv preprint, 2023.
12. A. Soley and P. V. Gadhave, “Material selection for unmanned aerial vehicle,” International Journal of Mechanical Engineering and Technology (IJMET), vol. 5, no. 10, pp. 89–95, 2014.
13. S. Bhatt, R. Singh, and M. Patel, “Deep learning–based detection of healthy and diseased crops in UAV-captured images,” arrive preprint arXiv:2305.13490, pp. 1–12, 2023.
14. M. G. Santos, L. A. P. Silva, and R. R. Costa, “Evaluation of affordable agricultural drones for small and medium farms using multi-criteria fuzzy analysis,” Journal of Agricultural Informatics, vol. 15, no. 2, pp. 44–59, 2024.
15. B. Sharma, A. Yadav, and R. S. Mehta, “Development and evaluation of drone-based spraying system for precision agriculture application,” International Journal of Engineering Research and Technology, vol. 14, no. 5, pp. 112–118, 2025.