"QUADCOPTER for crop health monitoring and precision farming"

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Abstract— **Agriculture drones are transforming modern farming by integrating and remote sensing. They assist in crop monitoring and pesticide spraying, enabling farmers to make data-driven decisions. These drones provide real-time insights, increasing efficiency and sustainability in agriculture. The use of drones reduces labour intensity, minimizes chemical overuse, and enhances productivity. Agriculture drones are evolving into intelligent farming tools capable of predictive analysis. This technology contributes to precision farming, and resource optimization, making it an essential component of future agriculture.**

Keywords— Single Channel Relay, Pump Control, Spraying Automation, ESP32, Switching Module.

I. INTRODUCTION

Agriculture today is entering a technological revolution, where smart drones are becoming a vital tool for precision farming and crop health monitoring. These unmanned aerial vehicles are equipped with imaging cameras like ESP32-CAM, GPS mapping, and AI-based analytics to observe crop conditions in real time. By collecting aerial images and sensor-based data, drones help farmers make informed decisions, optimize resources, increase crop yield, and reduce environmental impact. Modern agriculture struggles with challenges such as pest outbreaks, soil degradation, climate change, and inefficient use of pesticides. Traditional methods relied on manual labor and blanket spraying of chemicals, which caused higher costs and serious ecological damage. Smart agricultural drones provide a promising solution by enabling accurate pesticide spraying in affected areas only, saving chemicals while protecting workers from harmful pesticides. In addition to spraying, drones equipped with multispectral and NDVI sensors monitor plant health, detect early stress conditions, and identify pest-affected regions.

Using advanced machine-learning analysis, this information is converted into actionable insights, allowing farmers to take quick decisions and achieve sustainable and efficient farming practices.

II. OVERVIEW

This project presents an intelligent quadcopter designed for sustainable farming through automated pest control and smart crop health monitoring. The system combines a drone-based pesticide spraying mechanism with advanced sensors and image-processing tools to detect early plant stress, pest attack, and nutrient deficiency. Equipped with GPS, high-resolution or multispectral cameras, and a precision pesticide tank, the quadcopter performs real-time monitoring and targeted spraying using machine learning–based analysis. Instead of blanket spraying, the drone applies chemicals only on affected areas, which reduces pesticide consumption, lowers costs, and minimizes environmental impact. By integrating aerial mobility with precision agriculture, the system supports farmers in making faster, smarter, and more sustainable agricultural decisions.

III. LITERATURE REVIEW

In [1] S. Chavan, M. Kadam 2019 Solar Based Grass Cutter – A Review Discussed advantages of solar energy in gardening tools and proposed a model with basic safety and energy storage features.

In [2], Hunt et al. (2014) UAV Multispectral Imaging for Nitrogen Stres Used UAV-mounted multispectral cameras to assess nitrogen stress in wheat crops, proving the effectiveness of aerial sensing for nutrient monitoring.

In [3], Zhang and Kovacs (2012) UAVs for Precision Agriculture6Highlighted that UAVs are effective tools for precision farming tasks such as field mapping, crop scouting, and monitoring plant growth. Demonstrated that drones

equipped with RGB, multispectral, thermal, and LiDAR sensors can capture data on crop conditions, soil variability, and vegetation indices like NDVI. Helped detect nutrient deficiencies, pests, water stress, and diseases early, reducing manual labour and supporting better decision-making.

In [4], Berni et al. (2009) Thermal Imagery for Water Use Estimation Demonstrated that UAV-based thermal imaging can estimate evapotranspiration and water use in vineyards, supporting precise irrigation planning.

IV. PROBLEM STATEMENT

Modern agriculture is facing significant challenges due to inefficient pest management practices and the lack of timely crop health monitoring. Traditional pesticide spraying methods often involve manual labor and blanket application of chemicals, leading to excessive pesticide use, environmental pollution, and increased production costs. Furthermore, early signs of crop stress, disease, or pest infestation are often missed due to the limitations of manual field inspections, resulting in reduced yields and poor crop quality.

V. OBJECTIVES

The main objective of this project is to develop an intelligent quadcopter system capable of automated pest control and real-time crop health monitoring. The system aims to integrate GPS, cameras, and advanced sensors to enable accurate navigation, aerial surveillance, and plant health assessment. Another objective is to implement machine learning techniques to detect early signs of plant stress, pest infestation, and nutrient deficiencies using captured images. The project also focuses on designing a precision spraying mechanism that applies pesticides only on affected crop zones, thereby reducing chemical usage and minimizing environmental damage. Furthermore, the system seeks to reduce Labor, operational costs, and human exposure to harmful chemicals through automation, while improving overall agricultural productivity. Ultimately, this project aims to support sustainable farming practices by helping farmers make faster, smarter, and data-driven decisions.

VI. METHODOLOGY

Starting with the design and selection of components. First, a quadcopter frame is selected based on its payload capacity. It should be strong enough to carry the pesticide tank, pump, and spraying system. Essential components include a flight controller, like Pixhawk, brushless motors, ESCs (Electronic Speed Controllers), a GPS module, a telemetry unit, and a high-capacity LiPo battery. The flight controller is programmed to manage the quadcopter's movement and spraying operation. A water or pesticide pump is connected to a relay module. The flight controller controls this relay to turn spraying on or off during flight A camera can also be added for live monitoring and navigation. The system gets its power and connection through a distribution board and buck

converters when needed. The spraying mechanism is tested on the ground before any controlled test flights. The drone is calibrated and set up using ground control software. Flight paths can be pre-set or operated manually via the transmitter. Field trials are held to check for even pesticide distribution and system stability.
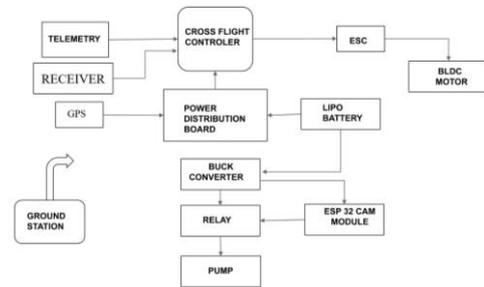

Fig 1. Block diagram of Pest-Spraying Quadcopter

Data from the telemetry and GPS modules assist in assessing performance and improving future spraying missions. field trials are conducted to evaluate spraying uniformity, system stability, and overall performance, while telemetry and GPS data are analysed to optimize and improve future spraying missions.

VII. USING COMPONENTS

Drone Frame S500

Fig 2: Drone Frame S500

The S500 drone frame is a lightweight and durable quadcopter frame widely used in DIY and research-based drone applications. It is made of strong carbon fibre–reinforced plastic, giving good rigidity and vibration resistance. The frame design provides spacious mounting space for flight controllers, GPS, cameras, and spraying modules, making it suitable for agricultural drones and payload-based operations. Its X-shape structure ensures stable flight performance, while the landing gear offers good ground clearance for sensors and camera installation. Overall, the S500 frame is reliable, cost-effective, and easy to assemble for medium-size quadcopters.

BLDC Motor

Fig 3: BLDC Motor

A Brushless DC (BLDC) motor is an electric motor that operates without brushes, utilizing electronic commutation instead of mechanical brushes and a commutator. In a BLDC motor, the rotor contains permanent magnets, while the stator comprises multiple winding powered by an electronic controller. This controller switches the current in the stator windings in a sequence that creates a rotating magnetic field, which the rotor follows, resulting in continuous rotation. The absence of brushes reduces mechanical wear, leading to higher efficiency, longer lifespan, and quieter operation

compared to traditional brushed motors. BLDC motors are widely used in applications requiring precise control, such as drones, electric vehicles, and various consumer electronics

Li-Po Battery

Fig 4: Li-Po Battery

A rechargeable battery with a nominal voltage of 14.8 volts is used in the system to store electrical energy efficiently. It plays a critical role in ensuring uninterrupted operation by acting as a backup power source when sunlight is insufficient or during nighttime. This battery stores the excess energy generated by solar panels during peak sunlight hours and supplies power to the motor and other electronic components when required. Its rechargeable nature makes it highly suitable for sustainable energy applications, as it reduces the need for frequent replacements and lowers overall operational costs. The 14.8 rating typically corresponds to a 4-cell Lithium-ion or Li-Po battery, known for their high energy density, lightweight, and long cycle life, making them ideal for portable solar-powered systems and electric tools.

ESC (Electronic Speed Controller)

Fig 5: ESC (Electronic Speed Controller)

An ESC (Electronic Speed Controller) is a crucial component in a pest spraying quadcopter that regulates the speed and direction of the brushless DC motors. It receives control signals from the flight controller and adjusts the power supplied to the motors based on the required maneuvering commands. The ESC converts the battery's DC voltage into a three-phase AC signal needed to drive the motors efficiently. In a quadcopter, four ESCs are typically used, one for each motor, ensuring balanced and stable flight. The ESC not only controls speed but also supports braking, reversing, and motor cutoff during critical conditions like low voltage or signal loss. In spraying drones, high-quality ESCs (such as 30A or more) are used to handle the current load, especially when the drone carries a heavy liquid payload. Proper functioning of ESCs is vital for smooth flight operation, stability, and accurate navigation during pesticide spraying missions

Transmitter and Receiver

Fig 6: Transmitter and Receiver

An RC transmitter and receiver allow manual remote control of the quadcopter by sending wireless commands to the flight controller. The transmitter sends control signals for throttle, direction, and mode switching, while the receiver mounted on the drone converts these signals into motor and system actions. This setup enables safe take-off, landing, and manual intervention during agricultural spraying operations.

Power Distribution Board

Fig 7: Power Distribution Board

A Power Distribution Board (PDB) distributes power from the main LiPo battery to all quadcopter modules, including the ESCs, flight controller, and spraying system. It simplifies wiring, reduces weight, and ensures stable and safe power delivery. High-current copper traces and voltage regulation support reliable operation for pest-spraying drones.

Cross Fight Controller

Fig 8: Cross Fight Controller

A flight controller is the core control unit of a quadcopter that processes sensor data and controls motor speed to maintain stable flight. It interfaces with modules such as GPS, ESCs, radio receiver, and telemetry units, enabling autonomous or manual navigation. Modern controllers integrate IMU sensors, communication ports, and firmware for functions such as altitude hold, waypoint navigation, and automated spraying operations, making them essential for agricultural UAV applications.

GPS (Global Positioning System)

Fig 9: GPS (Global Positioning System)

A GPS module in a quadcopter enables precise position tracking, navigation, and autonomous flight by receiving satellite-based location data. It provides real-time latitude, longitude, heading, and altitude information to the flight controller, which uses this data for waypoint missions and geo-referenced spraying operations. In agricultural drones, GPS support ensures accurate field mapping, targeted pesticide application, and repeatable flight paths, improving precision and operational efficiency.

ESP32 CAM Module

Fig 10: ESP32 CAM Module

The ESP32-CAM is a compact Wi-Fi enabled camera module based on the ESP32 microcontroller, integrating an OV2640 camera sensor for real-time image and video capture. It supports on-board processing, wireless data transmission, and low-power operation, which makes it suitable for embedded vision applications in drones. In agricultural UAVs, the ESP32-CAM allows remote crop monitoring, live video streaming, and image acquisition for plant health analysis, thereby enhancing automation and precision in field surveillance tasks.

Telemetry

Fig 11: Telemetry

A telemetry module enables wireless communication between the quadcopter and the ground control station by transmitting real-time flight data such as position, altitude, battery status, and mission progress. It allows the operator to monitor drone performance, modify parameters, and upload missions during flight. In agricultural applications, telemetry supports long-range control, field mapping, and safe execution of automated spraying missions by ensuring constant data exchange between the drone and the ground operator.

Water Pump

Fig 12: Water Pump

A water pump in a pesticide-spraying quadcopter is responsible for delivering liquid pesticides or fertilizers from the onboard tank to the spraying nozzles under controlled pressure. It is driven by the drone's power system and is typically interfaced with the flight controller through a relay or electronic switch for automated ON/OFF control during flight. Precise pump operation enables uniform droplet dispersion and targeted application on affected crop zones, which minimizes chemical usage and supports efficient and environmentally safe agricultural spraying.

Relay

Fig 13: Relay

A single-channel relay is an electronic switching device used to control high-power loads such as pumps or motors using low-power control signals from the ESP32 or flight controller. In the spraying drone, the relay enables precise ON/OFF control of the pesticide pump, allowing targeted spraying only when required and reducing chemical wastage.

VIII. RESULTS

The developed quadcopter demonstrated effective crop health monitoring and precision spraying using the ESP32 platform. The ESP32-CAM, integrated with an Edge Impulse machine-learning model, accurately detected crop stress through real-time image analysis and autonomously activated the pesticide pump via a relay module when affected areas were identified. The relay-controlled spraying enabled precise pesticide application, reduced chemical usage, and minimized manual intervention. Experimental tests confirmed stable flight and reliable detection, although performance was influenced by lighting variations and battery limitations. Overall, the system proved to be a low-cost and efficient solution for precision agriculture.

Fig 14: Drone Model with ESP 32 CAM

Fig 15: Mission Planner

IX. DISCUSION

The study shows that the ESP32-based quadcopter can successfully detect crop stress and perform targeted pesticide spraying using onboard AI and relay-controlled mechanisms. The system proved accurate and cost-effective, reducing chemical usage and manual effort. However, performance was affected by lighting conditions and battery limitations, suggesting that improved sensing and higher-capacity power sources could further enhance operation in real field environments.

X. CONCLUSION AND FUTURE SCOPE

The ESP32-based quadcopter proved capable of real-time crop health monitoring and precision pesticide spraying using onboard AI and relay-controlled mechanisms. The system significantly reduced chemical usage, manual Labor, and operational cost while improving spraying accuracy and crop management efficiency. Overall, the approach demonstrates a practical and low-cost solution for precision agriculture and sustainable farming practices.

Future Scope:

- Increase flight time using higher-capacity batteries or solar charging.
- Add autonomous mission planning and dynamic flight path generation.
- Integrate cloud-based data analytics for long-term crop monitoring.
- Expand payload capacity for large-scale field spraying.

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