International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 11 | Nov - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Multipurpose Agriculture Robotic Vehicle

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Abstract- Agriculture faces numerous challenges in the modern era, including labor shortages, inefficiencies in manual farming, and the growing demand for sustainable practices. To address these issues, automation and smart technologies are increasingly seen as transformative solutions. While various agricultural machines exist, most are designed for specific tasks and lack the flexibility required for small to medium scale farming operations. This gap highlights the need for a versatile, cost-effective solution capable of performing multiple tasks in varied farming conditions. The Multipurpose Agriculture Robotic Vehicle aims to bridge this gap by integrating functionalities such as seed sowing, pesticide spraying, Watering system and soil monitoring into a single robotic platform. Our robotic vehicle utilizes a modular design equipped with sensors, a microcontroller, and Relay Circuits to perform diverse tasks.

I. Introduction

In many parts of the world, agriculture still relies heavily on traditional methods that involve intense physical labor, time-consuming manual tasks, and often inefficient use of resources [1].

Figure1.A farmer manually spraying pesticides.

As the above Figure1, shows manual labor in farming is tiring, time-consuming, and less precise. These scenes, though common and deeply rooted in agricultural culture, highlight the growing challenges faced by today's farmers such as labor shortages, rising operational costs, and the physical toll of repetitive work [1].

In contrast, the integration of smart technology and robotics into farming offers a glimpse of a more efficient and less labor-intensive future [2].

This is the vision behind the Figure 2, Multipurpose Agriculture Robotic Vehicle a compact and affordable robotic system designed to perform multiple agricultural tasks with minimal human involvement [2].

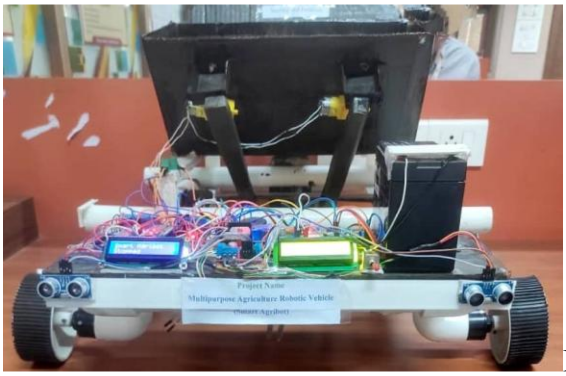

Figure 2. Robot operating in a small field

By referencing real-life farming conditions and comparing them with modern agricultural needs, this project aims to bridge the gap between tradition and innovation [2], [3].

II. Literature survey

Agriculture has been the backbone of human civilization for thousands of years, evolving from manual subsistence farming to large-scale industrial agriculture [1]. Early farming relied heavily on human and animal labor for operations like ploughing, sowing, watering, and harvesting. With the Industrial Revolution came mechanical advancements tractors, harvesters, threshers which drastically reduced the time and effort needed for farming tasks [1]. Despite these advances, many small and medium-scale farmers around the world, particularly in developing countries, still rely heavily on manual labour and traditional tools due to high costs and limited access to modern agricultural machinery [1]. This results in inefficiency, low yields, and increased labour costs. Efforts like semi-automated drip irrigation systems, battery-operated sprayers, and low-cost threshers have provided some relief, but they often serve only single purposes [1]. The rise of embedded systems and affordable microcontrollers has opened new possibilities in agricultural automation [2]. Technologies like the Internet of Things (IoT), robotics, and smart sensors enable real-time data collection and decision-making [2], [3]. Research into multipurpose agricultural robots has gained momentum, aiming to integrate diverse farming operations such as seeding, spraying, Monitoring, and irrigation into one adaptable platform [4]. Projects like MARV represent a convergence of traditional agricultural wisdom and modern technological advancement [5].

III. Objectives

The goal of MARV is to design and develop a low-cost, multipurpose agricultural robotic vehicle that can automate essential farming tasks such as seed sowing, fertilizer spreading, watering, pesticide spraying, and soil moisture monitoring, thereby reducing manual labour, optimizing resource usage, and increasing farming efficiency [1], [3]. Each functional module is critical for modern sustainable agriculture.

- **Seed Sowing:** Accurate seed placement is crucial for optimal crop growth. Uniform sowing ensures better nutrient absorption, reduces competition among plants, and maximizes overall yield potential.
- **Fertilizer Spreading:** Controlled fertilizer application promotes healthy plant growth while minimizing excessive chemical use. Precise spreading ensures nutrients are delivered only where needed, enhancing soil fertility and reducing environmental impact.
- **Pesticide Spraying:** Excessive and imprecise pesticide use increases farming costs and harms the ecosystem. MARV's smart spraying system applies pesticides accurately and only when necessary, reducing chemical runoff and protecting the surrounding environment.
- **Watering System:** Automated watering based on real-time soil moisture data helps conserve water resources. Targeted irrigation improves plant health, prevents overwatering, and supports sustainable farming practices.
- **Soil Moisture Monitoring:** Real-time monitoring of soil moisture allows for intelligent irrigation scheduling. This ensures plants receive optimal water levels, conserves water and enhances crop productivity.

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- **Obstacle Detection and Avoidance:** The vehicle autonomously detects and navigates around obstacles using ultrasonic sensors, ensuring uninterrupted operation without constant human supervision.
- **Rechargeable Battery Operation:** Powered by a durable 12V/24V battery setup, MARV is capable of full-day operations on a single charge, supporting off-grid farming environments efficiently.

IV. Proposed Work

The Figure 4, shows the block diagram of multipurpose agriculture robotic vehicle. Each block shows a component that interacts with the ESP32 microcontroller to perform tasks like seeding, spraying, and environmental monitoring.

- **ESP32**: Figure 3, shows ESP32 Board .The core microcontroller unit that controls the entire system. It processes sensor data and controls actuators based on programmed logic.

Figure 3: ESP32 Board

Input Components:

1. **Ultrasonic Sensor and Additional Required Sensors**: These sensors are used for obstacle detection and other required measurements like soil moisture, etc.
2. **Soil moisture Circuit**: Monitors soil moisture conditions and feeds data to the ESP8266.
3. **Power Supply / Battery (12V or 24V)**: Supplies the required operating voltage to the ESP32 and other connected components

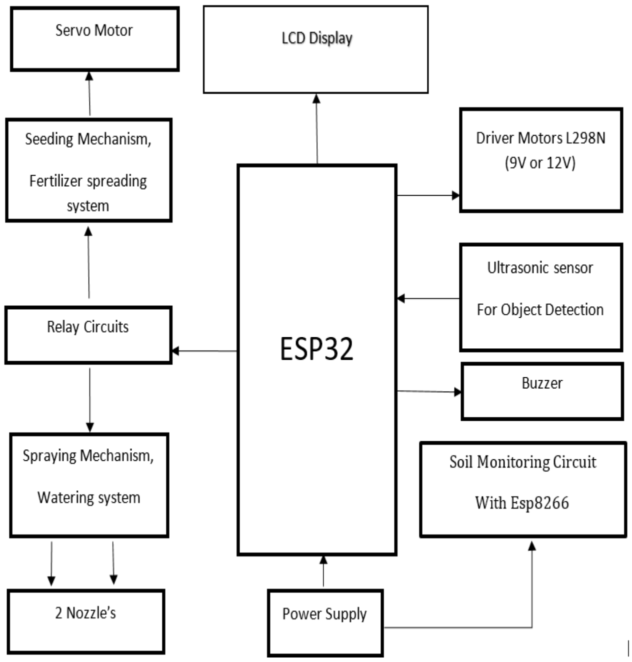

Figure 4: Block diagram of the Multipurpose Agriculture Robotic Vehicle

Output Components:

1. **LCD Display**: Displays data such as sensor readings and system status to the user.
2. **Driver Motors (L298N, 9V or 12V)**: Controlled by ESP32 to move the robot or operate mechanisms.
3. **Buzzer**: Used for alerts and notifications (e.g., warning signals).
4. **Servomotor**: Performs precise control and operations like rotating components (e.g., nozzle or direction control).
5. **Relay Circuits**: Switch higher power devices (e.g., pumps) based on control signals from the ESP32.
6. **Seeding Mechanism and Fertilizer System**: Controlled by ESP32 to dispense seeds at specific intervals.
7. **Spraying Mechanism and watering:** Sprays pesticides or water using the **2 Nozzles** connected to it.

VI. Results

The Multipurpose Agriculture Robotic Vehicle (MARV) is an advanced farming solution designed to automate essential agricultural tasks such as seed sowing, fertilizer spreading, watering, pesticide spraying, and soil moisture monitoring.

As you can see in Figure 5, At the core of the system is the ESP32 microcontroller, which acts as the central processing unit, coordinating inputs from various sensors and controlling multiple output components. The system is powered by a 12V or 24V rechargeable battery, regulated through a power supply module to ensure safe and stable operation of all electronic parts.

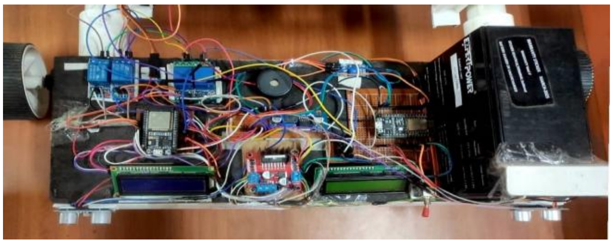

Figure 5. Circuit Connection of vehicle

1. Soil Moisture Monitoring Performance:

The soil moisture monitoring system is a critical component of the smart farming setup, enabling real-time tracking of soil hydration levels. By using moisture sensors embedded in the soil, the system collects data and sends it to the ESP8266 microcontroller for analysis. This data-driven approach ensures that irrigation or watering is only activated when the soil moisture drops below an optimal threshold, preventing water overuse and supporting healthy plant growth.

Figure.6 Soil moisture monitoring system

Figure.6, Shows the Soil moisture monitoring system in this system the Soil moisture readings enabled optimized watering schedules, offering potential water savings.

Upon activation of the ESP8266 handles initialization of all peripherals and begins monitoring soil moisture conditions using a soil moisture sensor integrated into the environment monitoring circuit.

Interpreted Soil Moisture Percentage: Soil moisture percentages can be categorized into different levels, which are typically based on the type of soil and the crop being grown.

- **Dry Soil (0-10% Moisture):**

Soil is very dry and may need irrigation. Crops may show signs of water stress or wilting.

- **Optimal Moisture (10-25 Moisture):**

Soil has enough moisture for most crops to thrive. Ideal range for crops like wheat, maize, and rice during certain growth stages.

- **High Moisture (25-40% Moisture):**

Soil is wet and may have poor drainage, which can lead to waterlogging, especially for plants that do not like excess water. Soil is fully saturated, and excess water may drain away.

Ideal for crops like rice that require a lot of water but can cause root rot for crops sensitive to overwatering.

2. Seed Sowing Mechanism Performance:

The Figure 7, shows robotic seed sowing mechanism uses relay-controlled timing to drop seeds at specific intervals, ensuring precision Seeding. The system is controlled by the ESP32 microcontroller and can be adjusted based on crop type and spacing needs.

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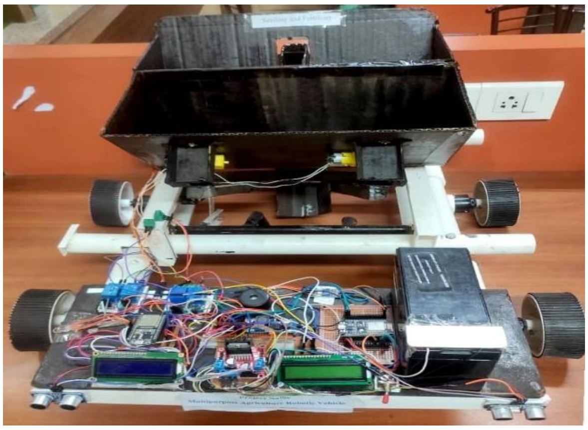

Figure 7. Seed Sowing Mechanism

Key Findings:

- Precise Seed Placement: Consistent spacing and depth.
- Reduced Seed Wastage: Relay system controls exact dispensing.
- Customizable Settings: Easy to program spacing for different crops.
- Labor Reduction: Automates a traditionally manual process.

3. Fertilizer Spreading System Performance:

This system uses dual nozzles to evenly spray fertilizers based on distance or time intervals. Controlled by the microcontroller, it ensures targeted application to reduce waste and enhance nutrient delivery.

Key Findings:

- Even Coverage: Dual nozzles spray uniformly.
- Efficient Use of Chemicals: Reduces fertilizer overuse.
- Automated Operation: Requires no manual intervention during fieldwork.
- Crop-Specific Programming: Adjustable based on crop and field needs.
- Less Environmental Impact: Prevents chemical runoff and pollution.

4. Pesticide Spraying Mechanism Performance:

As the Figure 8, shows below like the fertilizer system, the integrated pesticide spraying system in the robotic vehicle ensures efficient and targeted chemical application across crops.

For automated Pesticide spraying, an 8W submersible pump motor was integrated into the system, controlled through a relay based on manual activation. Testing showed that the pump effectively delivered water up to a height of 40 cm with an average flow rate of 150–180 mL/min. The Spraying mechanism achieved 92% efficiency in maintaining optimum continuous operation.

Figure 8. Pesticide Spraying Mechanism

Operated by dual nozzles and automated via programmable logic, the system distributes

pesticides evenly and only when needed based on set intervals or field segment detection. This automation significantly

Reduces human exposure to chemicals and avoids over-application, promoting safer and eco-friendly practices.

Key Findings:

- Uniform Application: Controlled spraying avoids over- or under-use.
- Increased Safety: Reduces farmer exposure to harmful chemicals.
- Timesaving: Covers large areas quickly without manual labor.
- Sensor-Controlled Safety: Pauses spraying when obstacles are detected.

- Supports Healthy Crops: Accurate spraying protects plants from pests effectively.

5. Watering System Performance:

The Figure 9, Shows automated watering system, guided by soil moisture data and timing logic, ensures plants receive optimal hydration without excess water usage.

Figure 9. Watering system

The system leverages either scheduled intervals or sensor feedback to trigger watering cycles, contributing to smarter water use, particularly in drought-prone areas.

For water level monitoring, an ultrasonic sensor was deployed, where the system activates a buzzer alarm if the water level drops below a threshold of 10 cm. During testing, the buzzer consistently activated when the water level fell between 10–12 cm, ensuring timely alerts for refilling. Experimental results showed a 95% accuracy in detecting low water levels under varying environmental conditions.

Key Findings:

- Efficient Water Use: Prevents overwatering.
- Consistent Irrigation: Delivers uniform watering throughout the field.
- Manual Override Available: Offers flexibility for farmers.
- Adaptable: Works with different soil and crop types.
- Healthier Crops: Prevents drought stress and root drying.

Additionally, relay circuits are utilized to switch high-power devices such as water pumps based on ESP32 control signals.

6. Obstacle Detection and Avoidance Performance: The robot autonomously navigated the test field with an obstacle detection success rate above 90%.

Future Enhancements: Planned upgrades include the integration of AI-based crop health detection, solar-powered battery recharging, and dynamic task scheduling using machine learning models for even smarter farming operations.

VI. Conclusion

The development and testing of the Multipurpose Agriculture Robotic Vehicle (MARV) demonstrate that a single, compact robotic platform can effectively automate multiple essential agricultural operations. By combining seed sowing, fertilizer spreading, pesticide spraying, watering, and soil moisture monitoring, MARV reduces manual labor, improves efficiency, and conserves resources. Its autonomous navigation and real-time soil monitoring capabilities ensure precision in farming tasks, while its wireless control offers operational flexibility. With future enhancements such as AI-based crop health analysis and solar-powered operation, MARV holds great potential for advancing smart, sustainable agriculture, particularly for small and medium-scale farmers.

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