AgroBot: AI-Powered Rover for Next-Gen Crop Monitoring

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***Abstract*—AgroBot Rover is a smart robot made to help farmers monitor their crops and reduce the need for manual work in the field. It has different sensors that measure important conditions such as soil moisture, soil pH, temperature, humidity, and location using GPS. The data collected by these sensors is sent wirelessly to a cloud system where it is processed and analyzed. Users can see this information on a web dashboard that shows real-time updates, past data trends, 2D and 3D maps, and automatic soil health reports. By combining robotics, IoT technology, and online data analysis, the system helps farmers make better decisions for farming. The design of the system is also flexible, which means new features can be added in the future.**

***Index Terms*—AgroBot Rover, Precision Agriculture, IoT, Soil Monitoring, Autonomous Rover, Cloud Monitoring, Web Dashboard, Smart Farming.**

I. INTRODUCTION

Agriculture is changing quickly as new technologies like ro-botics, automation, and data analysis are being introduced. Farmers are now focusing more on regularly checking soil and environmental conditions so they can improve crop pro-duction, use resources more efficiently, and reduce the need for heavy manual labour. In the past, most farm inspections were done through manual visits to the field or by using sep-arate sensor devices. This process often took a lot of time and sometimes the observations were not very accurate. Because of these limitations, autonomous rovers with built-in sensors are now being used as a practical solution to make farming easier and more efficient.To overcome the problems of tradi-tional crop monitoring, AgroBot was developed as an AI-based rover that can automatically monitor important condi-tions in the field.

The rover has different sensors that check soil moisture, soil pH, temperature, humidity, and GPS location. As the rover moves around the field, it collects environmental data in real time. Because it can move from one place to another, it can gather information from many parts of the farm instead of depending only on sensors placed in one fixed spot.

This helps cover a larger area of the field and gives a clearer idea of the overall field conditions. As a result, the data col-lected is often completer and more accurate than data from systems that stay in one place. The backend part is very important in the AgroBot system because it turns the raw sensor data into useful information. The data sent by the rover is received through API services and saved in a structured database so it can be stored and an-alyzed easily. The web dashboard is made using React, Type-Script, and Vite, and it shows the information in a simple and interactive way. Users can see the data through charts, 2D maps, 3D land views, and automatically created soil health reports. Tools like Leaflet and Cesium help track the rover's location on the map, allowing users to see both the field con-ditions and the rover's movement in real time.Systems based on IoT communication and real-time monitoring are widely used today because they help farmers make better and faster decisions in agriculture [25].

One of the main benefits of AgroBot is that it brings robotics, IoT communication, and web-based data analysis together in a single system. Because the rover collects data from specific locations in the field, farmers can understand their field con-ditions more clearly and make better decisions about crop care and management.Another important feature of AgroBot is its flexible design. The system can be used in different types of farms and for different crops, and new features can be added later if needed. For example, it can be improved to detect plant diseases, predict crop yield, or move more effi-ciently in the field. In this way, AgroBot can be a useful and scalable solution for modern farming, helping farmers follow more sustainable and data-driven agricultural practices [12].

II. LITERATURE SURVEY

The fast development of automation technologies and the growing interest in renewable energy have encouraged researchers to design solar-powered robotic and monitoring systems for different uses. Many studies show that solar energy can be combined with microcontrollers and sensors to build systems that work efficiently and can operate for long periods without depending heavily on external power. For instance, Malligeswari et al. [1] designed a solar-powered agricultural grass-cutting robot that uses sensors to detect obstacles and helps reduce manual work in farms. Anju and Joshua [2] studied traction and navigation systems for solar-powered rovers and explained how stable movement and obstacle avoidance are important when robots move through uneven or challenging environments. These works show that renewable energy and smart control methods can work together to support autonomous robotic systems.

In the area of agricultural monitoring, solar-powered sensing systems are becoming more useful and widely studied. Nwogwu et al. [3] presented a wireless soil monitoring system that measures soil moisture, temperature, and pH, making it possible to observe field conditions in real time. Other studies on wireless sensor networks for precision agriculture [11] and IoT-based smart farming systems [25] explain how energy-efficient communication and connected sensors can improve the way agricultural data is collected and shared. Earlier research on wireless sensing technologies in agriculture [26] also highlighted the importance of reliable communication systems that can function properly in open field environments. Taken together, these studies show how continuous monitoring of soil and environmental conditions can support better farming decisions.

Maintenance of renewable energy systems has also been an important research area. Mahale et al. [4] and Madhavan et al. [6] suggested IoT-based systems for cleaning and monitoring solar panels automatically so that their efficiency can be maintained without frequent manual work. In a similar direction, Sura et al. [5] introduced a solar hybrid rover that gathers soil information while running on solar energy. These examples demonstrate that combining solar power with IoT communication can make such systems more sustainable while also reducing the need for human effort.

Researchers have also explored different types of advanced agricultural robots. Das et al. [7], Veiros et al. [9], and Linford and Haghshenas-Jaryani [10] created robotic platforms that can be used for crop monitoring, soil analysis, and harvesting activities. Broader studies discussing agricultural robotics [13], challenges in harvesting automation [24], and recent trends in robotic mechanization [30] show that automation is slowly becoming an important part of modern farming practices. In addition, automatic guidance and navigation systems [27] help improve the accuracy and efficiency of machines working in agricultural fields.

Artificial intelligence is now playing a major role in modern agriculture. Research on machine learning and deep learning applications in agriculture [21], [22] shows how predictive models can help farmers manage crops and estimate yields more effectively. Big data technologies used in smart farming [12] also support large-scale agricultural planning and decision-making. More recent studies combining AI with explainable methods [20], [29] emphasize the need for transparency so that crop predictions and climate impact assessments can be better understood.

Policy reports and technology surveys [15]–[19] indicate that robotics, AI, and IoT are gradually being used in real farming environments. These technologies support smart irrigation systems, soil monitoring, automated harvesting, and data-based crop management, which help farmers deal with labor shortages and changing climate conditions. Recent developments in AI-based rover systems [8] also show that agriculture is moving toward more intelligent and integrated technological platforms.

Overall, the existing literature shows a clear movement toward agricultural systems that use solar power, sensors, artificial intelligence, and IoT connectivity. In areas such as renewable energy management, robotics, wireless sensing, and intelligent data processing, the main goal is to improve efficiency, sustainability, and real-time decision-making in farming. These developments create a strong base for designing integrated systems like AgroBot for precision agriculture.

However, most of the existing research focuses on individual areas such as solar-powered rovers, wireless sensing technologies, or AI-based prediction models. Very few systems combine autonomous movement, real-time dashboard visualization, AI-based soil analysis, and renewable energy support in one unified platform. AgroBot aims to address this gap by bringing these technologies together into a single integrated solution for precision agriculture.

III. METHODOLOGY

AgroBot has been built by integrating communication mechanisms, hardware elements, data processing functions, and visualization features into a cohesive system.

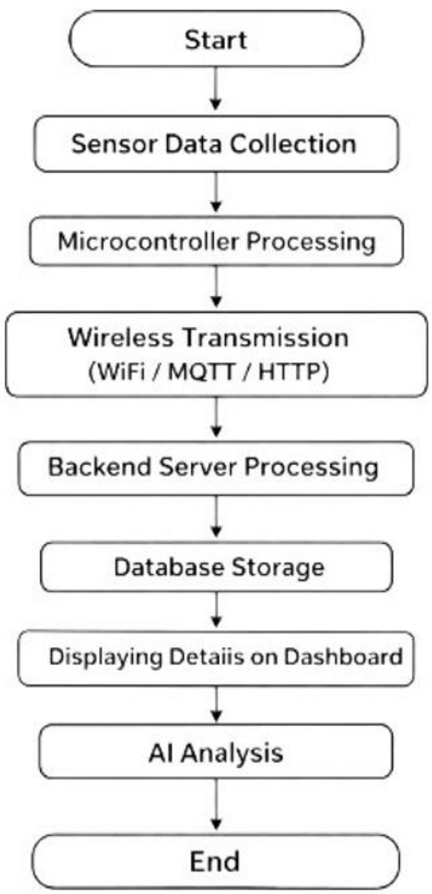

Figure 1. System Flowchart of AgroBot Operation

As shown in Fig. 1, the AgroBot system starts by collecting real-time soil and environmental data using sensors mounted on the rover. The ESP32/NodeMCU processes this data and sends it wirelessly to a backend server through Wi-Fi. The server stores the information and updates the dashboard with live sensor values and rover location. Finally, the AI module analyzes the data to provide soil insights and support better farming decisions.

The system begins by initializing the power supply and activating the microcontroller unit. The rechargeable battery,

supported by the solar charging module, provides stable power to all electronic components. Renewable energy-based field systems have demonstrated improved sustainability and outdoor reliability in agricultural applications [4], [5].

A. Sensor Data Collection

In this stage, real-time environmental and soil parameters are collected through integrated sensor modules. The rover includes soil moisture and pH sensors, DHT11/DHT22 for temperature and humidity, a gas sensor, and a GPS module for location tracking. As the 4-wheel drive rover moves across the field, these sensors continuously gather readings from different locations to ensure better spatial coverage. Similar ground-based agricultural robotic systems performing in-field soil monitoring and crop inspection have been reported in [7], [9], [10]. Wireless soil sensing approaches have also highlighted the importance of continuous environmental monitoring for precision farming [3], [28].

B. Microcontroller Processing

The collected sensor data is transmitted to the NodeMCU/ESP32 microcontroller, which acts as the central processing unit of the rover. The controller performs the following functions:

i. Reads and filters sensor inputs ii.Structures data into formatted packets
ii. Controls motor movement via motor driver modules
iii. Updates GPS positioning

Microcontroller-based IoT agricultural platforms have shown reliable coordination between sensing and control mechanisms [15], [16]. Navigation-assisted rover architectures integrating intelligent movement strategies have also been explored for precision agriculture [8], [27].

C. Wireless Transmission (Wi-Fi / MQTT / HTTP)

After processing, the structured data packets are transmitted wirelessly to a remote backend server using Wi-Fi communication protocols such as HTTP or MQTT. Each packet includes timestamped environmental data along with location information. Wireless sensor networks and IoT communication models play a crucial role in real-time agricultural monitoring systems [11], [25], [26]. Efficient wireless transmission ensures continuous data availability for remote supervision and decision-making.

D. Backend Server Processing

The backend server receives the transmitted data and performs validation, preprocessing, and computational analysis related to soil conditions. Server-side frameworks handle incoming requests and manage communication between the rover and the dashboard interface.

Big data-based smart farming systems emphasize structured server-side processing for large-scale agricultural monitoring [12], [22].

E. Database Storage

After validation, sensor readings are securely stored in a database. This allows historical data tracking, comparison of environmental changes over time, and generation of soil health reports.

Efficient data storage and structured agricultural information systems support long-term precision farming strategies [17], [18].

F. Displaying Details on Dashboard

The stored data is accessed through a web-based dashboard developed using React and TypeScript technologies. The dashboard provides:

i. Real-time rover tracking using 2D mapping (Leaflet)
ii. 3D terrain visualization (Cesium)
iii. Graphical representation of moisture, temperature, and other parameters
iv. Automated soil health reports

Data visualization and interactive agricultural dashboards improve decision support and user engagement in smart farming systems [19], [22].

G. AI Analysis

In the final operational stage, the collected environmental data is analyzed using AI-based models to generate soil insights and crop recommendations. Machine learning and deep learning techniques have been widely applied in agriculture for yield prediction and environmental assessment [20], [21]. Explainable AI approaches further enhance transparency and reliability in recommendation systems [29].

By integrating sensing, processing, communication, storage, visualization, and intelligent analysis within a single workflow, AgroBot functions as a complete precision agriculture platform rather than a standalone monitoring device.

The process completes one monitoring cycle and continues iteratively for continuous real-time agricultural supervision.

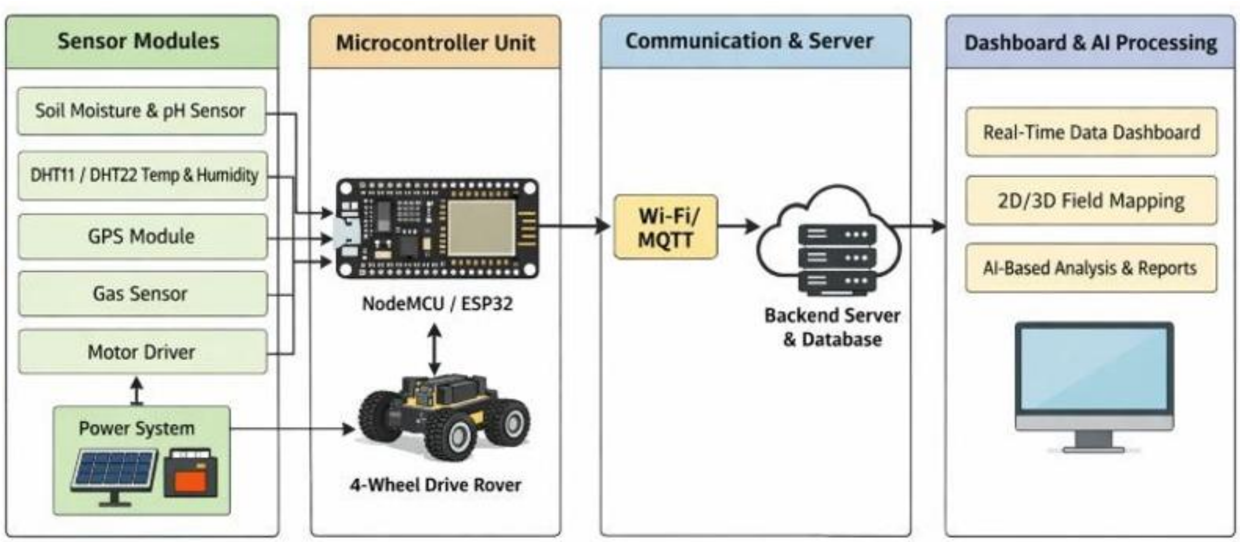

Figure 2. Overall System Architecture of the AI Rover

As shown in Fig. 2, the AgroBot system is divided into four main parts: sensor modules, a microcontroller unit, a communication layer, and the dashboard with AI processing. The sensors collect real-time field data such as soil moisture, soil pH, temperature, humidity, gas levels, and GPS location. This information is sent to the microcontroller (ESP32/NodeMCU), which works as the main control unit and organizes the collected data.

After processing, the data is sent wirelessly to the backend server using Wi-Fi. The dashboard then displays live sensor values, the rover's location, and the system status. At the same time, the AI module studies the data and generates soil health reports and crop suggestions. This layered design helps the system handle sensing, data processing,

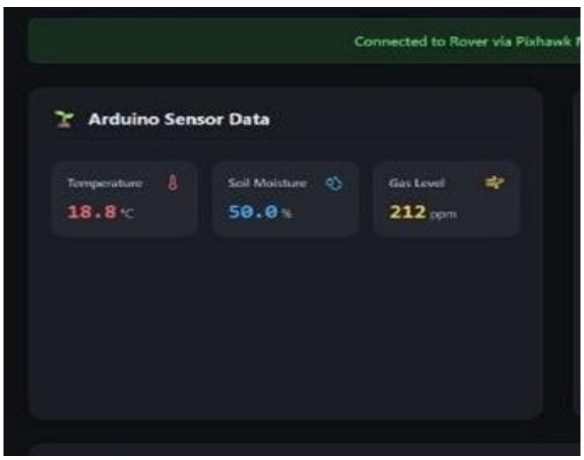

Figure 3. Dashboard 1 : (a) displaying Real Time Arduino sensor data

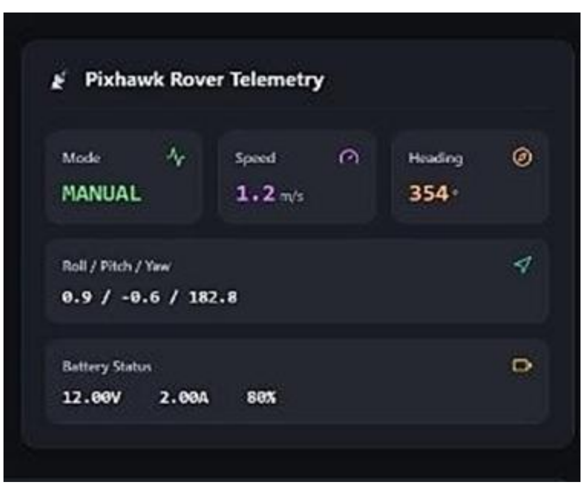

Figure 3. Dashboard 1 : (b) Real-Time Rover Telemetry and Sensor Data Dashboard

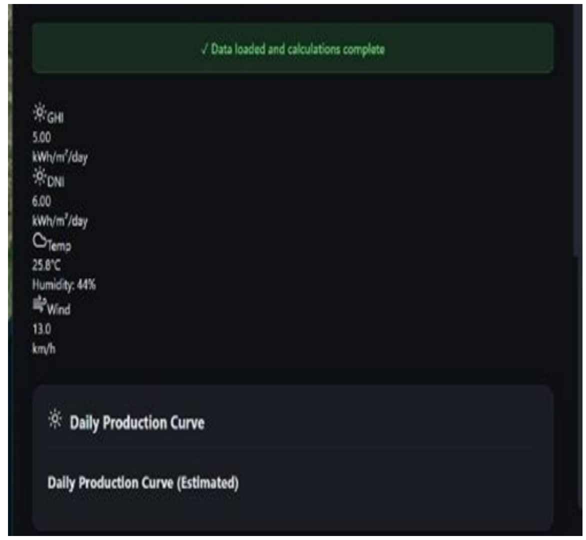

Figure 4. Dashboard showing solar energy analysis

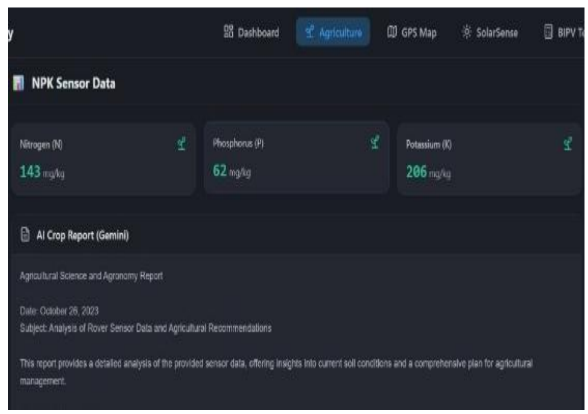

Figure 5: Dashboard Showing NPK Values and Crop Recommendation Report

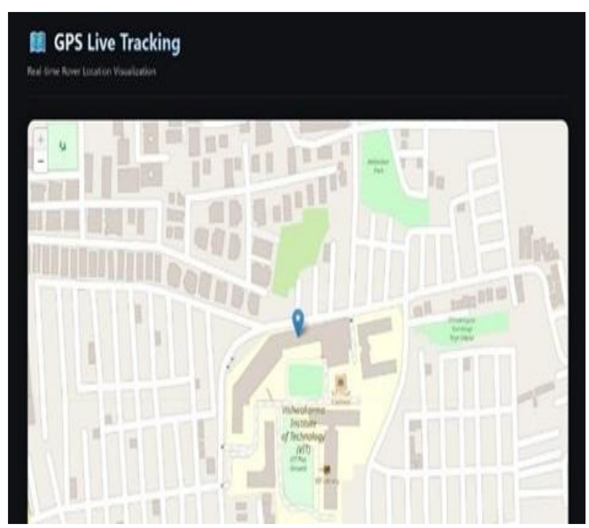

Figure 6 : GPS-Based Live Rover Tracking Interface with Real-Time Field Mapping

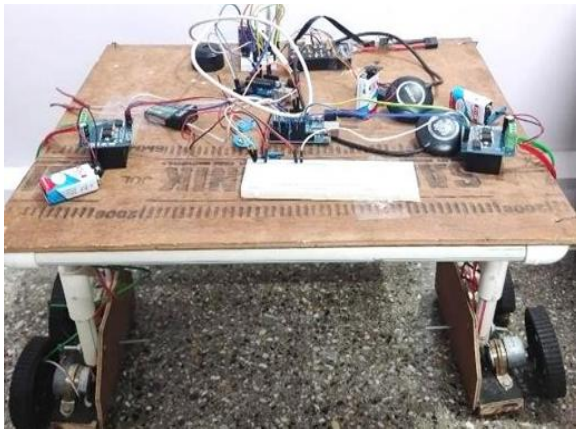

Figure 7 : Integrated AgroBot Rover Platform with Four-Wheel Drive System

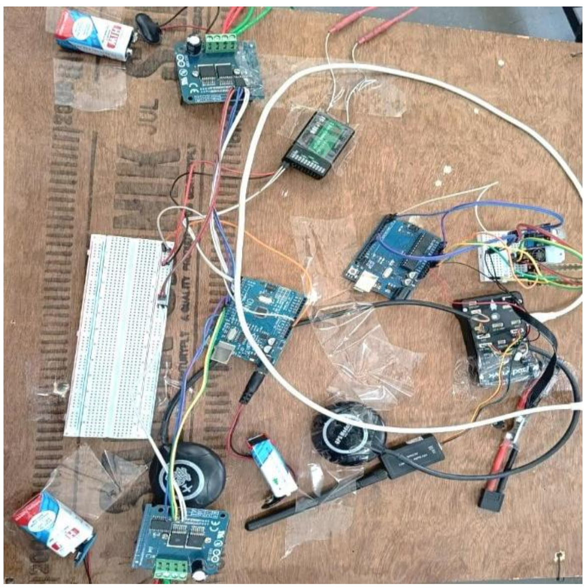

Figure 8. AgroBot Hardware Architecture Showing Sensor and MCU Integration

The dashboard retrieves data from APIs or through WebSock-ets, ensuring live updates as the rover moves and new sensor readings become available.The complete system is tested to check sensor accuracy, communication reliability, dashboard functionality, and rover movement. Field testing is carried out to ensure that the system works properly and performs consistently under actual agricultural conditions.

IV. RESULTS AND DISCUSSIONS

The completed AgroBot system showed that it can collect, send, and display data at the same time from both the farm environment and the rover. This information can be viewed through the connected web dashboard, as shown in the figures (Fig. 3. Real-Time Rover Telemetry and Sensor Data Dash-board, Fig. 6. GPS-Based Live Rover Tracking Interface with Real-Time Field Mapping). The rover regularly measured and reported values such as ambient temperature, soil moisture, gas levels, and NPK (Nitrogen, Phosphorus, Potassium). The hardware setup of the system is also shown in the figures (Fig.7. Integrated AgroBot Rover Platform with Four-Wheel Drive System, Fig. 8).

AgroBot Hardware Architecture Showing Sensor and MCU Integration). The measured temperature during testing was approximately 21°C. This temperature falls within the com-monly accepted range for most field crops, as many crops typ-ically grow well between 18°C and 30°C. The soil moisture content was recorded at 54.4%, suggesting that sufficient wa-ter was present in the soil to support proper plant growth. In general, soil moisture levels between 40% and 70% are con-sidered suitable for many crops, although the exact require-ment can vary depending on the specific crop type.

The measured gas concentration was 182 ppm, which indi-cates that the surrounding environment was within normal limits. No harmful gas levels were observed during the testing, which confirms that the rover's air quality monitoring sys-tem was functioning as expected.

Soil fertility was examined through NPK measurements. The nitrogen level was 141 mg/kg, representing a moderate amount in the soil. Phosphorus was recorded at 58 mg/kg, which falls within an acceptable range, and potassium meas-ured 196 mg/kg, indicating relatively good soil condition. These values are presented in Fig. 5. Dashboard Showing NPK Values and Crop Recommendation Report. Using the recorded sensor values, the AI module generated a soil health report along with practical recommendations for the field. The recommendations matched commonly followed agricul-tural practices, suggesting that the system was able to inter-pret the collected data properly and translate it into meaning-ful guidance for improving crop growth and overall produc-tivity.

The dashboard performance also demonstrated that the sys-tem could manage and present real-time data effectively. The GPS mapping module continuously tracked the rover's posi-tion across the field using interactive maps, as shown in Fig.6. GPS-Based Live

Rover Tracking Interface with Real-Time Field Mapping. In addition, telemetry data such as heading, speed, roll, pitch, yaw, and battery level were transmitted without noticeable interruption.

The SolarSense module was able to estimate the available so-lar energy potential and generate daily, monthly, and yearly projections based on the inputs given by the user. The corre-sponding results are illustrated in Fig. 4. SolarSense Module Showing Solar Energy Analysis and Production Estimation. These results suggest that the platform is not limited to agri-cultural monitoring alone but can also support applications related to renewable energy planning and management.

The experimental results show that AgroBot was able to per-form continuous environmental monitoring along with real-time data display and AI-based analysis under field condi-tions. The hardware components and the web dashboard worked together smoothly, as illustrated in Figs. 7 and 8, in-dicating that the system functions reliably and is suitable for practical use in agricultural environments. By enabling data-driven decisions, reducing manual effort, and offering clear insights, the system supports efficient and sustainable farm-ing practices.

V. CONCLUSION AND FUTURE SCOPE

Using AgroBot, farming becomes easier and more efficient with the help of smarter technology. By using a travelling rover along with a simple and interactive dashboard, farmers can regularly check their crops, soil health, and weather con-ditions in a clear and accurate way, reducing the need for con-stant manual checking, saving water and fertilisers, and help-ing improve overall crop production and productivity. The proposed rover telemetry system has potential for future im-provements and large-scale use for agricultural purposes. The AgroBot rover can be improved by additional things like an obstacle detection feature that helps it automatically change the direction of its wheels whenever something comes in its path, allowing it to move safely across fields without manual control. Simple sensors like ultrasonic or infrared sensors can be used so that the rover can sense objects ahead and avoid upcoming collisions. Another useful improvement would be adding a safety alert system that, if the temperature sensor de-tects extremely high heat that may indicate a fire or other dan-gerous condition, a buzzer can sound to warn people nearby. The system can also be made more user-friendly by additional support for multiple regional languages in the dashboard so that farmers can easily understand the data and suggestions in their own mother tongue. With these practical improvements, AgroBot can become more reliable, intelligent, and better suited for real-world agricultural applications.

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