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Agriaerox: Drone Based Soil and Air Quality Tester

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Abstract

Access to accurate soil and environmental data is essential for sustainable and data-driven agriculture. This project introduces AGRIAEROX, a drone-based soil testing and environmental monitoring system designed to automate field assessment and reduce the need for labor-intensive manual sampling. The system integrates an ESP32 microcontroller with a soil moisture sensor, a DHT11 module for temperature and humidity measurement, and an MQ135 sensor for detecting air quality indicators such as CO_2 and volatile compounds. Mounted on a lightweight UAV platform, the drone can navigate across large or difficult-to-reach areas, collecting data from multiple points with consistent precision. All sensor readings are transmitted wirelessly to a base station, where they are displayed in real time and logged for further analysis. This allows farmers and field managers to track spatial variations in soil and atmospheric conditions, detect potential issues early, and make informed decisions regarding irrigation, fertilization, and crop health management. Preliminary testing demonstrates stable communication, reliable sensor performance, and strong potential for large-scale deployment. Overall, AGRIAEROX represents a cost-effective, scalable, and efficient solution for advancing precision agriculture and environmental monitoring.

Keywords: Drone-based soil testing, precision agriculture technology, automated field monitoring, ESP32 microcontroller integration, wireless data transmission, soil moisture sensing, temperature–humidity analysis, air quality monitoring (MQ135).

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1. Introduction

Soil quality and environmental conditions are critical factors that influence agricultural productivity, ecosystem health, and sustainable land management. Traditional soil testing methods involve manual sample collection and laboratory analysis, which are often laborintensive, time-consuming, and limited in geographical coverage. These challenges are especially pronounced in remote or inaccessible areas, where reaching testing sites may be difficult or unsafe. Accurate and timely information about soil properties—such as moisture content, nutrient levels, and temperature is essential for making informed decisions in agriculture and environmental research.

Advancements in sensor technology and unmanned aerial vehicles (drones) have created opportunities to automate soil and environmental monitoring. Drones equipped with sensors can collect data from multiple locations efficiently, providing real-time insights into soil and air conditions. Key parameters for monitoring include soil moisture, temperature, humidity, and air quality, which collectively influence crop health, irrigation planning, and environmental sustainability. The integration of wireless communication and microcontroller-based systems enables data to be transmitted and visualized instantly, allowing researchers and farmers to take timely corrective actions or optimize agricultural practices.

The AGRIAEROX system leverages a drone-based platform combined with an ESP32 microcontroller, a soil moisture sensor, and a DHT-11 sensor for measuring temperature and humidity. An MQ135 is planned to assess environmental conditions further. By automating data collection and providing real-time monitoring, AGRIAEROX addresses the limitations of conventional soil testing methods, offering a scalable, efficient, and cost-effective solution for precision agriculture.

1.1 Objectives

The primary objective of this project is to design and develop a drone-based soil testing system that can efficiently analyze soil and environmental conditions in remote or inaccessible areas. The system aims to assist farmers, researchers, and environmental analysts in obtaining accurate and real-time data for better decision-making in agriculture and land management.

Specific objectives include:

a) To integrate sensors such as a soil moisture sensor, DHT-11 (for temperature and humidity), and an air quality sensor with an ESP32 microcontroller for multiparameter environmental monitoring.

b) To deploy the system on a drone to enable aerial soil testing and extend the range of data collection beyond human reach.

c) To implement wireless data transmission for real-time monitoring and storage of soil and environmental parameters.

d) To provide an efficient and cost-effective solution for precision agriculture, reducing the need for manual soil sampling and laboratory testing.

e) To support sustainable farming practices by offering timely insights into soil conditions, helping optimize irrigation, fertilization, and crop planning.

2. Literature Review

[1] Drone-Based GNSS-R Soil Moisture Retrieval (Zhu et al., 2021)

This study presents a drone-mounted GNSS-Reflectometry system using QZSS L5-band signals to measure soil moisture non-invasively. A UAV equipped with dual antennas collects raw IF data, which is processed to compute reflected/direct signal power ratios. Soil moisture values are derived with high temporal resolution and averaged for stability. Tests over farmland showed strong accuracy (RMSE 0.022–0.056), though performance varies with soil conditions and flight altitude. Despite sensitivity to environment and calibration needs, the approach proves feasible for low-cost, scalable soil moisture monitoring.

[2] Drone Use in Long-Term Construction Projects for Cash Flow Management (Shankar & Dakshayini)

The paper proposes a conceptual framework where drones support accounting and auditing by providing real-time site inspection data. By improving progress monitoring, drones enhance the accuracy of revenue recognition under the percentage-of-completion method. Benefits include reduced manual effort, better data quality, increased safety, and improved financial decision-making. While theoretical, it highlights drones' potential role in modernizing financial oversight in construction.

[3] IoT and Drone-Enabled Precision Agriculture (Qasim et al.)

This paper discusses how drones integrated with IoT sensors can improve precision agriculture and crop monitoring. Drones act as remote inspection tools that automate data collection, reduce human error, and improve real time decision-making. The study highlights cost efficiency, improved monitoring accuracy, and potential large-scale adoption, though empirical validation is still needed.

[4] Drone-Based Data Collection from Underground Sensors (Elhesasy et al.)

A drone equipped with an XBee module is used to wirelessly retrieve data from underground soil sensors. Field tests showed stable communication up to 100 meters and efficient coverage of 4 hectares per 15-minute flight. With low power consumption (100 W for drone, 0.1 W for sensors), the system offers an automated, scalable, and energy-efficient method for soil monitoring in precision agriculture.

[5] Automatic Drone-Based Forest Fire Detection & Prevention (Alkhatib et al.)

This study proposes an autonomous drone system equipped with thermal cameras, sensors, and fire-suppression tools. The drones continuously monitor high-risk areas, detect fires instantly, and can respond immediately with extinguishing agents. Advantages include early detection, rapid intervention, improved safety, and operational efficiency compared to conventional firefighting.

3. Methodology

The methodology of the AGRIAEROX: Drone-Based Soil Tester project is structured in multiple stages, from system design to final hardware implementation. The system integrates drone-based mobility with sensor-based soil and environmental monitoring, along with IoT capabilities for real-time data collection and analysis.

The core of the system is an ESP32 microcontroller, which acts as the central control unit. Sensors including a soil moisture sensor, DHT-11 (for temperature and humidity), and an MQ135 air quality sensor are connected to the microcontroller to continuously monitor environmental conditions. The collected data is processed by the ESP32 and can be transmitted wirelessly to a base station or cloud platform, enabling real-time monitoring and analysis.

The drone is equipped and can be controlled and maneuvered over agricultural mentalists, and researchers to collect, transmit, and analyze a wide range of environmental data in real time. This integration not only enhances the precision and reliability of field measurements but also minimizes the need for manual data collection, saving both time and labor. The system's ability to operate in remote or hazardous environments ensures consistent monitoring of large agricultural areas, providing valuable insights into soil health, atmospheric conditions, and overall ecosystem performance. Ultimately, AGRIAEROX supports data-driven decision-making, helping optimize resource use, improve crop yields, and promote sustainable farming practices fields or remote locations by the operator. During flight, the sensors capture data from multiple points, which is either displayed on a local interface or sent via Wi-Fi/IoT connectivity for remote monitoring. Threshold values for soil moisture, temperature, and air quality can be pre-set, allowing alerts or notifications to be generated if readings fall outside acceptable ranges.

Before hardware implementation, the system design is validated through simulation. Software platforms such as Proteus or MATLAB can be used to simulate sensor behavior and data transmission, ensuring that the system performs accurately under different environmental conditions. After successful simulation, the sensors are physically integrated with the ESP32, and the drone is tested for stable flight and reliable data acquisition.

The final system offers a cost-effective, scalable, and fully autonomous solution for comprehensive soil and air quality monitoring. By integrating drone mobility with advanced sensor technology and IoT connectivity, AGRIAEROX enables farmers, environmentalists, and researchers to collect, transmit, and analyze a wide range of environmental data in real time. This integration not only enhances the precision and reliability of field measurements but also minimizes the need for manual data collection, saving both time and labor. The system's ability to operate in remote or hazardous environments ensures consistent monitoring of large agricultural areas, providing valuable insights into soil health, atmospheric conditions, and overall ecosystem performance. Ultimately, AGRIAEROX supports data-driven decision-making, helping optimize resource use, improve crop yields, and promote sustainable farming practices.

3.1 System design

The proposed system is an innovative system designed to simplify and modernize soil testing through the use of drone technology and IoT-based sensors. The project focuses on collecting real-time data from areas that are difficult to access manually, providing valuable insights into soil and environmental conditions.

The system is built around an ESP32 microcontroller, which processes data from sensors such as the soil moisture sensor, DHT-11 for temperature and humidity, and an air quality sensor (MQ135). This data is transmitted wirelessly for analysis and monitoring. By combining drone mobility with smart sensing, AGRIAEROX aims to assist farmers and researchers in improving agricultural practices, optimizing resource usage, and promoting sustainable development.

3.2 Block Diagram

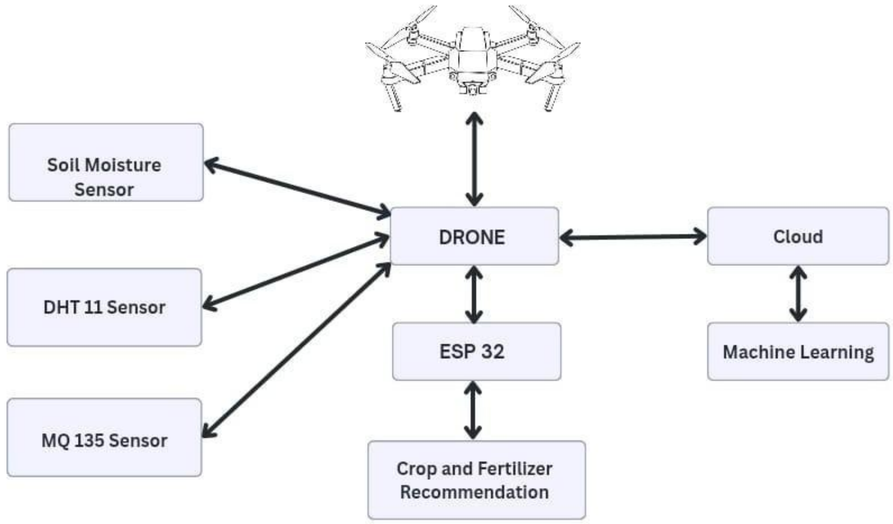

Figure 1: Block Diagram

3.3 Systems Used

a) **Sensors (Soil Moisture DHT11)**: The Soil Moisture Sensor measures the water content in the soil, while the DHT11 sensor records temperature and humidity data. These environmental parameters are essential for determining the crop condition and soil health.

b) **Arduino Controller**: The Arduino microcontroller acts as the central interface between the sensors and the drone. It collects real-time data from the sensors, processes basic readings, and sends the data to the drone module.

c) **Drone Unit:** The drone carries the sensors and Arduino setup to survey remote or inaccessible agricultural areas. It transmits the collected data wirelessly to the cloud for further analysis.

d) **Cloud Platform:** The cloud receives the sensor data from the drone, stores it securely, and performs preprocessing. The cloud ensures scalability and real-time access to the data from anywhere.

e) **Machine Learning Module:** Machine learning algorithms are implemented in the cloud to analyze sensor data and predict suitable crops and fertilizers based on environmental conditions and soil characteristics. The Soil Moisture Sensor measures the water content in the soil, while the DHT11 sensor records temperature and humidity data. These environmental parameters are essential for determining the crop condition and soil health.

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4. Working Principle

The drone-based soil testing system operates by integrating autonomous aerial mobility with compact soil-analysis technology to enable efficient assessment of terrains that are inaccessible or hazardous for human surveyors. The UAV platform is built around a lightweight multirotor frame equipped with a GPS-assisted navigation module, inertial measurement unit (IMU), optical/ultrasonic altitude sensors, and a dedicated soil-sampling mechanism.

During operation, the ground station uploads predefined waypoints generated through GIS mapping or manual selection. The drone takes off autonomously, stabilizing itself using closed-loop feedback from the IMU and barometric sensors. As it navigates toward each coordinate, onboard obstacle-avoidance (if present) ensures safe transit over uneven landscapes, vegetation, or debris.

At the specified sampling location, the UAV either performs a controlled soft landing or hovers at low altitude and deploys a downward-extending probe. Depending on the design, this probe may function in two modes:

i. **Physical Sampling Mode:**

A micro-auger or coring tool collects a small soil sample into a sealed chamber.

ii. **In-situ Measurement Mode:**

Integrated sensors measure soil moisture, temperature, conductivity, pH, or nutrient concentration (NPK) without extracting material.

In both modes, the system minimizes ground disturbance and sampling time to preserve flight efficiency and battery life.

Once the sample is collected or the parameters are measured, the data is digitized and transmitted in real time to the ground station using an IoT communication layer—typically LoRa, Wi-Fi, or LTE depending on range requirements. The data packet includes the sensor readings along with metadata such as GPS location, timestamp, and system health parameters. This ensures that each soil data point is spatially tagged for accurate mapping and post-processing.

After completing all assigned waypoints, the UAV returns to the base station using automated Return-to-Home logic. The collected soil samples (if any) can then be sent for laboratory analysis, while the digital data is immediately available for agricultural, geological, or environmental interpretation. This approach drastically reduces fieldwork time, improves personnel safety, and provides high-resolution, location-specific soil insights for precision farming or terrain exploration.

5. Circuit Diagram

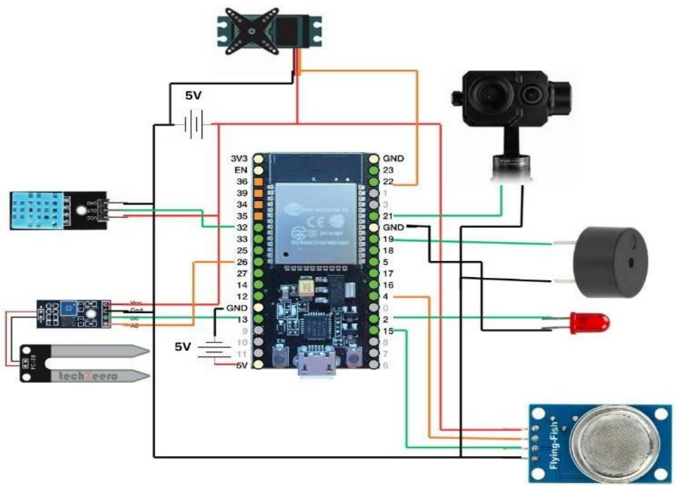

Figure 2: Circuit of AGRIAEROX

This circuit is built around an ESP32 microcontroller, which acts as the central unit that collects and processes data from all connected sensors. The DHT11 provides temperature and humidity readings, the soil-moisture module measures ground conditions through its analog output, and the MQ gas sensor detects the presence of harmful gases. These inputs allow the ESP32 to continuously assess environmental status. Based on the readings, the ESP32 controls several output devices: a buzzer for audible alerts, an LED for visual indication, a servo motor for performing mechanical actions such as moving a sampling arm, and a camera module for capturing images whenever a specific condition is triggered. Everything shares a common 5V power supply and ground, ensuring stable operation. Overall, the circuit forms a compact multi-sensor monitoring system capable of detecting environmental changes, responding automatically, and recording useful data for further analysis.

5.1 Simulation Diagram

The system performed well under simulated conditions, accurately tracking changes in soil and air quality parameters and displaying the data on the smartphone. The alert system functioned as expected, with notifications being sent to the user when the sensor readings exceeded the predefined thresholds. The system's response time was swift, ensuring that users would be notified of any contamination within seconds of detection. The simulation environment also helped identify potential issues, such as the calibration of sensors and the sensitivity of alert triggers, which were adjusted accordingly.

The use of simulation tools provided several advantages. First, it allowed for cost effective testing, as no physical components were required during this phase. Second, it enabled rapid iteration of design changes, allowing the system to be fine-tuned before moving to hardware. Lastly, it provided a safe environment for testing extreme water quality scenarios, which would have been difficult to replicate with real sensors.

6. Result

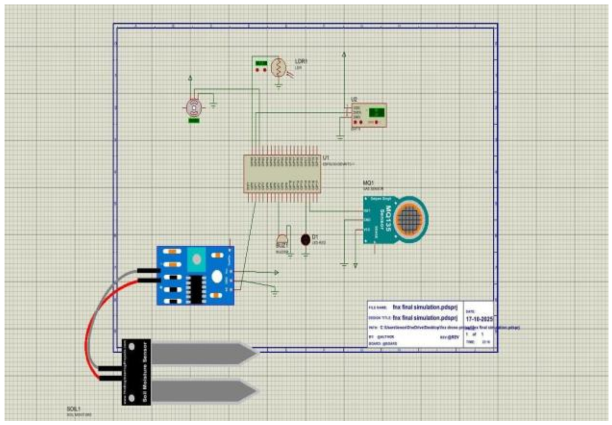

Figure 3: Simulation Diagram

The simulation phase of the proposed soil and air quality tester was conducted to evaluate its ability to monitor key soil quality parameters—pH, humidity, and temperature—and to trigger alerts when contamination levels exceeded safe thresholds. The system was designed and tested in a simulation environment, allowing for the observation of its behavior under various conditions and ensuring that the sensor data was processed effectively before moving to any hardware phase.

6.1. Simulation Results

The simulation was carried out using software tools such as MATLAB or Proteus, where virtual sensors for soil moisture, temperature, humidity, and air quality (MQ135) were modeled. Each sensor was configured with specific thresholds to simulate variations in environmental conditions. The system successfully displayed real-time sensor data on a virtual interface, which mimicked the final drone-based setup. As the soil and air conditions fluctuated, the system responded dynamically by updating the displayed values, ensuring accurate real-time monitoring. Alerts were generated based on the pre-set thresholds for each parameter. For example, When the simulated soil moisture dropped below a safe level or the MQ135 readings indicated poor air quality, the system triggered alert notifications. These notifications were simulated to be sent via Wi-Fi or IoT connectivity, confirming the functionality of the remote monitoring system. The results demonstrated that the simulation effectively modeled real-world soil and environmental conditions, providing accurate readings for soil moisture, temperature, humidity, and air quality. The simulation environment also allowed for early identification of issues, such as incorrect threshold settings or delayed alerts, which were corrected before finalizing the hardware design.

7. Discussion

The results from the simulation phase demonstrate the effectiveness of the proposed system in real-time soil and Air quality monitoring and alert generation. The simulation provided valuable insights into the system's behavior, allowing for optimization of the sensor thresholds and ensuring that the alert system responded promptly to fluctuations in values. The use of virtual sensors to simulate pH, humidity, temperature and pollution readings enabled thorough testing of the system's functionality before any physical implementation.

8. Conclusion

AGRIAEROX: Drone-Based Soil Tester demonstrates how drone mobility combined with sensor-based monitoring can transform soil and air analysis. Traditional soil testing requires manual sampling, lab work, and access to the site, which limits speed and coverage. AGRIAEROX overcomes these barriers by allowing drones to collect real-time data from remote or difficult-to-reach areas, giving farmers, researchers, and environmental analysts quicker and more reliable insights for decision-making in agriculture and land management.The system uses an ESP32 microcontroller to integrate multiple sensors, including soil moisture probes, a DHT11 temperature-humidity sensor, and an MQ135 air quality module. This multi-parameter approach provides a broader understanding of soil conditions and surrounding environmental factors. With continuous monitoring, users can make informed decisions about irrigation, fertilization, and crop planning, improving productivity while reducing resource waste.

IoT connectivity further strengthens the system by enabling wireless transmission of sensor data to a remote interface. This allows long-range monitoring, remote alerts, and the possibility of cloud-based analytics for trend analysis and predictive insights. The simulation stage played a key role in validating sensor behavior, refining thresholds, and ensuring the reliability of communication and alert mechanisms before hardware deployment.

AGRIAEROX also presents strong potential for future upgrades, such as nutrient-level sensing, improved air-quality modules, cloud storage, dedicated mobile apps, GPS-based autonomous flight, machine-learning predictions, and multi-drone coordination. These enhancements can greatly expand its precision and scalability.

In summary, AGRIAEROX offers a cost-effective, scalable, and efficient solution for real-time soil and air quality monitoring, supporting smarter, more sustainable agricultural practices and laying a solid foundation for advanced precision-farming technologies

9. Future Scope

The proposed drone-based soil and air quality system has demonstrated its effectiveness in real-time monitoring of soil and air quality and alert generation. However, there are several areas in which the system can be expanded and improved in future iterations.

The following points outline the potential developments that could enhance the system's functionality and broaden its applicability.

1. Additional Soil Sensors
2. Advanced Air Quality Monitoring
3. Cloud-Based Data Storage
4. Mobile/Web Application
5. Autonomous Flight Planning

6. Solar-Powered Drone
7. Machine Learning Integration
8. Multi-Drone Coordination

10. References

[1]. Qasim, A., El Refae, G. A., & El Etter, S. (2022). Utilizing drones in long-term construction projects: The impact on cash flow management. In 2022 International Arab Conference on Information Technology (ACIT) (pp. 1–4). IEEE. https://doi.org/10.1109/ACIT57182.2022.9994144

[2]. Zhu, Y., & Gao, F. (2024). Analysis of drone-based GNSS-R soil moisture retrieval from QZSS GEO L5-band signal.

[3]. IEEE Geoscience and Remote Sensing Letters, 21, Article 2503805. https://doi.org/10.1109/LGRS.2024.3417426

[4]. Gaonkar, G. V., Bhagwat, R. M., & Agarwal, T. (2025). The potential of IoT and sensor-enabled drones for precision agriculture and crop monitoring. In 2025 International Conference on Automation and Computation (AUTOCOM) (pp. 1057–1062). IEEE. https://doi.org/10.1109/AUTOCOM64127.2025.10957030

[5]. Elhesasy, M., Shashati, M., & Alzeyoudi, S. (2024). Drone-based data collection for precision agriculture applications. In 2024 IEEE Global Conference on Artificial Intelligence and Internet of Things (GCAIoT) (pp. 1–6). IEEE. https://doi.org/10.1109/GCAIoT63427.2024.10833576

[6]. Alkhatib, A. A., Jaber, K. M., & AlMadi, M. (2024). A proposed automatic forest fire extinguishing and prevention system using drones. In 2024 IEEE International Humanitarian Technologies Conference (IHTC) (pp. 1–6). IEEE. https://doi.org/10.1109/IHTC61819.2024.10855034

[7]. Choi, H.-W., Kim, H.-J., Kim, S.-K., & Na, W. S. (2023). An overview of drone applications in the construction industry. Drones, 7(8), Article 515. https://doi.org/10.3390/drones7080515

[8]. Guebsi, R. (2024). Drones in precision agriculture: A comprehensive review of applications, technologies, and challenges. Drones, 8(11), Article 686. https://doi.org/10.3390/drones8110686