

An Intelligent IoT-Based Framework for Plant Disease Detection and Crop Advisory Using CNN and ESP32

Dr. A. Rajani¹, Bandaru Anuhya²

¹Assistant Professor, Department of ECE, JNTUK Kakinada

²Scholar, Department of ECE, JNTUK Kakinada

Abstract:- The increasing demand for sustainable agricultural production has created a need for intelligent systems that continuously monitor crop-growing conditions and support timely agricultural decision-making. Conventional farming practices largely depend on manual observation for monitoring environmental conditions and identifying plant diseases, which can be time-consuming and require expert knowledge. This paper presents an intelligent IoT-based plant disease monitoring and crop advisory system integrating an ESP32 microcontroller, environmental sensors, a Convolutional Neural Network (CNN), and a Flask-based web application. The system continuously monitors temperature, humidity, soil moisture, soil pH, water level, light intensity, and air quality. Sensor readings collected through the ESP32 are processed, stored, and displayed on a real-time web dashboard. Users can also upload plant leaf images, which are preprocessed and analyzed using a trained CNN model to identify disease categories based on visual characteristics such as colour, texture, and disease patterns. The system provides disease information and preventive recommendations. Furthermore, the crop advisory module compares real-time sensor values with predefined crop requirements and generates recommendations for irrigation, soil moisture, pH management, and crop maintenance. The integrated framework reduces dependence on manual inspection and supports data-driven agricultural decisions, providing a practical, scalable, and cost-effective approach to smart agriculture

Keywords: : IoT, Smart Agriculture, ESP32, Convolutional Neural Network, Plant Disease Detection, Crop Advisory, Deep Learning, Precision Agriculture, Flask (Web Application).

1. Introduction

Agriculture is a fundamental sector for food production, economic development, and sustainable livelihoods. However, increasing population, changing climatic conditions, limited water availability, soil degradation, and plant diseases create significant challenges for modern farming. Conventional agricultural practices mainly depend on manual observation and farmer experience for monitoring crop conditions and identifying diseases. Such approaches can be time-consuming and may result in delayed disease identification and inefficient resource management.

The development of the Internet of Things (IoT) and Artificial Intelligence (AI) has created new opportunities for improving agricultural monitoring and decision-making. IoT-based systems enable continuous monitoring of environmental parameters through sensors, while deep learning techniques can analyze plant images and identify disease symptoms. The integration of these technologies can provide farmers with timely information about both crop-growing conditions and plant health.

Plant diseases are a major factor affecting crop productivity and quality. Conventional disease identification generally relies on visual inspection, which may require agricultural expertise and can be difficult when symptoms are similar. CNN-based image classification provides an automated approach for analyzing leaf images and identifying disease categories based on learned visual features such as colour, texture, and disease patterns.

The proposed framework further incorporates a crop advisory module that compares real-time environmental conditions with predefined requirements for the selected crop. Based on the comparison, the system generates recommendations related to irrigation, soil moisture, pH management, and crop maintenance. The Flask web application integrates sensor monitoring, leaf image upload, CNN-based disease prediction, historical data visualization, and crop advisory services within a unified platform.

The main objective of this work is to develop an integrated and practical smart agriculture framework that combines IoT-based environmental monitoring with deep-learning-based plant disease detection and crop advisory. By reducing dependence on manual inspection and providing data-driven recommendations, the proposed system aims to support timely decision-making, efficient resource utilization, and sustainable agricultural practices.

2. Literature Survey

Recent advancements in smart agriculture have led to the increasing adoption of Internet of Things (IoT), machine learning, and deep learning technologies for crop monitoring and disease management. Traditional plant disease identification mainly relies on manual observation and agricultural expertise, which can be time-consuming and may result in delayed diagnosis. Deep learning, particularly Convolutional Neural Networks (CNNs), has demonstrated significant potential for automatically identifying plant diseases from leaf images.

Sladojevic et al. [1] proposed a deep neural network-based approach for recognizing plant diseases using leaf images. Ferentinos [2] investigated deep learning models for plant disease detection and diagnosis across multiple crop categories. Durmus et al. [3] demonstrated the application of deep learning for detecting diseases in tomato leaves. Kamilaris and Prenafeta-Boldú [4] reviewed the applications of deep learning in agriculture and highlighted its potential for automated agricultural analysis. Barbedo [5] emphasized that dataset size and image diversity significantly influence the effectiveness of deep learning models for plant disease classification.

In parallel, IoT-based agricultural systems have been developed for continuous monitoring of environmental conditions. Parameters such as temperature, humidity, and soil moisture can be collected through sensors and used to support precision farming and resource management. Uddin et al. [13] presented an IoT-based solution for precision agriculture, demonstrating the usefulness of connected sensing technologies for agricultural monitoring.

Although these studies demonstrate the effectiveness of deep learning for disease detection and IoT for environmental monitoring, many existing approaches concentrate on individual functionalities rather than integrating disease detection, environmental monitoring, and crop advisory into a unified platform. Therefore, the proposed work combines ESP32-based IoT sensing, CNN-based plant disease detection, Flask-based web monitoring, and crop-specific advisory to provide an integrated and practical solution for smart agriculture.

3. Methods

The proposed system integrates IoT-based environmental monitoring, CNN-based plant disease detection, and crop advisory services into a single web-based smart agriculture platform.

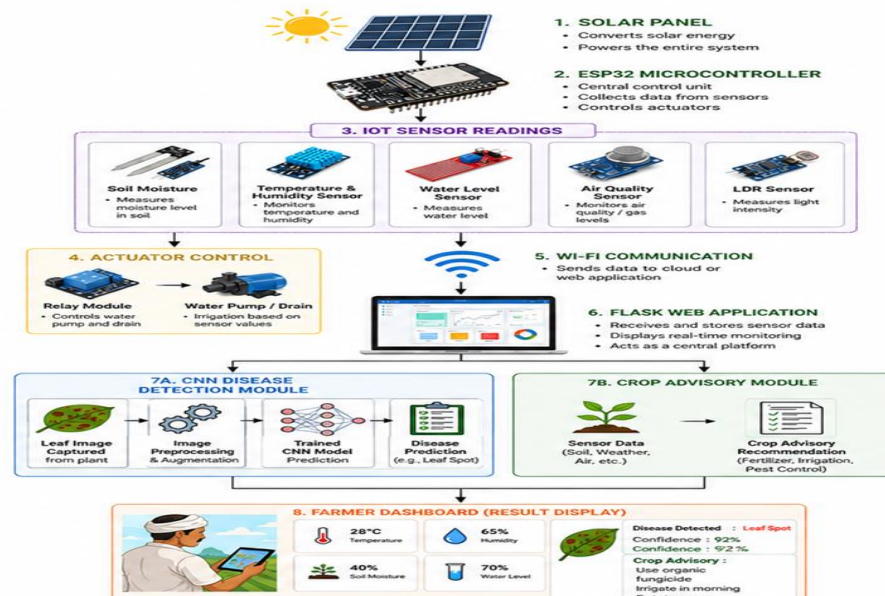
A. System Architecture

The proposed Smart Solar Agriculture System is an integrated IoT and artificial intelligence-based solution developed to support efficient and sustainable crop management. The system combines solar energy, ESP32-based sensor monitoring, automated irrigation, CNN-based plant disease detection, and crop advisory services in a single platform. As shown in Fig. X, the solar panel provides renewable electrical energy to operate the system, reducing dependence on conventional power sources and making the system suitable for agricultural environments.

The ESP32 microcontroller serves as the central control unit of the system. It collects real-time information from different IoT sensors, including soil moisture, temperature and humidity, water level, air quality, and light intensity (LDR). These sensor readings provide important information about the crop's growing environment and soil conditions. The ESP32 processes the collected data and communicates with the web application through Wi-

Fi. Based on the soil moisture and water-level conditions, the system can also control the water pump and drainage system through a relay module, enabling automatic and efficient irrigation.

The collected sensor data is transmitted to a Flask-based web application, The application receives, stores, and displays the sensor readings in real time, allowing the farmer to monitor field conditions remotely. The system also provides two important intelligent functions: CNN-based disease detection and crop advisory. In the disease detection module, a leaf image captured or uploaded by the user is first subjected to image preprocessing and augmentation.



Fig

.1:Workflow of smart Agricultural system

In parallel, the crop advisory module analyzes the sensor readings and compares the current environmental conditions with the required conditions for the selected crop. Based on this analysis, the system provides suitable recommendations related to irrigation, fertilizer application, soil conditions, and crop management. This helps farmers take timely corrective actions and improve crop growth. Finally, all important information is presented through the farmer dashboard, including real-time temperature, humidity, soil moisture, water level, disease prediction, prediction confidence, and crop recommendations. Therefore, the proposed system provides a complete platform for real-time agricultural monitoring, automated irrigation, early plant disease identification, and intelligent crop management. By integrating renewable solar power with IoT and CNN technologies, the system aims to improve resource utilization, reduce manual monitoring, and support sustainable and data-driven agriculture.

4. Results

The proposed Plant Disease Monitoring and Crop Advisory System was implemented and tested using plant leaf images and real-time environmental sensor data. The experimental results demonstrate the successful integration of IoT-based monitoring, CNN-based disease detection, and crop advisory services within a single Flask-based web application.

A. Environmental Monitoring Results

The ESP32 successfully collected data from the connected sensors, including temperature, humidity, soil moisture, water level, light intensity, and air quality. The collected values were transmitted to the Flask application and displayed through the web dashboard. The dashboard provides real-time sensor readings in environmental conditions over time. The continuous availability of sensor information enables farmers to monitor field conditions without performing frequent manual measurements.

The collected environmental data also provide the input required by the crop advisory module for evaluating the suitability of the current conditions.

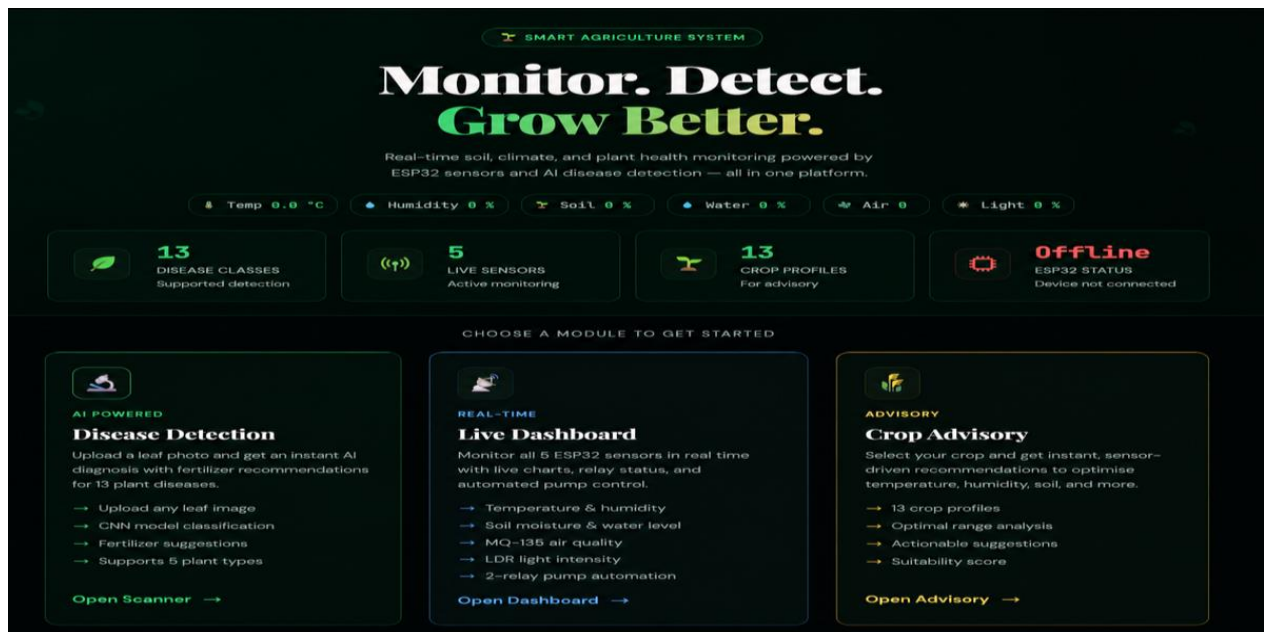


Fig.4: User Friendly Dashboard

A. Plant Disease Detection Results

The disease detection module was tested by uploading plant leaf images through the web interface. The uploaded images were processed by the trained CNN model and classified according to the learned disease patterns.

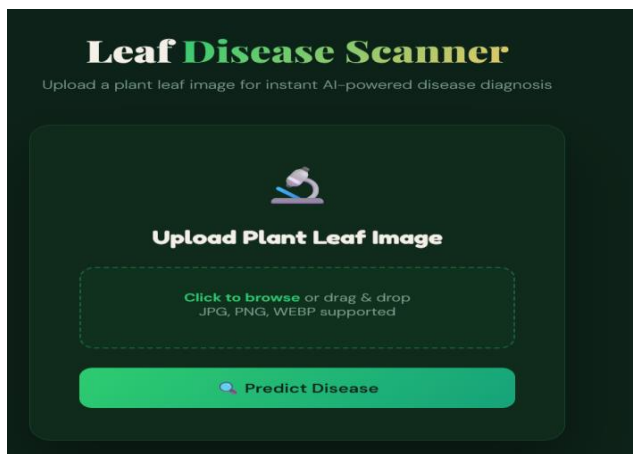


Fig.5: Leaf Image Upload Interface

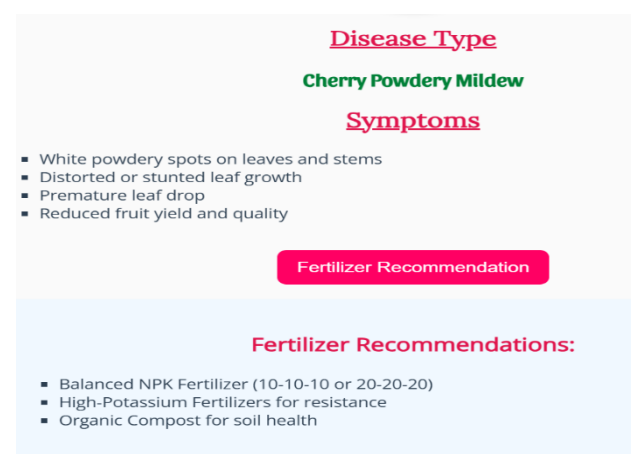


Fig.6: Disease Prediction Result

The system successfully generated a predicted disease category and displayed associated information, including symptoms and recommended preventive measures.

The image-based prediction provides automated support for preliminary disease identification and reduces the need for continuous manual visual inspection. The model analyzes visual characteristics of the leaf, such as colour variations, texture, and disease patterns, to generate the classification result.

C. Crop Advisory Results

The crop advisory module uses the real-time environmental readings to generate crop-specific recommendations. The current sensor conditions are compared with predefined requirements for the selected crop. Based on this comparison, the system provides recommendations related to irrigation, soil moisture, ventilation, and general crop maintenance.

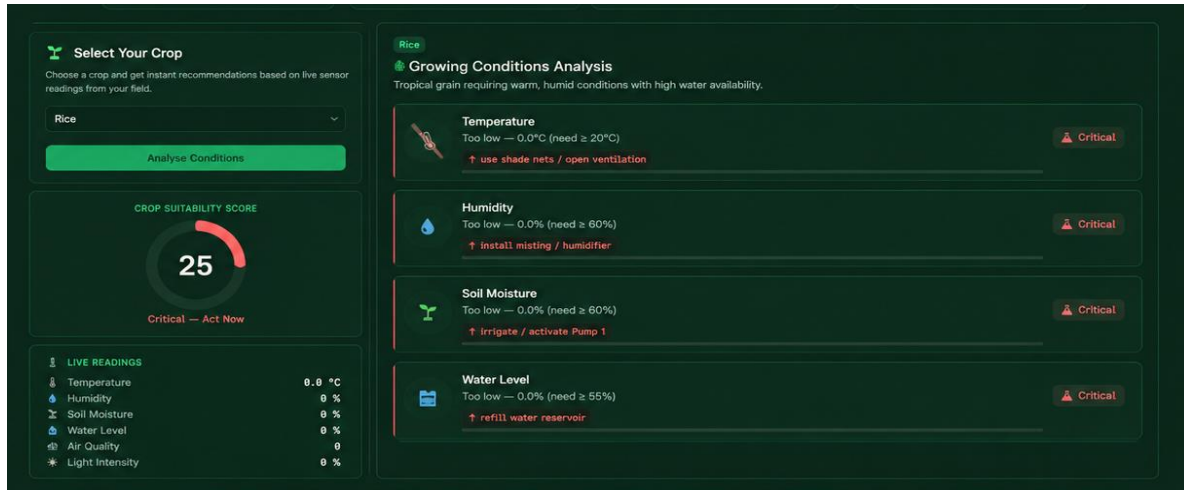


Fig.7: output of Crop Advisory

This approach converts raw sensor measurements into understandable agricultural guidance. Therefore, the farmer can use both the current field conditions and the generated recommendations to support timely crop-management decisions.

Overall, the results indicate that the proposed system provides a practical approach for real-time agricultural monitoring, automated plant disease identification, and crop-specific decision support. The integration of these functions reduces dependence on separate monitoring and diagnostic systems and provides farmers with a centralized platform for data-driven agricultural management.

5. Conclusion and Discussion

This paper presented an intelligent IoT-based Plant Disease Monitoring and Crop Advisory System that integrates ESP32-based environmental sensing, CNN-based plant disease detection, and a Flask-based web application. The developed system continuously monitors important agricultural parameters, including temperature, humidity, soil moisture, soil pH, water level, light intensity, and air quality, and presents the collected information through a real-time dashboard. The CNN-based module enables automated plant disease identification from uploaded leaf images and provides relevant disease information and preventive measures. In addition, the crop advisory module compares real-time environmental conditions with predefined crop requirements and generates recommendations for irrigation, soil management, and crop maintenance. The integration of these modules provides a unified platform for environmental monitoring, disease identification, and agricultural decision support. The developed framework reduces dependence on manual crop inspection and supports timely, data-driven decisions for crop management. Overall, the proposed system demonstrates the practical application of IoT and deep learning technologies in smart agriculture and provides a scalable foundation for future enhancements such as additional crops, larger datasets, automated irrigation, and advanced predictive analytics.

References

- [1] S. Sladojevic, M. Arsenovic, A. Anderla, D. Culibrk, and D. Stefanovic, "Deep Neural Networks Based Recognition of Plant Diseases by Leaf Image Classification," *Computational Intelligence and Neuroscience*, vol. 2016, pp. 1–11, 2016.
- [2] K. P. Ferentinos, "Deep Learning Models for Plant Disease Detection and Diagnosis," *Computers and Electronics in Agriculture*, vol. 145, pp. 311–318, 2018.

- [3] H. Durmus, E. O. Gunes, and M. Kirci, "Disease Detection on the Leaves of the Tomato Plants by Using Deep Learning," in Proc. IEEE Int. Conf. Agro-Geoinformatics, pp. 1–5, 2017.
- [4] A. Kamilaris and F. X. Prenafeta-Boldú, "Deep Learning in Agriculture: A Survey," Computers and Electronics in Agriculture, vol. 147, pp. 70–90, 2018.
- [5] J. G. A. Barbedo, "Impact of Dataset Size and Variety on the Effectiveness of Deep Learning for Plant Disease Classification," Computers and Electronics in Agriculture, vol. 153, pp. 46–53, 2018.
- [6] M. Abadi et al., "TensorFlow: A System for Large-Scale Machine Learning," in Proc. 12th USENIX Symp. Operating Systems Design and Implementation (OSDI), pp. 265–283, 2016.
- [7] F. Chollet, Deep Learning with Python, 2nd ed. Manning Publications, 2021.
- [8] Flask Development Team, "Flask Web Development Framework." [Online]. Available: <https://flask.palletsprojects.com/>