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AI-POWERED MONITORING OF CROP HEALTH, SOIL CONDITION, AND PEST RISKS USING MULTISPECTRAL/HYPERSPECTRAL IMAGING AND SENSOR DATA

[1]Dr. Y. Chitti Babu,[2]G. Deepthi,[3]B. Dayakar Reddy,[4]D. Balaji Reddy

[1]Professor, Dept of Computer Science and Engineering, St. Ann's College of Engineering and Technology, Chirala-523187, India.

[2,3,4]U. G Student, Dept of Computer Science and Engineering, St. Ann's College of Engineering and Technology, Chirala-523187, India.

ABSTRACT- ***Agriculture is increasingly embracing intelligent technologies to improve crop productivity while ensuring sustainable resource utilization and environmental conservation. This paper presents an AI-powered framework for monitoring crop health, soil condition, and pest risk by integrating multispectral/hyperspectral imaging with IoT-based sensor data. The proposed system combines spectral features extracted from crop images with real-time environmental parameters, including soil moisture, temperature, humidity, pH, and essential soil nutrients such as nitrogen, phosphorus, and potassium, to provide a comprehensive assessment of field conditions. A feature fusion approach integrates heterogeneous data from imaging and sensor sources, enabling machine learning models to perform crop health evaluation, nutrient status assessment, and pest risk prediction with improved reliability. To support precision agriculture, the framework introduces a Crop Health Score that summarizes the overall field condition by considering plant vigor, soil quality, and environmental stability. Based on predictive analysis, the system generates timely recommendations for irrigation, fertilizer application, and pest management, enabling preventive rather than reactive interventions. A web-based dashboard presents real-time monitoring results, risk levels, and actionable insights through an intuitive interface. The proposed framework demonstrates the effectiveness of combining artificial intelligence, spectral imaging, and sensor-driven monitoring to optimize agricultural resource utilization, reduce unnecessary chemical inputs, enhance crop productivity, and promote sustainable farming practices under dynamic environmental conditions.***

Keywords: ***Artificial Intelligence (AI), Precision Agriculture, Multispectral/Hyperspectral Imaging, IoT Sensor Data, Crop Health Monitoring***

INTRODUCTION

Agriculture is essential for global food security, but challenges such as soil degradation, pest infestations, and climate variability reduce crop productivity.

Traditional monitoring methods are often time-consuming and unable to detect crop stress at an early stage. This paper proposes an AI-powered agricultural monitoring system that integrates multispectral/hyperspectral imaging with IoT sensor data to assess crop health, soil condition, and pest risk. Using machine learning techniques, the system provides timely recommendations for irrigation, fertilizer application, and pest management, supporting precision agriculture, improving resource utilization, enhancing crop yield, and promoting sustainable farming practices.

LITERATURE SURVEY

AI-powered agricultural monitoring systems have gained significant attention in recent years due to rapid advancements in Artificial Intelligence (AI), Internet of Things (IoT), and remote sensing technologies.

An AI-powered agricultural monitoring system is generally defined as a farming environment that integrates multispectral/hyperspectral imaging, sensor technologies, and intelligent data analysis to monitor crop health, soil condition, and pest risk. The core concept of AI-powered agricultural monitoring revolves around continuous monitoring and intelligent decision-making using real-time data collected from imaging systems and environmental sensors.

RELATED WORK

Several researchers have developed AI-powered agricultural monitoring systems to improve crop health, soil management, and pest detection. Early research mainly focused on manual field inspections and periodic soil testing to assess crop conditions. These methods were time-consuming and provided limited real-time information. Recent advancements in Artificial Intelligence (AI), Internet of Things (IoT), and multispectral/hyperspectral imaging have enabled intelligent systems that support continuous monitoring and data-driven decision-making in precision agriculture.

EXISTING SYSTEM

The existing agricultural monitoring systems mostly depend on manual field inspections, periodic soil testing, or individual sensor readings. Farmers must regularly monitor crop conditions to identify diseases, nutrient deficiencies, and pest infestations. These methods are time-consuming and may not provide timely information for effective decision-making. Most existing systems rely on a single data source, such as soil sensors or image analysis, limiting the accuracy of

crop assessment. Continuous real-time monitoring is often unavailable, making early detection of crop stress and pest risks difficult. Overall, the existing systems lack integrated data analysis, intelligent prediction, and comprehensive monitoring capabilities.

PROPOSED SYSTEM

The proposed system implements an AI-powered agricultural monitoring framework for assessing crop health, soil condition, and pest risk using multispectral/hyperspectral imaging and IoT sensor data. It continuously collects real-time information from crop images and environmental sensors to monitor field conditions. Machine learning algorithms analyze the integrated data to detect crop stress, evaluate soil quality, and predict pest risks. The system provides timely recommendations for irrigation, fertilizer application, and pest management, enabling informed decision-making. A web-based dashboard displays monitoring results and recommendations in an easy-to-understand format. This integrated approach supports precision agriculture by improving crop productivity, optimizing resource utilization, and promoting sustainable farming practices.

SYSTEM ARCHITECTURE

The AI-powered agricultural monitoring system integrates multispectral/hyperspectral imaging, IoT sensors, machine learning models, a recommendation engine, and a web-based dashboard. The imaging system captures crop images, while IoT sensors collect real-time environmental data such as soil moisture, temperature, humidity, pH, and nutrient levels. The collected data is preprocessed and analyzed using machine learning models to evaluate crop health, assess soil conditions, and predict pest risk. Based on these results, the recommendation engine provides irrigation, fertilizer, and pest management suggestions. The web-based dashboard presents monitoring results, risk levels, and recommendations, enabling farmers to make timely and informed decisions for precision agriculture.

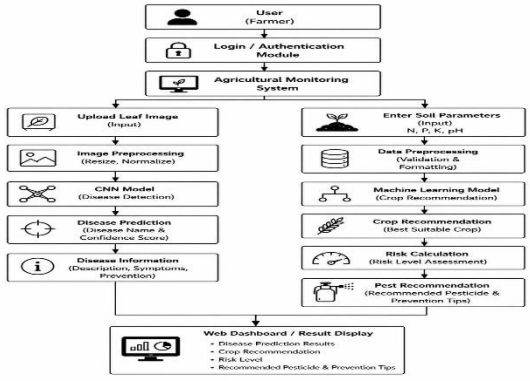


Fig 1: System Architecture

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METHODLOGY DESCRIPTION

The methodology of the AI-powered agricultural monitoring system is designed to provide intelligent monitoring and analysis of crop health, soil condition, and pest risk using Artificial Intelligence, multispectral/hyperspectral imaging, and IoT sensor data. The system follows a structured approach that includes data acquisition, image preprocessing, sensor data processing, machine learning-based prediction, risk assessment, and recommendation generation.

RESULTS AND DISCUSSION

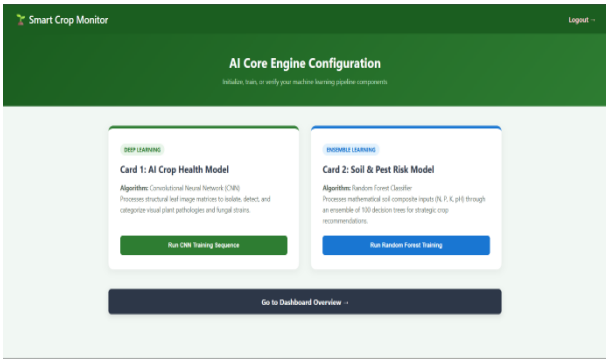


Fig2: Home page of Training Models

Home page of the AI-powered crop monitoring system, providing a centralized interface for configuring the Crop Health Model and Soil & Pest Risk Model before accessing the dashboard.

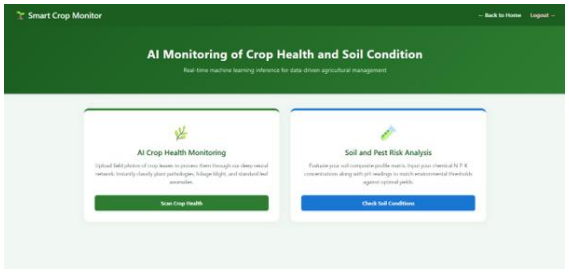


Fig 3: Dashboard for Crop Detection

Dashboard of the AI-Powered Crop Monitoring System, providing access to AI Crop Health Monitoring for disease detection and Soil and Pest Risk Analysis for crop recommendation, risk assessment, and soil condition evaluation.

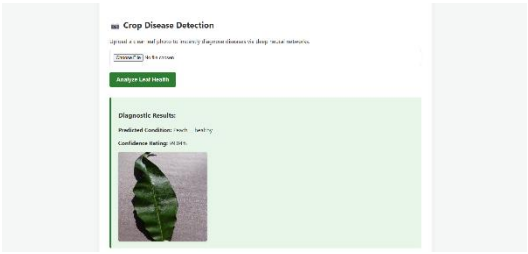


Fig 4: Crop Disease Detection

Crop Disease Detection module of the AI-Powered Crop Monitoring System, displaying the uploaded leaf image, predicted crop disease/health status, and confidence score generated using the deep learning model.

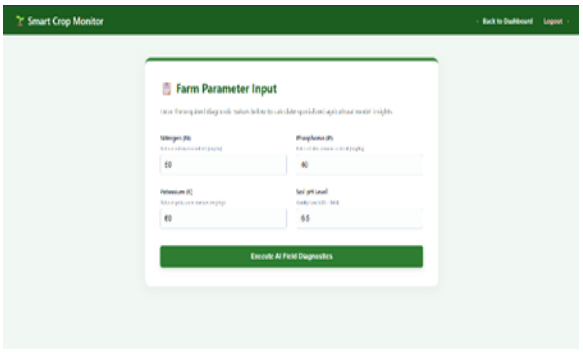


Fig 5: Soil values for prediction

Farm Parameter Input interface of the AI-Powered Crop Monitoring System, allowing users to enter soil nutrient values (Nitrogen, Phosphorus, Potassium, and pH) for crop recommendation, soil risk assessment, and agricultural diagnostics.

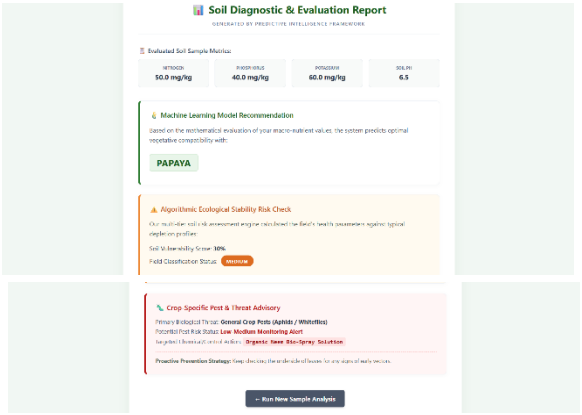


Fig 5: Soil Diagnostic Report

Soil Diagnostic & Evaluation Report generated by the AI-Powered Crop Monitoring System, displaying the recommended crop, soil risk level, and crop-specific pest advisory based on the entered soil nutrient parameters.

CONCLUSION

he AI-powered crop monitoring system enhances agricultural productivity and sustainability by enabling early crop disease detection, intelligent crop recommendation, soil risk assessment, and pest advisory using machine learning techniques. By providing accurate, real-time insights based on crop images and soil parameters, the system supports informed decision-making, reduces crop losses, optimizes resource utilization, and promotes efficient and sustainable farming practices.

FUTURE SCOPE

The proposed system can be enhanced by integrating advanced deep learning models for improved crop disease detection. IoT-based sensors can provide real-time monitoring of soil moisture, temperature, humidity, and nutrient levels. Multispectral and hyperspectral imaging can improve crop health analysis. Drone and satellite imagery can enable large-scale field monitoring. Cloud and mobile applications can provide remote access to real-time reports. These enhancements will improve precision agriculture, resource management, and crop productivity.

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