

PREDICTIVE AGRICULTURAL ANALYTICS FOR CROP HEALTH AND PEST MANAGEMENT USING HYPERSPECTRAL IMAGING TECHNIQUES

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ABSTRACT:

AgriVision AI is a sophisticated agricultural platform that employs artificial intelligence, hyperspectral imaging (HSI), and sensor-based analytics to improve crop yield and sustainability. The technology enables accurate monitoring of crop health, soil conditions, and insect problems, aiding contemporary farmers in making educated decisions. The methodology is methodically organized and includes operations such as data loading, preprocessing, model training, hyperspectral analysis, soil suggestion, and plant disease prediction, among others. The technology utilizes Convolutional Neural Networks (CNN) and transfer learning to identify plant illnesses from leaf images. XGBoost facilitates soil-based crop recommendations by using nutrient and climatic attributes. Three-dimensional convolutional neural network models are used for hyperspectral land cover classification. A consolidated dashboard offers explainable AI features that provide confidence evaluations, clarify risks, and suggest remedies. AgriVision AI utilizes a combination of image analysis, soil intelligence, and spectral-spatial data processing to provide a holistic AI-driven solution for precision agriculture and food security, enabling early pest detection, optimizing fertilizer application, reducing chemical waste, and fostering sustainable agricultural practices.

Keywords: Crop Health Monitoring, Hyperspectral Imaging (HSI), Multispectral Imaging, Plant Disease Detection, Soil Condition Analysis, Pest Risk Prediction, Sustainable Agriculture, Food Security.

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I. INTRODUCTION

Traditional agricultural practices often depend on reactive decision-making, manual oversight, delayed identification of crop illnesses, inadequate soil management, and insect infestations; yet, agriculture is vital for economic advancement and food security. Contemporary digital technology facilitates

data-driven oversight and intelligent decision support, becoming precision agriculture a widespread method for improving agricultural productivity.

The amalgamation of artificial intelligence (AI) with multispectral and hyperspectral imaging in agricultural applications facilitates the prompt identification of plant stress, soil nutrient deficits and insect problems, beyond

conventional imaging methods. By collecting comprehensive spectral and geographical data, these technologies improve our understanding of agricultural and environmental conditions, enabling timely intervention when necessary.

The AgriVision AI platform utilizes artificial intelligence (AI), sensor intelligence (SI), and spectral imaging to assess soil quality, insect risks, and crop health. The system utilizes machine learning and deep learning models, such as CNN, XGBoost, and 3D-CNN, for the diagnosis of plant diseases, the recommendation of soil-specific crops, and the classification of hyperspectral land cover. A consolidated dashboard features Explainable AI capabilities to provide treatment suggestions, risk evaluations, and transparent forecasts.

II. LITERATURE REVIEW

B. Ramana Reddy, Gauri Kalnoor, and Mudigonda Devashish suggested a method for identifying plant leaf diseases using Convolutional Neural Networks (CNNs). Resizing the picture to $224 \times 224 \times 3$ and applying normalization were two preprocessing procedures that their study shown considerably improved classification results. The computer accurately recognized illnesses like Tomato Target Spot and facilitated a 16-class categorization system by delivering confidence ratings for the top three guesses. This study demonstrates the use of deep learning for the automated detection of plant diseases.

Research has concentrated on hyperspectral picture cubes, such as the 200-band Indian Pines dataset, which include hundreds of spectral bands, using 3D-Convolutional Neural Networks (3D-CNNs). Hyperspectral imaging, in contrast to traditional RGB imaging, acquires detailed spectral data, facilitating the identification of previously undiscovered soil properties and signs of crop stress. The study revealed that land-cover classifications, including Soybean-mintill and Corn-notill, can be accurately identified using 3D-CNN models in conjunction with patch-based preprocessing.

A research used tabular agricultural data to assess the effectiveness of the XGBoost algorithm in crop recommendation based on

soil conditions. The model achieved remarkable precision in predicting appropriate crops by examining soil nutrient parameters, including Nitrogen (N), Phosphorus (P), Potassium (K), and pH, in conjunction with climate variables such as precipitation and humidity. These results suggest that machine learning approaches might facilitate precision agricultural tasks, including soil health evaluation and crop selection. The suggested method seeks to improve proactive agricultural practices by facilitating early insect identification, improving fertilizer application, reducing chemical waste, and promoting sustainable farming management. This should thus lead to improved agricultural productivity and precision agriculture.

III. EXISTING SYSTEM

The current agricultural monitoring system mostly use conventional and labor-intensive techniques to evaluate crop health, soil quality, and pest problems. Manual field scouting is a labor-intensive and constrained method used by agronomists and farmers to visually evaluate crops for signs of disease, insect infestations, or nutritional shortages. The use of standard RGB photography via mobile devices or digital cameras gathers information just within the visible spectrum, consequently neglecting to reveal concealed crop stress. Soil samples must be physically collected and sent to labs for analysis to conduct a physical soil test. This technique entails further time and expenses for the recommendation process. In conventional agricultural techniques, fertilizers and insecticides are often used only upon the emergence of visible symptoms, according to a reactive management strategy. The limitations of these methods for modern precision agriculture include suboptimal resource utilization, reduced overall productivity, labor-intensive oversight, increased operational costs, delayed disease and pest detection, inability to identify hidden stress conditions, and insufficient scalability for large agricultural fields.

DISADVANTAGES

- Significant crop loss may have already transpired by the time diseases and insect problems become visible.

- Routine manual assessments of vast agricultural land are laborious, costly, and inefficient.

IV. PROPOSED SYSTEM

AgriVision AI improves agricultural production and sustainability by precisely monitoring crop health, soil conditions, and insect problems with a robust AI-driven smart agriculture framework. The system utilizes a combination of machine learning, deep learning, sensor intelligence, and multispectral/hyperspectral imaging to address the shortcomings of conventional agricultural practices, which rely on delayed reactions and human observation. The organized workflow consists of components for data collection, preprocessing, model training, prediction, and recommendation. Convolutional Neural Networks (CNN) and transfer learning facilitate plant disease detection by leaf image analysis, whilst XGBoost is used for crop selection by assessing soil nutrients and climatic factors. Furthermore, spectral-spatial land-cover categorization and the detection of hidden crop stress are achieved with the use of 3D-CNN models for hyperspectral data processing. The system's unified dashboard presents visible performance metrics, pest risk evaluations, illness forecasts, confidence assessments, and treatment suggestions. Explainable AI functionalities improve transparency by summarizing and clarifying risks to end users. The proposed system includes the optimization of fertilizer use, the minimization of excessive chemical application, the advancement of sustainable precision agriculture via proactive management, and the early detection of crop stress and pest threats. It facilitates precise disease diagnosis.

ADVANTAGES

- Detects crop stress and pest threats promptly, enabling timely action to reduce output loss.
- Enables precise identification of plant diseases using AI-based picture analysis.

V. SYSTEM MODEL

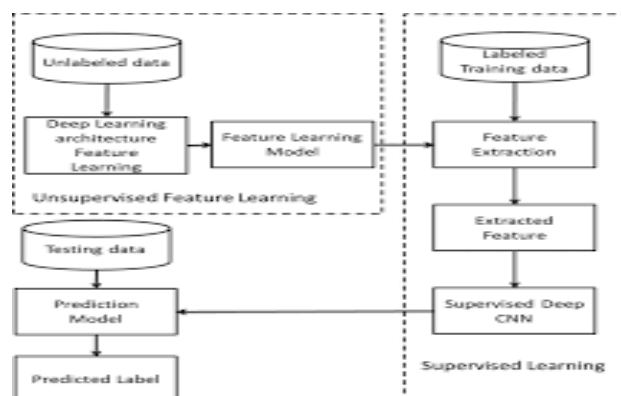


Fig 1. System Model

VI. MODULES

- **User Management & Authentication**–This module enables authorized access and tracks user advancement throughout the agricultural analysis process via secure user registration, login, and session management.

- **Data Loading & Exploration**–This module is capable of importing and analyzing diverse agricultural datasets, including photos of plant leaves, soil property CSV files, and hyperspectral image cubes.

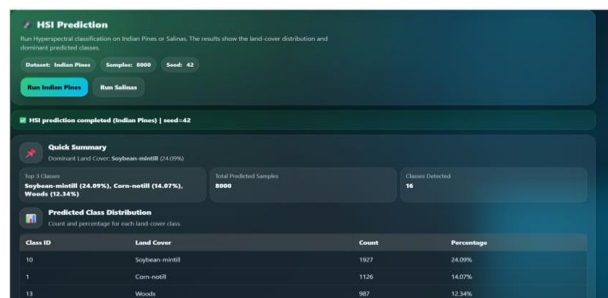
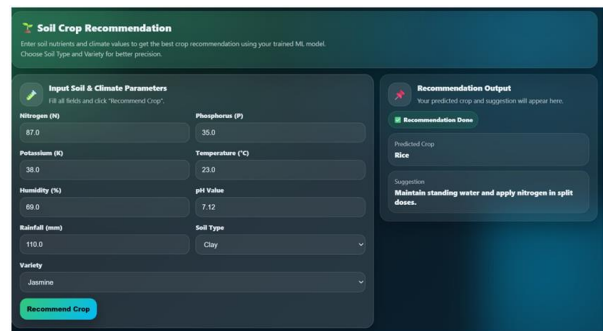
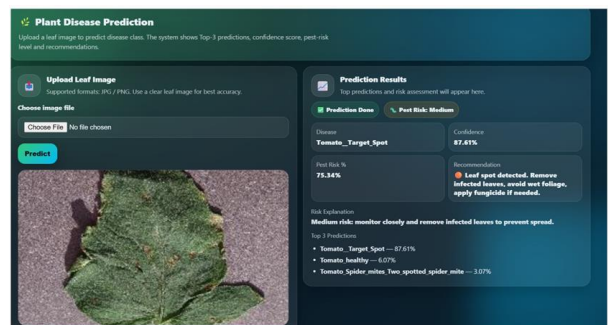
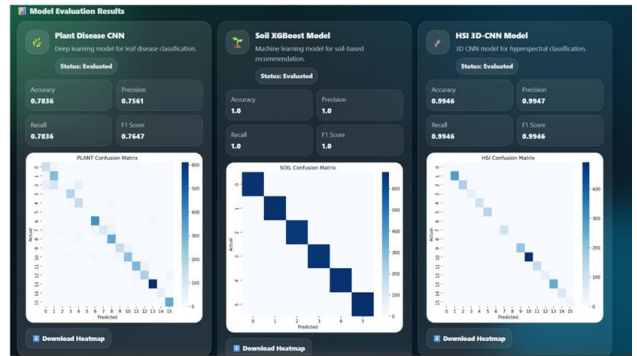
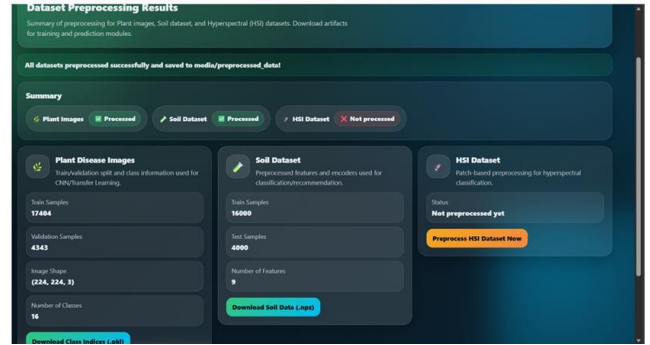
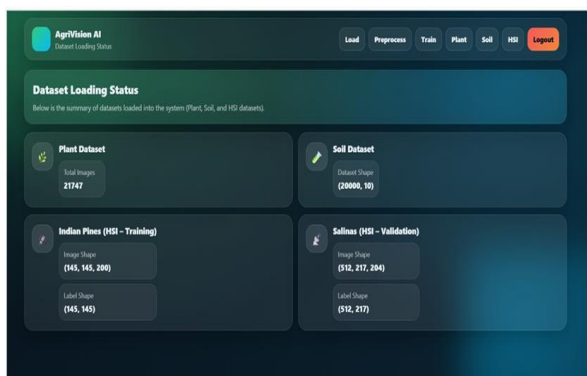
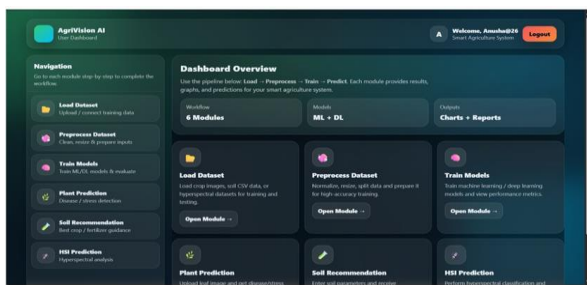
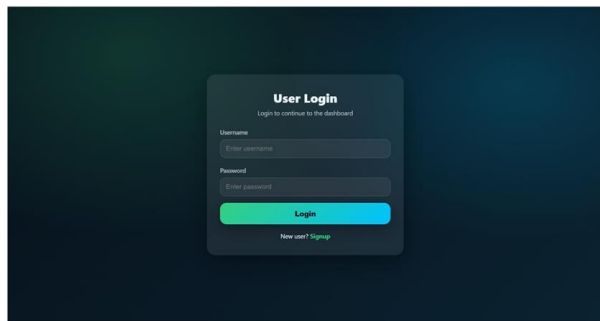
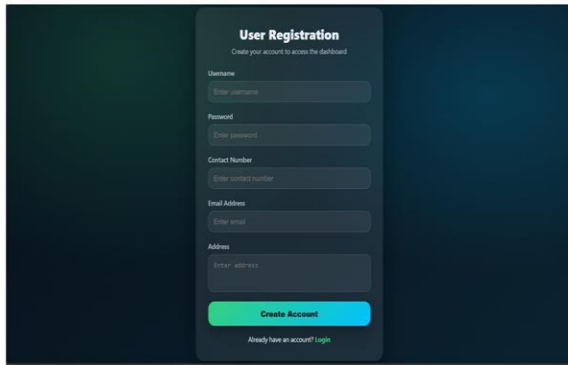
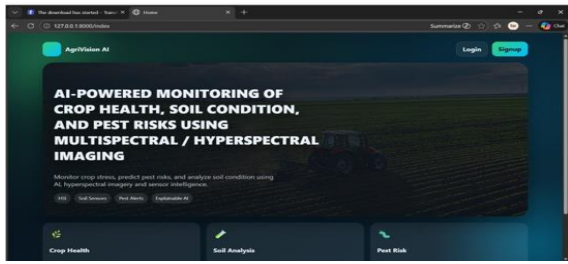
- **Data Preprocessing**–This module processes agricultural data for precise model training by cleansing, normalizing, standardizing, identifying essential characteristics, and dividing the data into training sets.

- **Model Training and Performance Evaluation** – This module instructs AI models, including CNN, XGBoost, and 3D-CNN, for disease diagnosis, soil-based crop recommendations, and land-cover classification. Performance is evaluated by accuracy metrics, confusion matrices, and loss graphs.

- **Prediction and Decision Support**–This module utilizes trained algorithms to enhance agricultural decision-making by providing real-time predictions, including disease detection, crop recommendations, and hyperspectral land-cover mapping.

- **Explainable AI (XAI) & Actionable Insights**–This module aids users in making educated agricultural choices by assessing model results and delivering pest danger warnings, treatment suggestions, and practical farming insights.

VILSCREENSHOTS



Class ID	Land Cover	Count	Percentage
10	Sophian road	1627	24.04%
1	Con road	1126	14.07%
13	Woods	967	12.54%
9	Sophian road	767	9.84%
2	Con road	625	7.94%
5	Con trees	514	7.17%
11	Sophian Green	454	5.87%
4	Con pasture	378	4.72%
7	Hay harvested	343	4.39%
14	Buildings	302	3.77%
3	Con	184	2.36%
12	Water	161	2.05%
15	Stone-Steel Towers	75	0.97%
0	Other	37	0.48%
6	Con pasture mixed	17	0.22%
8	Other	15	0.19%

VIII.CONCLUSION

AgriVision AI provides an innovative solution for contemporary precision agriculture with its powerful AI techniques. It enables thorough agricultural management and informed decision-making. The system provides a comprehensive 360-degree evaluation of agricultural health by using Machine Learning (XGBoost) for soil analysis, 2D Convolutional Neural Networks (CNNs) for plant disease identification, and 3D Convolutional Neural Networks (CNNs) for hyperspectral land-cover classification. The powerful Explainable AI architecture, along with an exceptional 99.46% accuracy in land-cover categorization, guarantees that farmers get not only precise forecasts but also important insights. AgriVision AI significantly improves global sustainability in agriculture and food security via its data-driven agricultural choices, early disease diagnosis, environmental risk assessment, and efficient resource management capabilities.

IX.FUTURE ENHANCEMENTS

Future enhancements may augment the accuracy, scalability, and real-time precision of AgriVision AI's agricultural applications. The incorporation of Internet of Things (IoT) sensors, drone surveillance, and real-time satellite data enables continuous field monitoring and accelerated decision-making. To enhance the effectiveness of disease detection and land-cover classification, advanced deep learning models such as Vision Transformers (ViT), hybrid CNN-Transformer architectures, and ensemble techniques may be used. Weather and climate prediction models may enhance suggestions for irrigation, fertilization, and pest management. To enhance AgriVision AI's efficiency, scalability, and impact on sustainable agriculture and global food security, it is recommended to develop a mobile, multilingual farmer-support

application, therefore improving accessibility for rural regions. Furthermore, the use of secure blockchain-based agricultural data management and the improvement of Explainable AI dashboards will boost transparency, trust, and traceability.

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