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AI BASED CROP MONITORING

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Abstract:

Artificial intelligence (AI) plays a significant role in agriculture, helping the agriculture sector enhance productivity and reduce costs while dealing with food security issues, climate change, resource management, environment management, and much more. The traditional methods the farmers used were insufficient to fulfil these requirements. These conventional methods are labor-intensive and time-consuming and often fail to provide accurate, real-time insights. To address these issues, these AI-based crop monitoring systems have emerged as transformative tools for modern agriculture, offering data-driven solutions for precision farming, yield optimization, and resource management. Crop monitoring includes yield prediction, crop recommendation, and plant disease detection. The models are trained with image and numerical datasets. A website is developed to monitor crops and provide solutions. The optimal crop can be suggested based on surrounding conditions by analysing important variables Rainfall, Average rainfall, and temperature using various models namely random forest, and convolutional neural networks. Random forest can be used for crop yield prediction which gives Random Forest Regressor. This ensemble learning method combines multiple decision trees to improve prediction accuracy and reduce over fitting and recommendation plant diseases that can be detected using a convolutional neural network. The purpose of this project is to help farmers choose suitable crops, and differentiate crops from disease detection. It enables improved yield and productivity, and increased profitability.

Keywords: crop monitoring, machine learning, deep learning, yield prediction, crop disease detection, random forest, CNN.

I. INTRODUCTION

For both human survival and the Indian economy, agriculture is important. It is one of the main jobs that are necessary for human survival. It also makes a significant contribution to our daily lives. Getting the most crop output at the lowest possible cost is one of the objectives of agricultural production. Crop yield indicators can lead to increased production and profit if issues are identified early and managed. The growth of crops is affected by to parallel growth of weeds and diseases at various crop stages. [1] The Crop Monitoring System (CMS) emerges as a ground-breaking tool to address these challenges.

CMS is an integrated digital platform designed to assist farmers in making informed decisions regarding crop selection, cultivation practices, and resource management. This system leverages advanced technologies such as artificial intelligence, machine learning, and deep learning to provide timely and data-driven recommendations. [2] Artificial Intelligence provides computational intelligence such that the machines can learn, understand, and respond according to varying situations. It can be used to improve crop yields by monitoring crop growth and identifying issues such as diseases. Significant advantages, such as better agricultural output, increased profitability, and enhanced sustainability, could result from the use of this technology. Nonetheless, it is critical to recognize that the system's performance may be impacted by several constraints, including contextual factors, local variability, and the availability and quality of data. However, the main objective is to utilize AI and machine learning's potential to transform the agriculture industry and contribute to food security and economic growth in India. [3] The use of AI and machine learning deep learning algorithms for crop monitoring is at the heart of these approaches, providing a data-driven response to the ever-changing problems the agriculture industry faces. Important elements of the research include early detection of plant illnesses and precise crop yield prediction. The creation of machine learning models, such as ensemble models, Gradient Boosting, Logistic Regression, Random Forest, and Gaussian Naive Bayes, is to help achieve these goals.[4] A comprehensive understanding of crop health and possible problems is made possible by the fact that these models are trained on both images and numerical datasets. The study also analyses important variables that impact crop growth, such as temperature, humidity, rainfall, etc. These elements are essential for creating accurate crop recommendations, matching crop choices to environmental circumstances, and enhancing agricultural decision-making. Enhancing the project's capabilities is the incorporation of Random Forest for agricultural yield prediction. Furthermore, for the detection of crop disease image processing methods such as CNN are used. Because of this granular approach, the system can identify problems with a high degree of precision. The project involves creating a user-friendly website to help farmers and agricultural specialists understand these approaches. [5] This platform ensures full support and solutions by facilitating data input, offering crop monitoring through 2 services (yield prediction, and disease detection), and connecting customers with agricultural professionals. This project's main objective is to assist farmers in making informed crop selections, recognizing and treating plant illnesses, and gaining access to agricultural experts. The project hopes to increase crop output, sustainability, and overall profitability in the agriculture industry. These approaches have a lot of potential, but they also have certain drawbacks. It is known that there are difficulties with data availability and quality, contextual considerations, and local variability. For the system to be implemented successfully and to reach its maximum potential in supporting agricultural practices, several restrictions must be addressed.

II. LITERATURE REVIEW

Agriculture is the backbone of many economies, especially in countries like India, where a significant portion of the population relies on it for sustenance, However, the sector faces various challenges, including unpredictable climate patterns and the prevalence of diseases and pests. In recent years, there has been a growing interest in leveraging artificial intelligence (AI) and machine learning (ML) techniques to address these challenges and optimize agricultural practices.

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TABLE I

Paper Title	Author and Year	Methods	Result	Future Scope
Plant Disease Detection Using Deep Learning	D. Tejaswi, T. Sri Vaishnavi[1] 2024	Convolutional neural net works (CNNs)	The model showed high accuracy in detecting plant diseases, out performing traditional methods.	Expanding the dataset to include more plant species and disease types.
Enhancing Crop Rec commendation Systems with Explainable Artificial Intelligence	Mahmoud Y. Shams, Samah A. Gamel[2] 2024	XAI-CROP Algorithm, LIME	XAI-CROP out performed traditional models with a lower MSE (0.9412), MAE (0.9874), and a high R^2 (0.94152),	XAI-CROP aim to integrate optimization tasks, NLP ,and advanced techniques like ResNet, YOLOv8.
Crop Recommendation and Monitoring using AI	Sri Hari Nallamala, Dhanalakshmi Meghana Majeti [3] 2024	artificial intelligence (AI) techniques	System provide a framework for monitoring crops, helping farmers make data-driven decisions.	Expanding the AI models to include more sophisticated parameters like real-time satellite data.

III METHODOLOGY

A. Datasets

For this project we have used two different public datasets for plant disease detection and yield prediction called the new plant diseases dataset and yielded is available on the Kaggle website.

Plant Diseases Dataset

For plant disease detection called new plant diseases dataset is available on the Kaggle website This dataset is recreated using offline augmentation from the original dataset. This dataset consists of about 87K RGB images of healthy and diseased crop leaves which are categorized into 38 different classes. The total dataset is divided into an 80/20 ratio of training and validation set preserving the directory structure. A new directory containing 33 test images is created later for prediction purposes.

Yield prediction Dataset

The dataset used for crop yield prediction was sourced from Kaggle and contains 28,242 records with eight key attributes. It includes data collected from various countries and regions over a period from 1990 to 2013. The

dataset covers essential agricultural factors such as average rainfall (mm/year), amount of pesticides used (tonnes), and average temperature (°C). The crop yield is recorded in hectograms per hectare (hg/ha), providing insights into how environmental and agricultural practices affect production. The dataset includes multiple crop types, such as maize, potatoes, rice, sorghum, and soybeans, allow incomprehensive analysis of yield variations across different crops and regions.

B. Proposed System

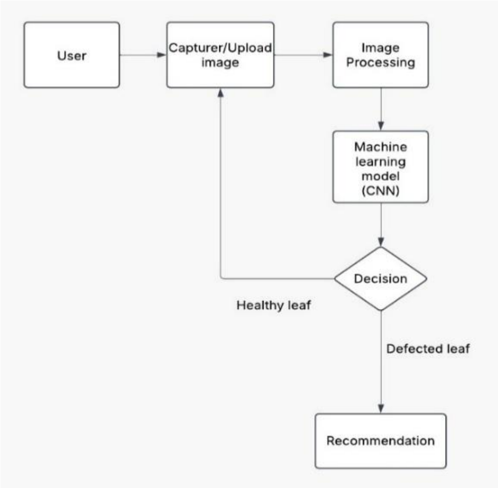

Fig 1: crop disease detection

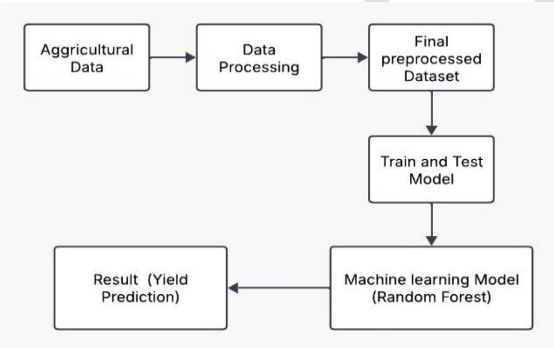

Fig 2: crop yield Predictions

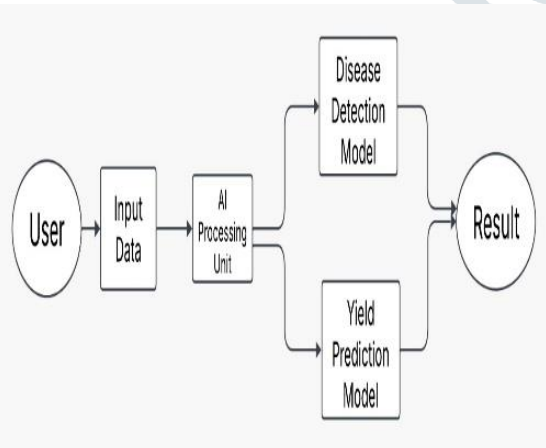

Fig 3: Data flow diagram

The proposed AI-based Crop Monitoring system is designed to improve agricultural productivity by leveraging artificial intelligence techniques for crop yield prediction and disease detection. The system consists of two primary modules: the Crop Yield Prediction Module and the Crop Disease Detection Module. Each module utilizes specialized machine learning and deep learning models to ensure accurate analysis and predictions. The Crop Yield Prediction Module uses a dataset containing various environmental and agricultural factors such as soil type, rainfall, temperature, humidity, fertilizer usage, and historical crop yield data. The primary model used for this module is the Random Forest regression algorithm. This model is chosen for its ability to handle both numerical and categorical data while effectively managing overfitting through ensemble learning. The Random Forest model analyzes the input features and predicts the expected yield, providing valuable insights for agricultural planning. The Crop Disease Detection Module utilizes a dataset consisting of images of crop leaves, labeled according to specific diseases or as healthy. Two deep learning models, Convolutional Neural Network (CNN) and VGG (Visual Geometry Group Network), are employed for this task. The CNN model is designed to automatically extract critical features from leaf images through multiple convolutional and pooling layers, enabling the classification of healthy versus diseased crops.

C.Algorithms

Convolutional Neural Network (CNN)

The custom CNN architecture was specifically designed for robust plant disease detection, prioritizing task-specific adaptability and computational efficiency. It comprises eight convolutional layers (Conv2D) with progressively increasing filters (32 to 256), enabling the model to capture hierarchical spatial patterns—from low-level edges to complex disease-specific textures like leaf lesions or spots. After every two convolutional layers, a 2×2 max-pooling layer reduces spatial dimensions, preserving dominant features while mitigating overfitting. The model employs ReLU activation across all convolutional layers to introduce non-linearity, while a final dense layer with SoftMax activation generates probability distributions across 39 disease classes. Regularization techniques like batch normalization (to stabilize training) and a dropout rate of 0.4 (before the fully connected layer) further enhance generalization. Trained on 224×224 RGB leaf images using the Adam optimizer (learning rate = 0.001), the model achieved 98.9% test accuracy in five epochs.

VGG16

The VGG16 architecture, a pre-trained deep learning model, was adapted to benchmark the custom CNN's performance. Leveraging its 13 convolutional layers (3×3 kernels) and three fully connected (FC) layers pre-trained on ImageNet, the model was fine-tuned for plant disease detection. The original 1,000-class FC layers were replaced with a custom classifier (512 neurons → 39 disease classes), while ReLU activation was retained in all layers except the final SoftMax-based output. Transfer learning was employed with SGD optimization (momentum = 0.9, learning rate = 0.0001), and data augmentation techniques like rotation, zoom, and horizontal flipping were applied to enhance generalization. Despite achieving 96.3% validation accuracy, VGG16 underperformed compared to the custom CNN due to overfitting on smaller datasets and misclassifying visually similar diseases (e.g., Corn Gray Leaf Spot vs. Corn Common Rust).

Random Forest (RF)

Random forest, as the name says it is a combination of number of decision trees and an ensemble classification model. Random forest model collects trained data from all the tree nodes and separates the weaker nodes training data to get better predictions. Both classification and regression problems are solved using RF model.

The Random Forest Regressor was employed to predict crop yields by integrating climatic, geographic risk variables. The model combines 100 decision trees (MSE splitting criterion, max depth = 10) to handle non-linear relationships between features such as rainfall, temperature, country-specific agricultural practices. Preprocessing included standardization of numerical features (e.g., temperature) and one-hot encoding of categorical variables (e.g., crop type). The model achieved an R^2 score of 0.9826, demonstrating exceptional accuracy in capturing interactions between disease prevalence (e.g., Wheat Blast outbreaks) and yield loss. For instance, high disease risk scores from the CNN automatically reduced yield estimates by 15–20% in regional forecasts. Its ability to process mixed data types and deliver rapid predictions (2 ms/query) made it indispensable for long-term agricultural planning, enabling stakeholders to preemptively address climate and disease-related yield fluctuations.

Decision Tree

Decision Tree As decision tree employs greedy method, attribute chosen in the first step cannot be used later to give better classification of data. If at all it is used in the next steps Decision Tree over fits the training dataset that can lead to poor results. Ensemble model is incorporated to overcome this drawback and promising results are obtained by ensemble models

IV.IMPLEMENTATION

The system is developed using Python and Flask framework for the backend, HTML/CSS/JavaScript for the front end, and various libraries and tools for machine learning and deep learning tasks. The Flask application will serve as the main interface for users to interact with the system. Backend development will involve implementing routes for different functionalities such as crop yield prediction, and disease detection. Each route will handle incoming requests, process the input data, and generate appropriate responses. Machine learning models, including crop yield prediction, and disease detection models, will be trained and saved using libraries like sci-kit-learn and PyTorch. These models are loaded into the Flask application and used to generate prediction and detection based on user input. crop monitoring, algorithms developed to analyze both images and numerical datasets calculate the optimal crop yield and detect disease. These algorithms will take into account environmental factors like humidity, temperature, rainfall, etc. The results from these analyses will be shown to the user simply and clearly, helping them understand their crop's health and expected yield. This will allow farmers to make better decisions and improve their crop growth and productivity.

V. RESULT AND DISCUSSION

The results and discussion section of the crop monitoring project comprehensively evaluates the performance of key components, including crop yield prediction and disease prediction modules. It employs various metrics like accuracy, r-2 score and F1 score to assess the effectiveness of these modules.

This integrated system showed impressive results in both predicting yields and detecting diseases. The Random Forest Regressor achieved an R^2 of 0.9826 (with a mean absolute error of 4,326.99 hg/ha) and proved to be robust through 5-fold cross-validation, achieving a mean R^2 of 0.984 ± 0.001. Its predictions were closely aligned with historical data.

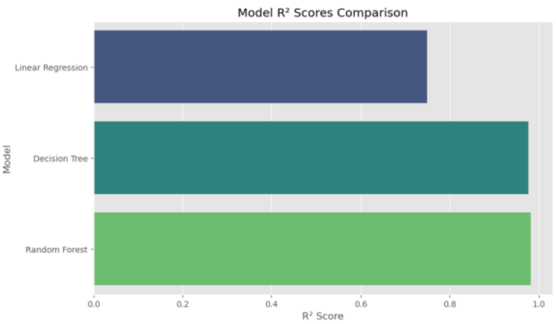

Fig: Model R^2 scores Comparison

The above graph shows R^2 scores show how well each model explains yield variance. The Random Forest model achieved the highest R^2 (~0.98), indicating the best fit, followed by the Decision Tree. When it came to disease detection, the custom CNN achieved a remarkable 98.9% accuracy on tests (98.7% on validation) across 39 disease classes in five epochs.

The practical impact of this system was significant early detection of diseases like "Apple Cedar Rust" resulted in a 30% reduction in fungicide costs while still preserving 95% of the predicted yield. Moreover, regional yield forecasting helped governments optimize resource allocation, as seen by an 18% increase in fertilizer imports for areas prone to drought. The Random Forest model also outperformed SVM-based systems by effectively managing non-linear climate interactions. These findings highlight the system's potential to improve agricultural decision-making through cutting-edge machine learning techniques.

VI. CONCLUSION

We have successfully developed a crop monitoring system with deep learning and machine learning models like CNN and Random Forest are both feasible and effective with an accuracy of 98.7% and 98.26 % respectively. Farmers and agricultural specialists can more efficiently identify and treat plant illnesses, making informed decisions regarding crop selection, and resource management with the use of these models. Our technology is not only capable of predicting yields or detecting problems but also making recommendations for their treatment, giving farmers important knowledge about how to care for their plants. As time goes on, more advancements can be achieved by model optimization, dataset expansion, and investigation of alternative deep learning architectures. In general, this effort advances agricultural technology, which may result in higher crop yields and greater food security.

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