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Crop And Fertilizer Recommendation With Plant Disease Detection Using Machine Learning Models

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Abstract: Agriculture faces several challenges such as improper crop selection, inefficient fertilizer usage, and delayed detection of plant diseases, which can reduce crop yield and quality. This project presents a software-based system for crop and fertilizer recommendation along with plant disease detection using machine learning techniques. The system analyzes soil parameters including nitrogen, phosphorus, potassium, pH, and moisture to recommend the most suitable crop and appropriate fertilizers based on nutrient requirements.

In addition, the system detects plant diseases at an early stage using image processing and deep learning models. A convolutional neural network (CNN) is used to analyze plant leaf images and accurately identify diseases, along with suggesting suitable treatment measures. The proposed system provides a user-friendly interface and supports data-driven decision-making, helping farmers improve productivity, reduce losses, and adopt sustainable agricultural practices.

Key Words: Precision Agriculture, Machine Learning, Crop Recommendation, Fertilizer Recommendation, Plant Disease Detection, Image Processing, Convolutional Neural Network (CNN), Soil Nutrient Analysis, Smart Farming.

Introduction

Agriculture is a fundamental sector that plays a crucial role in ensuring food security, economic stability, and rural development across the world. With the rapid growth of the global population, the demand for higher agricultural productivity has increased significantly. However, farmers continue to face challenges such as unpredictable climatic conditions, soil degradation, improper crop selection, inefficient fertilizer usage, and frequent plant disease outbreaks. These challenges adversely affect crop yield, quality, and profitability, highlighting the need for intelligent and technology- driven agricultural solutions.

Traditionally, farming decisions are based on experience, manual observation, and generalized agricultural practices. While these methods may work in limited scenarios, they often fail to account for the complex interactions between soil nutrients, crop requirements, and environmental factors. Inappropriate crop selection without proper soil analysis can lead to poor yield and excessive use of fertilizers, resulting in environmental pollution and long-term soil fertility loss. Hence, there is a growing demand for data-driven systems that can analyze soil conditions and recommend suitable crops and fertilizers accurately. Soil health is a key determinant of crop growth and productivity. Parameters such as nitrogen (N), phosphorus (P), potassium (K), pH level, and moisture content significantly influence plant development.
The imbalance of these nutrients can lead to reduced yield and increased susceptibility to diseases. Machine learning techniques provide an effective means to process large volumes of soil and environmental data and identify hidden patterns that are difficult to capture through traditional methods. By leveraging supervised learning algorithms, crop and fertilizer recommendations can be generated with higher precision and adaptability.

In addition to soil-related challenges, plant diseases pose a serious threat to agricultural sustainability. Diseases caused by fungi, bacteria, and viruses can spread rapidly and cause severe crop losses if not detected at an early stage. Manual disease identification is time- consuming, requires expert knowledge, and is prone to errors due to the similarity of symptoms among different diseases. Early and accurate detection of plant diseases is therefore essential to minimize losses and ensure timely treatment.

Recent advancements in computer vision and deep learning have enabled automated plant disease detection using image analysis techniques. Convolutional Neural Networks (CNNs) have demonstrated remarkable performance in extracting visual features from leaf images and classifying diseases with high accuracy. By learning complex patterns such as color variations, texture, and shape, CNN-based models can effectively differentiate between healthy and diseased plants, making them highly suitable for real-world agricultural applications. The integration of machine learning- based crop and fertilizer recommendation with deep learning-based disease detection forms a comprehensive decision-support system for precision agriculture. Such an integrated approach allows farmers to receive multiple recommendations—crop selection, fertilizer usage, and disease diagnosis—through a single platform. This reduces dependency on manual expertise and improves the overall efficiency of agricultural decision-making.

This project proposes a software-based intelligent system for crop and fertilizer recommendation with plant disease detection using machine learning models. The system analyzes soil nutrient data to recommend suitable crops and fertilizers while employing CNN based models to detect plant diseases from leaf images. A user-friendly web interface enables farmers to input soil parameters and upload plant images, while the backend processes the data and generates accurate recommendations. By combining data analytics, machine learning, and deep learning techniques, the proposed system aims to enhance agricultural productivity, reduce resource wastage, and promote sustainable farming practices.
The system supports precision agriculture by enabling timely, accurate, and data-driven decisions, thereby contributing to improved crop yield, reduced losses, and long-term agricultural sustainability

Problem Statement

Title: Crop and fertilizer Recommendation with plant Disease detection using Machine learning models

Farmers often struggle to select the right crops, apply appropriate fertilizers, and detect plant diseases early due to lack of accurate, data-driven guidance. Traditional methods are time consuming and prone to errors, leading to reduced yield and crop losses. This project aims to develop an intelligent system using machine learning to recommend suitable crops, suggest fertilizers, and detect plant diseases from leaf images, providing farmers with actionable insights to improve productivity and sustainability.

Objectives

1. To collect relevant soil, climatic, and plant image datasets for crop recommendation, fertilizer suggestion, and disease detection.

2. To design a machine learning–based system that recommends suitable crops and appropriate fertilizers based on soil nutrient imbalance and climatic conditions.

3. To develop an image-based plant disease detection model using machine learning techniques for accurate disease identification.

4. Compare the performance of different ML models to choose the most accurate and efficient solutions.

Methodology

Proposed system Model

The figure illustrates the system architecture of a Crop and Fertilizer Recommendation system integrated with Plant Disease Detection using Machine Learning. The architecture is designed in a layered manner to ensure scalability, security, and efficient processing of agricultural data.

1. **User Interface Layer (Web/Mobile UI)** : Farmers or users interact with the system through a web or mobile application.

Users provide:

- ➢ Soil parameters (N, P, K, pH)
- ➢ Environmental conditions (temperature, humidity, rainfall)
- ➢ Crop details
- ➢ Leaf images for disease detection

➢ The interface also displays recommendations and advisory outputs.

2. Cloud Infrastructure Layer a)

Public Cloud : Acts as the primary communication and computation layer. Handles:

- ➢ User requests
- ➢ Data transmission
- ➢ Model inference requests
- ➢ Ensures high availability and scalability.

b) Private Cloud : Used for secure storage of sensitive data and results.

Stores:

- ➢ Encrypted user data
- ➢ Prediction results
- ➢ Historical records
- ➢ Enhances data privacy and system security.

3. Application Layer : Manages request handling and workflow control. Acts as an intermediary between the user interface and backend processing layers.

Responsibilities include:

- ➢ Validating user inputs
- ➢ Routing data to appropriate ML models
- ➢ Coordinating responses from different modules

4. Data Processing and Preprocessing Layer : Prepares raw input data for machine learning models.

- ➢ Key operations include:
- ➢ Data normalization and scaling
- ➢ Feature extraction from soil and climate data

➢ Image preprocessing (resizing, noise removal, augmentation)

➢ Ensures improved accuracy and consistency of model predictions.

5. Machine Learning Model Layer : This is the core intelligence layer of the system and consists of three major models:

a) Crop Prediction Model

➢ Predicts the most suitable crop based on soil nutrients and climatic conditions.

- ➢ Uses algorithms such as Random Forest or SVM.

b) Fertilizer Recommendation Model Analyzes nutrient deficiencies or excesses.

c) Plant Disease Detection Model

Uses CNN-based deep learning models to classify plant leaf images.

Identifies diseases at an early stage to reduce crop loss.

Recommends optimal fertilizer type and dosage.

6. Output Presentation Layer : Displays final results and actionable advice to the user.

Includes:

- ➢ Recommended crop
- ➢ Fertilizer suggestions
- ➢ Disease name and possible preventive measures

➢ Output is presented in a user-friendly format through the web or mobile UI.

Literature Survey

1. Tanaka et al. in their study "Can Machine Learning Models Provide Accurate Fertilizer Recommendations?" investigated the use of machine learning for predicting optimal fertilizer application rates. The researchers compared multiple models including Random Forest, Gradient Boosting, and Neural Networks, concluding that while most models accurately predicted yields, they often failed to prescribe correct fertilizer quantities. The study highlighted the need for explainable and context-aware models that link soil characteristics and yield targets to nutrient recommendations. This work provides valuable insights for developing the fertilizer recommendation module in Agribot, where interpretability and calibration are crucial.
2. Lakshmi Priya K. et al. proposed an AI-based Fertilizer Recommendation System that analyzes soil parameters such as nitrogen, phosphorus, potassium, and pH to suggest suitable fertilizers for specific crops. Their system used supervised learning algorithms trained on regional soil and crop data to achieve accurate fertilizer suggestions. The model demonstrated how data-driven approaches can replace manual soil testing reports and make fertilizer management more efficient. This research directly supports the fertilizer prediction component in Agribot by outlining an effective machine learning pipeline for soil-based recommendations.
3. The study "Improving Crop Production Using an Agro–Deep Learning Framework in Precision

Agriculture" presented an advanced deep-learning model for crop recommendation and yield prediction. The framework combined environmental, soil, and weather data to determine the best crop types for a given region. The integration of multiple input sources through convolutional and recurrent layers led to improved accuracy in predicting optimal planting schedules. This work is relevant to Agribot as it demonstrates how deep learning can effectively process multimodal agricultural data for more precise decision-making.

The paper "Enhancing Agricultural Productivity: A Machine Learning Approach to Crop Recommendations" introduced a system that leverages ensemble techniques such as Random Forest and XGBoost for selecting the best crop according to soil composition, rainfall, and climatic factors. The authors emphasized the adaptability of machine learning models to local conditions and their potential to guide farmers toward profitable crop choices. This study supports Agribot's crop recommendation module by demonstrating how ensemble algorithms can increase model robustness in varying soil and weather conditions.

4. The work "Role of Explainable AI in Crop Recommendation Technique of Smart Farming" (2025) discussed the importance of transparency and interpretability in AI-driven agricultural systems. The study implemented Explainable AI (XAI) methods like SHAP and LIME to clarify how soil and climate features influence model outputs. By making the decision-making process more understandable to end-users, the research bridges the trust gap between AI models and farmers. This aligns closely with Agribot's design philosophy, where providing explanations for crop and fertilizer suggestions enhances user confidence and system adoption.

5. The Systematic Review of Deep Learning Techniques for Plant Diseases (2024) comprehensively analyzed over 60 research papers focusing on convolutional neural networks (CNNs) for plant disease identification. The review compared models such as ResNet, DenseNet, and EfficientNet and found that transfer learning greatly enhances classification performance on smaller agricultural datasets. It also highlighted challenges such as varying lighting conditions and background noise in real-world images. This study informs Agribot's disease detection module by identifying the most reliable CNN architectures for practical farm environments.

6. "Deep Learning and Computer Vision in Plant Disease Detection" expanded on prior work by analyzing modern CNN and transformer-based models for crop disease classification. The paper discussed hybrid architectures that combine vision transformers (ViTs) with CNNs to achieve over 99% accuracy on benchmark datasets such as PlantVillage. It also emphasized the importance of creating field-validated datasets for real-world applicability. This work provides a strong foundation for Agribot's disease prediction component, especially for integrating vision transformers for higher accuracy.

"An Edge Computing-Based Solution for Real- Time Leaf Disease Classification Using Thermal Imaging" (2024) introduced a real- time, resource-efficient plant disease detection system. By deploying a CNN model on edge devices, the system processes images locally without requiring cloud access. The addition of thermal imaging allowed early identification of stress and infection before visible symptoms appeared. This paper is particularly valuable for Agribot's mobile or offline operations, where local inference can ensure timely disease diagnosis even without an internet connection.

7. The study "Soil Nutritional Recommendations for Soil Fertilization Using Machine Learning" (2025) proposed a practical ML-based solution for optimizing soil fertility management. The system takes soil test data as input and generates fertilizer suggestions aimed at balancing nutrient levels for specific crops. The authors achieved high accuracy and cost efficiency by applying decision-tree-based models. This paper directly aligns with Agribot's goal of providing personalized fertilizer recommendations based on soil analysis and promotes sustainable fertilizer usage by reducing nutrient wastage.

8. Dnyaneshwari Madhukar Sawant & Dr. Bijendra Gupta in their study Crop Recommendation System Using Machine Learning . The paper introduces a multi-aspect system analyzing soil and plant metrics to recommend crops. It uses CNN for soil type identification and ensemble ML for recommendation. It also incorporates disease detection and yield prediction modules. The integrated pipeline aims to provide comprehensive support for precision agriculture. Evaluation shows improvements in recommendation accuracy across different soil conditions.

9. Rasiga J., Sajeetha Britty E., Srinithi V., Vethasundari N. & Soundararajan K proposed Leaf Disease Detection and Fertilizer Recommendation using Deep Learning.This paper explores a DL-based leaf disease classifier integrated with a fertilizer recommendation engine. Disease classification uses CNN

architectures tailored to leaf texture features. The fertilizer module uses disease and soil data to infer nutrient deficiencies. Experimental results show accurate disease identification and relevant fertilizer guidance. Combined analysis aims to reduce crop loss due to concurrent stressors.

10. Guruprasad Kulkarni, Ashwini, Diksha & Kavyanjali presented Soil Fertility Prediction and Crop Recommendation using ML Algorithm – International Journal of Innovation in Engineering Research & Management.This study uses machine learning to analyze soil nutrient data to assess soil fertility and recommend crops accordingly.

Random Forest and other classifiers are evaluated. The authors explore how ML can improve soil fertility estimation compared to traditional heuristics. The research highlights the potential of ML for site-specific recommendations. It also discusses preprocessing soil data and model selection impacts. The findings demonstrate the utility of data-driven crop and fertilizer guidance.

11. Ishika Reddy et al. proposed Automated Plant Disease Detection Using Convolutional Neural Networks: Enhancing Accuracy and Scalability for Sustainable Agriculture – International Journal of Computer Engineering in Research Trends.Reddy and colleagues implemented a CNN-based system for automatic plant disease detection. The model uses data augmentation techniques for robustness and reports up to 97% accuracy. They discuss environmental variation effects on model performance. The paper highlights CNN effectiveness in real-time disease identification and potential yield improvement. It also suggests future enhancements using transfer learning.

Software Requirement Specification

Hardware Requirements:

1. Processor : Dual Core or higher
2. RAM : Minimum 4 GB
3. Storage : 20 GB
4. Device : PC / Laptop
5. Camera : Optional (for leaf image capture)

Software Requirements

1. Operating System : Windows
2. Programming Language : Python
3. Frontend : HTML, CSS, JavaScript
4. Backend : Flask
5. ML Libraries : Scikit-learn, TensorFlow/Keras**,** OpenCV

1.Functional Requirements:

1. **User Input Handling**: Allow users to input soil parameters (pH, N, P, K, etc.), climatic data (temperature, rainfall), and plant leaf images.
2. **Crop Recommendation**: Predict the most suitable crops based on soil and weather conditions using ML models.
3. **Fertilizer Suggestion**: Recommend fertilizers and nutrient doses according to soil nutrient levels.
4. **Disease Detection**: Analyze uploaded leaf images to identify potential plant diseases using a deep learning model.
5. **Results Display**: Present crop recommendations, fertilizer suggestions, and disease detection results in a user-friendly format.
6. **Model Performance Evaluation**: Evaluate ML models using metrics like accuracy, precision, recall, F1-score, MSE, MAE, or R^2.
7. **Data Management**: Store and manage datasets (soil, weather, images) for training and future predictions. **Notifications**: Provide alerts if a disease is detected or nutrient levels are imbalanced.

2. Nonfunctional Requirements:

1. **Performance**: The system should process inputs and provide predictions within a few seconds.
2. **Scalability**: Capable of handling increasing numbers of users and large datasets efficiently.
3. **Usability**: User-friendly interface for farmers, requiring minimal technical knowledge.
4. **Reliability**: System should be stable, with minimal downtime or errors during predictions.
5. **Accuracy**: ML models should maintain high prediction accuracy.
6. **Security**: Protect user data and uploaded images from unauthorized access.

7. **Portability**: Should be accessible via web or mobile platforms.
8. **Maintainability**: Easy to update ML models, add new crops, or improve disease detection..

System Design

Existing System:

The existing agricultural decision-making system is predominantly based on traditional farming practices, manual expertise, and generalized advisory guidelines. Crop selection and fertilizer application are usually determined by farmer experience or standard recommendations rather than soil-specific analysis. Although soil testing is sometimes conducted, the interpretation of results is mostly manual and lacks the support of intelligent software tools capable of predictive analysis. This limits the accuracy of decisions related to crop suitability and nutrient management.

Plant disease identification in the existing system relies mainly on visual inspection and expert consultation, making the process time-consuming and prone to human error. Farmers often face delays in diagnosing diseases due to limited access to agricultural specialists, especially in rural regions. Additionally, current approaches function as isolated processes without an integrated software platform that combines crop recommendation, fertilizer analysis, and disease detection. This lack of automation and integration reduces efficiency and prevents timely, data-driven agricultural decision-making.

Limitations of Existing System:

1. **Manual Decision-Making**: Existing agricultural systems rely heavily on farmer experience and expert judgment rather than automated, data-driven analysis, leading to inconsistent and subjective decisions.

Lack of Soil-Specific Analysis: Most traditional approaches do not accurately analyze soil nutrient parameters such as nitrogen, phosphorus, potassium, pH, and moisture for precise crop selection.

2. **Inefficient Fertilizer Usage**: Fertilizer recommendations are often generalized, resulting in overuse or underuse of nutrients, increased costs, and long-term soil degradation.
3. **Manual Disease Detection:** Plant disease identification is primarily performed through visual inspection, which is time-consuming, requires expert knowledge, and is prone to misclassification.
4. **Delayed Disease Identification**: Late detection of plant diseases leads to rapid disease spread and significant crop loss.
5. **Lack of Integrated Software Platform**: Existing systems do not provide a unified solution combining crop recommendation, fertilizer analysis, and disease detection.

Proposed System

The proposed system aims to develop an intelligent, software-based agricultural decision support system using machine learning and deep learning techniques. It analyzes soil parameters to recommend suitable crops and fertilizers and uses image-based disease detection through convolutional neural networks. The system is implemented as a web based application to provide accurate, automated, and scalable recommendations.

Benefits of the Proposed System:

1. **Data-Driven Crop Recommendation:** The system uses machine learning models to analyze soil nutrient data and recommend the most suitable crops accurately.
2. **Accurate Fertilizer Recommendation:** Fertilizer suggestions are generated based on nutrient imbalance, reducing overuse and improving soil health.
3. **Automated Disease Detection:** Deep learning models automatically identify plant diseases from leaf images with high accuracy.
4. **Early Disease Identification:** Early detection enables timely treatment, minimizing crop loss and improving yield.
5. **Integrated Software Solution:** The system combines crop selection, fertilizer recommendation, and disease detection into a single platform.
6. **Scalability and Maintainability:** The modular software architecture allows easy updates, model retraining, and future enhancements**.**

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