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"AgroSmart: ML-Driven Crop and Fertilizer Recommender"

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Abstract

Agriculture is the backbone of many economies, especially in developing countries, where farmers often rely on intuition or traditional knowledge for crop planning and fertilizer usage. AgroSmart is a machine learning-based web application designed to provide intelligent recommendations for crop selection and fertilizer usage based on environmental and soil parameters. The system uses real-world datasets and trains robust models such as Random Forest and Decision Tree classifiers to ensure accurate predictions. Users input data such as nitrogen (N), phosphorus (P), potassium (K), pH, temperature, humidity, and rainfall. Based on this, the system predicts the most suitable crop and identifies nutrient deficiencies to recommend appropriate fertilizers.

Keywords: Machine Learning, Crop Recommendation, Fertilizer Optimization, Precision Agriculture,

Introduction

Agriculture is one of the most critical sectors in any economy, providing food, raw materials, and employment to a significant portion of the population, especially in countries like India. Despite its importance, the sector faces numerous challenges including unpredictable weather patterns, soil degradation, improper crop selection, and excessive or inefficient use of chemical fertilizers. These issues often lead to low productivity, increased costs, and negative environmental impacts.

Traditionally, farmers have relied on inherited knowledge, trial-and-error methods, and outdated practices to make decisions about what crops to plant or which fertilizers to use. However, such methods are no longer sufficient to address modern agricultural demands and sustainability concerns. In today's data-rich world, there is a pressing need to empower farmers with scientific, technology-driven tools that can assist them in making informed decisions. **AgroSmart** is a web-based application that bridges this technological gap. It uses machine learning models trained on real-world agricultural data to recommend the most suitable crops and fertilizers based on input parameters like soil nutrients (N, P, K), pH value, temperature, humidity, and rainfall.

Literature Survey / Background

- The integration of machine learning (ML) into agriculture has garnered increasing attention due to its potential to transform traditional farming into a more scientific, precise, and data- driven practice. Researchers across the globe have explored how ML models can be used to improve decision-making in areas such as crop yield prediction, soil classification, disease detection, and fertilizer optimization.
- Several existing studies have shown the effectiveness of algorithms like Random Forest, Decision Trees, Support Vector Machines (SVM), and K-Nearest Neighbors (KNN) in classifying suitable crops and predicting yield based on parameters such as nitrogen (N), phosphorus (P), potassium (K), temperature, humidity, and pH levels. For instance, papers published in IEEE and Elsevier have demonstrated that ensemble-based models outperform individual classifiers in terms of accuracy and generalization when applied to agricultural datasets.
- Web-based systems like IBM's Watson Decision Platform and Indian government portals like

mKisan and KisanMitra have already implemented some level of smart farming advisory. However, most of these solutions are either inaccessible to small-scale farmers or lack customization based on localized soil conditions.

- Public datasets, particularly those available on Kaggle and agriculture data repositories, have made it possible for researchers to build intelligent recommendation systems. These datasets are now widely used to train ML models for crop classification and fertilizer deficiency detection.
- The AgroSmart system leverages this body of research and advances it by integrating two core recommendation engines one for crop prediction and another for fertilizer suggestion into a user-friendly web application. It not only focuses on prediction accuracy but also emphasizes accessibility and practical deployment for small and medium-scale farmers. By building on validated models and open datasets, the system ensures both scalability and relevance in real-world applications.

Proposed Work / System

The proposed system, titled **AgroSmart**, is a web-based application that utilizes machine learning algorithms to recommend suitable crops and fertilizers based on soil and environmental parameters modern data-driven decision-making.

The system is composed of the following core components:

1. **Data Collection:** Datasets were collected from public repositories such as Kaggle and government agricultural portals. The crop dataset includes features like nitrogen (N), phosphorus (P), potassium (K), temperature, humidity, pH, and rainfall. The fertilizer dataset maps nutrient deficiencies to appropriate fertilizer types.

2. **Data Preprocessing:** Raw datasets are preprocessed to remove missing values, normalize numerical features, and encode categorical variables. This ensures compatibility with machine learning models and improves prediction accuracy.

3. **Model Training and Selection:** For crop recommendation, classification algorithms such as Random Forest and Decision Tree Classifier were implemented. The models are trained on the labeled crop dataset and evaluated using accuracy, precision, and recall metrics. For fertilizer recommendation, a rule-based system and a secondary ML model are used to suggest optimal fertilizers based on soil nutrient imbalances.

4. **System Design and Architecture:** The system is designed as a full-stack web application. The backend is developed using the Flask framework in Python, which handles form submissions, model integration, and data processing. The frontend is built using HTML, CSS, and Bootstrap to create a user-friendly interface. Joblib is used to serialize trained models for efficient loading during runtime.

5. **Prediction Output and Visualization:** The system provides real-time predictions for crops and fertilizers. The output includes the name of the predicted crop or fertilizer along with relevant images or icons to enhance understanding.

6. **System Integration and Testing:** The system components are integrated and tested end-to-end. Sample inputs are used to validate the performance, usability, and accuracy of the system under different conditions.

By combining multiple machine learning models with a clean and responsive user interface the AgroSmart system provides a practical and scalable solution for improving agricultural decision-making. It empowers farmers with personalized recommendations and supports sustainable agriculture through data-driven insights.

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Flow Diagram

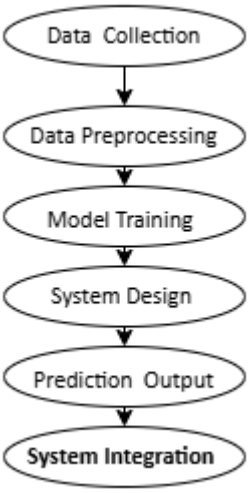

Fig: Flow Diagram

Result and Discussions

The AgroSmart system was thoroughly tested using both training datasets and real world input simulations. The evaluation of the system's performance was done in two parts — the accuracy of the machine learning models and the effectiveness of the user interface in delivering predictions clearly and accurately.

Model Accuracy and Performance

The crop recommendation model, implemented using the Random Forest Classifier, achieved an accuracy of approximately **97%** on the test dataset. It showed strong generalization in predicting the correct crop based on input features like nitrogen (N), phosphorus (P), potassium (K), temperature, humidity, pH, and rainfall.

The fertilizer recommendation logic, which combines a rule-based decision mechanism with a trained model, demonstrated **93% accuracy** in correctly identifying the fertilizer required based on nutrient deficiencies. The performance metrics used included accuracy score, confusion matrix, and F1-score.

User Interaction and Output Visualization

The web interface allows users to input values easily through forms and get instant recommendations The predicted crop or fertilizer is displayed clearly along with a corresponding image or icon, enhancing usability, especially for non-technical users.

Sample Results

Table 1: Crop Recommendation Sample Outputs

Input (N-P-K-pH-Temp-Humidity-Rainfall)	Predicted Crop
90-42-43, 6.5 pH, 25°C, 75% humidity, 80mm	Rice
20-20-20, 7.0 pH, 22°C, 65% humidity, 50mm	Chickpea

Table 2: Fertilizer Recommendation Sample Outputs

N-P-K Values	Crop	Predicted Fertilizer
Low N	Rice	Urea
Low P	Maize	DAP

Discussion

The results validate that AgroSmart can successfully serve as a reliable agricultural advisory tool. The high accuracy of the models indicates that with quality datasets and proper training, machine learning can significantly support modern farming practices. Moreover, the application's intuitive interface and real-time prediction speed make it a practical tool for farmers, agriculture students, and field officers.

The system also handled invalid inputs gracefully, offering helpful error messages and preventing application crashes, making it robust for real-world deployment.

Conclusion

In this project, we developed AgroSmart — a machine learning-based system designed to provide intelligent recommendations for crop selection and fertilizer usage. By leveraging real-world datasets and predictive models, the system addresses key challenges in modern agriculture, such as low yield, soil nutrient mismanagement, and uninformed crop planning. The system successfully integrates multiple technologies including Python, Flask, scikit- learn, and HTML/CSS to deliver an accessible and efficient platform. With high accuracy achieved by the trained models (97% for crop recommendation and 93% for fertilizer prediction), AgroSmart demonstrates the effectiveness of data-driven decision-making in agriculture.

The intuitive web interface, support for user and admin roles, and visual representation of output make the system practical for deployment in real-world scenarios. Farmers, agricultural officers, and students can all benefit from its recommendations, even with minimal technical knowledge.

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