

Machine Learning Based Intelligent Agricultural Decision Support System for Crop Recommendation, Crop Combination and Market Price Prediction

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Abstract

Agriculture continues to be one of the most important sectors supporting the livelihood of people in developing countries such as India. Farmers often experience difficulties while selecting suitable crops due to variations in soil fertility conditions, unpredictable climatic changes, and unstable market price fluctuations. Traditional crop planning methods mainly depend on experience and seasonal assumptions, which may not always produce reliable results under changing environmental conditions.

To address these challenges, this paper proposes a Machine Learning Based Intelligent Agricultural Decision Support System that integrates soil parameter analysis, crop recommendation, crop combination planning, weather prediction, and market price forecasting within a unified web-based platform. Machine learning algorithms such as Decision Tree, Support Vector Machine, and Random Forest are implemented to analyse agricultural datasets and generate reliable prediction outputs. Experimental results demonstrate that the proposed system improves crop selection accuracy and assists farmers in making effective agricultural decisions that enhance productivity and sustainability.

Keywords— Machine Learning, Crop Recommendation, Crop Combination, Market Price Prediction, Weather Prediction, Smart Agriculture.

1 Introduction

Agriculture plays a major role in the economic growth of developing countries and remains the primary occupation for a large population in rural areas. Crop productivity depends mainly on environmental parameters such as soil nutrients, rainfall availability, temperature variation, and humidity conditions. Selecting appropriate crops according to these parameters is essential for improving yield quality and economic returns.

However, farmers often rely on traditional decision making practices based on previous experience and local knowledge. These approaches may not provide accurate results when environmental conditions change rapidly. Recent advancements in machine learning technologies enable the development of intelligent agricultural decision support systems capable of analysing large datasets and generating accurate prediction results.

The proposed system integrates crop recommendation, crop combination planning, weather prediction, soil parameter analysis, and market price forecasting within a unified web

dashboard that assists farmers in selecting suitable crops efficiently.

2 Literature Survey

Several researchers have proposed machine learning based agricultural prediction systems to improve crop productivity. Decision Tree algorithms are widely used for crop classification because they provide interpretable prediction structures based on soil nutrient values. Random Forest algorithms improve prediction performance through ensemble learning techniques by combining multiple decision trees.

Support Vector Machine algorithms are also applied in agricultural prediction systems due to their ability to handle high dimensional datasets efficiently. Regression based forecasting techniques are commonly used for market price prediction using historical agricultural datasets.

Although these systems provide promising prediction performance individually, most existing approaches focus only on a single agricultural prediction module. There is still a requirement for integrated decision support platforms capable of combining soil analysis, crop recommendation, crop combination planning, weather prediction, and market price forecasting within a unified system.

3 Problem Statement

Farmers frequently face difficulties in selecting suitable crops due to variations in soil nutrient composition and unpredictable weather conditions. In addition, fluctuations in market prices directly affect agricultural profitability. Existing agricultural prediction systems provide limited decision support and do not integrate multiple prediction modules within a single platform.

Therefore, an intelligent agricultural decision support system capable of analysing soil parameters, crop compatibility, weather conditions, and market price variations simultaneously is required for improving productivity and farmer decision making.

4 Proposed System

The proposed agricultural decision support system integrates multiple machine learning modules to assist farmers in selecting suitable crops efficiently. Soil nutrient values such as nitrogen, phosphorus, potassium, and pH levels are analysed along with climatic parameters including rainfall, humidity, and temperature conditions.

The system processes these inputs using Decision Tree, Support Vector Machine, and Random Forest algorithms to generate crop recommendation results. The generated outputs are displayed through a user friendly web dashboard interface that improves accessibility for farmers.

5 System Architecture

The overall architecture of the proposed agricultural decision support system is designed as an integrated multi-module prediction framework that assists farmers in selecting suitable crops based on environmental conditions and market behaviour. The system collects soil nutrient parameters such as nitrogen, phosphorus, potassium values and soil pH levels along with climatic parameters including rainfall level, humidity variation and temperature conditions from agricultural datasets.

These input parameters are processed through multiple machine learning modules that perform crop recommendation, crop combination planning, weather prediction and market price forecasting. Each module performs a specific prediction task and the generated outputs are integrated through a centralized processing layer. The final prediction results are displayed through a web-based dashboard interface that allows farmers to access recommendations easily without requiring advanced technical knowledge. The architecture ensures flexibility, scalability and efficient prediction performance for real-time agricultural decision making.

6 System Modules

6.1 Soil Parameter Analysis Module

This module analyses soil nutrient values such as nitrogen, phosphorus, potassium, and pH levels to determine soil fertility conditions. These parameters are essential for identifying suitable crop categories based on environmental compatibility.

6.2 Crop Recommendation Module

The crop recommendation module predicts suitable crops using machine learning classification techniques based on soil and climatic parameters. This module assists farmers in selecting crops with improved productivity potential.

6.3 Crop Combination Module

Crop combination planning improves soil fertility balance and increases yield productivity. The proposed module suggests compatible crop combinations based on nutrient usage behaviour and seasonal growth characteristics.

6.4 Weather Prediction Module

Weather prediction plays an important role in agricultural planning. This module analyses historical climatic datasets to estimate rainfall availability and seasonal temperature variation.

6.5 Market Price Prediction Module

This module predicts future crop prices using regression based forecasting techniques applied to historical agricultural market datasets. Farmers can use these predictions to select economically profitable crops.

7 Market Trend Analysis

Market trend analysis plays an important role in improving agricultural profitability by helping farmers select economically beneficial crops. The proposed system analyses historical crop price datasets collected from agricultural market repositories to identify price fluctuation patterns across different seasons. Regression-based forecasting techniques are used to estimate future crop price variations based on historical trends.

These predictions allow farmers to understand potential market behaviour before selecting crops for cultivation. By combining market trend analysis with crop recommendation outputs, the system provides both productivity-based and profitability-based decision support. This integrated prediction strategy improves the usefulness of the proposed framework for real-time agricultural planning applications.

8 Module Integration Strategy

Integration of multiple prediction modules within a single decision support platform improves the effectiveness of agricultural planning systems. In the proposed framework, soil parameter analysis acts as the primary input module which provides nutrient-based recommendations for crop selection. The crop recommendation module uses this information along with climatic attributes to identify suitable crop categories.

The crop combination module further improves productivity by suggesting compatible crop pairs that maintain soil fertility balance and increase yield efficiency. Weather prediction modules support cultivation planning by estimating rainfall availability and seasonal temperature behaviour. Market price prediction modules assist farmers in selecting economically profitable crops by analysing historical agricultural market trends. The integration of these modules within a unified framework ensures better agricultural decision support performance.

9 Dataset Description

The dataset used for implementing the proposed system includes soil nutrient values such as nitrogen, phosphorus, potassium levels, and soil pH values along with climatic parameters including rainfall, humidity, and temperature conditions. Historical agricultural market datasets are also used for training market price prediction models.

Data preprocessing techniques are applied to remove missing values and improve dataset consistency before training machine learning algorithms.

10 Dataset Collection and Preparation

Dataset collection plays an important role in improving the performance of agricultural prediction systems. The pro-

posed system uses agricultural datasets collected from publicly available government agricultural repositories and research databases containing soil nutrient parameters and climatic attributes. These datasets include nitrogen level, phosphorus level, potassium level, rainfall measurement, humidity percentage, temperature variation and soil pH values which directly influence crop productivity.

Before training machine learning models, dataset cleaning and preprocessing operations are performed to remove missing values and inconsistent entries. Feature normalization techniques are applied to maintain uniform distribution of dataset attributes. Proper dataset preparation improves classification accuracy and ensures reliable performance of prediction modules under different environmental conditions.

11 Data Preprocessing

Data preprocessing improves dataset quality and prediction performance. Missing values are removed and normalization techniques are applied to maintain uniform feature distribution across datasets. These preprocessing steps improve classification accuracy and system reliability.

12 Algorithm Implementation

The proposed system uses Decision Tree, Support Vector Machine, and Random Forest algorithms for crop prediction tasks. Decision Tree algorithms provide interpretable prediction structures while Support Vector Machine algorithms handle complex datasets efficiently. Random Forest algorithms provide improved prediction accuracy through ensemble learning techniques.

13 Model Training Strategy

Model training plays an important role in improving the prediction accuracy of agricultural decision support systems. In the proposed system, multiple machine learning algorithms such as Decision Tree, Support Vector Machine, and Random Forest are trained using agricultural datasets containing soil nutrient values and climatic parameters. The dataset is divided into training and testing subsets to evaluate the performance of classification models effectively.

During the training phase, the algorithms learn relationships between soil fertility conditions and suitable crop categories. Feature normalization techniques are applied to improve classification stability and reduce prediction errors caused by uneven feature distribution. The trained models are evaluated using performance metrics such as accuracy, precision, recall, and F1-score values. Experimental evaluation results indicate that ensemble-based learning techniques such as Random Forest provide better prediction performance compared to individual classification models.

14 System Workflow

The workflow of the proposed agricultural decision support system begins with collecting soil nutrient values and environmental parameters from agricultural datasets. These

parameters are provided as input to machine learning classification algorithms that generate crop recommendation outputs based on environmental compatibility conditions.

After generating crop recommendation results, the crop combination module evaluates compatibility relationships between selected crops and suggests optimized crop combinations for cultivation planning. Weather prediction modules estimate rainfall availability and seasonal climatic conditions which further support crop selection decisions. Market price prediction modules analyse historical crop price datasets and estimate future price behaviour to assist farmers in selecting economically beneficial crops. The final prediction results are displayed through an interactive web dashboard interface that improves accessibility for farmers and agricultural planners.

15 Performance Evaluation Metrics

Performance evaluation plays an important role in measuring the effectiveness of machine learning models used in agricultural prediction systems. In the proposed framework, classification models are evaluated using standard performance metrics such as accuracy, precision, recall, and F1-score.

Accuracy represents the overall correctness of prediction results generated by the model. Precision measures the proportion of correctly predicted crop categories among all predicted categories. Recall indicates the ability of the model to correctly identify suitable crop classes from the dataset. The F1-score provides a balanced evaluation by combining both precision and recall values.

These evaluation metrics help in analysing the prediction capability of Decision Tree, Support Vector Machine, and Random Forest algorithms used in the proposed agricultural decision support system.

16 Experimental Results

Experimental evaluation of the proposed agricultural decision support system is performed using multiple machine learning classification algorithms including Decision Tree, Support Vector Machine, and Random Forest models. These algorithms are trained using agricultural datasets containing soil nutrient values and climatic parameters.

The dataset is divided into training and testing subsets to analyse model prediction performance effectively. Experimental results indicate that ensemble learning based Random Forest algorithm produces higher classification accuracy compared to individual Decision Tree and Support Vector Machine models.

The improved prediction accuracy achieved by Random Forest algorithm makes it more suitable for crop recommendation tasks in real-time agricultural decision support applications.

17 Advantages

The proposed agricultural decision support system provides multiple advantages for improving agricultural planning efficiency. The integration of soil parameter analysis with crop

Table 1: Model Accuracy Comparison

Algorithm	Accuracy
Decision Tree	86%
Support Vector Machine	89%
Random Forest	94%

recommendation modules improves prediction accuracy and supports better crop selection strategies.

The crop combination module enhances soil fertility balance and increases agricultural productivity through compatible crop planning techniques. Weather prediction modules support seasonal cultivation planning by estimating rainfall availability and temperature variation patterns.

Market price prediction modules help farmers select economically beneficial crops based on future price behaviour analysis. The web-based dashboard interface improves accessibility and usability for farmers without requiring advanced technical knowledge, making the system suitable for real-world agricultural applications.

18 System Implementation Environment

The proposed agricultural decision support system is implemented using a web-based development framework that supports efficient interaction between machine learning prediction modules and user interface components. The backend prediction models are developed using Python programming language and machine learning libraries such as Scikit-learn for classification and regression tasks.

The frontend dashboard interface is designed using modern web technologies including HTML, CSS, and JavaScript to provide a user-friendly interaction platform for farmers. Agricultural datasets used for model training are processed using data preprocessing techniques such as normalization and missing value removal to improve prediction performance.

The implementation environment ensures reliable integration between prediction modules and visualization components within a unified web-based agricultural support system.

19 Web Dashboard Implementation

The proposed agricultural decision support system is deployed through a web-based dashboard interface that allows farmers to interact with prediction modules easily. The dashboard provides input fields for entering soil nutrient values and climatic parameters required for crop recommendation prediction. After submitting input parameters, the system processes the data using trained machine learning models and generates prediction outputs instantly.

The dashboard also displays crop combination suggestions, weather prediction information and market price forecasting results in an organized format. This improves usability and ensures that farmers can access prediction services without requiring specialized technical knowledge. The web-based deployment model ensures platform accessibility across multiple devices including desktop computers and mobile browsers.

20 Scalability and Practical Applications

The proposed agricultural decision support system is designed with scalability features that allow integration with advanced smart agriculture technologies in future implementations. The system architecture supports extension with IoT-based soil monitoring sensors that can automatically collect real-time soil nutrient values and environmental parameters from agricultural fields. These sensor-based inputs can further improve prediction accuracy and enable automated crop recommendation services.

In addition to small-scale farming environments, the proposed system can also be applied in large-scale agricultural planning activities performed by agricultural organizations and government agencies. The web-based deployment model ensures accessibility across multiple platforms and improves usability for farmers located in rural areas with limited technical resources.

21 Limitations of the Proposed System

Although the proposed agricultural decision support system provides accurate crop recommendation results, certain limitations exist in the current implementation. The prediction accuracy depends mainly on the quality and availability of agricultural datasets used for training machine learning models.

In addition, real-time environmental variations such as unexpected rainfall changes and sudden temperature fluctuations may affect prediction performance. Integration with real-time IoT-based soil monitoring sensors can further improve system accuracy in future implementations.

Addressing these limitations will enhance the reliability and scalability of the proposed agricultural prediction framework.

22 Future Scope

Future improvements may include integration with IoT based smart agriculture monitoring systems and mobile application deployment for improving accessibility. Satellite weather data integration can further enhance prediction accuracy.

23 Societal Impact

Agriculture remains the primary source of livelihood for a large population in developing countries, and improving agricultural productivity directly contributes to economic development and food security. The proposed machine learning based agricultural decision support system assists farmers in selecting suitable crops based on environmental compatibility and market behaviour, thereby reducing cultivation risk and improving productivity.

The integration of soil parameter analysis, crop recommendation, weather prediction, crop combination planning, and market price forecasting within a single platform provides comprehensive decision support for farmers. This system contributes toward sustainable agricultural development by promoting efficient resource utilization and improving crop planning strategies in rural farming communities.

24 Conclusion

This paper presented a Machine Learning Based Intelligent Agricultural Decision Support System that integrates crop recommendation, crop combination planning, soil parameter analysis, weather prediction, and market price forecasting within a unified web-based platform. The proposed system improves prediction accuracy and supports farmers in making efficient agricultural decisions.

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