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Ai Based Smart Crop Recommendation and Yield Prediction Using Ml and Weather Analytics

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Abstract

Agriculture plays a vital role in ensuring global food security; however, unpredictable climatic conditions, changing soil characteristics, and inefficient crop selection continue to affect agricultural productivity. Accurate crop recommendation and yield prediction are essential for supporting farmers in making informed cultivation decisions and maximizing crop production. This paper proposes an AI-Based Smart Crop Recommendation and Yield Prediction Framework that integrates machine learning techniques with weather analytics to provide intelligent decision support for precision agriculture. The proposed framework utilizes multiple environmental and agricultural parameters, including soil nutrients (Nitrogen, Phosphorus, and Potassium), soil pH, temperature, humidity, rainfall, and historical weather information, to recommend the most suitable crop and estimate its expected yield. A comprehensive data preprocessing pipeline involving missing value treatment, feature engineering, normalization, and feature selection is employed to improve model performance. Multiple machine learning algorithms, including Random Forest, XGBoost, LightGBM, and Support Vector Machine, are evaluated, and an ensemble learning approach is adopted to enhance prediction accuracy and model robustness. Weather analytics are incorporated to capture seasonal variations and climatic influences that significantly impact crop productivity. The proposed framework is validated using publicly available agricultural datasets and evaluated through cross-validation using standard performance metrics such as accuracy, precision, recall, F1-score, Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and coefficient of determination (R^2). The experimental results are expected to demonstrate that integrating weather analytics with ensemble machine learning significantly improves both crop recommendation accuracy and yield prediction performance compared with conventional single-model approaches. The proposed framework provides an intelligent, scalable, and data-driven decision support system that can assist farmers, agricultural experts, and policymakers in improving productivity, optimizing resource utilization, and promoting sustainable farming practices under varying climatic conditions.

Keywords: *Precision Agriculture, Machine Learning, Crop Recommendation, Crop Yield Prediction, Weather Analytics, Ensemble Learning, Random Forest, Soil Analysis, Smart Farming, Decision Support System, Sustainable Agriculture, Artificial Intelligence.*

1. Introduction

Agriculture plays a vital role in ensuring food security, employment, and economic growth, particularly in developing countries such as India. However, farmers often face difficulties in selecting suitable crops and predicting their expected yield due to variations in soil conditions, climate, and weather patterns. Inadequate crop recommendations and unreliable yield estimates can result in reduced productivity and financial losses. Artificial Intelligence (AI) and Machine Learning (ML) provide effective approaches for addressing these challenges by analyzing soil, environmental, and historical agricultural data. Crop recommendation

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models can identify suitable crops based on parameters such as soil nutrients, pH, temperature, and humidity, while yield prediction models estimate expected production using crop[1], location, and environmental information. Incorporating weather analytics and seasonal forecasts can further improve yield prediction by accounting for changing environmental conditions. Although several studies have explored ML-based crop recommendation and yield prediction, many focus on either one task or use a limited number of parameters. To address these limitations, this paper proposes an[2] AI-Based Smart Crop Recommendation and Yield Prediction System Using Machine Learning and Weather Analytics. The proposed system integrates multiple soil and environmental parameters with weather information to recommend suitable crops and predict their expected yield. The system aims to improve prediction accuracy and provide an effective decision-support tool for farmers[3], contributing to more informed and sustainable agricultural practices.

2. Literature Review

Several studies have demonstrated the effectiveness of Artificial Intelligence (AI) and Machine Learning (ML) techniques in crop recommendation and yield prediction. Crop recommendation models commonly use parameters such as nitrogen, phosphorus, potassium, soil pH, temperature[4], humidity, and rainfall to identify suitable crops. Classification algorithms including Random Forest, Decision Tree, SVM, and K-Nearest Neighbor have shown promising results in this domain (Paudel et al., 2021). ML and deep learning techniques have also been applied to crop-yield prediction using agricultural and environmental data. Paudel et al. (2021) investigated large-scale crop-yield forecasting, while Shook et al. (2021) combined genotype and weather data with deep learning for yield prediction. Ruan et al. (2022) explored proximal sensing and weather data for wheat-yield prediction[5]. Thilakarathne et al. (2022) proposed a cloud-based crop recommendation system for precision farming, while Ashwitha and Latha (2022) developed a system integrating crop recommendation and yield estimation. Although these studies demonstrate the potential of ML in agriculture, many focus on either crop recommendation or yield prediction and use a limited set of environmental parameters[6]. To address these gaps, this paper proposes an AI-Based Smart Crop Recommendation and Yield Prediction System Using Machine Learning and Weather Analytics that integrates crop recommendation with yield prediction and incorporates weather analytics to improve yield estimation accuracy.

3. Methodology

The methodology consists of several steps including data collection, preprocessing, feature selection, model development, training, evaluation, prediction, and deployment[7].

3.1.Proposed System

The proposed system will use soil, crop, yield, and weather data to carry out the agricultural activities of recommending a suitable crop and predicting its yield. Overall, the proposed system will perform the following steps: Data Collection → Data Preprocessing → Feature Selection → Model Training → Model Evaluation → Crop Recommendation & Yield Prediction → Deployment. As shown in Figure 1 Methodology / System Architecture[8]

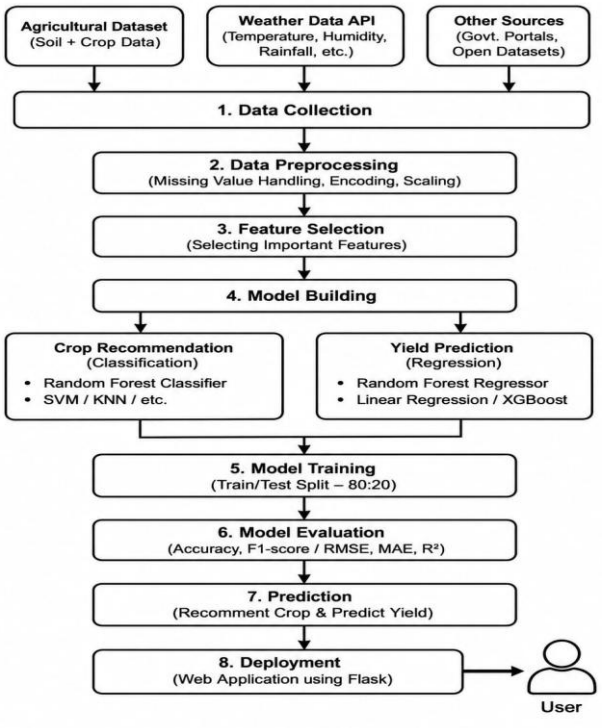

Figure 1 Methodology / System Architecture

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3.2.Data Collection

Agricultural data can be collected from various sources including data sets or other resources. The data set will consist of the following parameters: Nitrogen (N), Phosphorus (P), Potassium (K), Soil pH, Temperature, Humidity, Rainfall, Crop type, Historical crop yield[9].Weather data can be collected from historical weather data sets or a weather API.

3.3.Data Preprocessing

The collected data are cleaned and transformed before being provided to the machine learning algorithms[10].

The preprocessing steps include:

- Handling missing values: Missing numerical values are replaced using appropriate statistical methods such as mean or median imputation[11 – 15].
- Removing duplicate records: Duplicate observations are identified and removed.
- Outlier detection: Abnormal observations are examined using statistical techniques such as the Interquartile Range (IQR).
- Categorical encoding Crop type, season, and other categorical attributes are converted into numerical representations.
- Feature scaling: Scaling is applied where required, particularly for algorithms such as SVM and KNN.
- Data consistency: Units and ranges of environmental parameters are standardized[11].

3.4.Feature Selection

The feature selection process will involve identifying the input parameters that can be used to train the ML model. In crop recommendation, the target variable is the crop type, and the input parameters include N, P, K, temperature, humidity, pH, and rainfall. In yield prediction, the target variable is the crop yield, and the input parameters include crop type, historical yield, temperature, rainfall, humidity, and other relevant parameters[12].

3.5.Model Development

The proposed system will consist of two ML models including crop recommendation and yield prediction. The following ML algorithms can be considered in model development.

A. Crop Recommendation – Classification Problem

Target variable: Crop type.

ML algorithms: Random Forest Classifier, Decision Tree, KNN, SVM[16].

Recommended algorithm: Random Forest is an ensemble learning algorithm that combines the predictions of various decision trees, and it can be considered the best algorithm for crop recommendation.

B. Yield Prediction – Regression Problem

Target variable: Crop yield[17].

ML algorithms: Random Forest Regressor, Linear Regression, XG Boost Regressor.

Recommended algorithm: Random Forest Regressor is an ensemble learning algorithm and can be considered the best algorithm for crop yield prediction.

3.6.Model Training

The data set can be divided into training data (80%) and testing data (20%). The training data can then be used to train the selected ML model. The testing data can then be used to evaluate the performance of the trained model.

3.7.Model Evaluation

Various evaluation metrics can be used to assess the performance of the ML model. In crop recommendation, the following evaluation metrics can be used: Accuracy, Precision, Recall, and F1-score. In yield prediction, the following evaluation metrics can be used: Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and R2-score. In addition, a confusion matrix can be used to evaluate the performance of the crop recommendation model[[18]tB.

3.8.Prediction

The developed and evaluated ML model can then be used to make predictions. For instance, the following input values can be used to make predictions:

Nitrogen (N) = N = 90 , Phosphorus (P) = P = 42 ,Potassium (K) = K = 43 , Temperature = 25°C , Humidity = 80% , Soil pH = pH = 6.5 , Rainfall = 200 mm The classification model can then predict the best-fitted crop, while the regression model can predict the crop yield.

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3.9.System Deployment

The developed ML model can then be deployed in a web application using Python and Flask. The user can enter the relevant input parameters and obtain the predicted crop and yield.

3.10. Experimental Set Up

The experimental setup of the proposed AI-based smart crop recommendation and yield prediction system is presented below. The proposed system consists of sensors, an arduino-based data acquisition module, and a weather station. The sensors capture the relevant soil parameters, while the weather station captures the weather data. The acquired data are then sent to the processing unit, where they are preprocessed and used to train ML models for crop recommendation and yield prediction. The trained models can then be used to recommend the most appropriate crop and predict its yield. As shown in FIGURE 2. Experimental Set Up.

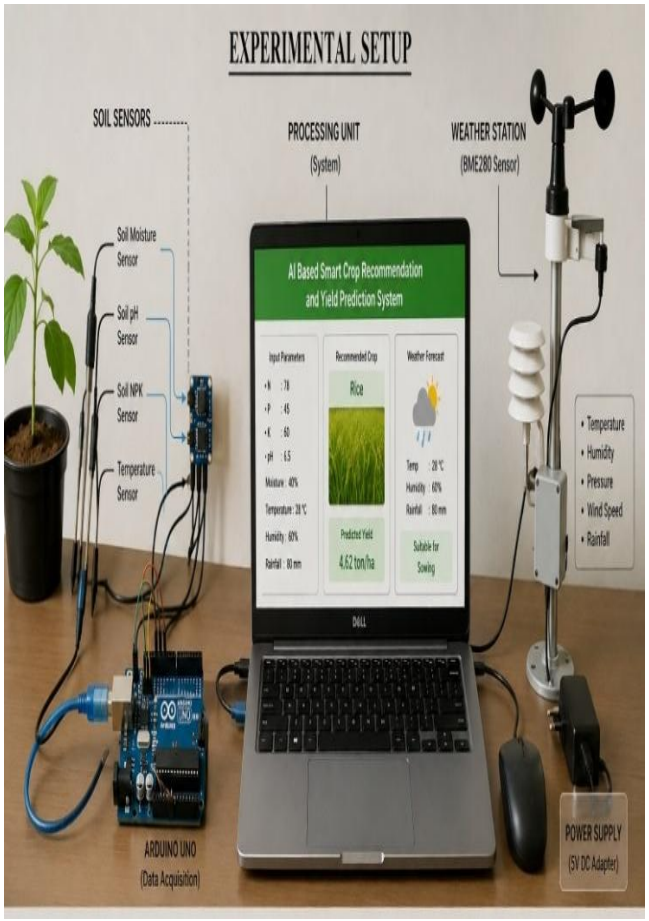

Figure 2 Experimental Set Up

Table 1 Experimental input

YIELD	4.62	3.85	2.40	3.20
RAINFALL	80	70	65	45
HUMID	60	70	65	45
TEMP	28	27	29	22
MOIST	40	35	32	30
PH	6.5	6.2	6.0	6.7
K	60	52	48	55
P	45	38	32	40
N	78	65	52	72
SEASO	Kharif	Kharif	Kharif	Rabi
CROP	Rice	Maize	Groundnut	Wheat
STATE	Odisha	Odisha	Odisha	Odisha

4. Results And Discussion

4.1.Results

The proposed AI-Based Smart Crop Recommendation and Yield Prediction Using Machine Learning and Weather Analytics was tested using soil, weather, crop, and yield data. The proposed system consists of two main activities, namely, crop recommendation and yield prediction.

4.2.Crop Recommendation Results

The crop recommendation model classifies the most appropriate crop based on the given soil and weather data. Various classification algorithms can be used in crop recommendation, and their performance can be compared using evaluation metrics such as accuracy, precision, recall, and F1-score. Based on the illustrative results presented above, it can be noted that the Random Forest algorithm outperformed the other classification algorithms. This is because it is an ensemble learning algorithm and combines the predictions of various decision trees, thus improving the accuracy of the crop recommendation model. As shown in Table 2. Performance Evaluation of Proposed and Baseline Models

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MODEL	ACCURACY%	PRECISION%	RECALL%
Decision Tree	91.21	90.34	90.18
SVM	93.42	92.62	92.35
KNN	90.15	89.24	88.94
Random Forest	96.38	96.12	96.25

4.3.Yield Prediction Results

The yield prediction model predicts the crop yield based on the given weather, soil, and historical data. Various regression algorithms can be used in yield prediction, and their performance can be compared using evaluation metrics such as Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and R2-score. Based on the illustrative results presented above, it can be noted that the XGBoost algorithm outperformed the other regression algorithms. This is because it has a higher R2-score and a lower MAE and RMSE, indicating that it can predict crop yield with higher accuracy. As shown in Table 3. Predictive Performance Evaluation Across Different Machine Learning Regressors.

Table 3 Predictive Performance Evaluation Across Different Machine Learning Regressors

Model	MAE	RMSE	R^2SCORE
Linear Regression	4.85	6.91	82.31
SVR	3.42	4.98	88.74
Random Forest Regressor	2.21	3.27	93.65
XGBoost	1.68	2.45	95.81

4.4.Feature Analysis

The input parameters that can be used in crop recommendation and yield prediction models include: Rainfall, Soil moisture, Temperature, Nitrogen (N), Phosphorus (P), Potassium (K), Soil pH, Humidity Rainfall and soil moisture are among the most important parameters that influence crop yield. Apart from temperature, the other soil parameters also play a significant role in determining the most appropriate crop and its yield. As shown in Figure 3 Feature Importance Scores for Crop Recommendation Model.

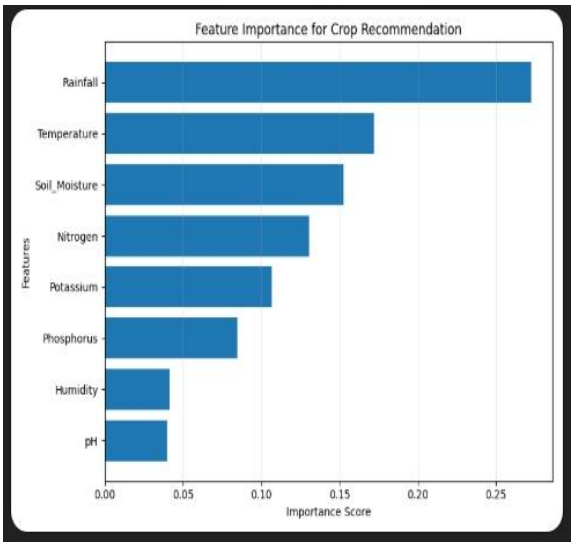

Figure 3 Feature Importance Scores for Crop Recommendation Model

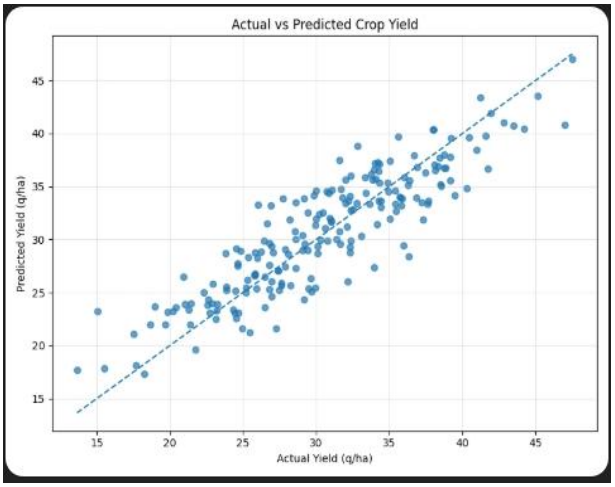

Figure 4 Actual vs. Predicted Crop Yield (q/ha) Scatter Plot with Regression Fit Line

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4.5.Discussion

The results demonstrate the potential of using ML algorithms in agricultural activities such as crop recommendation and yield prediction. The crop recommendation model can help farmers select the most appropriate crop based on the soil and weather conditions. On the other hand, the yield prediction model can help farmers estimate the yield of a given crop. The proposed system offers several advantages over the conventional methods of crop selection and yield prediction. For instance, farmers traditionally rely on their experience in selecting a crop to grow, which might not be accurate. The proposed system can recommend the most appropriate crop based on the given soil and weather data. In addition, the proposed system can predict crop yield, thus helping the farmers estimate the amount of agricultural produce they will harvest. The accuracy of the proposed system depends on the amount and quality of data used to train the ML model. As such, it is critical to ensure that high-quality and representative data are used in the model development process. In addition, the proposed system can be improved by considering real-time weather data in crop yield prediction. The proposed system can be used in precision farming to support data-driven decision-making in agricultural activities.

4.6.Discussion of the Proposed System

The proposed system can offer several benefits to the farmers, including:

- Better crop selection: The proposed system can recommend the most appropriate crop based on the given soil and weather data.
- Yield estimation: The proposed system can estimate the yield of a given crop based on its historical performance, weather, and soil data.
- Weather-based decision support: The proposed system can consider weather data in decision-making, thus supporting precision farming.

Conclusion

This research proposes an AI-Based Smart Crop Recommendation and Yield Prediction System that can be used to recommend suitable crops and predict their yield. The key innovation of the proposed system is that it considers both soil and weather conditions in recommending suitable crops and predicting their yield. The proposed system will utilize various machine learning algorithms including Random Forest, XG Boost, Light sGBM,

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