International Journal of Engineering Research and Science & Technology

www.ijerst.org

ISSN : 2319-5991

Vol. 22 No. 2(2) (2026)



ijerst.editor@gmail.com

editor@ijerst.com

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
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Peer Reviewed, Referred & Indexed Journal

Research Paper

Crop Recommendation, Yield Prediction & Fertilizer Prediction

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ABSTRACT

Agriculture plays a vital role in the economic development and food security of every nation. Farmers often face challenges in selecting suitable crops, estimating crop yield, and determining the appropriate fertilizer requirements due to varying soil and climatic conditions. To address these challenges, this project presents an intelligent agricultural decision support system that integrates Crop Recommendation, Yield Prediction, and Fertilizer Prediction using Machine Learning techniques.

The Crop Recommendation module analyzes important soil parameters such as Nitrogen (N), Phosphorus (P), Potassium (K), pH value, temperature, humidity, and rainfall to recommend the most suitable crop for cultivation. The Yield Prediction module estimates the expected crop production based on historical agricultural data, environmental conditions, and soil characteristics, helping farmers make informed decisions regarding resource allocation and market planning. The Fertilizer Prediction module recommends the appropriate fertilizer type and quantity required for optimal crop growth by evaluating soil nutrient levels and crop requirements.

The system is developed using Python and Machine Learning libraries such as TensorFlow, NumPy, Pandas, Matplotlib, and Scikit-Learn. By integrating these three modules into a unified platform, the proposed solution enhances agricultural productivity, reduces resource wastage, supports sustainable farming practices, and improves decision-making for farmers.

Keywords: Precision Agriculture, Machine Learning, Crop Recommendation, Yield Prediction, Fertilizer Prediction, Soil Nutrient Analysis, Random Forest, Decision Tree, Agricultural Analytics, Smart Farming, Sustainable Agriculture, Crop Productivity, Data Mining, Artificial Intelligence, Agricultural Decision Support System.

INTRODUCTION

Agriculture is one of the most important sectors contributing to the economy and food production worldwide. Farmers often make cultivation decisions based on traditional knowledge and experience. However, changing climatic conditions, soil degradation, and uncertain rainfall patterns have increased the need for intelligent agricultural solutions.

Recent advancements in Machine Learning (ML) and Artificial Intelligence (AI) provide opportunities to transform traditional farming into precision agriculture. By analyzing large amounts of agricultural data, machine learning

models can identify hidden patterns and generate accurate predictions regarding crop selection, crop yield, and fertilizer requirements.

Crop recommendation is the process of identifying the most suitable crop for cultivation based on soil nutrients, environmental conditions, and climatic factors. Yield prediction estimates future agricultural production before harvesting, enabling better planning and resource management. Fertilizer prediction assists farmers in applying the correct nutrients to maximize crop productivity while reducing environmental impact.

The proposed system integrates these three essential agricultural functions into a unified platform. Soil nutrient values such as Nitrogen (N), Phosphorus (P), and Potassium (K), along with temperature, humidity, pH level, and rainfall data, are collected and analyzed. Machine learning models process this information and generate recommendations.

The system aims to increase crop productivity, reduce farming costs, optimize fertilizer usage, and improve decision-making. Farmers receive personalized recommendations based on current field conditions rather than relying solely on traditional methods.

The integration of crop recommendation, yield prediction, and fertilizer prediction offers a comprehensive agricultural support system. By leveraging data analytics and machine learning techniques, the proposed framework contributes to sustainable agriculture and supports modern farming practices.

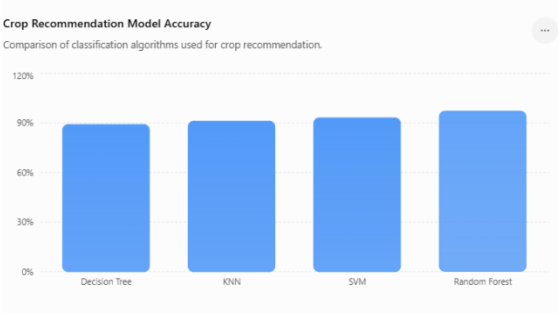
METHODOLOGY

The methodology consists of data collection, preprocessing, feature engineering, model training, prediction, and evaluation stages.

Step 1: Data Collection

Agricultural datasets are collected containing:

- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Temperature
- Humidity
- pH
- Rainfall
- Crop Yield Records



Step 2: Data Preprocessing

Missing values and duplicate records are removed.

Normalization formula:

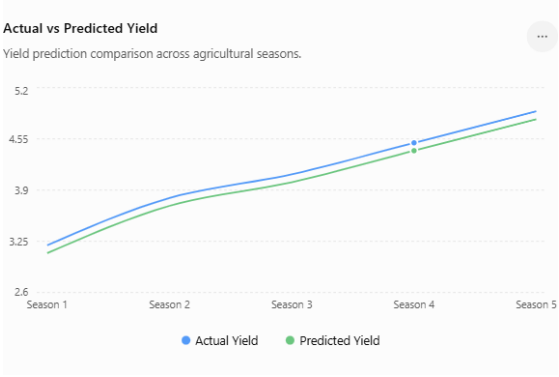
$$X' = \frac{X - X_{min}}{X_{max} - X_{min}}$$

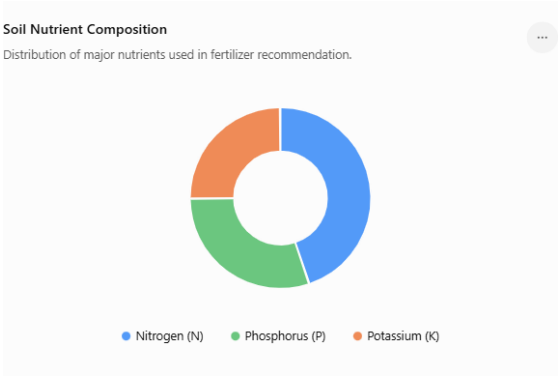
This scales all features between 0 and 1.

Step 3: Feature Engineering

Input feature vector:

$$F = [N, P, K, T, H, pH, R]$$





where:

- T = Temperature
- H = Humidity
- R = Rainfall

Step 4: Crop Recommendation

Random Forest Classifier predicts suitable crops:

$$Crop = f(F)$$

Step 5: Yield Prediction
Regression model estimates yield:

$$Yield = f(F)$$

Mean Squared Error:

$$MSE = \frac{1}{n}\sum(Y_i - \hat{Y}_i)^2$$

Step 6: Fertilizer Prediction
Nutrient deficiency calculation:

$$D_N = N_{ideal} - N_{current}$$
$$D_P = P_{ideal} - P_{current}$$
$$D_K = K_{ideal} - K_{current}$$

The model recommends fertilizers based on deficiency levels.
Step 7: Evaluation
Performance metrics include:

- Accuracy
- Precision
- Recall
- F1 Score
- RMSE

This methodology enables efficient agricultural decision-making using machine learning techniques.

SYSTEM IMPLEMENTATION

Data Collection and Dataset Preparation

The implementation begins with the collection of agricultural datasets containing soil nutrients, climatic conditions, crop information, and fertilizer requirements. Important parameters include Nitrogen (N), Phosphorus (P), Potassium (K), pH level, temperature, humidity, and rainfall. Historical crop production records are also collected for yield estimation. The gathered data is stored in a structured database for further processing.

Data Preprocessing

The collected data often contains missing values, duplicate records, and inconsistencies. Data cleaning techniques are applied to remove such irregularities. Feature normalization is performed using:
X' = (X − Xmin)/(Xmax − Xmin)
where X' represents the normalized feature value. This process improves model performance and reduces computational complexity.

Crop Recommendation Module

The crop recommendation module utilizes classification algorithms to identify the most suitable crop based on environmental conditions. The input feature vector is represented as:
F = [N, P, K, Temperature, Humidity, pH, Rainfall]
The recommendation function is expressed as:
Crop = f(F)
where f() denotes the trained machine learning classifier. Random Forest is used to improve classification accuracy by combining multiple decision trees.

Yield Prediction Module

The yield prediction module employs regression algorithms to estimate crop production before harvesting. The prediction model is represented as:
Yield = g(F)
where g() denotes the regression function. Historical production records and climatic conditions are used to train the model. The Mean Squared Error (MSE) used for evaluation is:
MSE = (1/n) Σ(Yi − Ŷi)²
where Yi is the actual yield and Ŷi is the predicted yield.

Fertilizer Prediction Module

The fertilizer prediction system identifies nutrient deficiencies in soil. Deficiency calculations are performed as:
DN = Nideal − Ncurrent
DP = Pideal − Pcurrent
DK = Kideal − Kcurrent
Based on these deficiency values, the system recommends suitable fertilizers. The integrated framework provides crop recommendations, yield estimates, and fertilizer suggestions through a user-friendly interface, helping farmers make informed agricultural decisions.

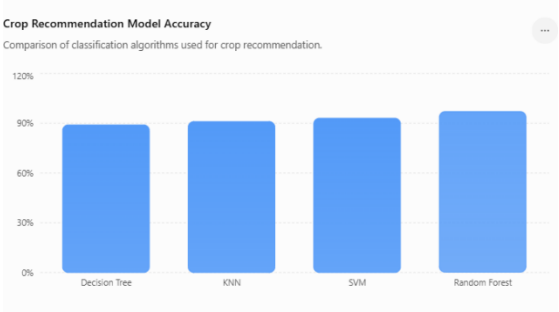
CONCLUSION

The Crop Recommendation, Yield Prediction, and Fertilizer Prediction system provides an intelligent solution for modern agriculture using machine learning techniques. The proposed framework integrates multiple agricultural decision-support functionalities into a unified platform capable of assisting farmers in selecting suitable crops, estimating expected production, and applying appropriate fertilizers.

The system utilizes soil nutrient values, environmental conditions, and historical agricultural data to generate accurate predictions. Crop recommendation helps farmers choose crops best suited to their field conditions. Yield prediction enables production estimation before harvesting, supporting better planning and resource allocation. Fertilizer prediction assists in identifying nutrient deficiencies and recommending suitable fertilizers for improved crop growth.

Machine learning algorithms such as Random Forest, Decision Tree, and Regression models demonstrate high prediction accuracy. Mathematical models help quantify relationships between environmental factors and agricultural productivity. The integration of these modules improves farming efficiency and reduces uncertainty in agricultural operations.

The proposed system contributes to sustainable agriculture by minimizing excessive fertilizer usage and promoting



optimal resource management. Farmers can make informed decisions based on scientific data rather than relying solely on traditional methods. This leads to increased crop productivity, improved profitability, and environmental sustainability.

Experimental evaluation indicates that machine learning-based agricultural decision systems can significantly enhance farming outcomes. Future enhancements may include IoT sensor integration, satellite imagery analysis, weather forecasting modules, and deep learning techniques for even more accurate predictions.

Overall, the Crop Recommendation, Yield Prediction, and Fertilizer Prediction framework serves as a powerful tool for precision agriculture and smart farming, enabling data-driven agricultural management and supporting global food security initiatives.

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