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Crop Recommendation Using Machine Learning Based on Soil, Weather, and Other Agronomic Factors

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Abstract: ***Agriculture remains a critical sector for food production and rural livelihood across the globe. However, climate change, unpredictable rainfall patterns, declining soil fertility, and improper crop selection often lead to reduced agricultural productivity. Traditionally, farmers rely on experience or local knowledge for crop selection, which may not always result in optimal yield. With the advent of Artificial Intelligence (AI) and Machine Learning (ML), there is a significant opportunity to revolutionize agriculture by providing intelligent crop recommendation systems. This research focuses on developing a machine learning-based crop recommendation model that utilizes key parameters such as soil nutrient composition (Nitrogen, Phosphorus, Potassium), temperature, humidity, pH level, and rainfall. Various supervised learning algorithms were employed, including Decision Trees, Random Forests, and Support Vector Machines, to predict the most suitable crop for a given set of environmental and soil conditions. The Random Forest algorithm emerged as the most accurate with an average prediction accuracy of over 96%.***

Keywords: Soil Features, Weather Features, Soil Health, Weather Features.

I. INTRODUCTION

Agriculture in many developing and underdeveloped countries is facing challenges such as low productivity, climate volatility, and limited access to modern technologies. A critical factor influencing productivity is the choice of crops grown in a specific location. Often, inappropriate crop selection, driven by tradition or poor information, leads to low yields and soil degradation. The need for a scientific, data-driven approach to guide farmers in crop selection has become increasingly urgent.

Machine Learning (ML), a subfield of Artificial Intelligence (AI), has shown promising applications in agricultural domains including disease detection, yield estimation, and soil analysis. One of the key applications of ML in agriculture is crop recommendation based on historical and real-time data. This paper explores the development and implementation of a ML model that analyzes soil and climatic data to recommend the most appropriate crops for cultivation in a given region. The research aims to build a system that reduces uncertainty, improves yield, and supports sustainable agriculture practices. Choosing the right crop to cultivate is a critical decision for farmers, impacting productivity, sustainability, and profitability. machine learning model that recommends crops suitable for specific soil and climatic conditions, aiming to support precision agriculture and informed farming practices

II. LITERATURE SURVEY

Numerous studies have demonstrated the utility of machine learning in agricultural decision- making. A survey of the existing literature reveals the following:

1) Patil and Kumar (2017) applied Decision Tree algorithms to classify suitable crops based on NPK values and rainfall. Their system achieved moderate accuracy but lacked environmental inputs like temperature and humidity.

2) Singh et al. (2019) implemented a Random Forest model on soil and weather data, improving prediction accuracy for rice, maize, and wheat. Their model emphasized the importance of combining environmental and soil data for better recommendations.

3) Sharma et al. (2020) explored hybrid models incorporating SVM and KNN algorithms to build dynamic crop recommendation systems. Their research highlighted the challenge of overfitting and the need for balanced datasets.

4) Jha et al. (2021) introduced a deep learning-based model using satellite imagery and weather forecasting data, proposing a futuristic approach, though requiring substantial computational resources.

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5) Kaggle (2023) provides a benchmark dataset widely used in agricultural ML applications, offering a standardized base for crop recommendation research.

Although promising, many of these studies either rely on limited parameters or do not translate well into real-time applications accessible to local farmers. This research builds on these foundations and proposes a comprehensive and accessible model.

III. METHODOLOGY

The proposed crop recommendation model follows a structured pipeline from data collection to model evaluation:

A. *Data Collection*

The dataset consists of agricultural parameters sourced from:

1) Kaggle Crop Recommendation Dataset (2023)
2) Indian Meteorological Department (IMD) for climatic data
3) Soil Health Card Scheme for soil nutrient records

Key attributes:

- Soil Features: Nitrogen (N), Phosphorus (P), Potassium (K), pH value
- Weather Features: Temperature (°C), Humidity (%), Rainfall (mm)

B. *Data Preprocessing*

Preprocessing steps included:

1) Handling Missing Values: Replaced using mean/mode imputation
2) Normalization: Min-max scaling applied to all numerical features
3) Label Encoding: Categorical crop labels encoded for model training

C. *Model Selection*

Multiple supervised classification algorithms were tested:

1) Decision Tree Classifier: Simple but prone to overfitting
2) Support Vector Machine (SVM): Effective in high-dimensional spaces
3) Random Forest Classifier: Ensemble method with high accuracy and resistance to overfitting
4) K-Nearest Neighbors (KNN): Simple but computationally expensive on large datasets

D. *Model Training and Validation*

1) Train-Test Split: 80% training, 20% testing
2) Evaluation Metrics: Accuracy, Precision, Recall, F1-Score
3) Cross-Validation: 10-fold cross- validation to avoid overfitting

E. *Performance Results*

Algorithm	Accuracy (%)	Precision	Recall	F1 Score
Decision Tree	90.2	0.89	0.90	0.89
SVM	92.7	0.91	0.92	0.91
KNN	91.0	0.90	0.90	0.89
Random Forest	96.4	0.96	0.96	0.96

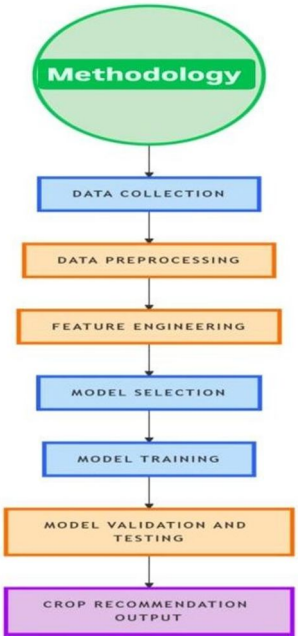
F. *System Deployment*

A web-based or mobile application interface was designed to:

1) Accept user input (soil and climate parameters)
2) Return a recommended crop
3) Provide additional advice on fertilizer and water needs

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Tools used for front-end: HTML, CSS, JavaScript
Back-end and model hosting: Python Flask / Django with scikit-learn Flow chart

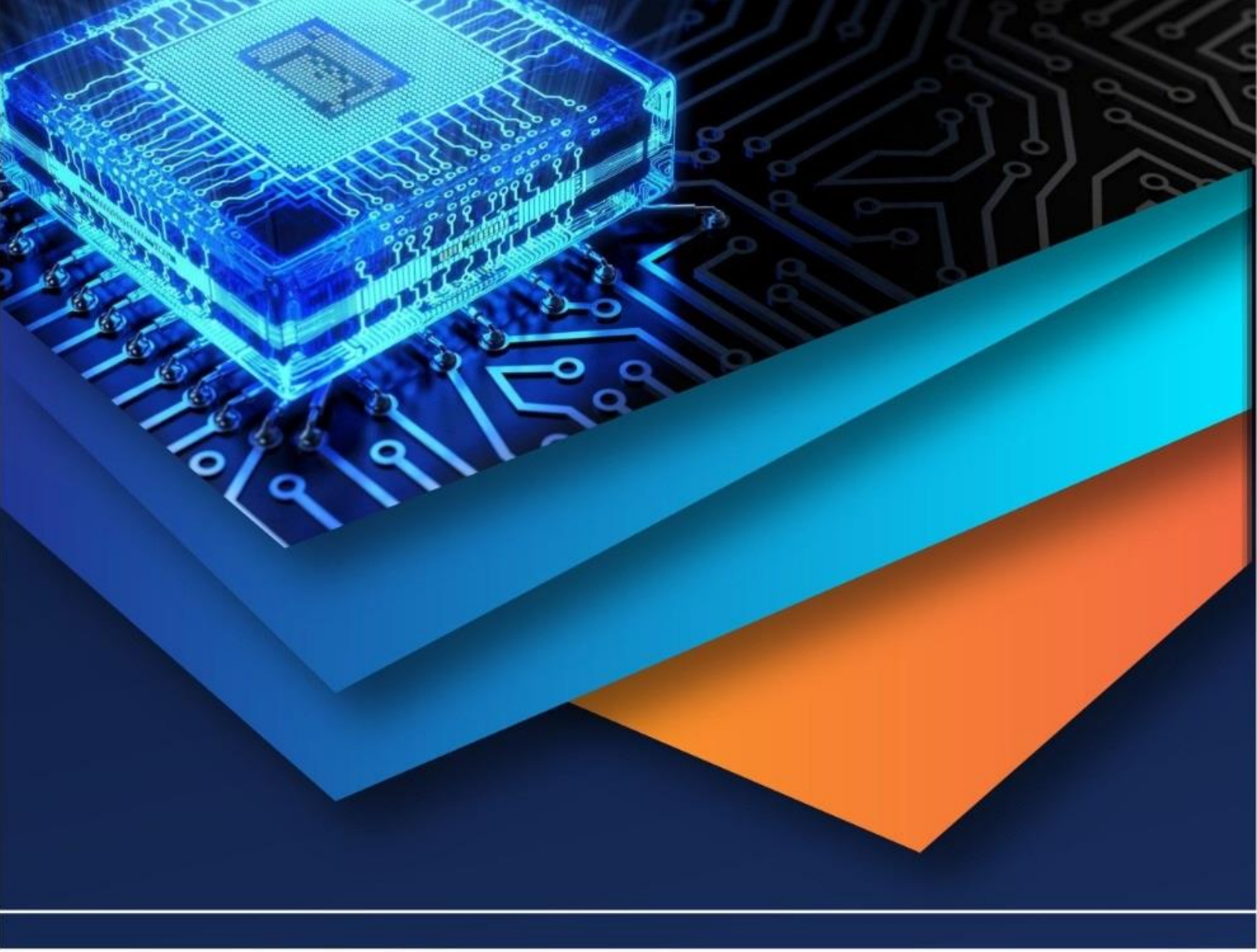


IV. CONCLUSION

The research successfully demonstrates the potential of machine learning in recommending optimal crops based on soil and weather parameters. The Random Forest model outperforms others in terms of accuracy, robustness, and generalization. By integrating this model into a user-friendly application, farmers can receive real-time, location-specific crop recommendations. Such tools have the potential to improve agricultural productivity, reduce input waste, and promote sustainable farming. Future enhancements include real- time weather integration, region- specific tuning, multi-language support, and integration with market demand data to optimize profitability. This research demonstrates the potential of machine learning in transforming traditional agriculture through intelligent crop recommendations. By analyzing a combination of soil properties, weather data, and agronomic features, the system provides farmers with scientifically backed suggestions that can enhance yield and sustainability. Future work will involve real- time data integration, localization of recommendations based on region, and multi- language interfaces for broader accessibility.

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