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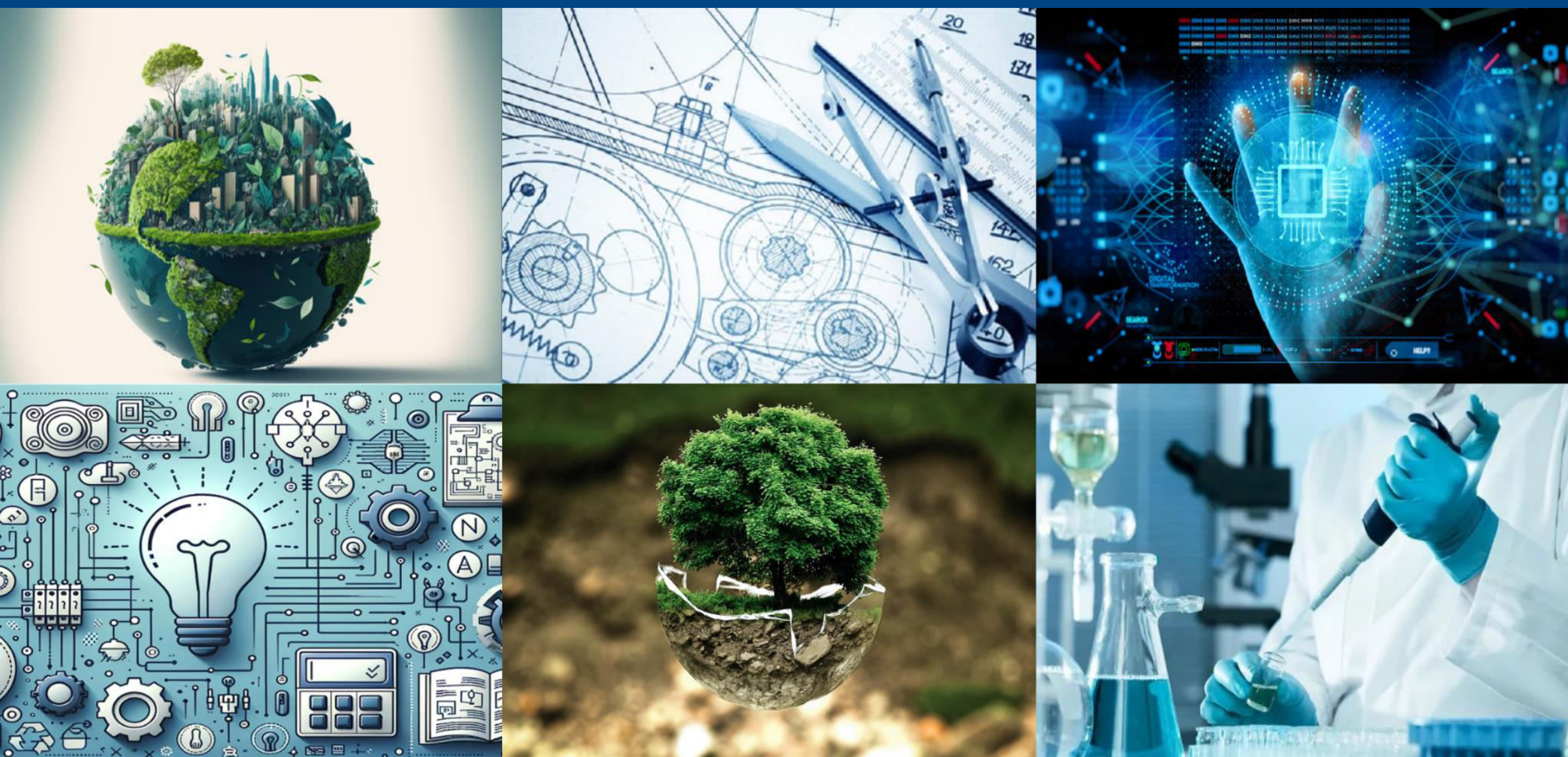

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Precision Agriculture using Machine Learning

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ABSTRACT: Agriculture is a major source of income and employment in India. The most prevalent problem faced by Indian farmers is that they do not select the appropriate crop for their land and do not use the appropriate fertilizer. They will experience a significant drop in production as a result of this. Precision agriculture has been used to solve the farmers' difficulty. Precision agriculture is a modern farming strategy that employs research data on soil properties, soil types, and crop yield statistics to recommend the best crop to farmers as well as fertilizer recommendations based on site-specific features. This decreases the number of times a crop is chosen incorrectly and increases productivity.

In this paper, this problem is solved by proposing a recommendation system through ML models with majority voting technique using Random Forest, Naive Bayes, Support Vector Machine (SVM), Logistic Regression and Random Forest, as learners to recommend a crop for the site specific parameters with high accuracy and efficiency. The fertilizer recommendation system is purely python logic based. In this we compare the data (optimum nutrients for growing the crop) with the user's entered data. Then nutrient having maximum difference is made as HIGH or LOW and according to that suggestions will be fetched.

KEYWORDS: Precision agriculture, Recommendation system, Random Forest, Support Vector Machine (SVM), Logistic Regression.

I. INTRODUCTION

In most cases, a farmer's decision on which crop to cultivate is influenced by his intuition as well as other irrelevant factors such as generating quick money, being unaware of market demand, overestimating a soil's ability to support a specific crop, and so on. The farmer's financial situation could be severely strained if he makes a poor judgement. Perhaps this is one of the numerous factors contributing to the innumerable farmer suicide cases that we hear about in the news on a daily basis. Such an incorrect judgement would have bad consequences not only for the farmer's family, but for the entire economy of a region in a country like India, where agriculture and allied sectors account for around 20.4 percent of the country's Gross Value Added (GVA).

As a result, we consider a farmer's decision on which crop to plant during a given season to be quite serious. The need of the hour is to create a system that can provide Indian farmers with predictive insights, allowing them to make better decisions about which crops to produce. With this in mind, we propose a system, an intelligent system that would consider environmental parameters (temperature, rainfall, geographical location in terms of state) and soil characteristics (N, P, K, pH value, soil type and nutrients concentration) before recommending the most suitable crop to the user. In addition to that a fertilizer suggestion is also made which is based on the optimum nutrients of the crops grown.

II. MOTIVATION

Agriculture is that the backbone for developing countries like India as quite 70% of population depends on agriculture. Agriculture in India plays a predominant role in economy and employment. The common problem existing among the Indian farmers are they don't choose the proper crop supported their soil requirements and also which fertilizer to be used for his or her crop. thanks to this they face a heavy setback in productivity. This problem of the farmers has been addressed through precision agriculture.

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III. EXISTING SYSTEM

Several researchers have addressed the challenges of Indian agriculture by developing models that utilize meteorological data and historical records. Some approaches use machine learning models such as Artificial Neural Networks, K-Nearest Neighbors, and Regularized Greedy Forest to predict crop yield. However, most existing systems focus only on single parameters, such as weather or soil, rather than integrating multiple crucial factors.

IV. PROBLEM DEFINITION

In India, agriculture is one of the most important professions. Many of the people do agriculture but are unable to determine which types of crops are more suitable to their soil. Means there are variety of crops which are only suitable for wet soil, some requires medium humidity in the soil to grow but this knowledge is less known to farmers as well as newbies who develop some interest in farming. As of now there are very less resources as well as software's which will help them to improve quality. Such type of software is Precision agriculture using machine learning.
Such type of software is Precision agriculture using machine learning.

V. OBJECTIVE OF THE PROJECT

[1] To build a robust model to provide correct and accurate prediction of crop sustainability in a given state for the particular soil type and climatic conditions.
[2] Provide recommendation of the most effective suitable crops within the area in order that the farmer doesn't incur any losses.
[3] Provide fertilizer suggestion for crops supported chemical features.

VI. LITERATURE SURVEY

In Reference Paper [1] presents a machine learning-based soil classification system employing KNN, Logistic Regression, and SVM algorithms to analyze soil characteristics and generate crop suitability recommendations for agricultural planning.

Reference Paper [2] introduces a computer vision approach utilizing convolutional neural networks for automated texture analysis and feature extraction to enable precise identification and classification of plant leaf diseases in precision agriculture systems. In Paper [3] describes an intelligent decision support system that integrates Random Forest and XGBoost machine learning classifiers to provide optimized fertilizer recommendations tailored to specific soil conditions and crop requirements.

Paper [4] develops an advanced ensemble learning framework that simultaneously addresses crop type classification and yield prediction tasks through sophisticated feature engineering and model integration techniques. In Reference Paper [5] proposes a comprehensive analytical framework combining principal component analysis with different algorithms to process multi-dimensional soil data and generate data-driven crop recommendations. Reference Paper [6] provides a methodological review and comparative analysis of machine learning techniques applied in precision agriculture.

Paper [7] designs an intelligent agricultural advisory platform incorporating multiple machine learning architectures to process diverse environmental parameters and generate contextual crop recommendations. In Reference Paper [8] develops an innovative plant recognition system that combines wavelet transform-based feature extraction with convolutional neural networks and principal component analysis for enhanced botanical identification.

Reference Paper [9] creates an automated plant disease detection system using Random Forest classification for early identification of pathological conditions in crops. In Paper [10] implements a comparative study of machine learning approaches for agricultural decision-making, evaluating KNN and Random Forest algorithms for crop recommendation tasks in varying environmental conditions.

In reference Paper [11] builds an smart agriculture platform that combines soil datasets with machine learning models to enable in precision agriculture. Reference Paper [12] constructs a multi-purpose agricultural monitoring system utilizing machine learning architecture models for comprehensive detection of weeds, diseases, and pests in crop fields.

VII. DRAWBACKS

One shortcoming that we identified in all these notable published works was that the author's of every paper focused on one parameter (either weather or soil) for predicting the suitability of crop growth. However, in our opinion, both these factors should be taken together into consideration concomitantly for the most effective and most accurate prediction. This is because, a specific soil type could also be it for supporting one variety of crop, but if the climatic conditions of the region don't seem to be suitable for that crop type, then the yield will suffer.

VIII. PROPOSED SYSTEM

To eliminate the aforementioned drawbacks, we propose an efficient Crop Recommendation system which takes into consideration all the appropriate parameters including temperature, rainfall, location and soil condition, to predict crop suitability. This system is fundamentally concerned with performing the primary function of Agro Consultant, which is providing crop recommendations to farmers. We also provide the fertilizers to be used for crops grown in different states which gives the user an easy and reliable insight to decide and plan the crops.

IX. PLAN OF IMPLEMENTATION

The steps involved in this system implementation are:

a) Acquisition of Training Dataset:

The accuracy of any machine learning algorithm depends on the amount of parameters and therefore correctness of the training dataset. For the system, we are using various datasets all downloaded from government website and Kaggle.

Datasets include: Yield dataset, Fertilizer dataset, Soil nutrient content dataset, Rainfall Temperature dataset.

b) Data Preprocessing:

This step includes replacing the null and 0 values for yield by -1 so that it does not effect the overall prediction. Further we had to encode the dataset so that it could be fed into the our ML models.

c) Training ML model:

After the preprocessing step we used the dataset to train different machine learning models like Random forest, Decision Tree, Support Vector Machine(SVM) and Logistic regression to attain accuracy as high as possible.

d) Model Evaluation and Saving Model:

All the ML models which are trained would be evaluated by comparing their performance (Evaluations Metrics) and Final efficient model is saved using pickle library.

e) Model Exportation and Integration with Web app:

The saved efficient ML model would be integrated with Flask Web Application which would further meant for prediction in user friendly web interface.

X. EXTERNAL INTERFACE REQUIRMENTS

User Interfaces:

- Front End Software: Flask Framework integrated with HTML, CSS, BOOTSTRAP
- Back End Software: Machine Learning (Python)

Hardware Interfaces:

- RAM - Minimum 512 MB.
- Processor - i3 or above and above with 2.5 GHz

Software Interfaces:

- OS: Ubuntu, Windows, Mac
- Tools: VScode or Python IDE and Jupyter Notebook.
- Programming Language: Python flask, HTML, CSS, BOOTSTRAP.
- Dataset: A Dataset which is openly available in kaggle.
- Libraries/Tools:

1. Pandas
2. Numpy
3. Matplotlib
4. Sickit-Learn

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XI. COMPARATIVE ANALYSIS

The underneath desk represents the analysis of 12 studies papers. The research papers had been taken in between year 2020 to 2025. Numerous algorithms and deep getting to know fashions and feature selection have been used. The highest accuracy of various research papers is listed under.

Table 1: Analysis chart based on prediction and accuracy

Ref. no.	Year	Paper name	Feature Selection	Highest Accuracy
1	2020	Classification of Soil and Crop Suggestion Using Machine Learning Techniques	KNN, Logistic Regression, Bagged Tree, SVM	91.09%
2	2021	Intelligent Crop Recommendation System using Machine Learning	Decision Tree, KNN, Logistic Regression, SVM, Naïve Bayes	93.00%
3	2021	Convolutional Neural Networks for Texture Feature Extraction: Applications to Leaf Disease Classification in Precision Agriculture	CNN, Texture Analysis	89.20%
Ref. no.	Year	Paper name	Feature Selection	Highest Accuracy
4	2023	Crop and Fertilizer Recommendation System Applying Machine Learning Classifiers	Random Forest	96.50%
5	2023	Crop Recommendation Based on Soil Properties: A Comprehensive Analysis	PCA, Random Forest	90.80%
6	2023	Plant Disease Identification and Detection Using Machine Learning Algorithms	HOG Features, Random Forest	95.00%
7	2023	Precision Agriculture - Machine Learning Based Approach	Random Forest,KNN	87.30%
8	2023	Recommendation of Crops and Fertilizer, Detection of Crop Weed, Pest and Diseases using Machine Learning	Detection Feature of Crop Weed, Pest	91%
9	2024	Crop Classification and Yield Prediction Using Robust Machine Learning Models for Agricultural Sustainability	Ensemble Learning, Time-Series Analysis	93.50%
10	2024	Evaluation of Machine Learning Approaches for Precision Farming in Smart Agriculture System: A Comprehensive Review	Meta-Analysis of 25+ ML Models	82.15%
11	2024	Precision Agriculture Revolution: Enhancing Crop Recommendations with Machine Learning Algorithms for Optimal Yield and Environmental Sustainability	Random Forest, KNN	94% (RF), 78% (KNN)
12	2025	Plant Leaf Identification Using Feature Fusion of Wavelet Scattering Network and CNN With PCA Classifier	CNN	91.20%

This study includes the survey on the research papers between the year 2020 to 2025.

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XII. SYSTEM ARCHITECTURE

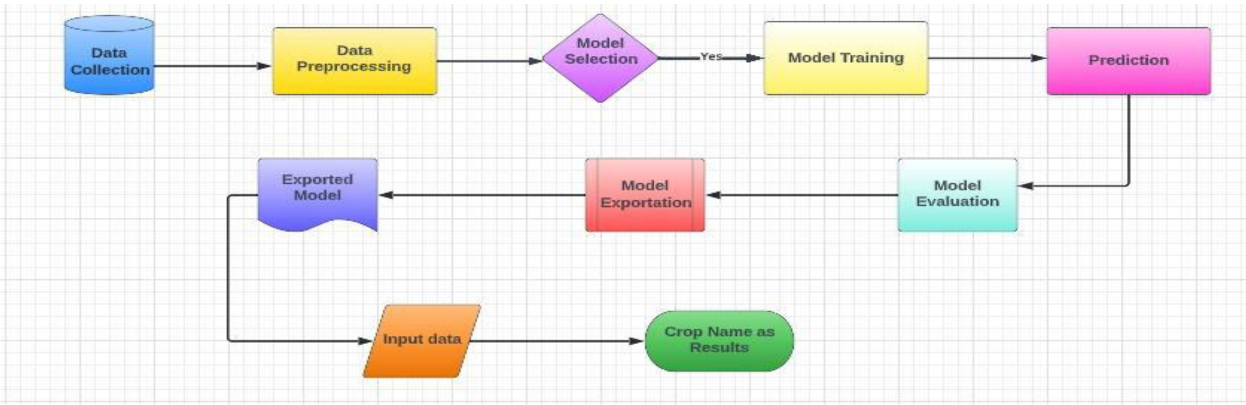

Fig.1 System architecture diagram.

The system architecture consists of the following components:

1. Data Collection: Gathering soil, weather, and crop data from reliable sources.
2. Data Preprocessing: Cleaning and preparing the data for ML models.
3. Model Training: Training multiple ML algorithms (Random Forest, SVM, etc.).
4. Recommendation System: Providing crop and fertilizer suggestions based on model predictions.
5. User Interface: Web application for farmers to input data and receive recommendations

A system architecture is a conceptual model using which we can define the structure and behavior of that system. It is a formal representation of a system. Depending on the context, system architecture can be used to refer to either a model to describe the system or a method used to build the system. Building a proper system architecture helps in analysis of the project, especially in the early stages. Figure 1 depicts the system architecture and is explained in the following section.

XIII. RESULTS & PERFORMANCE ANALYSIS

For the purposes of this project we have used four popular algorithms:
Decision Trees, Logistic regression, Support Vector Machine and Random Forest. All the algorithms are based on supervised learning. Our overall system is divided into two modules:

- Crop recommender
- Fertilizer Recommender/Suggestion

Accuracy Comparison of ML Models:

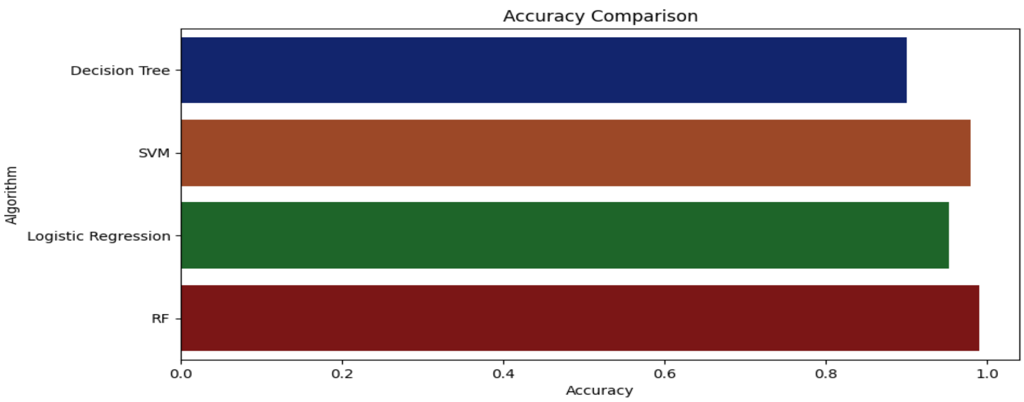

Fig.2 Accuracy comparison.

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Algorithm	Accuracy (%)
Decision Tree	90%
SVM	97%
Logistic Regression	95%
Random Forest	99%

Hence, Random Forest is our Final efficient model.

XIV. RESULTS

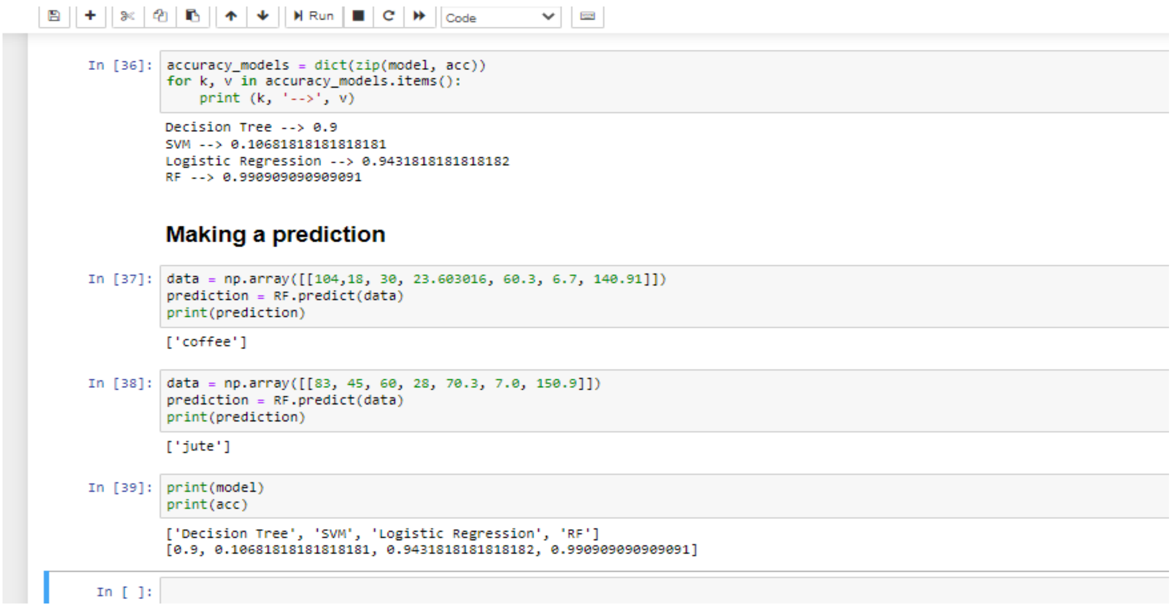

Fig.3 Making a prediction

XV. FERTILIZER RECOMMENDER/SUGGESTION

The fertilizer recommendation system is purely python logic based. In this we compare the data (optimum nutrients for growing the crop) with the user's entered data. Then nutrient having maximum difference is made as HIGH or LOW and according to that suggestions will be fetched.

XVI. ADVANTAGES

1. Improved farm management efficiency through data-driven recommendations.
2. Sustainable and environmentally friendly farming practices.
3. Reduced dependency on excessive chemical usage.
4. Optimized use of resources to enhance land productivity.

XVII. LIMITATIONS

1. Extremely demanding work particularly collecting and then analyzing the data.
2. Accuracy depends upon input dataset.
3. Most of the farmer not aware of such program like precision agriculture using machine learning farmer don't know the technology.
4. Complexity grows with data.

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XVIII. CONCLUSION

This system helps the farmer to choose the right crop by providing insights that ordinary farmers don't keep track of thereby decreasing the chances of crop failure and increasing productivity. It also prevents them from incurring losses. The system can be extended to the web and can be accessed by millions of farmers across the country. We could achieve an accuracy of 90 percent from the Decision Trees, an accuracy of 70.6 percent from the Support Vector Machine, an accuracy of 94.30 percent from the Logistic Regression and an accuracy of 99.09 percent from the Random Forest model. Further development is to integrate the crop recommendation system with another subsystem, yield predictor that would also provide the farmer an estimate of production if he plants the recommended crop.

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