

Machine Learning-Based Crop Recommendation System for Enhanced Yield Production

K. Shekhar^{1*}, Gugulothu Sravanthi², Porandla Sadhashiva², Hemanth Moutam², Boragala Divyasri²

¹Assistant Professor, ²UG Student, ^{1,2}Department of Computer Sciences and Engineering,

^{1,2}Vaagdevi College of Engineering (UGC - Autonomous), Bollikunta, Warangal, Telangana.

*Corresponding author: K. Shekhar (shekhar_k@vaagdevi.edu.in)

ABSTRACT

Agriculture plays a critical role in ensuring that there is enough food to feed our ever-growing global population. With the challenges posed by climate change and its uncertainties, it has become increasingly important to adopt sustainable practices in agriculture. One crucial aspect of this is optimizing how we use our land, water resources, and fertilizers while also increasing crop yields. Traditionally, farmers relied on their own experience, local knowledge, and trial-and-error methods to decide which crops to grow in their specific regions and soil types. Unfortunately, this subjective approach often led to uncertainties, reduced productivity, and economic losses. Inappropriate crop choices were also common, resulting in suboptimal yields and wasted resources. To address these issues, we are working on developing a Machine Learning-based Crop Recommendation System. This system holds immense promise in transforming agriculture by offering farmers data-driven insights to make informed decisions about their crop selection and management practices. The system uses a wealth of data, including historical crop performance, soil characteristics, and climate patterns, to empower farmers with intelligent recommendations. By analysing this vast array of information, the system guides farmers in making data-driven choices, reducing the risk of crop failure, and increasing profitability. Furthermore, it promotes the adoption of sustainable farming methods, thereby minimizing environmental impacts and preserving precious natural resources for future generations. Implementing this recommendation system can have far-reaching benefits. It can lead to economic advantages for farmers, ensuring food security, and encouraging the adoption of sustainable agricultural practices to protect our environment. By providing valuable insights, the system empowers farmers to make informed decisions that ultimately lead to improved crop yields, reduced resource wastage, and increased profitability. With the potential to revolutionize crop selection, this novel approach paves the way toward a more sustainable and food-secure future for all of us.

Keywords: Sustainable Practices, Agriculture, Crop Recommendation, Machine Learning.

1. INTRODUCTION

Agriculture is the cornerstone of global food security and sustenance, making it an industry of paramount importance. However, the efficiency and productivity of agricultural practices are often constrained by factors such as soil quality, climate conditions, and crop choice. In this context, the development of a "Machine Learning-Based Crop Recommendation System for Enhanced Yield Production" emerges as a pivotal endeavour that holds the potential to revolutionize the way crops are cultivated and harvested. At its core, this research aims to bridge the gap between traditional agricultural practices and cutting-edge technology [1]. It leverages the power of machine learning, a subset of artificial intelligence, to optimize crop selection decisions made by farmers. This innovation is of immense significance given the growing challenges faced by the agriculture sector, including the need to feed an expanding global population, mitigate climate change impacts, and reduce resource wastage. The primary motivation behind this research lies in addressing several pressing issues. Firstly, the unpredictable effects of climate change have significantly altered weather patterns and precipitation

levels, making it increasingly difficult for farmers to make informed crop choices based on historical data alone [2]. Additionally, soil quality can vary dramatically even within a single farm, necessitating a more nuanced approach to crop selection. Traditional methods, which often rely on anecdotal knowledge and experience, are no longer sufficient to ensure optimal yield and resource efficiency. Machine learning offers a novel and data-driven solution to this dilemma. By analyzing a myriad of factors, including historical weather data, soil composition, and past crop performance, machine learning algorithms can provide personalized and accurate crop recommendations. This not only optimizes yield but also promotes sustainable farming practices by reducing the unnecessary use of water, pesticides, and fertilizers [3].

Furthermore, the research recognizes the global imperative of sustainable agriculture. In a world grappling with issues of food security and environmental conservation, the ability to recommend crops that are not only high-yielding but also environmentally responsible is crucial. Machine learning models can factor in environmental impact considerations, helping farmers make choices that align with conservation and resource preservation goals [4].

In this introductory overview, we will delve into the key components and objectives of this research. Firstly, we will explore the challenges faced by farmers and the limitations of conventional crop selection methods. Next, we will introduce the concept of machine learning-based crop recommendation systems, highlighting their potential to revolutionize agriculture. We will also discuss the role of data sources, including historical data, satellite imagery, and soil assessments, in training these models. Additionally, ethical considerations, such as data privacy and equitable access to technology, will be addressed [5]. The research on a "Machine Learning-Based Crop Recommendation System for Enhanced Yield Production" seeks to empower farmers with data-driven decision-making tools that can optimize crop selection, enhance yield, and promote sustainable agricultural practices. By harnessing the capabilities of machine learning, this research endeavours to usher in a new era of precision agriculture that is not only more productive but also environmentally responsible and equitable [6]. The research motivation for a "Machine Learning-Based Crop Recommendation System for Enhanced Yield Production" is deeply rooted in the critical challenges facing agriculture today. As the global population continues to grow, the pressure on the agricultural sector to produce more food intensifies. This demand necessitates not only increased agricultural productivity but also a more efficient approach to crop selection [7]. Traditional farming methods often rely on historical practices and lack the adaptability required to optimize crop choices in the face of evolving climate conditions and soil quality. This research is motivated by the urgent need to bridge this gap between traditional farming practices and cutting-edge technology, as it holds the potential to significantly enhance global food security. Climate change further compounds the challenges in agriculture, introducing unpredictability into weather patterns and exacerbating the uncertainty surrounding crop selection. Farmers require adaptive strategies to cope with these changing conditions, and machine learning-based crop recommendation systems provide a promising solution by analyzing historical weather data and climate projections to offer data-driven guidance. Additionally, resource inefficiency in agriculture, including the excessive use of water, fertilizers, and pesticides, poses significant environmental and economic concerns [8]. By recommending crops that align with local conditions and resource availability, this research aims to optimize resource utilization, reduce waste, and promote sustainable farming practices, thereby mitigating environmental degradation [9]. Sustainability is a global imperative, and agriculture plays a pivotal role in this pursuit. The research is motivated by the goal of fostering sustainable farming practices that address environmental impact issues such as soil erosion, water pollution, and habitat destruction. Machine learning-based recommendations not only prioritize high-yield crops but also consider their environmental footprint, contributing to responsible land management and conservation efforts. Moreover, this research is driven by the desire to empower

smallholder farmers, who often lack access to advanced agricultural technology and expertise. By providing accessible and user-friendly crop recommendation systems, it seeks to empower these farmers, improve their livelihoods, and reduce poverty [10].

In an era of big data, agriculture stands to benefit significantly from data-driven decision-making. The research motivation lies in harnessing vast datasets, including historical agricultural data, satellite imagery, and soil information, to enhance crop recommendations. This approach promises to usher in a more efficient and informed era of precision agriculture, where every decision is underpinned by comprehensive data analysis. Finally, ethical considerations underpin the research, as ensuring that machine learning-based crop recommendations are developed and deployed ethically is paramount. This involves addressing issues related to data privacy, fairness, and ensuring equitable access to technology to ensure that the benefits of these systems are accessible to all, irrespective of their resources or geographical location.

2. LITERATURE SURVEY

Prakash, et al. [11] proposed a Machine learning-based crop suggestion system. an intelligent model in crop suggestion predicts the right kind of crop that suits the soil and other environmental factors by using a machine learning algorithm. Temperature, wetness of the soil, environment dampness and pH are the essential information for crop suggestion in the agriculture field. Many existing works of IoT in the field of agriculture are related to yield prediction and few related to crop suggestion use fewer parameters and learning algorithms. Indira, et al. [12] proposed A Machine Learning based New Recommendation System to the Farmer. An algorithm called MobileNet uses an image of a leaf to identify the disease present in a plant. The XGBoost model predicts a suitable crop based on the local soil nutrients and rainfall. Random Forest [RF] model was used to propose fertilizer and develop ideas for improving soil fertility depending on nutrients present in the soil. When compared to other approaches, the proposed model delivers a high level of accuracy. Jeevaganesh, et al. [13] proposed a machine learning algorithm: AdaBoost to predict the yield of crops based on the parameters like state, district, area, seasons, rainfall, temperature, and area. To enhance the yield, this research study also suggests a fertilizer based on soil conditions like NPK values, soil type, soil PH, humidity, and moisture. Fertilizer recommendation is primarily done by using the Random Forest [RF] algorithm.

Wen, et al. [14] proposed Optimizing machine learning-based site-specific nitrogen application recommendations for canola production. This work employed four machine learning models, namely, support vector machine (SVM), gradient boosting (GB), random forest (RF), and ridge regression (RR) to predict the site-specific EONR values of canola crops, based on a 22-site-year field study across eastern Canada. SSL, et al. [15] proposed An Intelligent Crop Recommendation System using Deep Learning. The purpose of this work is to examine the approaches employed in extracting the water bodies utilizing the mode of satellite remote sensing. The goal of the proposed work is to collect the data of temperature and humidity and utilize the algorithm of clustering with the method of k-Nearest Neighbor to find out the patterns which are all hidden in them with a help of huge amount of dataset.

Chowdhary, et al. [16] proposed An Ensemble Model to Predict Crops using Machine Learning Algorithms. The authors tried to form an ensemble model using various machine-learning algorithms for better rice production. Crop production prediction utilizing AI Strategies aims to deliver improved outcomes, but the ensemble model provides better predictive results compared to the individual algorithm. we tried to use a combination of symmetric machine-learning algorithms to form an ensemble model for better prediction. Suresh, et al. [17] proposed a solution based on IoT and deep learning for improving paddy output. The system collects data through sensors and transfers it to the cloud in order to diagnose plant stress caused by soil fertility, environmental imbalance, and crop diseases (AWS EC2 Server). The proposed system is implemented in three stages. The stages of

production are divided into three categories: the start stage (planting to panicle initiation), the middle stage (panicle initiation to flowering), and the end stage (flowering to maturity).

Raviraja, et al. [18] proposed machine learning-based mobile applications for autonomous fertilizer suggestion. In this work, the smartphone app will be used to construct an autonomous fertilizer suggestion system for farmers. The dataset was gathered from the website Kaggle. The encoding technique is used to make the data entries numeric. Three Machine Learning (ML) models K-Nearest Neighbour (KNN), Random Forest (RF), and Decision Tree (DT) are employed to predict fertilizer based on environmental and soil characteristics. Mamatha, et al. [19] proposed Machine learning-based crop growth management in a greenhouse environment using hydroponics farming techniques. In this proposed system, in hydroponics for germination organic coconut coir medium is used rather than rock wool, because rock wool is not bio-degradable and is composed of volcanic materials. In the proposed research of hydroponics, the system is automated on a wide scale covering the entire green house with different crops produced in different climatic conditions. Oikonomidis, et al. [20] proposed Hybrid deep learning-based models for crop yield prediction. The authors had developed deep learning-based models to evaluate how the underlying algorithms perform with respect to different performance criteria. The algorithms evaluated in our study are the XGBoost machine learning (ML) algorithm, Convolutional Neural Networks (CNN)-Deep Neural Networks (DNN), CNN-XGBoost, CNN-Recurrent Neural Networks (RNN), and CNN-Long Short-Term Memory (LSTM).

Apat, et al. [21] proposed an IoT-HELE-based smart farming prediction and intelligent agriculture analytics model and a decision support system that effectively predicts crop production by utilizing cutting-edge machine learning and deep learning techniques. In this model, ensemble voting results in a more efficient, sustainable, and profitable agriculture enterprise. The multi-source dataset from the National Research Council (CNR), an ISTAT, and an IoT sensor will be analyzed. Kumar, et al. [22] proposed Crop recommendations using machine learning algorithms. The proposed system in which ML is used for crop recommendation is based on previously recorded measurements of soil parameters. This technique lessens the possibility of soil degradation and aids in crop health maintenance. Temperature, pH, and N, P, K, humidity are analyzed using machine learning algorithms such as random forest, Naive Bayes, KNN, decision tree, Logistic regression on which suggestions are made for growing a suitable crop.

Sandhya, et al. [23] proposed Crop Recommendation System Using Ensembling Technique. This work focuses on figuring out the best crop to cultivate in order to get optimum yield based on the site-specific parameters. Our proposed model takes the data of soil characteristics, environmental characteristics of a farm and the appropriate crop recommendations are given to the farmer based on the parameter values. Crop Recommendation is done through an Ensemble model using KNN, Random Forest, Gaussian Naïve Bayes, Logistic regression, SVM as base learners. Muhammed, et al. [24] proposed a user-friendly crop recommendation system called UACR. The users only need to insert their farm location and the system can automatically obtain other necessary information (e.g., rain level, soil type) based on the requested location and recommends the best crop(s) for growing in the location. To support and implement the proposed system, an architecture based on Artificial Intelligence of Things (AIoT) technology, as one of the main enablers for smart agriculture, is also proposed.

Venkatesan, et al. [25] proposed a machine learning-based prediction model for peak energy use by analyzing energy-related data collected from various environmental and growth devices in a smart paprika farm of the Jeonnam Agricultural Research and Extension Service in South Korea between 2019 and 2021. The proposed model may contribute to the development of various applications for environmental energy usage in a smart farm, such as a notification service for energy usage peak time or an energy usage control for each device.

3. PROPOSED METHODOLOGY

The system leverages data analysis, visualization, machine learning models, and evaluation techniques to provide farmers with informed crop recommendations. It ensures that data is appropriately prepared and understood, models are trained and evaluated, and predictions are made using the learned patterns from historical data. The goal is to optimize crop yield based on environmental conditions and nutrient levels. Figure 4.1 shows the proposed system model. The detailed operation illustrated as follows:

step 1: Data Import and Preparation:

- Data is a critical component in machine learning-based systems. In this context, data includes information about different crops, such as their nutrient requirements (N, P, K), temperature preferences, humidity tolerance, pH levels, and rainfall needs.
- Data is typically stored in structured formats like CSV files. The system uses libraries like Pandas and NumPy for data manipulation. Pandas allows for efficient data storage, retrieval, and manipulation, while NumPy provides numerical operations for data analysis.

step 2: Exploratory Data Analysis (EDA):

- EDA is the process of summarizing and visualizing key characteristics of a dataset. It helps understand the data's distribution, potential outliers, and relationships among variables.
- The `df.tail()` function displays the last few rows of the dataset, providing a glimpse of the data.
- `df.size` and `df.shape` reveal the overall size and dimensions of the dataset, respectively.
- `df.columns` lists the column names, which are essential for identifying features and the target variable.

step 3: Data Visualization:

- Data visualization techniques, like count plots and heatmaps, are employed to gain insights from data.
- Count plots help visualize the distribution of different crops in the dataset, which is vital for understanding class imbalances and model biases.
- A heatmap is used to visualize the correlation between features. High positive or negative correlations between features can impact the model's performance. For instance, if temperature and humidity are highly correlated, the model may struggle to distinguish their individual effects on crop growth.

step 4: Feature Selection and Target:

- Features are the variables used as input to the machine learning model. In this case, features include factors like nutrient levels (N, P, K), environmental conditions (temperature, humidity, pH), and rainfall.
- The target variable ('label') represents the outcome or prediction the model is designed to make, which is the type of crop to recommend.

step 5: Model Training and Evaluation:

- Model training involves using historical data (features) and their corresponding outcomes (target) to teach the machine learning model how to make predictions.
- Two models are used here: Logistic Regression and Random Forest.
- Evaluation metrics like accuracy scores, precision, recall, F1-score, and classification reports are used to assess model performance. Accuracy measures how often the model makes correct predictions, while precision and recall provide insights into the model's ability to avoid false positives and negatives.

step 6: Confusion Matrix:

- A confusion matrix is a table used to describe the performance of a classification model. It shows the number of true positives, true negatives, false positives, and false negatives.
- True positives are instances where the model correctly predicts a positive class, while true negatives are instances where the model correctly predicts a negative class. False positives and false negatives represent prediction errors.

step 7: Accuracy Comparison Plot:

- The bar plot comparing the accuracies of different models helps users understand which model is more effective in making crop recommendations. Accuracy is a widely used metric for comparing models, but it may not tell the whole story, especially if class imbalances exist.

step 8: Making Predictions:

- Once the model is trained and evaluated, it can be used to make predictions for new, unseen data points. Users can input environmental conditions, and the model will predict the most suitable crop based on the patterns it learned during training.

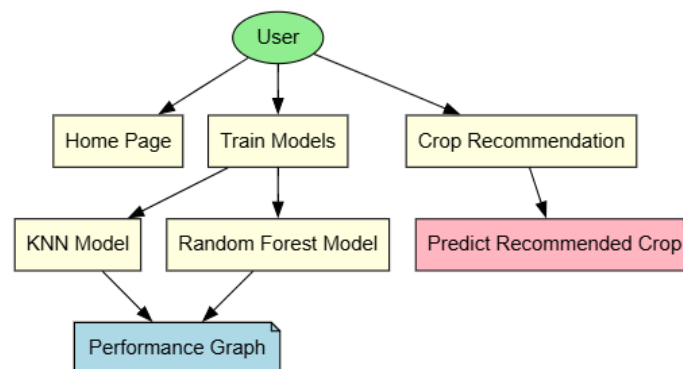


Figure 1. Proposed system model.

3.1 PROPOSED ALGORITHM

Random Forest is a popular machine learning algorithm that belongs to the supervised learning technique. It can be used for both Classification and Regression problems in ML. It is based on the concept of ensemble learning, which is a process of combining multiple classifiers to solve a complex problem and to improve the performance of the model. As the name suggests, "Random Forest is a classifier that contains a number of decision trees on various subsets of the given dataset and takes the average to improve the predictive accuracy of that dataset." Instead of relying on one decision tree, the random forest takes the prediction from each tree and based on the majority votes of predictions, and it predicts the final output. The greater number of trees in the forest leads to higher accuracy and prevents the problem of overfitting.

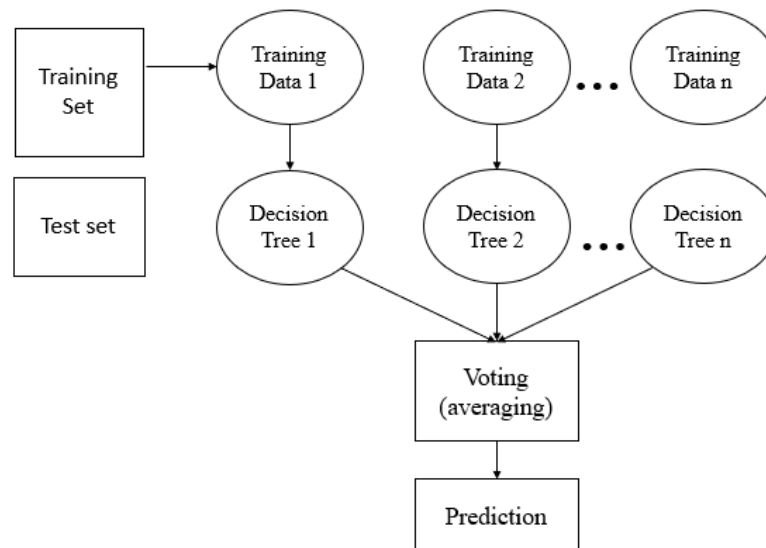


Fig. 2: Random Forest algorithm.

Algorithm:

Step 1: In Random Forest n number of random records are taken from the data set having k number of records.

Step 2: Individual decision trees are constructed for each sample.

Step 3: Each decision tree will generate an output.

Step 4: Final output is considered based on Majority Voting or Averaging for Classification and regression respectively.

Important Features of Random Forest

- **Diversity**- Not all attributes/variables/features are considered while making an individual tree, each tree is different.
- **Immune to the curse of dimensionality**- Since each tree does not consider all the features, the feature space is reduced.
- **Parallelization**-Each tree is created independently out of different data and attributes. This means that we can make full use of the CPU to build random forests.
- **Train-Test split**- In a random forest we don't have to segregate the data for train and test as there will always be 30% of the data which is not seen by the decision tree.
- **Stability**- Stability arises because the result is based on majority voting/ averaging.

Assumptions for Random Forest

Since the random forest combines multiple trees to predict the class of the dataset, it is possible that some decision trees may predict the correct output, while others may not. But together, all the trees predict the correct output. Therefore, below are two assumptions for a better Random Forest classifier:

- There should be some actual values in the feature variable of the dataset so that the classifier can predict accurate results rather than a guessed result.
- The predictions from each tree must have very low correlations.

Below are some points that explain why we should use the Random Forest algorithm

- It takes less training time as compared to other algorithms.
- It predicts output with high accuracy, even for the large dataset it runs efficiently.
- It can also maintain accuracy when a large proportion of data is missing.

4. RESULTS AND DISCUSSION

The dataset contains agricultural-related information with various features related to the cultivation of different crops. Here are columns in the dataset:

- N: This column appears to represent the nitrogen content in the soil, which is an essential nutrient for plant growth.
- P: This column likely represents the phosphorus content in the soil, another crucial nutrient for plant development.
- K: This column could represent the potassium content in the soil, which is important for various plant processes.
- Temperature: This column represents the temperature of the environment in which the crops are grown. Temperature significantly affects plant growth and development.
- Humidity: This column likely represents the humidity level of the environment. Humidity can influence plant transpiration and overall moisture conditions.
- pH: This column represents the pH level of the soil. Soil pH affects nutrient availability to plants.
- Rainfall: This column could represent the amount of rainfall in the region where the crops are cultivated. Rainfall is a critical factor in determining irrigation needs and water availability.
- Label: This column appears to be the target variable or the label that indicates the type of crop being grown. It seems to be a categorical variable representing different types of crops, such as "rice" and "coffee."

The dataset is organized with rows corresponding to different instances or observations, each with values for the different features (N, P, K, Temperature, Humidity, pH, Rainfall) and a label indicating the type of crop. This kind of dataset is used for various machine learning tasks, such as classification (predicting the crop type) or regression (predicting some numerical outcome based on the features). Figure 3 demonstrates the home page of proposed crop recommendation system, where it contains the tasks like model training, and crop recommendation. Figure 4 shows the performance evaluation of ML models such as KNN, and RFC with accuracy, precision, recall, f-score. In Fig. 5, its showing the sample entry of test data for predicting the crop using the best ML model. Finally, Fig. 6 demonstrate the outcome of recommendation by the ML model based on given test attributes.



Fig 3: Home Page

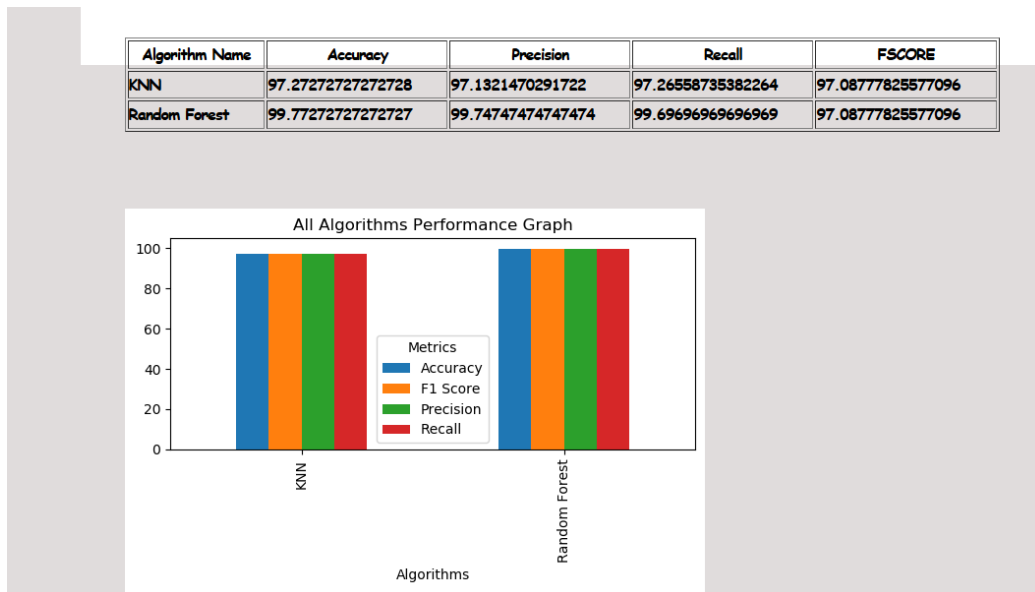


Fig. 4: Performance of Algorithms

Browser address: http://127.0.0.1:5000/crop-recommend

Nitrogen

Phosphorous

Pottasium

ph level

Rainfall (in mm)

Temperature (in Celsius)

Humidity (in %)

Predict

Fig. 5: Input Data for Prediction



Figure 6: Prediction results for Random Forest classifiers

5. CONCLUSION

This research represents a comprehensive approach to empower farmers with data-driven insights for making informed decisions about crop selection. This system operates on fundamental principles of data science and machine learning. Beginning with data import and preparation, the system recognizes the critical role of data in its operations. It leverages libraries like Pandas and NumPy for efficient data handling, ensuring that historical information about various crops' growth requirements is readily accessible. Exploratory Data Analysis (EDA) forms the foundation for understanding the dataset's characteristics. By utilizing functions like `df.tail()`, `df.size`, and `df.shape`, it gains insights into the data's structure and size. Furthermore, examining the dataset's columns with `df.columns` sets the stage for feature selection and target variable identification. Data visualization techniques, including count plots and heatmaps, enable a visual understanding of crop distribution and feature correlations. These visuals provide invaluable context, aiding in better-informed decisions during subsequent stages of model development. Feature selection involves extracting relevant factors such as nutrient levels (N, P, K), environmental conditions (temperature, humidity, pH), and rainfall. These features become the basis for training machine learning models, and the target variable ('label') defines the model's prediction goal. The training and evaluation of models, specifically Logistic Regression and Random Forest, embody the heart of this system. Model performance is rigorously assessed using metrics like accuracy, precision, recall, and F1-score. These evaluations ensure that the models can make accurate crop recommendations. A critical aspect is the confusion matrix, which provides a detailed breakdown of prediction results, highlighting true positives, true negatives, false positives, and false negatives. This aids in understanding model strengths and weaknesses. The system also facilitates model selection by comparing accuracies through a bar plot, enabling users to identify the most suitable model for their specific needs. Finally, the ability to make predictions for new data points based on environmental conditions allows farmers to apply the system's insights directly to their farming practices, potentially leading to optimized crop yield production.

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