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Crop Recommendation System

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ABSTRACT:

This project presents an integrated Crop Recommendation System (CRS) employing machine learning to enhance precision agriculture. The system incorporates four key features: Crop Prediction, Fertilizer Recommendation, Agriculture Policy Scheme Integration, and Weather Forecasting. Leveraging historical data, climate patterns, and soil characteristics, the CRS predicts optimal crops for a region, facilitates personalized fertilizer prescriptions, aligns recommendations with government policies, and integrates real-time weather data. This holistic approach aims to empower farmers with informed decision-making tools, fostering sustainable and economically viable farming practices in the face of dynamic environmental and policy conditions. Proposed integrated Crop Recommendation System harnesses machine learning to provide farmers with precise, data-driven insights, optimizing crop selection, resource utilization, and policy compliance for sustainable and resilient agriculture.

[Keywords- Crop Recommendation, Machine Learning, Precision Agriculture, Crop Prediction, Fertilizer Recommendation, Agriculture Policy Integration, Weather Forecasting, Sustainable Farming]

INTRODUCTION:

In modern agriculture, maximizing crop yield and quality necessitates a holistic understanding of various cultivation factors. This paper presents a pioneering Crop Recommendation System (CRS) empowered by machine learning, aiming to redefine farming methodologies. By amalgamating soil parameter analysis, personalized fertilizer recommendations, precise weather forecasting, and insightful agricultural scheme suggestions, the CRS empowers farmers with data-driven insights for informed decision-making. Central to the CRS is its meticulous soil analysis, tailoring crop recommendations to specific soil conditions. Additionally, the system provides dynamic fertilizer prescriptions based on crop growth, ensuring efficient resource utilization and promoting healthier crops. Real-time weather forecasting enhances precision by predicting climate patterns crucial for crop management.

Furthermore, the CRS integrates with agricultural schemes, aiding farmers in accessing relevant subsidies or grants. By generating comprehensive reports encompassing soil analysis, crop recommendations, weather forecasts, and agricultural schemes, the CRS facilitates informed decision-making and fosters sustainable farming practices. This system epitomizes the synergy between advanced technology and agricultural innovation, empowering farmers for optimized crop production, resource efficiency, and economic sustainability. Ease of Use

METHEDOLOGY :

The Crop Recommendation System is designed with a structured architecture that integrates diverse datasets encompassing historical crop yields, soil characteristics (N, P, K levels, pH), and environmental variables such as rainfall, temperature, and humidity. Following data preprocessing, these datasets are utilized by machine learning algorithms to predict optimal crops based on specific agricultural conditions. To assess the efficacy of different machine learning algorithms in this system, several models were evaluated:

- **Decision Tree**: The Decision Tree model achieved an accuracy rate of 90% in predicting crop recommendations based on the provided dataset. This model's performance highlights its ability to effectively interpret the given agricultural data, identifying patterns and making decisions that lead to accurate crop recommendations. The Decision Tree's structure allows it to handle categorical variables and interactively split the data based on the most significant features, which is critical in understanding the complex relationships within agricultural datasets.
- **Naive Bayes**: The Naive Bayes model demonstrated the highest accuracy among all the evaluated models, achieving an impressive accuracy rate of 99.09%. This high performance underscores the model's strength in classifying optimal crop choices by leveraging the probabilistic relationships between features. Despite its simplicity and the assumption of feature independence, Naive Bayes has proven to be highly effective in this application, making it a reliable tool for making accurate crop recommendations based on the given dataset.
- **Support Vector Machine (SVM)**: The Support Vector Machine (SVM) model attained an accuracy rate of 97.95%, showcasing its powerful capability to classify crops accurately based on the input variables. SVM's use of hyperplanes to separate different classes within the data contributes to its effectiveness in dealing with complex and high-dimensional datasets. This model's performance illustrates its potential to provide precise crop recommendations, ensuring that the most suitable crops are suggested based on the detailed input data provided by users.

- **Logistic Regression**: The Logistic Regression model showed an accuracy rate of 95.23%, providing reliable predictions for crop recommendations. This model is known for its ability to handle binary classification problems and its interpretability, making it a useful tool for understanding the influence of various input features on crop selection. The model's solid performance indicates that it can effectively contribute to accurate and dependable crop recommendations, aiding farmers in making informed decisions.
- **Random Forest**: The Random Forest model equaled the performance of the Naive Bayes model, achieving a remarkable accuracy rate of 99.09%. This result highlights the model's robustness in handling complex datasets and diverse agricultural scenarios. Random Forest's ensemble approach, which combines multiple decision trees to improve accuracy and prevent overfitting, makes it particularly well-suited for the intricacies of agricultural data. Its ability to manage a variety of input variables and capture the nuances within the data ensures highly accurate crop recommendations, supporting optimal farming practices.

```
Decision Tree --> 0.9
Naive Bayes --> 0.990909090909091
SVM --> 0.9795454545454545
Logistic Regression --> 0.9522727272727273
RF --> 0.990909090909091
```

Fig. 1 -Algorithm with accuracy

SELECTION OF ALGORITHM :

Among the evaluated algorithms, Random Forest was selected for deployment in the Crop Recommendation System due to its exceptional performance metrics, particularly its accuracy and robustness. The Random Forest algorithm excels in handling complex datasets by constructing multiple decision trees during training and then aggregating their predictions through a voting mechanism. This ensemble learning approach not only enhances predictive accuracy but also mitigates the risk of overfitting, making it particularly well-suited for practical applications in the agricultural sector.

- **Accuracy**: Accuracy measures the proportion of correctly predicted crop recommendations out of all predictions made by the model. It is a key metric in assessing the overall performance and reliability of the recommendation system, ensuring that the majority of the recommendations provided to the users are correct.
- **Precision**: Precision indicates the accuracy of positive crop predictions. It is calculated as the ratio of correctly predicted positive instances (true positives) to the total predicted positive instances (true positives plus false positives). High precision means that when the model predicts a crop, it is likely to be the correct recommendation.
- **Recall**: Recall represents the ability of the classifier to correctly identify positive crop recommendations. It measures the ratio of correctly predicted positive instances (true positives) to all actual positive instances in the dataset (true positives plus false negatives). High recall ensures that most of the actual positive cases are captured by the model
- **Support**: Support indicates the number of occurrences of each crop recommendation in the test dataset. It provides insight into the distribution of the dataset and ensures that the model has been evaluated on a sufficient number of instances for each crop type.
- **F1 Score**: The F1 Score is the harmonic mean of precision and recall. It provides a single metric that balances both precision and recall, offering a comprehensive evaluation of the model's performance. By considering both false positives and false negatives, the F1 Score ensures a balanced assessment, making it a crucial metric for understanding the effectiveness of the crop recommendation system.

By leveraging these performance metrics, the Random Forest model ensures that the crop recommendation system delivers accurate, reliable, and practical suggestions to farmers, thereby enhancing agricultural productivity and decision-making.

Random Forest's Accuracy is: 0.990909090909091

	precision	recall	f1-score	support
apple	1.00	1.00	1.00	13
banana	1.00	1.00	1.00	17
blackgram	0.94	1.00	0.97	16
chickpea	1.00	1.00	1.00	21
coconut	1.00	1.00	1.00	21
coffee	1.00	1.00	1.00	22
cotton	1.00	1.00	1.00	20
grapes	1.00	1.00	1.00	18
jute	0.90	1.00	0.95	28
kidneybeans	1.00	1.00	1.00	14
lentil	1.00	1.00	1.00	23
maize	1.00	1.00	1.00	21
mango	1.00	1.00	1.00	26
mothbeans	1.00	0.95	0.97	19
mungbean	1.00	1.00	1.00	24
muskmelon	1.00	1.00	1.00	23
orange	1.00	1.00	1.00	29
papaya	1.00	1.00	1.00	19
pigeonpeas	1.00	1.00	1.00	18
pomegranate	1.00	1.00	1.00	17
rice	1.00	0.81	0.90	16
watermelon	1.00	1.00	1.00	15
...				
accuracy			0.99	440
macro avg	0.99	0.99	0.99	440
weighted avg	0.99	0.99	0.99	440

Fig. 2- Classification report of Random Forest algorithm

EXPERIMENT RESULT

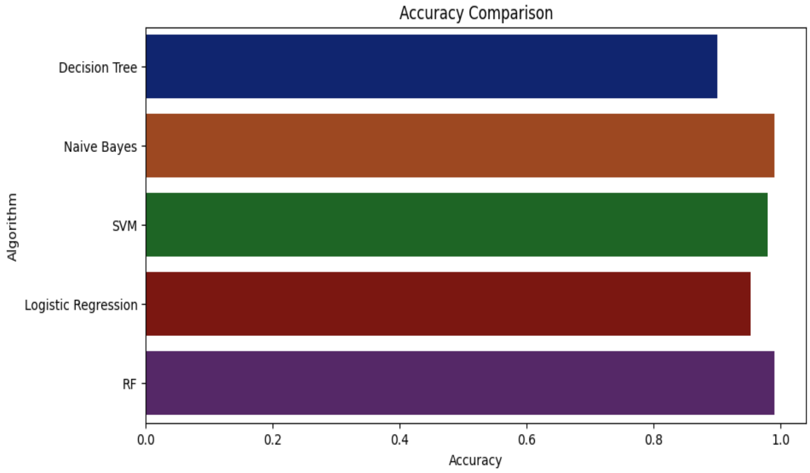

Fig. 3 – Accuracy Comparison

SYSTEM ARCHITECTURE

The system architecture for the crop recommendation app is designed to seamlessly guide farmers from input to actionable insights through several key components. It begins with a user-friendly interface (UI) where farmers input essential parameters such as soil type, climate data, and crop preferences. This intuitive UI ensures that farmers can easily provide the necessary information without technical difficulties.

Once the inputs are provided, they are directed to the data collection and preprocessing module. This module gathers data from various sources, including local weather stations, soil databases, and agricultural research institutions. The collected data undergoes cleaning to remove inconsistencies and preprocessing to transform it into a format suitable for analysis. This step includes normalization, encoding of categorical variables, and handling of missing values. The core of the system is the machine learning model, such as Random Forest, trained on the pre-processed data.

Random Forest is chosen for its robustness and high accuracy in handling complex datasets. Once trained, the model can evaluate new farming scenarios in real-time, providing personalized crop recommendations based on the input parameters. This architecture ensures a streamlined flow from user input to actionable insights, leveraging advanced technologies to optimize crop selection and enhance agricultural productivity.

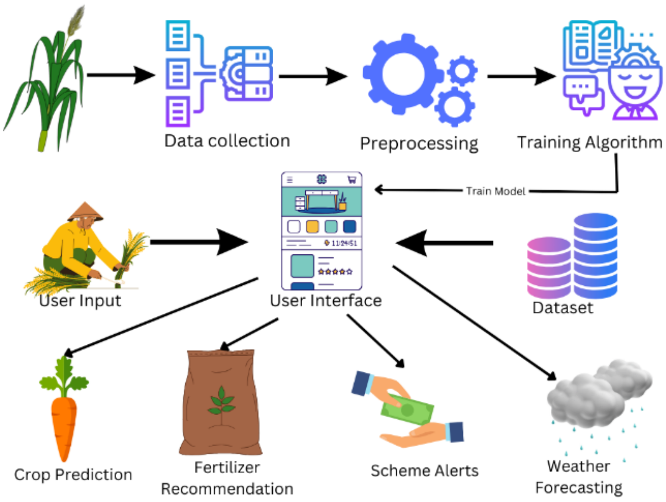

Fig. 4– System Architecture

WORKFLOW

- *Random Forest Algorithm*: Develop a comprehensive machine learning model utilizing the Random Forest algorithm, which involves training the model on a substantial dataset. This process includes the selection and preprocessing of data, feature selection, and the tuning of hyperparameters to ensure optimal model performance. The resulting trained model benefits from the ensemble method's ability to mitigate overfitting and enhance predictive accuracy, leveraging multiple decision trees to produce reliable crop recommendations

- *Machine Learning Trained Model*: Utilize the trained machine learning model to generate predictions based on new input data. This involves the application of the model to real-world agricultural scenarios, where it can process various input parameters and deliver precise crop recommendations. The model's predictions are derived from its extensive training on historical data, ensuring that it can accurately reflect the underlying patterns and relationships within the dataset.
- *Flask REST API*: Deploy the trained model's predictive capabilities via a Flask REST API, providing a set of API endpoints to facilitate seamless access to the model's predictions. This setup allows external applications and services to interact with the machine learning model, enabling them to submit input data and receive output predictions in a standardized format. The Flask REST API serves as a bridge between the trained model and the end-users or other systems that require its insights.
- *Open Weather API*: Integrate weather data retrieval into the system by using the Open Weather API. This involves making API calls to fetch current and forecasted weather conditions, which are critical for making informed agricultural decisions. The weather data includes parameters such as temperature, humidity, rainfall, and more, all of which are essential for predicting crop suitability and optimizing farming practices.
- *Krishi Maharashtra Portal*: Retrieve comprehensive agricultural data from the Krishi Maharashtra Portal. This portal provides valuable information on various aspects of farming, including soil health, crop patterns, pest control measures, and government schemes. By incorporating this data into the system, the app ensures that users have access to the most relevant and up-to-date agricultural information, enhancing the accuracy and relevance of the recommendations provided.
- *Ministry of Good Samaritan*: Access detailed social services information from the Ministry of Good Samaritan. This includes data on support programs, subsidies, and other resources available to farmers. Integrating this information helps users stay informed about the assistance they can receive, ensuring they can take full advantage of the available support to enhance their farming operations.
- *Flutter Application*: Develop a user-friendly Flutter application that integrates multiple data sources and functionalities:

a) Integrate predictions from the Flask REST API to provide real-time crop recommendations based on user input.
b) Incorporate weather data fetched from the Open Weather API, allowing users to view current and forecasted weather conditions.
c) Include agricultural data retrieved from the Krishi Maharashtra Portal, ensuring users have access to comprehensive farming information.
d) Add social services information from the Ministry of Good Samaritan, providing users with insights into available support and resources.
e) Present a combined, intuitive interface that makes it easy for users to access all these integrated features and make informed farming decisions

- *User*: Interact with the Flutter application to utilize the integrated data for informed decision-making or staying updated. Users can input their farming parameters, view crop recommendations, check weather conditions, access agricultural information, and learn about available social services, all through a cohesive and user-friendly platform designed to enhance their farming efficiency and productivity.

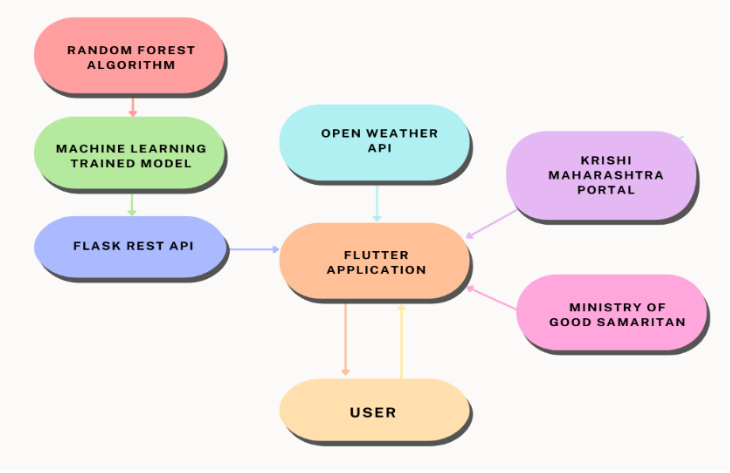

Fig. 5–Application Workflow

MODELING AND ANALYSIS :

Crop Recommendation System encompass defining its core operations. These include analyzing soil data, calculating crop recommendations, providing real-time weather forecasts, and enabling user interactions. Each function specifies inputs, behavior, and outputs, crucial forthe system's effective performance. These requirements serve as the foundation for the system's development, ensuring it delivers the intended functionalities.

- **User Authentication**: This module allows farmers to securely create accounts and log in to the Crop Recommendation System. Each user has a unique profile, ensuring data protection and personalized recommendations. The authentication process includes secure password management.
- **Crop Recommendation Modul**e: This module analyzes various soil attributes, such as pH levels, nutrient composition (N, P, K levels), moisture content, and texture. Based on the soil analysis results, the system generates tailored crop recommendations, helping farmers select the best crops suited to their soil conditions.

- **Weather Forecast Integration**: This module retrieves real-time weather data for the user's geographical location. It provides weather forecasts that are crucial for crop planning and management, such as predicting rainfall, temperature changes, and humidity levels. By integrating weather forecasts, farmers can make informed decisions about planting, irrigation, and harvesting schedules to optimize crop yield and minimize risks.
- **Fertilizer Recommendation System:** This module offers personalized fertilizer prescriptions by considering soil characteristics and crop requirements. It recommends the type and number of fertilizers needed, along with suitable application methods, to enhance crop growth and productivity. The system ensures that farmers use fertilizers efficiently, reducing costs and environmental impact. **Agricultural Scheme Integration**: This module displays information about available agricultural schemes or subsidies that align with the recommended crops and practices. It helps farmers stay informed about government programs, financial aids, and other beneficial schemes, making it easier for them to access support and resources for sustainable farming.

RESULT AND DISCUSSION :

The application seamlessly guides users through a captivating journey, starting from an engaging landing page that captures their attention with its visually appealing design. This leads to an intuitive signup process, offering a smooth onboarding experience and granting users access to a plethora of features designed specifically to enhance farming efficiency. Upon logging in, users are greeted with a wealth of valuable resources, including real-time weather updates that provide crucial insights for making informed farming decisions.

One of the app's standout features is its personalized crop recommendations, which are tailored based on user-input farming parameters such as soil type, climate conditions, and crop preferences. Additionally, the app offers fertilizer suggestions, scheme access for government agricultural programs, and a rich repository of insightful blogs covering various farming techniques and industry updates.

By inputting their farming parameters, users receive not just recommended crops but also detailed soil reports that delve into soil components, optimizing productivity and ensuring sustainable farming practices. The app's modules, coupled with expert insights, significantly elevate farming practices by providing users with a comprehensive toolkit for success

- **User Authentication and Home page:**

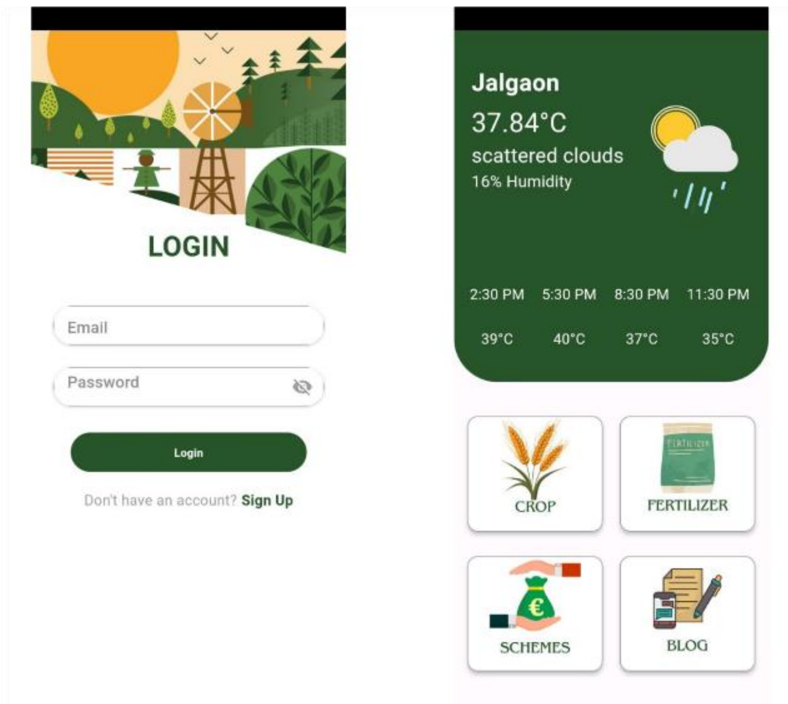

Fig. 6–User Authentication and Home Page

After authenticating on the Krishi app, users are immediately directed to the home page. Here, they can access live weather updates crucial for farming decisions. The home page also offers an overview of key features, including personalized crop recommendations, fertilizer suggestions, government agricultural scheme information, and insightful blogs on farming techniques and industry updates. This comprehensive view equips users with the tools needed for efficient and modern farming practices.

- **Crop Recommendation Modul**e:

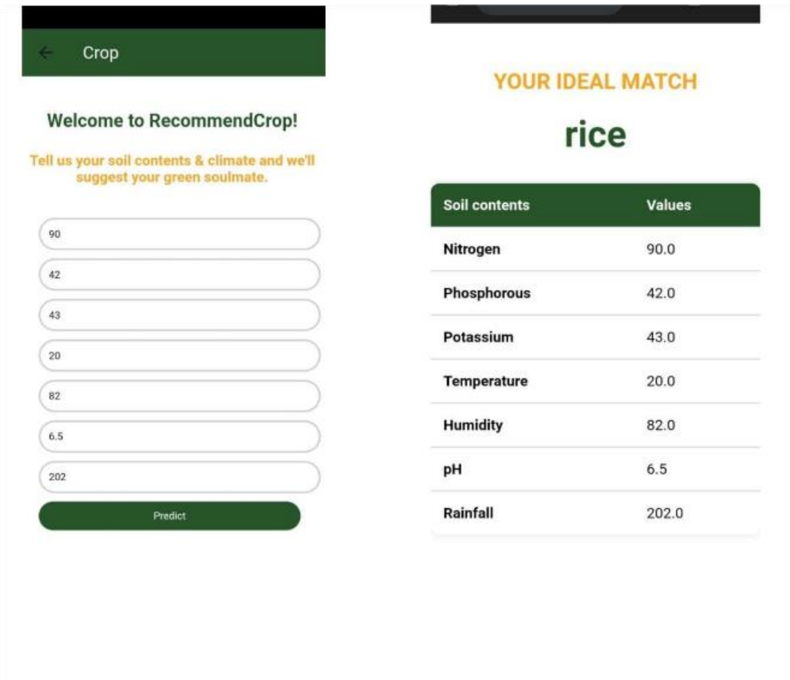

Fig. 7–Crop Recommendation Module

Users are prompted to input N, P, K values, rainfall, temperature, humidity, and pH, users can click the "Predict" button on the Krishi app to receive recommended crops and a detailed soil report, including all soil components, empowering them with comprehensive insights for optimal farming decisions and practices.

- **Fertilizer Recommendation and Agriculture Scheme Module:**

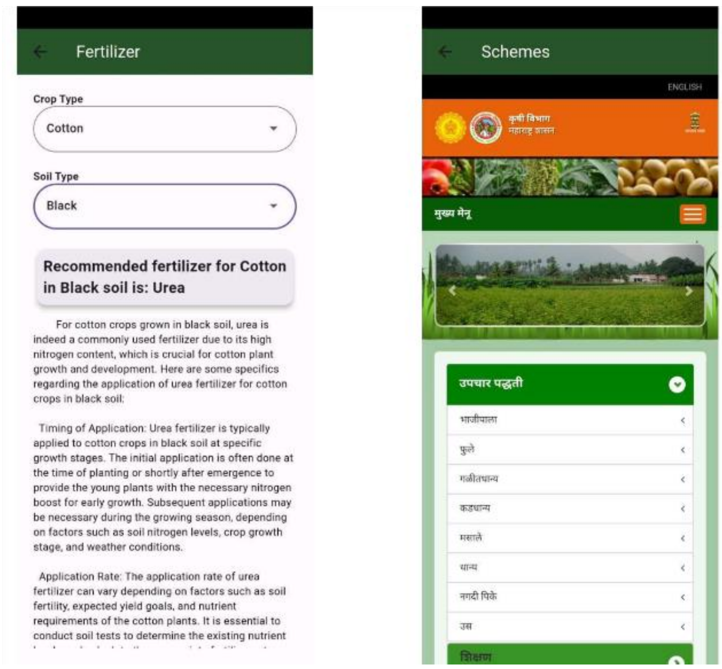

Fig. 8–Fertilizer Recommendation and Agriculture Scheme Module

For fertilizer recommendation, users input crop type and soil type into the Krishi app's Fertilizer Recommendation tool. They receive customized fertilizer suggestions tailored to their specific crop and soil conditions, optimizing agricultural productivity and sustainability.

In the Agriculture Scheme Portal section of the Krishi app, users can explore and access government agricultural schemes relevant to their region. This centralized platform provides valuable information on subsidy programs, financial assistance, and policy updates, enabling farmers to capitalize on available resources and maximize their farming potential.

CONCLUSION :

The project was designed to revolutionize farming practices by implementing a sophisticated agricultural management system. We started with extensive data collection and preprocessing, followed by in-depth exploratory analysis to uncover patterns influencing crop selection and optimization. This analysis informed the design phase, where we crafted a robust framework integrating machine learning algorithms to provide personalized crop recommendations based on critical inputs such as N, P, K values, climate conditions, and soil characteristics.

Furthermore, we integrated modules for fertilizer recommendations, a scheme portal for accessing government agricultural initiatives, a blog section for insightful agricultural articles, and a live weather module for real-time weather updates. Meticulous feature engineering and model selection were pivotal in enhancing system accuracy and efficiency, underlining the importance of a comprehensive understanding of farming dynamics. This comprehensive approach from data collection to model design laid a solid foundation for the subsequent implementation and evaluation phases, driving towards a future of enhanced productivity, sustainability, and prosperity in the agriculture sector.

ACKNOWLEDGMENT

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