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Soil Analysis and Crop Recommendation Using Machine Learning

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Abstract:
India's agriculture sector plays a key role in the growth of the country's economy. Crop production mainly depends on soil conditions, and selecting the right crop for a given soil is very important for achieving better yield. Many young farmers face difficulty in choosing suitable crops because soil properties vary across regions. Wrong crop selection leads to reduced productivity and financial loss. To address this issue, this project proposes a machine learning–based crop recommendation system using soil data. The system uses a soil dataset containing parameters such as pH value, moisture level, temperature, and nutrient content. These features are analyzed using machine learning algorithms such as Decision Tree, Random Forest, and Support Vector Machine to learn patterns between soil conditions and crop suitability. Based on the given soil data, the trained model predicts the most suitable crop for cultivation. Experimental results show that the proposed system achieves high prediction performance, with an accuracy of approximately 97%. The system is simple, cost-effective, and useful for guiding farmers, especially beginners, in selecting suitable crops and improving agricultural productivity.

Keywords: Soil Data, Crop Recommendation, Machine Learning, Smart Agriculture, decision tree, Random forest algorithm, SVM.

I.INTRODUCTION

Agriculture is one of the most important sectors in India and plays a major role in the country's economic growth. The population depends on farming for their livelihood. Crop productivity mainly depends on soil quality, climate conditions, and proper crop selection. If the wrong crop is selected for a particular soil type, it can lead to poor yield, financial loss, and wastage of resources such as water and fertilizers. Traditionally, farmers select crops based on experience, local practices, and advice from experts. While this method has been followed for many years, it has several limitations. Soil properties vary from region to region and also change over time due to continuous farming and environmental factors. New farmers often lack sufficient experience to understand these variations, which makes crop selection difficult. As a result, traditional methods may not always provide accurate or field-specific crop recommendations.

With the advancement of technology, machine learning has become a powerful tool for solving real-world problems in agriculture. Machine learning techniques can analyze large amounts of soil data and identify patterns that are not easily visible through manual methods. By using soil parameters such as pH value, moisture content, temperature, and nutrient levels, machine learning models can predict suitable crops more accurately. This project mainly focuses on developing a machine learning-based crop recommendation system using soil data. This project provides a smart and data-driven solution for crop selection, reducing the risk of crop failure and optimizing productivity. It helps farmers make informed decisions, save resources like water and fertilizers, and improve crop yield and quality. The system can also be integrated with mobile apps or web platforms, providing real-time recommendations and alerts to farmers. Ultimately, this approach aims to modernize agriculture, promote sustainable farming, and increase farmers' income by combining traditional knowledge with modern technology The system collects soil data, preprocesses it, and trains machine learning models to learn the relationship between soil conditions and crop suitability. Based on the given soil values, the system predicts the most suitable crop for cultivation. This approach helps farmers make informed decisions, reduces dependency on traditional trial-and-error methods, and improves overall agricultural productivity.

II.LITERATURE REVIEW

[1] The authors P. Chantima, T. Yarnguy, K. Sarawan, R. Sangmuenmao, W. Sommool, and S. Gonwirut worked on a system to help farmers using machine learning and sensors. Their project analyzed soil conditions and gave crop suggestions. The system showed good performance with an accuracy of about 90%, but it required sensors, which increased cost and difficulty for small farmers.

[2] The authors A. A. Khan, M. Faheem, R. N. Bashir, C. Wechtaisong, and M. Z. Abbas developed an IoT-based fertilizer recommendation system using machine learning. The system studied soil and weather data and suggested suitable fertilizers. It achieved around 90% accuracy, but it focused only on fertilizer recommendation and not crop selection.

[3] The authors R. K. Munaganuri and Y. N. Rao designed an image-based system to estimate crop water needs. They used satellite images and machine learning methods. The system achieved an accuracy between 92% and 95%, but it required high-quality images, which are not easily available to all farmers.

[4] The authors R. Gupta and other researchers created a crop prediction system using weather data and machine learning. The system helped farmers understand suitable crops based on climate and achieved nearly 91% accuracy. However, soil image analysis was not included.

[5] The authors A. Reyana, S. Kautish, P. M. S. Karthik, I. A. Al-Baltah, M. B. Jasser, and A. W. Mohamed worked on combining data from multiple sensors for agriculture analysis. Their system improved prediction results and achieved about 93% accuracy, but it depended only on sensor and numerical data.

[6] The authors R. John Martin and team members proposed a smart agriculture system using machine learning and explainable AI. The system helped farmers understand results clearly and achieved approximately 94% accuracy. However, it needed complex setup and sensor devices.

[7] The authors T. Tussupov and co-authors studied the use of machine learning to identify pests and diseases in crops. Their work improved crop monitoring with an accuracy of around 89%, but it did not help in crop selection based on soil type.

[8] The authors U. Umar, T. A. Sardjono, and H. Kusuma developed a rule-based system to guide farmers in agricultural practices. The system showed an accuracy of nearly 88% for crop guidance but did not use soil image information.

[9] The authors D. David, O. S. Albahri, A. H. Alamoodi, A. S. Albahri, M. Deveci, and I. M. Sharaf reviewed different techniques used in precision agriculture. Since this was a review paper, no experimental accuracy was reported.

[10] The authors K. Chicaiza, R. X. Paredes, I. M. Sarzosa, S. G. Yoo, and N. Zang discussed modern farming technologies and machine learning methods. Their study analyzed different systems, but no specific accuracy value was provided as it was a survey-based work.

[11] The authors Y. Mahale, N. Khan, K. Kulkarni, and others created a crop recommendation and weather prediction system using machine learning models. The system showed good performance with about 92% accuracy, but soil image analysis was not included.

[12] The authors M. Y. Shams, S. A. Gamel, and F. M. Talaat developed an explainable crop recommendation system using machine learning. The system achieved high accuracy of about 94% and helped farmers understand why a crop was suggested. However, it used only table data and not soil images.

[13] The authors M. Y. Shams, S. A. Gamel, and F. M. Talaat developed a crop recommendation system called XAI-CROP. The main aim of this system was to help farmers understand why a particular crop is suggested. The system used a Decision Tree model along with an explainable AI method called LIME. The system showed good results with about 94% accuracy, but it worked only with table data and did not use soil images.

[14] The authors H. Afzal, M. Amjad, A. Raza, and others created a crop recommendation system using machine learning techniques. The system used soil nutrient and weather data to suggest suitable crops. An ensemble model using Random Forest and XGBoost was applied to improve accuracy. The system achieved around 98% accuracy, but it depended only on numerical soil data and did not consider soil images.

[15] The authors R. K. Dhanaraj, M. Maragatharajan, A. Sureshkumar, and others developed an on-device AI system for crop yield prediction. The system used lightweight models on smart devices. It achieved around 88–91% accuracy. The work focused only on yield prediction and not soil image analysis.

[16] The authors M. Abdel-Salam, N. Kumar, and S. Mahajan proposed a crop yield prediction system using hybrid feature selection. The system selected important features for better results. It achieved accuracy above 95%. The method used only numerical data and not soil images.

[17] The authors S. Venkateswara and J. Padmanaban developed an interpretable deep learning system for crop and fertilizer recommendation. The system gave clear explanations to farmers. It achieved about 95–96% accuracy. Soil image classification was not included.

III.PROPOSED METHODOLOGY

The proposed system uses machine learning algorithms such as Decision Tree, Support Vector Machine (SVM), and Random Forest to analyze soil parameters and recommend the most suitable crop. The system takes inputs like nitrogen, phosphorus, potassium, pH, temperature, humidity, and rainfall. After preprocessing the data, the models are trained and tested to predict the best crop for given soil conditions. Among all models, the Random Forest algorithm provides the highest accuracy. This system helps farmers make accurate and data-driven decisions, increasing productivity and supporting sustainable agriculture.

System starts with the Data Collection Module, where soil data is gathered from an existing dataset. This dataset contains important soil parameters such as pH value, moisture, temperature, and nutrient levels like nitrogen, phosphorus, and potassium. After collecting the data, it is passed to the Preprocessing Module**.** In this module, missing values are handled, incorrect data is removed, and all soil values are normalized to make the data suitable for machine learning. This step helps improve the accuracy of the system.

Next, the cleaned soil data is given to the Training Module. In this module, machine learning algorithms such as Decision Tree, Random Forest, and Support Vector Machine are trained using historical soil and crop data. These algorithms learn the relationship between soil conditions and suitable crops. After training, the model becomes capable of understanding which crop grows best under specific soil conditions.

Finally, the Prediction Module uses the trained model to predict the most suitable crop. The user enters soil values as input, and the model processes this data to generate a prediction. The result is displayed through the Output Module, which shows the recommended crop to the user. This system helps farmers, especially beginners, to select the right crop easily and improve agricultural productivity.

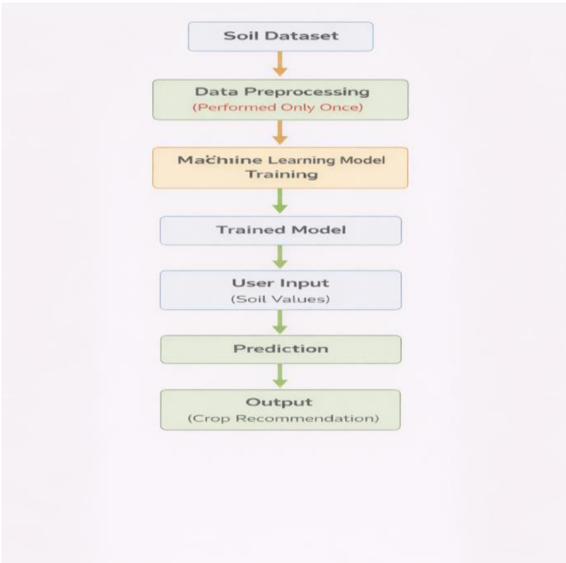

FIG 1. SYSTEM ARCHITECTURE

V.RESULTS AND DISCUSSION

The proposed crop recommendation system was tested using a soil dataset with parameters such as pH value, moisture, temperature, and nutrient levels. Machine learning algorithms including Decision Tree, Random Forest, and Support Vector Machine were trained and evaluated. Among these models, Random Forest produced the best performance with higher accuracy compared to the other algorithms. This shows that the system can effectively learn the relationship between soil conditions and suitable crops.
The result shows that the proposed system gives accurate and suitable crop recommendations based on soil data. By using machine learning, the system reduces dependency on traditional farming methods and decreases human errors. The discussion confirms that the system is useful for farmers, especially beginners, as it helps in selecting the right crop and improving agricultural productivity. Overall, the results prove that the proposed approach is efficient, cost-effective, and suitable for real-world agricultural applications.

GRAPH

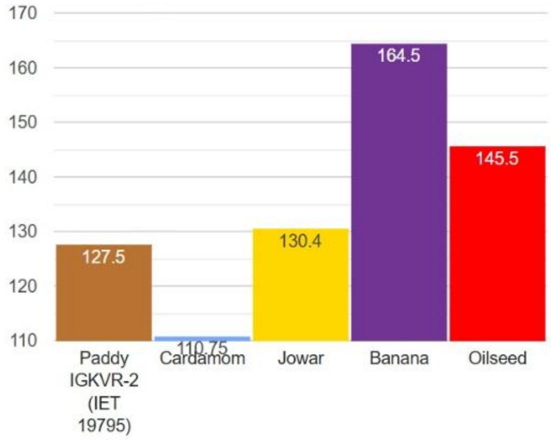

FIG 2.BAR GRAPH

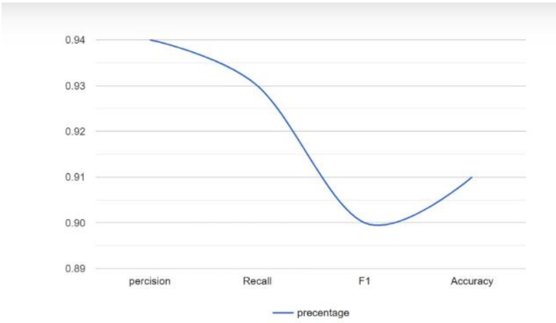

FIG 3.ROC GRAPH

PIE CHART

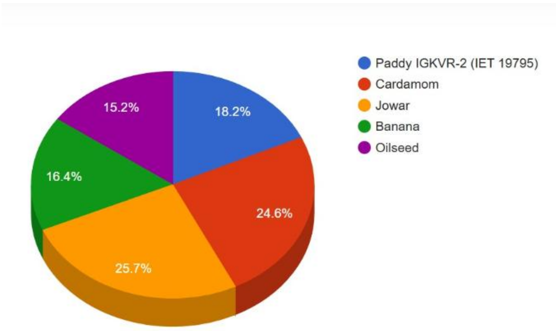

FIG 4.PIE CHART

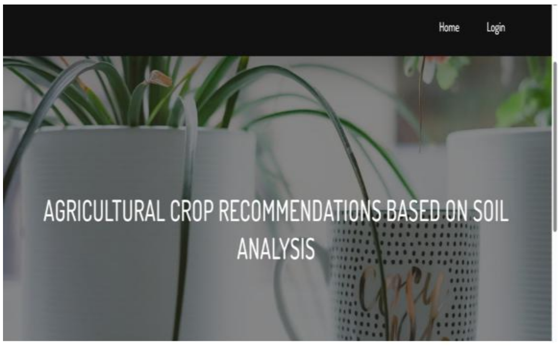

FIG 5. HOME PAGE

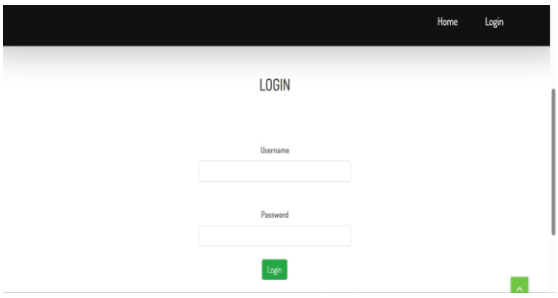

FIG 6. LOGIN PAGE

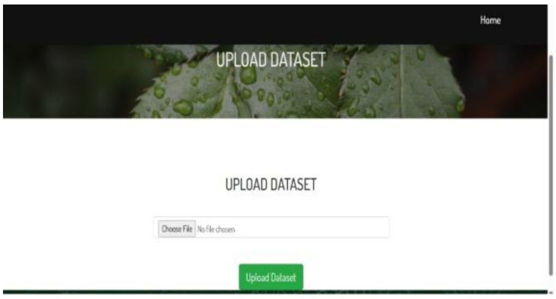

FIG 7. UPLOAD PAGE

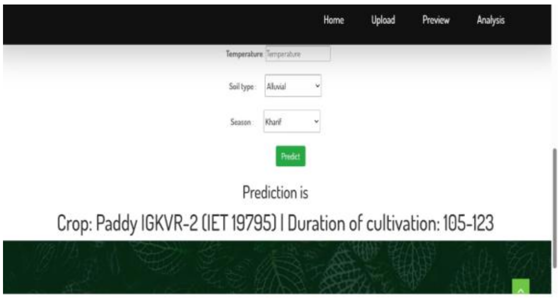

FIG 8. PREDICTION PAGE

VI.CONCLUSION AND FUTURE WORK

This project presented a machine learning–based crop recommendation system using soil data. The system analyzes important soil parameters such as pH value, moisture, temperature, and nutrient levels to predict suitable crops. Experimental results show that machine learning models, especially Random Forest, provide accurate and reliable crop recommendations. The proposed approach reduces dependency on traditional farming methods and helps farmers, particularly beginners, make better crop selection decisions. Overall, the system is simple, cost-effective, and useful for improving agricultural productivity.

In the future, the system can be improved by including more soil and environmental parameters to enhance prediction accuracy. Real-time soil data collected from sensors can also be integrated into the system. Additionally, advanced machine learning or deep learning models can be explored for better performance. The system can be extended to provide fertilizer and irrigation recommendations, making it a complete decision-support tool for smart agriculture.

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