Agro-Insight: Recommendation System Using Machine Learning

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Abstract: Optimizing crop and fertilizer recommendations is paramount for productivity and sustainability in agriculture sector. Traditionally reliant on labor-intensive expert knowledge, this process now shifts towards automation with machine learning techniques. Our study on the existing system includes Random Forest, Logistic Regression, Naive Bayes, SVM, Decision Tree, KNN, Bagging, extra trees and Gradient Boosting algorithms to optimize crop and fertilizer. Recommendations for arid lands. Proposed method used Random Forest classifier for prediction of crops and Decision Tree classifier for prediction of fertilizer. By considering soil composition and climate evaluation, we achieved consistent accuracy rates exceeding 90%, with the highest at 99%. This approach has the potential to revolutionize crop recommendation system and fertilizer recommendations, benefiting farmers by enhancing yields and sustainability. Integrating cutting-edge technology like machine learning into agricultural practices addresses the needs for increased production while ensuring environment sustainability and food security.

Keywords: Crop Recommendation, Fertilizer Recommendation, Machine Learning, Random Forest, Logistic Regression, Naive Bayes, SVM, Decision Tree, KNN, Bagging, Gradient Boosting, Extra Trees, Sustainability, Arid Land, Agricultural Productivity, Food Security.

1 Introduction

Agriculture is the foundation of human civilization, serving as the backbone of sustenance, economic sustainability, social development. Not only nourishes billions of people worldwide but also contribute significantly to employment, trade, and industrial growth. Furthermore, it plays a crucial role in environment conservations, as sustainable agriculture practices promote soil health, biodiversity, and carbon sequestration. In essence, agriculture is not just about cultivating crops or raising livestock, it represents a fundamental pillar of human existence, ensuring the well-being of present and future generation.

One of the crucial challenges in agriculture lies in the selection of crop and fertilizer that suited to specific soil conditions. Failure to consider soil characteristics can severely impact crop growth and yield potential. Different crops have varying requirement regarding soil pH, texture, drainage, and nutrient levels. Ignoring these factors can lead to suboptimal performance, increased susceptibility to pests and

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disease, and reduce overall productivity. For instance, attempting to grow crops that require well drained soil in waterlogged areas can result in root rot and stunted growth. Conversely, planting crops unsuited to acidic or alkaline soil conditions can lead to nutrient deficiencies and poor yields. Therefore, careful soil analysis and selection of crops and fertilizers adapted to local soil types are essential for successful agricultural practices and sustainable land management. Introduced method for recommendation of crops and fertilizer based on soil detailed below sections. Section 2 shares information about techniques which are existed previously, Section 3 deals with proposed system to surmount the existing problems for crop production. Section 4 handles workflow of introduced method, section 5 covers outcomes of proposed method, section 6 follows conclusion of proposed method.

2 Literature Review

Selection of suitable crops based on the condition of soil is crucial. Researchers proposed many technologies for suitable selection of crops.

P. Ayesha Barvin, et al, [2023] compared GNN and GCN, outlining their strengths and weaknesses. Explores the frontiers of graph-based models' innovation of agriculture, showcasing ability to revolutionize precision agriculture. Aditya Motwani, et al, [2022] introduced a method for recommendation of crops using Random Forest and Convolution Neural Networks (CNNs) based on analysis of soil. Angu Raj, et al, [2021] suggested a method with internet of things to resolve principal issues by data analysis for in cultivation of suitable crop at suitable time. With help of Graphical User Interface (GUI) and sensors.

Murali Krishna Senapathy, et al, [2023] introduced a soil nutrient categorization and crop suggestion system empowered by IoT technology for suggesting of crops and helps to reduce the usage of chemicals in soil and to increase the productivity. Prasad Gavas, et al, [2022] introduces different methodologies for analysis of nutrients and prediction of rainfall with decision tree and simple moving Average (SMA) decision tree through extracting features. Pruthviraj, et al, [2021] introduced a method using machine learning algorithm named as support vector machine (SVM) for identifying suitable cultivations based on condition of soil and got high accuracy as compared to other methodologies.

Biplob Dey, et al, introduced a XGBoost algorithm, for recommendation for crops and compared with other techniques. Using a database from Kaggle repository to develop practical recommendations. Sudarshan Reddy Palle, et al,[2023] introduced a method with Logistic Regression for sorting of data depends on soil and weather condition. Suruliandia, et al, [2021] presented technology with machine learning for classification and prediction of crop protection based on the land. P.S.S. Gopi, et al, [2024] introduced Red Fox Optimization using machine learning algorithms such as Ensemble Recurrent Neural Network for prediction of yield and crop recommendation which can use of three deep learning Algorithms such as Long Short-term memory (LSTM), Gated Recurrent Unit (GRU), and Bidirectional LSTM(BiLSTM).

Sangeetha Subramani, et al, [2024] introduced a methodology WHO YOLO Net for detecting different types of soils and suggested crops based on database. Results expose accurate detection as compared to other available methods. Mohammed Omar Abdullahi, et al,[2024] researched that shows influence of machine leaning and IoT technologies to development of decisions of agriculture by comparing Decision Tree, K-NN and Random Forest. Among those algorithms Decision Tree algorithm performs accurate results.

J. Madhuri, et al, [2023] introduces a Big data framework that provides data obtaining various sources, efficient storage, analysis and crop recommendation. Including real time soil and data of weather through Neural networks and Decision tree algorithms for suitable crop recommendation. Neeelam Agarwal, et al, [2024] introduced a machine learning method to overcome the problem of prediction of crops accordance with soil provides accurate results. Tilottama Goswami, et al, [2024] recommended machine learning algorithms and ensemble methods for advising crop depends on soil condition

3 Proposed model

Available methodologies for recommendation of crops based on soil condition have been observed significant limitations suggesting of crops. Only focusing on either weather or soil parameter when predicting soil suitability. Moreover, the Fragmented nature of agricultural services represents another notable drawback in existing system. Currently, different platforms offer separate functionalities, such as crop recommendation and fertilizer recommendation

Separate approach complicates accessibility for farmers and hinders the seamless utilization of available resources. To overcome the drawbacks, proposed efficient Agro-Insight Recommender System, which takes into all considerations incorporating some parameters such as location, rainfall, soil and temperature condition to forecast crop and fertilizer suitability. This system is primarily focused on fulfilling the essential role of agricultural consultants, which involves delivering crop and fertilizer suggestions to farmers depends on conditions.

Agro-Insight: Recommendation System Using Machine Learning is the proposed system mentioned in Fig.1 here is the detailed information about the proposed method.

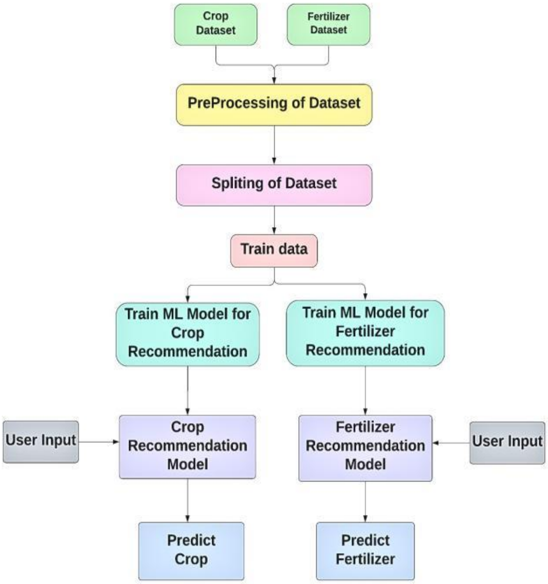

Fig.1 Proposed Agro-Insight: Recommendation System Using Machine Learning

Acquisition of Training Dataset

To enhance agricultural productivity and optimize crop yield, the acquisition of comprehensive crop and fertilizer dataset is crucial. The crop dataset should encompass a wide range of variables such as crop type, growth requirements, climate suitability, and yield performance across various regions.

Simultaneously, the fertilizer dataset should include the information on soil composition, nutrient levels, and the effectiveness of different fertilizers in promoting crop growth. By analysing datasets collectively, advanced classifiers can be deployed to suggest appropriate crops based on specific soil conditions.

Pre-processing

In process of recommendation crops based on soil characteristics, pre-processing of soil data is fundamental for accurate and reliable results. Initially, data cleaning procedures are employed to rectify any inconsistencies, eliminating missing values, and address outliers within the soil dataset, ensuring data integrity. Feature engineering steps may involve the creation of composite indicators that combine multiple soil attributes, thus providing a more comprehensive representation of soil fertility and composition. Additionally, soil classification methodologies utilized to group similar soil types, facilitating tailored recommendations based on distinct soil profiles. Ultimately, the pre-processed soil data is seamlessly integrated with crop datasets, allowing for the alignment of variables such as nutrient requirements, climate suitability and soil characteristics to generate informed and personalized recommendation for optimal agricultural outcomes.

Process visualization

In the process visualization of recommending crops and fertilizers based on soil conditions, several stages unfold to offer a comprehensive understanding of the approach. Initially, soil samples are meticulously collected from diverse locations, each representing unique soil compositions and characteristics. These samples undergo thorough analysis to extract essential parameters such as pH levels, nutrient content, moisture levels, and texture. Once the soil data is obtained, it is visualized through various methods such as histograms, and heat maps to discern patterns and correlations among the different soil attributes. These visualizations offer insightful explanations of the connections between soil characteristics and their impact on crop suitability.

Subsequently, machine learning classifier like Random Forest or Decision Tree are employed to process the soil data and recommend suitable crops or fertilizer The application of these algorithms is visualized through flowcharts or decision trees, illustrating the decision-making process behind crop recommendations and fertilizer recommendations based on soil attributes.

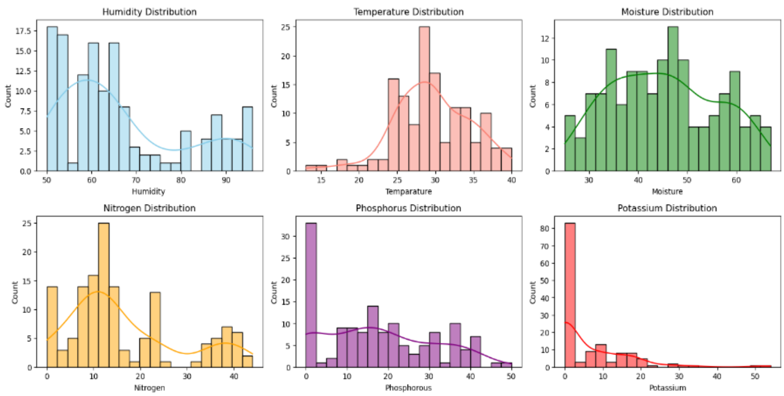

Fig. 2.a Distribution plot for Fertilizer feature.

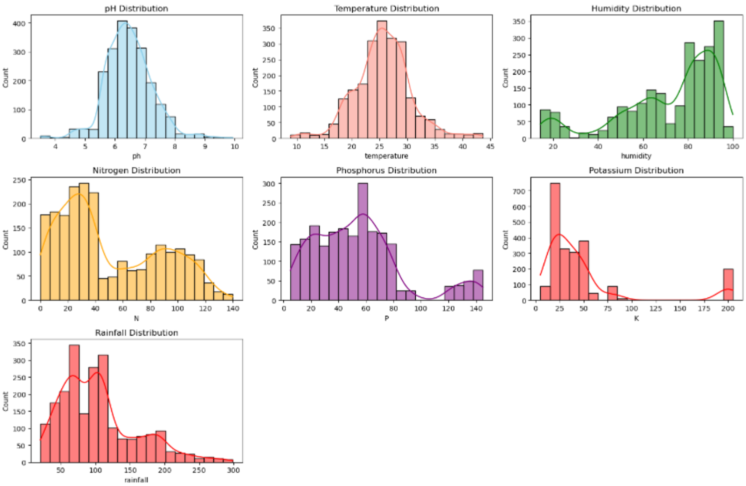

Fig. 2.b Distribution plot for Crop feature.

4 Experimental setup

To analyse the performance of Crop recommendation and recommendation system for fertilizer based on soil using Random Forest and Decision Tree algorithms respectively, soil samples are initially collected from various locations such as Crop-Recommendation.csv, dataset from Kaggle and Github and analysed for key parameters like pH, moisture control, nutrient levels, and texture. The Random Forest used for training data, and Decision Tree used for training fertilizer data. Evaluation of the system's performance is conducted using metrics such as Accuracy, Recall, Precision, and F1-score.

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \quad \text{-------(1)}$$

$$\text{Precision} = \frac{TP}{TP+FP} \quad \text{--------------(2)}$$

$$\text{Recall} = \frac{TP}{TP+FN} \quad \text{--------------(3)}$$

$$\text{F1-Score} = \frac{2(precision*recall)}{Precision+recall} \text{----(4)}$$

By analysing these performance metrics, we can identify the most suitable classifier for crop recommendation and classifier recommendation based on soil type. A classifier with high accuracy, precision, recall, F1-Score shows robust performance and accurately identifying suitable crops and fertilizers for specific soil conditions.

Table 1 represents the performance obtained by using Random Forest algorithms for recommendation of crops based on the condition of soil. Here are different types of crops to cultivate according to soil condition. The soil condition can be determined by verifying pH value, humidity, temperature, moisture, and nitrogen content in soil.

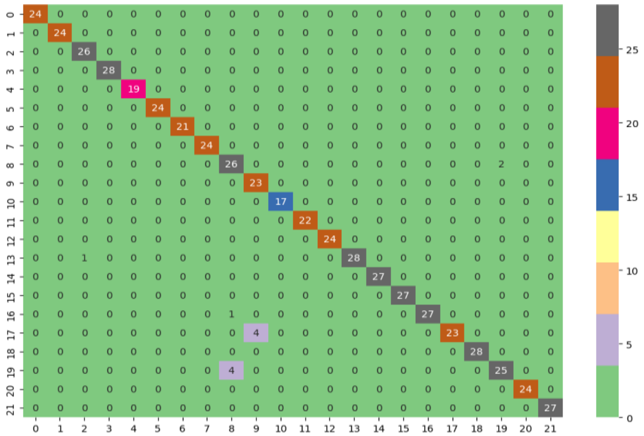

Fig.3 Confusion matrix for crop recommendation.

Confusion matrix is a tool used to evaluate the performance of recommended system in agriculture. Provides a concise summary of system predictions versus the actual outcomes. The examples in a predicted class are represented by each column, and the occurrences in an actual class are represented by each row.

	Precision	**Recall**	**F1-Score**	**Support**
Apple	0.99	0.99	0.99	24
Banana	0.99	0.99	0.99	24
Black gram	0.96	0.99	0.98	26
chickpea	0.99	0.99	0.99	28
Coconut	0.99	0.99	0.99	19
Coffee	0.99	0.99	0.99	24
cotton	0.99	0.99	0.99	21
Grapes	0.99	0.99	0.99	24
Juice	0.84	0.93	0.88	28

lentil	0.99	0.99	0.99	17
Maize	0.99	0.99	0.99	22
Moth beans	0.99	0.97	0.98	29
orange	1.00	1.00	1.00	27
papaya	1.00	0.96	0.98	28
Pigeon peas	1.00	1.85	0.92	27
pomegranate	0.99	0.99	0.99	28
rice	0.93	0.86	0.89	29
Watermelon	0.99	0.99	0.99	24
Wheat	1.00	1.00	1.00	27
accuracy			0.99	550
Macro avg	0.99	0.99	0.99	550
Weighted avg	0.99	0.99	0.99	550

Table 1 Performance Report of Crop Recommendation.

	Precision	Recall	F1-Score	Support
10-26-26	0.85	0.85	0.85	3
14-35-14	1.01	0.68	0.82	3
17-17-17	1.01	0.51	0.68	2
20-20	0.86	1.01	0.92	6
28-28	1.01	1.01	1.01	6
DAP	1.01	1.01	1.01	6
Urea	0.83	1.01	0.91	5
Accuracy			0.93	27
Macro avg	0.95	0.86	0.88	27
Weighted avg	0.94	0.93	0.92	27

Table 2 Performance Report of Crop Recommendation.

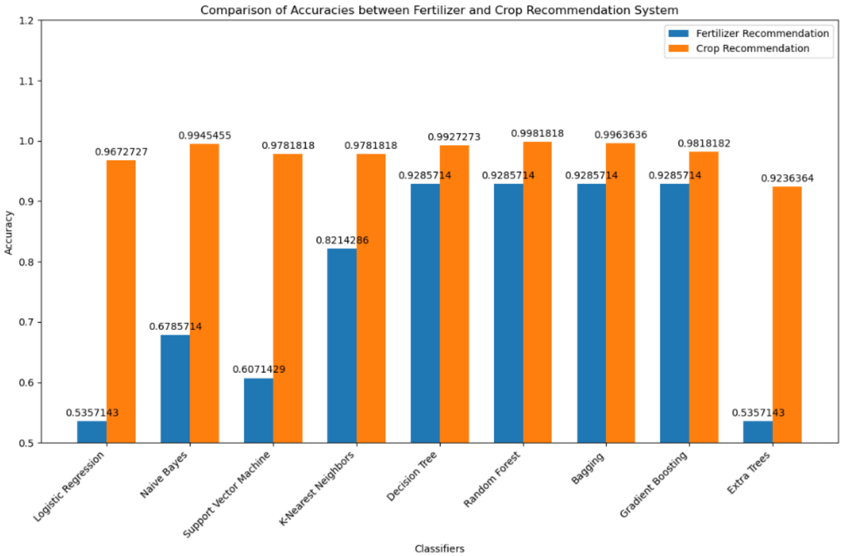

Fig.4 Comparison of Accuracy of various classifiers.

Comparing the accuracy of various classifiers for crop recommendation based on soil type is crucial for identifying the most effective algorithm for agricultural decision-making. In our study, we evaluated several classifiers, including Logistic Regression, Naive Bayes, KNN, Decision Tree, SVM, Random Forests, Bagging, Extra Trees and Gradient Boosting, to determine their performance in recommending crops based on soil characteristics.

The results revealed that different classifiers exhibited varying levels of accuracy in predicting suitable crops for specific soil types. Decision Tree demonstrated strong performance in capturing local patterns and classifying soil samples based on their proximity to similar instances in the feature space. Decision trees excelled in providing transparent decision paths, making it easier for farmers to understand the rationale behind each recommendation. Overall, the accuracy comparison highlighted how crucial it is to choose the right classifier depending on the unique properties of the soil dataset and the required degree of interpretability. While Random Forest and decision trees emerged as strong contenders for crop recommendation tasks due to their simplicity and effectiveness, other classifiers such as SVM, logistic regression, Extra Trees also demonstrated competitive performance, particularly in more complex scenarios.

5 Conclusion and Future Work

Concluded that, employing Random Forest and decision tree algorithms for crop recommendation and fertilizer recommendation respectively based on soil analysis yields promising outcomes for agricultural decision-making. Through the utilization of these techniques, farmers can leverage data-driven insights to optimize crop selection, enhancing both productivity and sustainability. The Random Forest algorithm's ability to classify soil characteristics and recommend suitable crops based on similarity metrics offers a straightforward and effective approach. On the other hand, the decision tree algorithm provides transparent decision paths, enabling farmers to understand the rationale behind each recommendation. By integrating these methodologies into agricultural practices, stakeholders can make informed choices tailored to specific soil conditions, ultimately fostering more efficient and resilient farming systems.

Integrating Internet of Things (IoT) technologies into our crop and fertilizer recommendation system can further enhance its capabilities by providing real-time data collection, monitoring, and control. Here are some ways you can incorporate IoT into our project in the future: Install various sensors in agricultural fields to collect data on environmental parameters such as humidity, temperature, light intensity, soil moisture and nutrient levels. These sensors can be connected to IoT devices for data transmission.Gather feedback from farmers and agricultural experts on the effectiveness of the recommendations. Use this feedback to iteratively refine the models and improve user satisfaction.Design the system to handle large-scale datasets and real-time data streams. Explore cloud-based solutions for scalability and consider deploying the system as a web application or mobile app for wider accessibility.

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