Krishi Mitra - Intelligent Crop And Fertilizer Recommender

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***Abstract*—Krishi Mitra - Intelligent Crop And Fertilizer Recommender System employs machine learning algorithms to provide personalized crop and fertilizer suggestions based on specific farming conditions, including various environmental parameters such as temperature, humidity, pH, rainfall, crop types, and soil nutrient (N,K,P) concentrations. The proposed research aims to enhance crop recommendations for farmers by predicting the most suitable crops for their unique agricultural settings. To enhance overall prediction accuracy, the crop recommendation model leverages an Ensemble approach, where an ensemble model is trained using Random Forest and XGBoost algorithms, and its performance is compared against that of the Artificial Neural Networks (ANN) algorithm. This comparative analysis allows for the selection of the most accurate model for crop recommendation and fertilizer customization. This approach optimizes crop selection and fertilizer recommendations, potentially leading to increased crop yields and improved farming productivity. The proposed implementation of this system holds the potential in revolutionizing agriculture by offering sustainable recommendations, bridging the gap between farmers and technology, and enhancing agricultural productivity and sustainability.**

***Keywords*—Fertilizer-recommendation, Machine-Learning, Ensemble models, Random Forest, XGBoost, Artificial Neural Networks, Agriculture, Sustainability**

I. Introduction

In the vast agricultural landscape of India, the persistent challenge of increasing crop yields and improving the financial well-being of the farming community is of paramount importance. Successful crop cultivation goes beyond sheer hard work; it relies on the careful selection of crops and the precise application of fertilizers. Unfortunately, many Indian farmers lack this crucial knowledge due to a shortage of scientific understanding. Recognizing this urgent need, this project seeks to provide an innovative solution—the Crop Recommendation and Fertilizer Recommendation System. This advanced tool, employing state-of-the-art machine learning techniques, holds the promise of significantly enhancing agricultural productivity and thereby empowering the farming community.

The foundation of the proposed recommendation system is built upon a meticulously curated dataset sourced diligently from Kaggle's extensive repositories. This dataset is a comprehensive collection of soil and environmental parameters, serving as the core of the model's cognitive capabilities. It encompasses a wide range of critical metrics, including humidity levels, soil pH levels, temperature variations, rainfall patterns, and the elemental composition of soil, specifically Phosphorus (P), Nitrogen (N) and Potassium (K). Within this diverse data lies the potential to uncover profound insights.

Furthermore, the research program aims to conduct a thorough evaluation of the performance of three prominent machine learning algorithms: Random Forest, used for its ability to handle extensive and complex datasets; Artificial Neural Networks (ANNs), inspired by the neural architecture of the human brain; and XGBoost, celebrated for its efficiency in processing structured data. This rigorous analysis seeks to identify the algorithm that offers the highest precision and reliability in providing recommendations to the discerning Indian farming population.

Upon the completion of the research, the algorithm demonstrating the utmost accuracy and reliability in crop and fertilizer recommendations will be implemented independently to benefit Indian farmers. This ensures the application of the most effective technology to address the pressing challenges of agricultural productivity.

II. Literature Review

A Crop Recommendation System was introduced for Farmers (RSF) that recommends crops based on user location and agricultural data. It uses various machine learning algorithms such as Logistic Regression,DT, Linear Regression, SVM, KNN, Naive Bayes and K-Means to enhance crop selection and productivity [1].

Precision agriculture is explored and ensemble techniques are employed such as CHAID, Naive Bayes, KNN and Random Forest, emphasizing the significance of data mining and ensemble techniques in decision-making [2]. Various machine learning techniques, like XGBoost, SVM, Naive Bayes, Random Forest, Logistic Regression and DT, were investigated to refine crop recommendations. Certainly,

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Random Forest performed exceptionally well, achieving an impressive accuracy rate of 96.34% [3].

Mobile app using GPS and user inputs for crop suggestions is developed, employing SVM, ANN, RF, MLR, and KNN algorithms. It achieves 95% accuracy with Random Forest in yield prediction and provides 14-day rainfall forecasts via the Open Weather API. Safety measures include withholding fertilizer when rainfall exceeds 1.25 mm. [4]

A web application is proposed for crop and fertilizer recommendation. Multiple machine learning algorithms, such as ANN, Random Forest, SVM , KNN, Naïve Bayes and DT, have been utilized for training in both the crop recommendation system and fertilizer recommendation.[5]

A web application-based system is developed for crop as well as fertilizer recommendation, and plant disease prediction. MobileNet algorithm is used to identify plant diseases using leaf images, XGBoost algorithm is employed to predict appropriate crops by considering soil nutrients and rainfall and Random Forest (RF) algorithm offers recommendations for fertilizers and strategies to enhance soil fertility, primarily based on soil nutrient data. These proposed models outperforms the existing classifiers in terms of accuracy.[6]

The BiLSTM-MANN algorithm is utilized to provide precise crop recommendations. The dataset is trained using BiLSTM-MANN, MLP and CNN models. Based on different evaluation metrics,BiLSTM-MERNN model outperforms , rest of the algorithms in context of crop recommendation systems.[7]

A crop recommendation system is proposed employing the Light GBM algorithm. The dataset undergoes training with both the Light GBM model and logistic regression. Based on accuracy score, Light BGM model provides more accuracy than logistic regression.[8]

Random Forest and Logistic Regression are combined for precise crop and fertilizer recommendations. A user-friendly web application ensures accessibility to farmers. Extensive experimentation reveals that the hybrid model outperforms individual algorithms like Logistic Regression, SVM, Logistic Regression, DT and Random Forest.[9]

A state-of-the-art Crop Prediction System is introduced that uses K-Nearest Neighbors (KNN) for accurate predictions based on soil characteristics. The K-Nearest Neighbors (KNN) Classifier, achieving a remarkable 90% precision. Real-time data on soil quality is acquired using an Arduino Uno and sensors. Future plans include integrating KNN with Geographic Information Systems (GIS) for even more accurate crop suggestions.[10]

Deep neural networks are employed for crop recommendation as well as plant disease detection. An artificial neural network is employed for crop recommendation, while a 2D CNN can be utilized to create a system for detecting plant leaf diseases [11].Crop and fertilizer recommendation and leaf disease prediction is integrated. Random Forest was identified as the best choice for crop recommendation. Fertilizer recommendation, driven by SVM and RF, achieves a remarkable 100% accuracy rate. For leaf disease prediction, CNN using the ResNet architecture was employed, offering deep learning capabilities and a 95% accuracy rate for early disease detection.[12]

The challenges posed by climate change while offering a unified platform for crop recommendation as well as plant disease identification. In the context of crop recommendations,five distinct machine learning algorithms were employed , namely Logistic regression,DT, SVM, multi-layer perceptron, and Random Forest. Random forest algorithm displayed a remarkable accuracy rate of 99.31%.In the realm of plant disease identification, training and evaluation were conducted using three different Convolutional Neural Network (CNN) architectures: VGG16, ResNet50, and EfficientNetV2. Among these, EfficientNetV2 displayed outstanding performance, boasting an accuracy rate of 96.06%.[13]

An innovative machine learning algorithm, AdaBoost, was introduced, for predicting crop yields and recommending fertilizers based on soil conditions. Additionally, the study recommends fertilizers employing the Random Forest (RF) algorithm. Further enhancements may explore the use of the Gradient Boost algorithm for prediction alongside potential algorithms like SVM and Decision Trees, in conjunction with Random Forest, to refine the prediction model.[14]

Farmers were empowered with insights and predictions.The system also includes a harvest prediction feature. It assists in selecting optimal pesticides, fertilizers, and recommended crops, using various algorithms like Random Forest, XGBoost, Random Forest, SVM, Logistic Regression, and Naive Bayes.[15]

Machine learning algorithms were employed on a well-prepared dataset for crop recommendation.We find that that Random Forest and XGBoost performed the best with accuracies of 98.9% and 98.2% respectively and Logistic Regression achieved an accuracy of 95.6%, and Decision Trees reached 95.3% accuracy. Future improvements could incorporate GPS coordinates and government rainfall forecasting for precise crop predictions.[16]

These projects collectively highlight the potential of machine learning approaches to revolutionize Indian agriculture, improving crop selection, yield prediction, and overall productivity while addressing the challenges faced by farmers.

Table I below shows the comparative study of the existing technologies done till date for the task of crop and fertilizer recommendation. The table mainly highlights the methodologies used. It also discusses advantages and disadvantages of the methodologies.

III. METHODOLOGY

In this section, the proposed methodology for developing the Crop and Fertilizer Recommendation System is described, which involves the utilization of two distinct datasets obtained from Kaggle, encompassing crop-related data and fertilizer-related data as shown in figure 1.

1. Dataset Collection: The data used in this study is crucial for the development of the Crop and Fertilizer Recommendation System. Two primary datasets were obtained from Kaggle, one comprising crop-related data and the other containing fertilizer-related information.

TABLE I. COMPARISON BETWEEN EXISTING TECHNOLOGIES

Paper title	*Author name*	*Methodology*	*Advantages*	*Limitations*
Crop Recommendation System Using Machine Learning Algorithms	Gaurav Chauhan, Alka Chaudhary	Random forest and decision trees to predict the crop and performance compared using WEKA Tool	Timely notifications about crop forecasts reach farmers.	Implementing and maintaining crop recommendation systems can be expensive, especially in resource-constrained regions.
A Crop Recommendation System for Precision Agriculture	S. Pudumalar, E. Ramanuja	Ensemble model with majority voting technique using Random trees, CHAID,KNN and naive bayes	By diversifying crops or choosing those suitable for specific conditions, farmers can reduce risks associated with weather fluctuations, pests, and diseases.	Gathering and sharing agricultural data may raise privacy concerns for farmers, which can limit data collection and analysis.
Machine Learning-Based Crop Recommendations for Precision Farming to Maximize Crop Yields	C. Sagana, M. Sangeetha, S. Savitha	Naive Bayes, SVM, Logistic Regression, Random Forest, Decision Trees and XGBoost, for crop recommendations. Random Forest stands out as the most accurate, achieving a 96.34% accuracy rate.	This will help to maximize the yields of crops which increase the profits of farmers. Based on comparison from different models RF gave more accuracy of 96.34%.	Can integrate plant disease prediction module as well
Crop Recommender System Using Machine Learning Approach	SHILPA MANGESH PANDE; PREM KUMAR RAMESH; ANMOL ANMOL; B. R AISHWARYA;	Employs various algorithms like SVM,MLR,RF,KNN,ANN to predict crops.RF outperforms them all.Provides fertilizer recommendation and recommends at what time is fertilizer to be used	Recommending time of fertilizer is a unique and useful module	Lack of interpretability, potential overfitting, longer prediction times, high memory usage.
AGRI-PRO: Crop, Fertilizer and Market Place Recommender for Farmers using Machine Learning Algorithms	Yalabaka Srikanth, Meghana Daddanala, Manchala Sushrith, Pranith Akula, Ch. Rajendra Prasad, Dasari Sindhu Sri	Compares various algorithms such as DT,NB,SVM,KNN,RF and ANN for crop and fertilizer recommendation modules. RF outperforms them all for both the modules	Provides services such as marketplace and farm discovery . The random forest algorithm provides the higher accuracy than other models	No multilingual support, can integrate pant disease identification as well
KRISHI RAKSHAN - A Machine Learning based New Recommendation System to the Farmer	D. N. V. S. L. S. Indira, M. Sobhana, A. H. L. Swaroop, V Phani Kumar	RF is used for fertilizer recommendation, XGB is used for crop recommendation and mobile net is used for crop disease detection.	predicts crop disease as well, RF, XGB and mobile net outperforms existing classifiers	No multilingual support.
Crop Recommendation with BiLSTM-MANN Algorithm for Precision Agriculture	J Sreemathy, N Prasath	BiLSTM-MERNN model outperforms Multilayer Perceptron and CNN model for crop recommendation system	effectively learn and understand complex temporal patterns related to weather conditions and soil properties, high accuracy, scalable to handle large dataset	no such specific interface or GUI which can be used by farmers, can integrate plant disease identification and fertilizer recommendation as well
An Enhanced Light GBM Model with Data Analytical Approach for Crop Recommendation	Namrata Bhatt, Sunita Varma	Light GBM model provides more accuracy than logistic regression model for crop recommendation system.	High efficiency, faster training, easily handle large dataset, high accuracy, high scalability	no such specific interface or GUI which can be used by farmers, can integrate plant disease identification and fertilizer recommendation as well
Crop Yield Prediction and Fertilizer Recommendation System Using Hybrid Machine Learning Algorithms	K P K Devan; B Swetha; P Uma Sruthi; S Varshini	Random Forest and Logistic Regression hybrid model outperforms individual models like RF,DCT,SVM,LR,etc.	High accuracy due to hybrid model	Hybrid models introduce complexity, have overfitting risks and hard to maintain
An Efficient Machine Learning Approaches for Crop Recommendation based on Soil Characteristics	Nidhi H Kulkarni; G N Srinivasan; B M Sagar; N K Cauvery	Real time data gathered using Arduino uno and sensors , KNN Classifier used for crop prediction	KNN is non-parametric and thus simple to construct	Can not handle large dataset
Machine Learning based Crop Recommendation on a Cloud	Mohammed Abdul Raheem; Mohammed Sabir Hussain; Syed Ayaan Ahmed	Model deployed on cloud for faster processing,RF gives best accuracy out of DCT,LR,XGB	A cloud platform allows organizations to rapidly deploy applications and services, and provides the ability to store and analyze large amounts of data.	Cloud Disadvantages include Downtime, data security, cost, vendor lock-in, latency, limited control.

Crop Recommendation and Disease Detection using Deep Neural Networks	Anuraj Singh, Amit Kumar Bhamboo	ANN is used for crop recommendation systems and 2d CNN is used for plant disease detection systems.	ANN can identify complex patterns and relationships between agricultural data and have high scalability. CNN are specializer for images, provides effective feature extraction, high accuracy, highly scalable and accurate	no such specific interface or GUI which can be used by farmers.can integrate fertilizer recommendation as well
ENSEMBLED CROPIFY – Crop & Fertilizer a System with Leaf Disease Prediction	K. Devi Priya; A. Sasi Samyogitha; A. Vamsi Krishna Reddy; B. Divya Sri	RF gives best accuracy for crop prediction, RF and SVM combined are use for Fertilizer recommendation , CNN with ResNet is used for leaf disease prediction	ResNet mitigate the overfitting problem making it easier to train Neural Networks and aids in preventing vanishing gradient problem	Computationally Expensive, less interpretability
Crop Recommendation using Machine Learning and Plant Disease Identification using CNN and Transfer-Learning Approach	Shivesh Tiwari; Somesh Kumar; Sunil Tyagi; Minakshi Poonia	RF emerged as most accurate algorithm for crop prediction and For Plant Disease Identification EfficientNetV2 outperformed other CNN architectures	Improved efficiency, better performance, parameter efficiency, faster training, state-of-the-art accuracy due to EfficientNetV2	Complexity, increased computational requirements due to EfficientNetV2
A Machine Learning-based Approach for Crop Yield Prediction and Fertilizer Recommendation	Jeeva Ganesh R; Harish D; Priya B	Government dataset is used, AdaBoot used for crop recommendation and Fr used for fertilizer recommendation	Ensemble models are use which grant stability , reduce overfitting, make better predictions thus increasing accuracy	Increased training time , is more complex and computationally expensive
Using A Two-Fold Machine Learning Approach for Crop And Fertilizer Recommendation System	Ginka Hemdeep; Anumukonda Sowjanya; . Matilda Florence	Crop prediction and fertilizer recommendation is done using DCT,NB,LR,RF,SVM,XGB. Comparative analysis was performed	Ensemble models are used which help increase accuracy and give better results overall	Can integrate plant disease prediction module as well

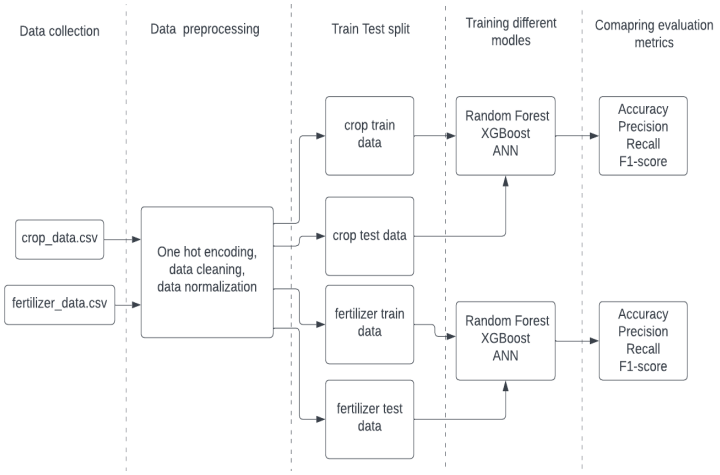

Fig. 1. Block Diagram

The crop-related dataset, presented as a CSV file, encompasses essential parameters such as Nitrogen (N), Phosphorous (P), Potassium (K) ratios in the soil, temperature, humidity, pH value, rainfall, and crop type. On the other hand, the fertilizer-related dataset, also structured as a CSV file, includes variables like temperature, moisture, soil composition, crop type, and the recommended N, P, K content, as well as the suggested fertilizer.

2. Data Preprocessing: Prior to model development, thorough data preprocessing was conducted. This phase involved several critical steps, including one-hot encoding of categorical variables to make them suitable for modeling, normalization of numerical features to bring them to a consistent scale, and rigorous data cleaning which involved removing duplicates and handling any missing values present in the datasets. These preprocessing steps were pivotal in ensuring the quality and suitability of the data for machine learning.

4. Splitting the Dataset: To assess model performance accurately, the dataset was split into two distinct subsets. The larger portion is designated as the training dataset. This subset served as the foundation for training the machine learning models. The remaining portion was reserved for the testing dataset, which was kept separate to evaluate the models performance. This clear segregation between training and testing data helps in minimizing overfitting and accurately gauging model generalization.

5. Training the Dataset: Three distinct machine learning models were employed such as XGBoost, Random Forest and an Artificial Neural Network for both, Crop as well as Fertilizer Recommendation Systems. These models were trained on the training dataset, learning patterns and relationships within the data. During the training process, each model was fine-tuned and optimized to make accurate predictions based on the input features.

i. Random Forest, an adaptable ensemble learning technique, is the preferred choice for navigating the complex landscape of the research's data. Its standout feature is its ability to handle large datasets with numerous variables, a characteristic that aligns seamlessly with the intricate agricultural data at hand. By harnessing the power of the

Random Forest algorithm, a network of decision trees is created. When combined, these decision trees result in robust and dependable recommendations. The goal is to leverage Random Forest's capabilities to provide precise guidance to the farming community, taking into account the intricate interplay of environmental and soil factors in crop selection and fertilizer application.

ii. XGBoost, a versatile gradient boosting algorithm, is a valuable asset in the research endeavor. It is known for its computational efficiency and a strong track record of predictive accuracy. XGBoost excels in handling structured data, making it well-suited for the complexities of the agricultural dataset. Its ability to capture intricate data relationships becomes particularly important when crafting tailored recommendations for farmers. Ongoing research will explore the extent to which XGBoost can optimize crop and fertilizer recommendations, ultimately leading Indian farmers toward increased crop yields and economic prosperity.

iii. Artificial Neural Networks (ANNs), inspired by the architecture of the human cerebral cortex, emerge as the third key element in the research effort. ANNs have earned recognition in various domains, from image recognition to natural language processing. In this agricultural context, ANNs hold the potential to reveal subtle patterns and nonlinear correlations hidden within the intricate dataset. By harnessing the deep learning capabilities inherent in ANNs, the aim is to build a recommendation system that empowers Indian farmers with unique insights into crop selection and fertilizer utilization. The ultimate aim is to facilitate informed decision-making, paving the way for improved crop yields and economic well-being.

6. Comparing Evaluation Metrics: Once the models have undergone training, they undergo thorough evaluation using a set of crucial performance metrics. These metrics encompass Precision, Accuracy, Recall, and F1-score, collectively offering a thorough assessment of the models' capabilities in providing precise crop and fertilizer recommendations. By comparing the results obtained from each model across these metrics, it is easy to identify the most effective and reliable model for both crop and fertilizer recommendation. The equations 1 to 4 discusses formulae to calculate performance metrics.

i. Accuracy: Accuracy measures the overall correctness of recommendations. It quantifies the percentage of correct predictions out of all predictions made.

$$Accuracy = \frac{True\ Positive + True\ negative}{True\ Positive + False\ Positive + True\ Negative + False\ Positive} \quad (1)$$

ii. Precision: Precision evaluates the model's ability to make relevant recommendations. It calculates the ratio of true positive recommendations to the total number of positive recommendations.

$$Precision = \frac{True\ positive}{True\ Positive + False\ Positive} \quad (2)$$

iii. Recall: Recall gauges the model's ability to identify all relevant recommendations. It calculates the ratio of true positive recommendations to the total number of actual positive cases.

$$Recall = \frac{True\ positive}{True\ Positive + False\ Negative} \quad (3)$$

iv. F1-Score: The F1 score is a metric that assesses the equilibrium between precision and recall when performing a classification task. It considers both false positives and false negatives and provides a single numerical value that represents the model's overall performance.

$$F1 - score = \frac{2 * precision * Recall}{Precision + Recall} \quad (4)$$

IV. Conclusion

This study proposed a system that represents an advancement in optimizing agricultural practices through machine learning and predictive analytics. The proposed model has been successfully developed to accurately predict suitable crops and fertilizers based on a rich dataset comprising features for better recommendations. The research involved data preprocessing, including cleaning, feature engineering, and normalization, which ensured the reliability of the results. The optimal model for recommendations, the proposed approach compared models like XGBoost, Random Forest, and Artificial Neural Networks (ANN) for both crop and fertilizer recommendation based on soil conditions. These comparisons will further refine the recommendation system's accuracy and utility. Looking ahead, the commitment to ongoing innovation aims to further enhance
sustainable agricultural resource management, offering substantial benefits to farmers and the global food supply chain.

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