

A Lightweight ML-Based Web System for Real-Time Crop and Fertilizer Recommendation

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Abstract—Agricultural productivity is significantly influenced by soil nutrients and environmental conditions, yet traditional crop selection methods often rely on limited knowledge, leading to inefficient resource utilization and reduced yield. This paper proposes a lightweight machine learning-based web system for real-time crop and fertilizer recommendation. The system analyzes key parameters such as nitrogen, phosphorus, potassium, temperature, humidity, rainfall, and soil pH to predict suitable crops and recommend appropriate fertilizers. Multiple machine learning models, including Decision Tree, Random Forest, SVM, KNN, and Logistic Regression, are evaluated. Experimental results show that the Random Forest model achieves the highest accuracy of 99.31%, while the Decision Tree model is selected for deployment due to its lower computational complexity and faster execution. The system is implemented as a web application using the Flask framework, enabling farmers to obtain real-time recommendations easily.

Index Terms—Artificial Intelligence, Crop Prediction, Decision Tree, Fertilizer Recommendation, Machine Learning, Precision Agriculture, Smart Farming, Soil Nutrient Analysis.

I. INTRODUCTION

Agriculture is really important for making sure we have food to eat. It also helps the economy in countries, like India that are still growing. Agriculture does a lot of things for these places. Crop yield is largely dependent on the nutrient status of the soil, climatic factors, and fertilizer management practices. However, farmers generally adopt conventional farming practices and human decision-making while choosing the crops to be cultivated, which might lead to low crop yield and economic losses for the farmers. Therefore, intelligent decision-making tools are of vital importance in the enhancement of agricultural productivity.

Artificial Intelligence and Machine Learning are getting better and better. This means we can make agricultural practices better by looking at all the information we get from the soil and the environment. Artificial Intelligence and Machine Learning can help us decide which crops to grow. We can use Machine Learning to figure out which crops will do well in our area. It checks things like how many nutrients are in the soil how

much rain we get, how humid it is and how hot or cold it is. It also checks how acidic or basic the soil is. All this information helps us choose the crops. The Machine Learning algorithms look at the soil and the weather to tell us which crops will grow well. We can use this information to grow crops that do well in our soil and weather. The soil needs to have the amount of nutrients for the crops to grow. The amount of rainfall and humidity and temperature all play a part in deciding which crops we can grow. The pH of the soil is also very important, for the crops. [1].

Many crop recommendation systems only think about what crop to plant and do not think about what fertilizer to use. This is a problem because fertilizer is just as important as the crop for keeping the soil healthy and making sure we get a lot of food from the farm. This system uses ML to find out what crop to plant and what fertilizer to use. It looks at the soil and the environment to make these decisions. The crop prediction and fertilizer recommendation system uses all of these things to decide what to do. The system is used for determining crops and suggesting fertilizers based on the condition of the soil and the environment.

In this approach, supervised machine learning methods are applied to data set preprocessing, training prediction models, and evaluating the performance of prediction models. To make this accessible to farmers, the system is built into a simple web app using the Flask framework, so recommendations can be delivered quickly and easily.

The main points of this study are summarized below:

- * We want to make a model that can predict which crops will grow well. This model will use information about the soil and the environment.

- * We also want to help farmers use fertilizers efficiently. This means creating a system that recommends the amount and type of fertilizer based on the soil's nutrients.

- * Lastly we plan to build a web application that farmers can use in real-time to get advice, on crop and fertilizer management.

The proposed work differs significantly from existing systems, as this work includes both crop prediction and fertilizer recommendations using a ML approach. This system provides real-time recommendations using a light-weight web application, thereby enhancing efficient decision-making by the farmer community.

The structure of this paper is described as follows: Section II: This section talks about studies that are related to crop prediction using machine learning-based techniques. Section III: This section concludes proposed methodology and system architecture for developing the crop prediction system using soil and environmental parameters. Section IV: This section concludes experimental results and performance evaluation of the proposed predictive models. Section V: This section concludes the overall work done in this research and provides possible future work.

II. LITERATURE REVIEW

Some people who study crops have tried to use machine learning to figure out how crops will do. They want to know how much crops will produce. Ramesh and his team came up with a way to predict crops using a method called forest. This method is good because it can handle the farm data. They are trying to predict crops with this method. The random forest algorithm is good for predicting crops because farm data is not always easy to understand. Patel and Shah proposed a model that can predict crops using SVM. They got results but it was hard to choose the right parameters. Kumar and his team proposed a way to predict crops using deep learning techniques. They got results but it took a lot of computer power to do it. Ramesh and his team used the forest method, for crop prediction. Crop prediction is what they are trying to do. They used the forest algorithm for crop prediction.

People who work with precision agriculture systems try to guess how crops will do. Kalmani and others made a system that suggests what crops to plant using XGBoost and Random Forest methods. This system is really good at making guesses. It gets it right 99.3 percent of the time. Sawan and others also made a system that tries to guess how crops will do. They used Random Forest, SVM and LSTM methods. This system is also very good. It has a score of 0.963. This score shows how well it makes guesses. Anwar proposed a way to predict crops based on weather conditions. He used Random Forest and SVR methods. The R^2 value was 0.875. There is no feature related to soil in his method. Crop prediction and soil conditions are very important. Random Forest and crop prediction are used together. The crop prediction system uses Random Forest. The system is good, at making crop predictions.

With the advent of advanced deep learning architectures, researchers have also used sequential models for time series agricultural data. Singh et al. [7] have also developed a framework using DNN, ANN, and LSTM techniques to reduce the Mean Absolute Error by 40%. In addition, the determining capability of the model was also improved under climate variability conditions. Similarly, Elbasi et al. [8] have also used a combination of LSTM and Random Forest techniques

to achieve $R^2 = 0.84$ by integrating remote sensing and crop growth data. In addition to this, Yan et al. [9] have also used a combination of Transformer and GRU techniques using reinforcement learning to achieve MAE = 0.85 and also improved irrigation efficiency by 35

Ensemble and Sensor-based Methods have also received considerable attention in recent days. Priyanka et al. [10] implemented a random forest, XGBoost, ANN, and LSTM-based system for the prediction of soil moisture, which proved to be highly reliable with a high $R^2 \geq 0.90$ for IoT-based datasets. Similarly, Javed et al. [11] implemented a random forest and GBM-based system for the prediction of maize yield, which proved to be highly reliable with a high $R^2 = 0.89$.

With the integration of remote sensing technologies, researchers have improved spatial prediction accuracy. Vijayabaskaran and Singla [12] used Random Forest, Gradient Boosting, and Decision Trees, achieving $R^2 > 0.75$. Mishra et al. [13] proposed early prediction models using Random Forest and regression techniques, achieving less than 26% error and enabling timely agricultural decision-making. Furthermore, Muruganatham et al. [14] introduced Vision Transformer-based approaches such as Prithvi-EO, achieving an RMSE of 0.44 and R^2 was 0.81, demonstrating strong performance in satellite-based yield prediction.

Recent advancements have also explored object detection and computer vision techniques in agriculture. Kolipaka and Namburu [15] proposed a YOLO-based framework that achieved mAP@0.5 was 93.3% for plant health detection, highlighting the potential of real-time monitoring systems, although it does not directly address yield prediction.

Even though we are making progress in predicting crops using ML and DL most research has focused on how accurate the predictions are, not on helping farmers make decisions. The proposed approach looks at the decision-making process. It combines the Decision Tree method with a web platform. These techniques are being used to make predictions more accurate. However the proposed approach goes further by integrating with a web platform. This integration makes the prediction process more efficient. Farmers can quickly get predictions. Make informed decisions. The Decision Tree approach is used to make predictions. It is a yet effective method. The web platform makes it easy to deploy and use. This system helps farmers make the decisions. It uses ML and DL to improve predictions. The proposed approach is a step in the direction. It addresses the limitations of research. The focus is, on a suggesting system. This system is fast, interpretable and deployable.

TABLE I: Comparative Literature Survey

Author	Year	Method	Strength	Limitation
Ramesh et al.	2020	Random Forest	High accuracy	No deployment
Patel & Shah	2021	SVM	Good classification	Complex tuning
Kumar et al.	2022	Deep Learning	Strong performance	High computation
Proposed Work	2026	Decision Tree + Web	Fast and deployable	Dataset dependent

III. MATERIALS AND METHODS

The system they are talking about is going to use the data to figure out what crops can be grown grounded on the nutrients in the soil and the weather. This system is supposed to help people make decisions when it comes to farming.

The system is shown in the picture : Fig. 1

The system has a lot of things to consider. The soil in the system has things like nitrogen and phosphorus and potassium. It also looks at the temperature. The system is really, about the soil and the weather and the crops that can be grown in it.

Preprocessing of the dataset is performed to handle missing values and normalize features using StandardScaler or Min-MaxScaler. Machine learning models are trained to determine patterns for crop suitability, and Decision Tree classifier provided a good trade-off between precision and efficiency. The trained model is used to develop a website based on Flask to give farmers real-time crop and fertilizer suggestions.

A. Inputs

- Nitrogen
- Phosphorus
- Potassium
- Temperature
- Humidity
- pH
- Rainfall

The method we are talking about is grounded on using intelligence and ML to Suggest crops and suggest the right fertilizers. This is done by looking at things that have to do with the soil and the environment. We use intelligence and machine learning to make these predictions and suggestions, about crops and fertilizers. The proposed architecture is divided into three different levels or sections, namely Data sourcing and aggregation , data preprocessing and feature engineering, and the modeling and prediction engine.

1) *Fertilizer Recommendation Logic*: The fertilizer recommendation is based on what the soil's missing, like nitrogen, phosphorus and potassium. We look at what nutrientsre not enough in the soil. Then we use the predicted crop and nutrient levels to figure out what fertilizer to use. This is done by following some rules to recommend the right fertilizers, for the soil and the crop like nitrogen and phosphorus and potassium fertilizers. For example, deficiency of nitrogen can be addressed by using urea, whereas phosphorus and potassium deficiencies can be addressed by using DAP and MOP fertilizers.

TABLE II: Datasets Used for Crop Prediction

Dataset Name	Description	No. of Records
Crop_recommendation.csv	Raw soil-climate dataset	2,200+
Preprocessed_data.csv	Cleaned data for ML training	2,000+
New_unseen_data.csv	Samples for testing	200+

B. Description of Collected Data

The data used for this study is grounded on a publicly available data set used for crop recommendations. The data set has approximately 2,200 records, and the features include data such as N, P, K, T, H, R, and pH. This data set has all kinds of environmental factors and crops, and it can be used for any kind of machine learning-based predictions. At this level, the data concerning agriculture is collected with the help of historical data concerning soil and climate. The attributes that are used at this level are N, P, K, T, H, R, and pH.

Each agricultural sample is represented as a feature vector defined as:

$$x = [N, P, K, T, H, R, pH] \quad (1)$$

The feature vector defined in (1) denotes the entire profile of environmental and soil conditions used for crop prediction.

C. Data Preprocessing

The agricultural data collected undergoes preprocessing to remove inconsistencies and improve model performance.

1) *Feature Scaling*: Since the attributes have different units and ranges, StandardScaler normalization is applied.

$$x_{scaled} = \frac{x - \mu}{\sigma} \quad (2)$$

2) *Label Encoding*: The crop data is converted into numerical data in order to be compatible with the machine learning model.

$$y = \text{LabelEncoder}(\text{crop}) \quad (3)$$

where y represents the encoded crop class.

3) *Train-Test Splitting*: The information we have is split into two parts: the train data and the test data.

$$D = D_{train} \cup D_{test} \quad (4)$$

Typically, 80% is used for training and 20% for testing to ensure unbiased evaluation.

D. Modeling and Prediction

Multiple supervised machine learning algorithms are evaluated for crop prediction.

1) *Random Forest Model*: Random Forest makes decision trees and then combines what they predict. We use this to make a guess, about what fertilizers to use, like nitrogen, phosphorus and potassium to help the crop grow.

$$\hat{y} = \frac{1}{T} \sum_{t=1}^T f_t(x) \quad (5)$$

where T is the number of trees and $f_t(x)$ represents the prediction of the t^{th} tree.

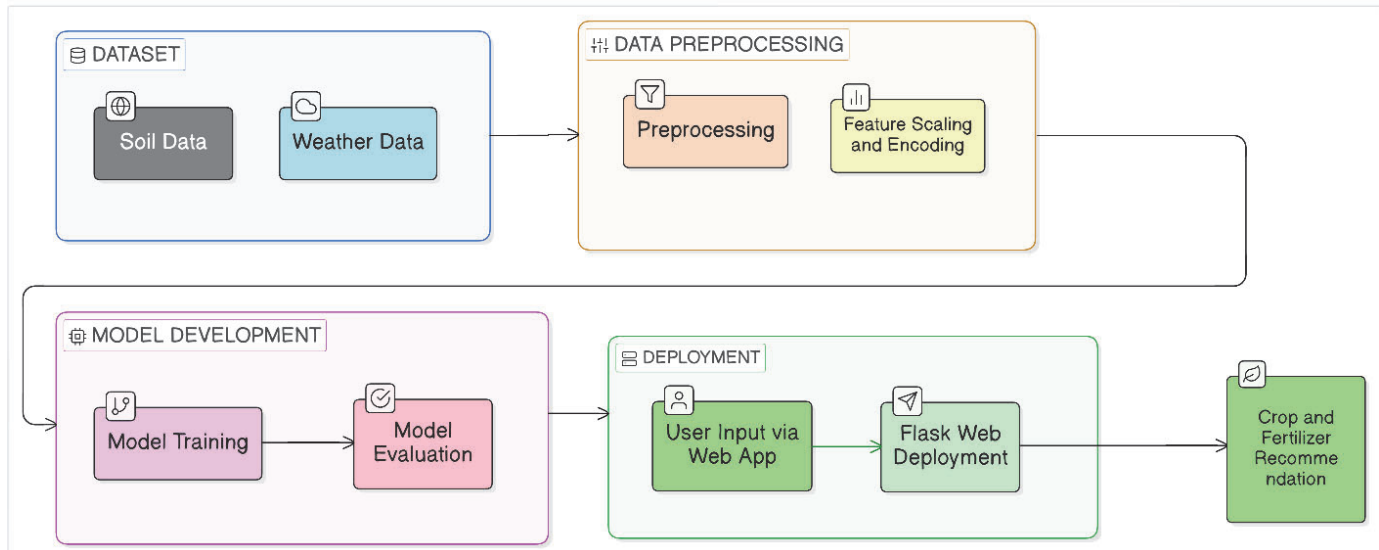


Fig. 1: Architecture of ML-Based Web System for Real-Time Crop and Fertilizer Recommendation

2) *Logistic Regression*: Logistic regression is a method that uses the sigmoid function to guess the chance of something belonging to a class.

$$P(y = 1|x) = \frac{1}{1 + e^{-(w^T x + b)}} \quad (6)$$

where w is the weight vector and b is the bias.

3) *Model Evaluation Metrics*: We look at how our models are doing by using some standard ways to measure how good they are, at putting things into categories and this helps us evaluate the performance of the fertilizer recommendation models specifically the models that recommend fertilizers.

Accuracy:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (7)$$

Precision:

$$Precision = \frac{TP}{TP + FP} \quad (8)$$

Recall:

$$Recall = \frac{TP}{TP + FN} \quad (9)$$

F1 Score:

$$F1 = 2 \times \frac{Precision \times Recall}{Precision + Recall} \quad (10)$$

where TP denotes True Positives, TN denotes True Negatives, FP denotes False Positives, and FN denotes False Negatives.

The Random Forest model had the highest accuracy of 99.31%, but the Decision Tree classifier was selected for the final implementation due to its lower computational complexity and faster execution time.

The proposed AI-based pipeline is a viable solution for precision agriculture, as it enables the farmer to make choices about crop selection and fertilizers.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The crop recommendation system was built using the Python programming language and Visual Studio Code Development Environment. The crop recommendation system was the central issue of analysis. This system uses machine learning algorithms to provide crop recommendations for the farmers. The crop recommendation system prepares the data, normalize the features, trains and deployed on the web for easier access. Various machine learning models were used in the development of this system. These models included Decision Tree, Random Forest, SVM, K-nearest neighbors and Logistic Regression. The above algorithms were used to analyze data based on soil and environmental conditions like Nitrogen, Phosphorous, Potassium, temperature, humidity, rainfall and pH value. The above algorithm was used to analyze data based on soil and environmental conditions to improve the crop recommendation system. The above factors affect the performance of the application. Therefore, this system uses these factors to make crop recommendations for farmers. Performance of the crop recommendation system was assessed through the analysis of the data generated by the experiment. It can be noted that the crop recommendation system is a great benefit to the farmers as it helps them in decision-making. Results From the experiment carried out in developing the precision crop recommendation system, it became evident that the random forest classifier performed better than other classifiers since it had accuracy of 99.31%. We compared the results we got from the machine learning model. Presented them in Table IV.

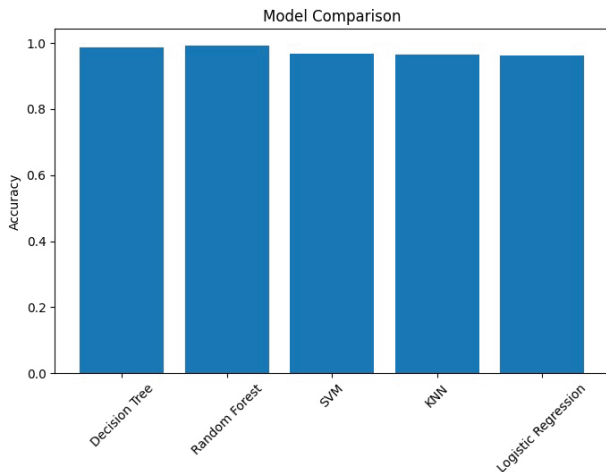


Fig. 2: Comparative Study of Algorithm Accuracy

A. Model Accuracy Comparison

Fig. 2 below shows the result obtained after performing the evaluation of different machine learning algorithms used for predicting crop production. Some of the best machine learning algorithms that can be used to predict crops include the random forest algorithm, decision tree algorithm, SVM, KNN, and logistic regression, among others.

B. Evaluation Using Confusion Matrix

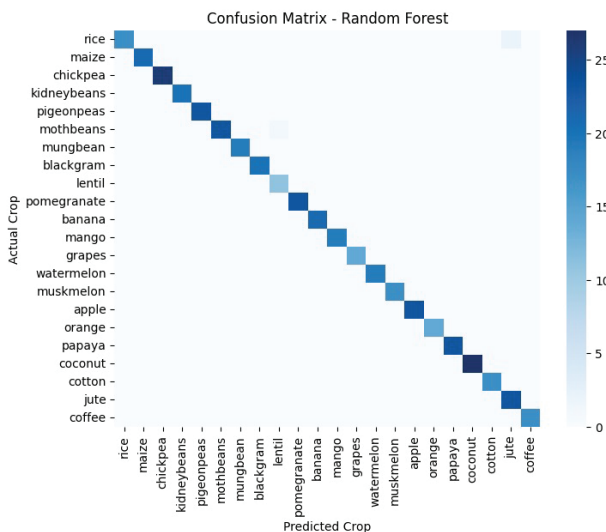


Fig. 3: Classification Analysis of Random Forest Crop Prediction Model

However, when considering the confusion matrix that was developed through the use of the random forest classifier shown in Figure 3, the crops which have been predicted by the developed model can be established. The observations from the confusion matrix above show that the predictions have been placed along the diagonal line. This is an indication that there

have been few mistakes made while predicting the types of crops through the random forest classifier model.

C. Model Evaluation Results

TABLE III: Analysis of Predictive Accuracy

Model	Accuracy
Random Forest	0.993182
Decision Tree	0.986364
SVM	0.968182
KNN	0.965909
Logistic Regression	0.963636

TABLE IV: Cross Validation Accuracy

Model	Mean CV Accuracy
Random Forest	0.9949
Decision Tree	0.9864
SVM	0.9847
KNN	0.9773
Logistic Regression	0.9699

As presented in table IV, the output of the Random Forest evaluation model shows an accuracy of 0.9931 in classifying the data. It is indeed worthy to be noted that the accuracy of the Random Forest model, according to the cross-validation test performed, showed an accuracy of 0.9949.

D. Feature Importance Analysis

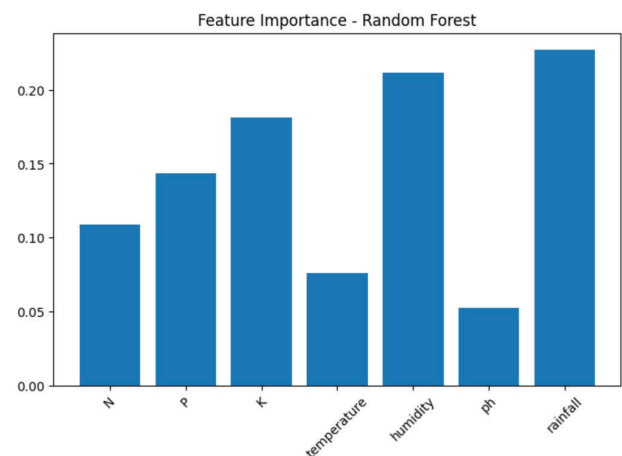


Fig. 4: Evaluation of Feature Relevance in Random Forest Model

This insight guides the selection and optimization of key variables to improve model accuracy and agricultural decision-making. As shown in Fig. 4, rainfall and humidity have significant influence on crop prediction, followed by soil nutrients such as potassium, phosphorus, and nitrogen. Temperature and pH also contribute to the prediction process.

E. System Interface

The trained model was used by deploying a machine learning model using a web application, making it easier for farmers to use. This is illustrated in Fig. 5, where one can input values

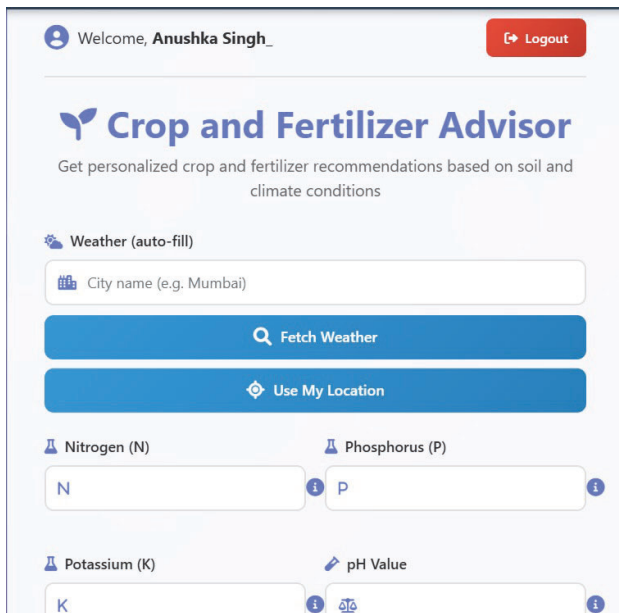


Fig. 5: Crop and Fertilizer Advisor Web Interface

for soil nutrient content, e.g., N, P, K, and pH, as well as environmental factors. Weather information may be obtained automatically based on the location of the user.

F. Prediction Output

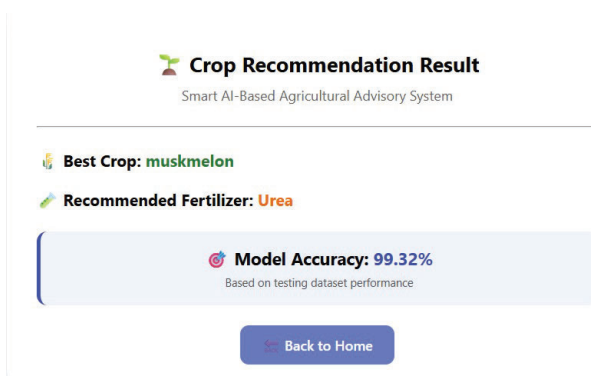


Fig. 6: Example crop recommendation output generated by the system

The last prediction output of the system is shown in Fig. 6. According to the input parameters provided to the system, the proposed model has predicted Muskmelon as the most suitable crop for planting and Urea fertilizer for use. The results we got from our experiment show that our intelligent crop recommendation system is really good at predicting what crops will do well. This system is very helpful for farmers who work in the field of agriculture and have to make decisions, about their crops. Our intelligent crop recommendation system gives farmers the information they need to make choices.

It is evident from the result that the suggested approach of Random Forest is more accurate than the suggested Decision Tree approach due to the complicated nature of the suggested

approach, but the suggested Decision Tree approach is fast in providing result in real time for farmers. The suggested approach is dependent on environmental conditions, like rainfall and humidity.

V. CONCLUSION AND FUTURE WORK

The work proposes a way to suggest crops and fertilizers. The system is designed to use machine learning for farmers make data-driven decisions. It looks at soil nutrient levels to recommend crops. The system also suggests fertilizers to improve soil nutrients. The goal is to make it easy for farmers to access and use. The system was built using machine learning steps. It has a web interface for easy access. The results show that this system is effective. It has accuracy and low computational complexity. This makes it suitable, for real-time use. The system can help farmers choose the crops and fertilizers. It considers soil nutrient values to make suggestions. The system aims to improve farming practices.

REFERENCES

- [1] W. Wang, Q. Zhang, and F. Yu, "Progress in Research on Deep Learning-Based Crop Yield Prediction," *Agronomy*, vol. 14, no. 10, 2024.
- [2] K. Meghraoui, I. Sebari, and J. Pilz, "Applied Deep Learning-Based Crop Yield Prediction: Current Developments and Challenges," *Technologies*, vol. 12, no. 4, 2024.
- [3] D. S. Dhaliwal and M. M. Williams, "Sweet Corn Yield Prediction Using Machine Learning Models," *Precision Agriculture*, 2024.
- [4] V. H. Kalmani, N. V. Dharwadkar, and V. Thapa, "Crop Yield Prediction using CNN-LSTM Deep Learning Algorithm," *Indian Journal of Agricultural Research*, 2025.
- [5] V. Sawan, R. Kumari, and M. Kayal, "Machine Learning Based Method for Forecasting Crop Yield," *Journal of Recent Innovations in Computer Science and Technology*, vol. 2, no. 3, 2025.
- [6] M. H. Anwar, "Crop Yield Prediction Using Machine Learning," *Journal of Innovative Computing and Emerging Technologies*, vol. 4, no. 2, 2024.
- [7] A. Singh et al., "Crop Yield Prediction using Machine Learning and Deep Learning Techniques," *Procedia Computer Science*, vol. 218, pp. 406–417, 2023.
- [8] E. Elbasi et al., "Crop Prediction Model Using Machine Learning Algorithms," *Applied Sciences*, vol. 13, no. 16, 2023.
- [9] A. Venugopal et al., "Crop Yield Prediction using Machine Learning Algorithms," *IJERT*, 2021.
- [10] P. Priyanka et al., "Crop Yield Prediction using Machine Learning," *IJARCCCE*, 2025.
- [11] M. A. Javed et al., "Crop Yield Prediction in Agriculture: A Comprehensive Review," *Heliyon*, 2024.
- [12] V. Vijayabaskaran and G. Singla, "Machine Learning Based Crop Yield Prediction: A Review," *Journal of Agricultural Science and Technology*, 2025.
- [13] S. Mishra et al., "Crop Yield Prediction using Machine Learning: A Systematic Review," *Agricultural Technology*, 2024.
- [14] S. Mishra et al., "Machine Learning for Precision Agriculture and Crop Yield Prediction," *International Journal of Intelligent Systems*, 2024.
- [15] J. Muruganantham et al., "Crop Yield Prediction with Deep Learning and Remote Sensing," *Remote Sensing*, vol. 14, no. 9, 2022.
- [16] Y. Yan, Y. Wang, and J. Li, "Crop Yield Prediction Based on Hybrid Machine Learning Models," arXiv preprint, 2025.
- [17] R. Kumar et al., "Hybrid Machine Learning Model for Crop Yield Prediction," *Research in Intelligent Automation*, 2023.
- [18] A. Patel et al., "Crop Yield Prediction Using Machine Learning," *International Journal of Innovative Science*, 2024.
- [19] R. Kolipaka and A. Namburu, "Machine Learning and Deep Learning Techniques for Crop Prediction," *IJCCTS*, vol. 14, no. 1, 2023.
- [20] S. Ramesh, P. Reddy, and K. Rao, "Prediction and Analysis of Crop Yield using Machine Learning Techniques," *IJERT*, vol. 10, no. 05, 2021.