# *Crop Yield Prediction and Recommender System Using Machine Learning*


Nandini V
*Associate Professor*
*Sona college of Technology*
*Salem,India*
*nandinivijaykumar@sonatech.ac.in*

Shailaja V
*UG Scholar*
*Sona college of Technology*
*Salem,India*
*shailajavasu1607@gmail.com*

Satviksreeram V
*UG Scholar*
*Sona college of Technology*
*Salem,India*
*satviksreeram007@gmail.com*

Pallavarapu Chandu
*UG Scholar*
*Sona college of Technology*
*Salem,India*
*chanduyadav8890@gmail.com*



***ABSTRACT -- Crop production was formerly done using farmers' firsthand experience. However, the effects of climate change on crop output are already very noticeable. Because of this, farmers cannot choose the best crops based on soil and environmental factors, and manually choosing the best crop or crops for a particular plot of land has more frequently failed.. Machine learning is used to predict the best crop to grow in a particular land based on the parameters like Soil minerals, moisture, and temperature. By analyzing these parameters optimal crops to grow in particular land will be predicted by models trained using Random Forest, Decision Tree and Linear Regression. The best crop to produce will be predicted based on inputs such as temperature, moisture, and the amount of land minerals such as phosphorus, potassium, nitrogen, and pH value. The dataset is first gathered, and pre-processing is done. The models of Crop Recommendation, Yield Prediction, and Fertilizer Recommendation are then trained using supervised machine learning algorithms, followed by model evaluation and prediction. Crop recommendation accuracy is 96.30%, yield prediction accuracy is 97.80%, and fertilizer recommendation accuracy is 98.73% by using the Random Forest Algorithm.***



***KEYWORDS:***

***Crop Recommendation, Yield Prediction, Fertilizer Recommendation, Soil Contents, Humidity, and Temperature.***


## *1.INTRODUCTION*

Crop yield prediction is an important area of research in agriculture that aims to forecast the number of crops that will be harvested in a given season. Accurate crop yield predictions can help farmers make informed decisions about their farming practices, optimize resource allocation, and plan for market demands.

In recent years, machine learning algorithms have gained popularity for their ability to accurately predict crop yields by analyzing large volumes of data, including weather patterns, soil properties, crop type, and previous harvest yields. These algorithms use sophisticated mathematical models to detect patterns and relationships in the data and make predictions based on these patterns.
The proposed system will investigate the application of machine learning methods for crop yield predictions and recommendations. The system examines several datasets comprising details on the characteristics of the soil, the weather, and crop yields, and utilize this knowledge to train several machine learning models. Further, evaluate the performance of these models using various metrics and select the most accurate and reliable model for predicting crop yield. By the end, this proposed work aims to develop a machine learning-based tool that can accurately predict crop yields and help farmers optimize their farming practices using recommender systems.

## *2.LITERATURE REVIEW*

[1] S.P. Raja, et Al. discussed the use of machine learning techniques for crop yield prediction in agriculture. The authors highlight the importance of efficient feature selection methods in preprocessing raw data to create a Machine Learning friendly dataset. They emphasize that only relevant features should be selected to ensure high precision and accuracy in the ML model. To make sure that only the most pertinent features are included in the model, they suggest optimal feature selection.

[2] The work proposed by K. Gangadhara Rao and his colleagues aims to conduct a descriptive analysis on agricultural data using multiple machine learning techniques for the purpose of crop yield prediction. The study utilizes three datasets: the clay dataset, precipitation dataset, and production dataset of Telangana state. To predict crop yield, the researchers employ three different algorithms, one of which is K-Nearest Neighbor (KNN).

[3] In order to study several machine learning (ML) techniques used in the field of crop yield estimation, D. Jayanarayana Reddy, et al. presented the task. They wanted to perform a systematic review of the features used for crop yield prediction (CYP). More over 50% of the population in India depends on agriculture for survival, making it an important sector of the country's economy. Yet, changes in weather, climate, and other environmental factors are now a significant threat to the continued success of agriculture. As a result, using ML as a decision support tool for CYP can aid with decisions on what crops to produce and what to do during the crops' growing seasons.

[4] K. Ramu et al. discussed the many artificial neural networks, decisions trees, and support vector machines and linear regression, that are machine learning techniques used to forecast agricultural yields. According to the authors, models based on machine learning can aid in properly forecasting crop production, lowering cultivation costs, and increasing farmers' revenue.

[6] Thomas Van Klompenburga, et al. the proposed study in this research intends to extract and synthesize the techniques and features utilized in agricultural yield prediction studies that rely on machine learning. Temperature, region are the factors used to predict crop production. The prediction is based only on the geographical location and temperature. Different regions and crops may have unique features that affect yield prediction, which were not captured in this paper.

[7] Vrushali C. Waikar, et al. whose goal was to create a model that guides farmers in choosing which crops to produce on their farms based on the type of soil they have. The goal of this study was to create a model that guides farmers in choosing which crops to produce on their farms according to the kind of soil they have. The model did not account for environmental factors that can affect crop growth, such as pests, diseases, and weather events. These factors can have a significant impact on crop yield and should be considered in the mode.

[8] Seema Patil, et al. proposed the work that aims to help farmers in India to check their soil quality and predict crop yield using machine learning and data mining techniques. The system analyzes data from different perspectives to provide useful information to farmers about their soil types and suggest suitable fertilizers to maximize crop yield.

[9] M. Kalimuthu And et al., discussed the effectiveness of different machine learning methods for predicting agricultural yields is compared in the study, including logistic regression, neural networks, decision tree, and support vector machines. The best methods for predicting crop yield, according to the authors, are support vector machines and artificial neural networks.

[10] P. S. Nishant and et al. in their paper offered a thorough analysis of agricultural yield prediction utilizing several machine learning methods, such as decision trees, neural networks, support vector machines, and random forests. The authors concluded that crop output predictions made using machine learning approaches are accurate and give farmers the information they need to make wise choices.

[12] V. S. Rajpurohit et al. used Logistic regression, neural nets, decisions tree, & support vector machines machine learning techniques and reviewed agricultural yield prediction. According to the authors, models based on machine learning can assist in increasing agricultural productivity and minimizing the effects of climatic change on agriculture.

[13] A. Nigam et al., discussed the many machine learning methods, such as artificial neural networks, decisions tree, and support vector machines, that are used to estimate agricultural yields. The authors concluded that machine learning approaches may considerably raise the accuracy of agricultural production forecast and lower crop loss.

## *3.RESEARCH GAP ANALYSIS*

According to the literature analysis, soil qualities where not considered when considering current climate factors, and vice versa. It has also been discovered that systems for recommending fertilizers based on soil contents are not incorporated along with information of diseases and growth guide. The proposed model does recommendation of best crop along with yield prediction for the factors of soil contents namely Nitrogen, Phosphorous, Potassium and pH level along with Humidity and Temperature. In fertilizer recommender model the parameters used for prediction is the soil contents which are similar as crop recommender and prediction models.

## *4.PROPOSED WORK*

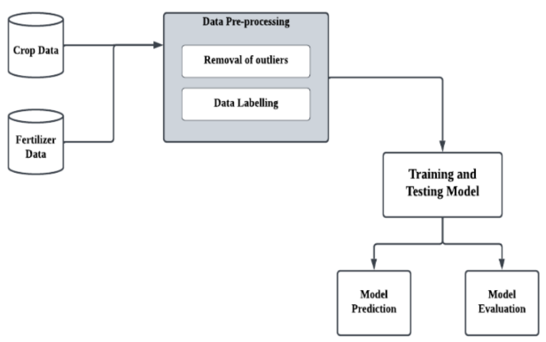


Figure. 4.1 System Architecture Diagram

A machine learning-based methodology was presented forth to recommend a crop and predict its yield utilizing input data related to soil contents (N, P, K, pH) and significant climate variables (humidity and temperature) as shown in Figure 4.1. Using a vast dataset of agricultural growth and production, the model is been trained to suggest crops, suggest fertilizers, and predict yield. Several data preparation methods, like labelling fertilizers and crops, have been used. The train-test split ratio for the crop and fertilizer dataset was 70:30.

In order to fine-tune the hyperparameters for the machine learning algorithm, a model was created using the Random Forest Algorithm with GridSearchCV. To suggest crops, fertilizers, and forecast yields, a UI based on Python Flask has been created.

### *4.1 DATASETS*

To utilize machine learning algorithms such as Random Forest, Decision Tree and logistic regression for predicting crop production and suggesting fertilizers, various data related to crop yield and its determining factors are typically gathered. These factors may include weather data, soil data, fertilizers used, types of crops, etc.

2200 data of crop development related to soil characteristics, humidity, and temperature can be found in the UCI Repository. The Kaggle database contains 2000 records of yield based on climate and soil characteristics and 1000 records of fertilizers related to soil components.


Figure. 4.2 Crops that are considered in proposed work.

Once the data is collected, it is cleaned, pre-processed, and prepared for analysis. This involves checking for missing or erroneous values, transforming the data into a suitable format for analysis, and selecting the relevant features that will be used for modeling and prediction.

### *4.2 DATA PRE-PROCESSING*

Data preprocessing, which involves preparing the original data for machine learning algorithms, is an important stage in crop production prediction using machine learning.

#### *4.2.1 DATA NORMALIZATION*

This involves transforming the data into a standard format by removing duplicates, normalizing values, and identifying outliers. Each column is eliminated with the outliers from the raw dataset.

### *4.2.2 DATA REDUCTION*

In this step, the dataset is reduced by eliminating irrelevant features which the proposed work don't account into prediction and recommendation.

### *4.2.3 DATA LABELLING*

Crop labelling is done to make it easier to predict the crop and recommend fertilizers since it include a lot of numbers.

| Actual | Encoded |
|---|---|
| ***Apple*** | 01 |
| ***Banana*** | 02 |
| ***Chicken peas*** | 03 |
| ***Coconut*** | 04 |
| ***Coffee*** | 05 |
| ***Cotton*** | 06 |
| ***Grapes*** | 07 |
| ***Jute*** | 08 |
| ***Kidney bean*** | 09 |
| ***Lentil*** | 10 |
| ***Maize*** | 11 |
| ***Mango*** | 12 |
| ***Moth bean*** | 13 |
| ***Mung bean*** | 14 |
| ***Musk melon*** | 15 |
| ***Orange*** | 16 |
| ***Papaya*** | 17 |
| ***Pigeon peas*** | 18 |
| ***Pomegranate*** | 19 |
| ***Rice*** | 20 |
| ***Watermelon*** | 21 |

Table 4.1 Crop Labelling

| *Actual* | *Encoded* |
|---|---|
| *Ten-Twenty Six-Twenty Six* | 01 |
| *Fourteen-Thirty Five-Fourteen* | 02 |
| *Seventeen-Seventeen-Seventeen* | 03 |
| *Twenty-Twenty* | 04 |
| *Twenty Eight-Twenty Eight* | 05 |
| *DAP* | 06 |
| *Urea* | 07 |

Table 4.2 Fertilizer Labelling

The preprocessed data has 2200 records. Based on the crop label all features are studied.

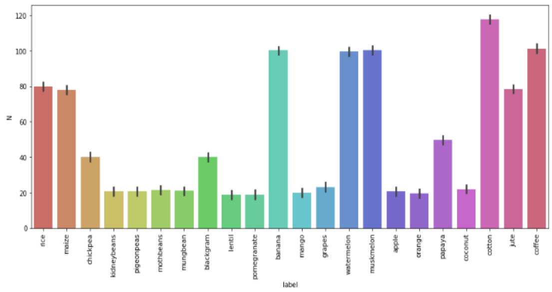


Figure 4.3 Relation between N(soil) to crop label.

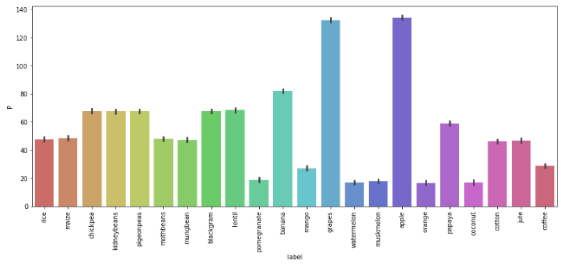


Figure 4.4 Relation between P(soil) to crop label.

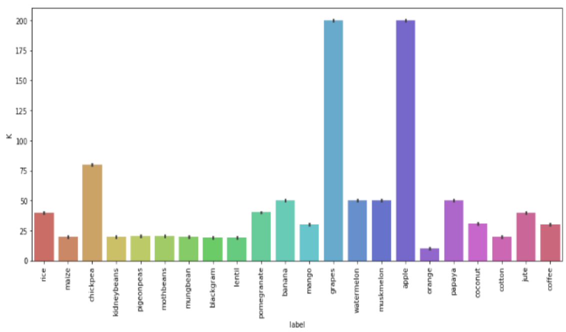


Figure 4.5 Relation between K(soil) to crop label.

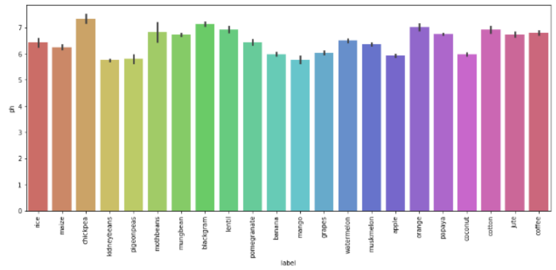

Figure 4.6 Relation between pH(soil) to crop label.

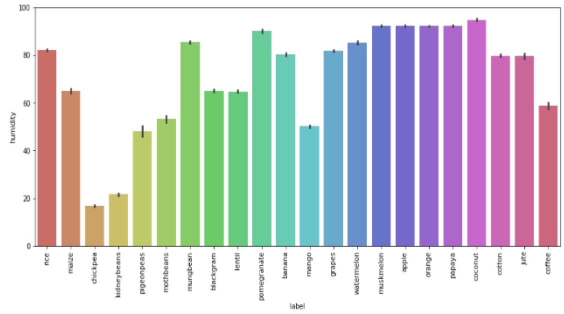

Figure 4.7 Relation between Humidity(climate) to crop label.

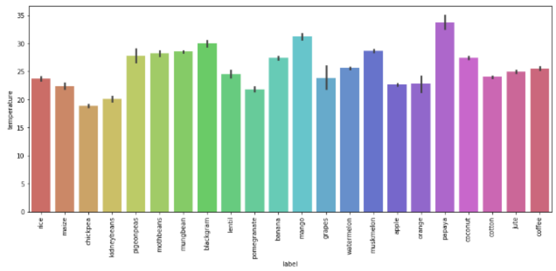

Figure 4.8 Relation between Temperature(climate) to crop label.

Figure 4.3, 4.4, 4.5 depicts the impact as for each Nitrogen (%), Phosphorus (%), Potassium (%) of the soil to the growth of each crop respectively whereas 4.6 depicts the pH value of the soil impacts the crops considered; And 4.7,4.8 depicts the impact of climatic features such as Humidity and Temperature to the growth of each crop respectively.

### *4.3 ALGORITHM*

The algorithms used in machine learning are the ones that allow software to autonomously forecast results, discover hidden patterns in data, and enhance performance. Currently, the preprocessed data has been divided into training and testing datasets at a proportion of 70:30. Random Forest, logistic regression, and decision tree were three distinct supervised learning algorithms that were implemented. Performance measures including accuracy, precision, and confusion matrix are used to assess the algorithm's performance.

#### *4.3.1 DECISION TREE*

The decision tree algorithm can solve both classification and regression problems in machine learning. It employs a tree-shaped model, where every internal node indicates a test conducted on a feature attribute. The branches of the tree represent the potential outcomes of the test, and the leaf nodes denote the predicted class label or regression value.

$$Gini\ index = 1 - \sum p^2 \qquad (1)$$

$$= 1 - [(p+)^2 + (p-)^2] \qquad (2)$$

where p+ denotes the likelihood that the answer is "yes" or "good" and p-, "no" or "bad."

The algorithm recursively splits the dataset based on the most significant features such as soil contents, creating branches that lead to leaf nodes containing the predicted results. Once the decision tree model is constructed, it can be used to predict results for new data by following the branches of the tree based on the values of the features in the data.

#### *4.3.2 RANDOM FOREST*

Random forest is a supervised learning approach that involves creating numerous decision trees by randomly selecting subsets of the training data. Unlike a single decision tree, this algorithm builds multiple trees and aggregates their predictions to generate the final output, as shown in Figure 4.9.

The algorithm can be trained using historical data on crop yields, weather conditions, soil quality, and other relevant variables. The algorithm will then learn to identify patterns and relationships between these variables and crop yields.

The key strength of the random forest algorithm is its ability to reduce overfitting and enhance the generalization performance of the model. It achieves this by introducing randomization in the tree-building process, which results in trees that are less sensitive to small variations in the training data.

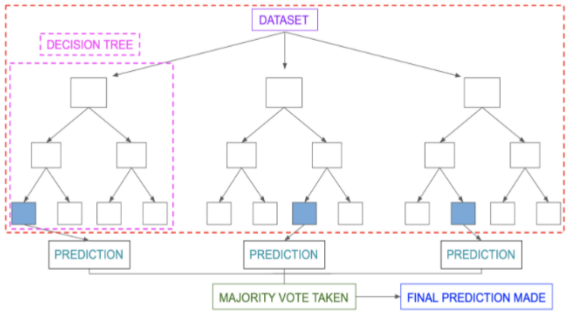


Figure 4.9 Concept of Random Forest Algorithm.

#### *4.3.3 LOGISTIC REGRESSION*

In logistic regression, the goal is to model the probability that an instance belongs to a certain class as a function of its features. This is achieved by fitting a logistic function, also known as a sigmoid function, to the training data. The logistic function maps any input value to a value between 0 and 1, which can be interpreted as the probability of the input belonging to a certain class.

$$\text{sigmoid}(x) = 1 / (1 + \exp(-x)) \qquad (3)$$

where x is the input to the function.

The logistic regression model uses a sigmoid function which is shown in equation (3) to transform the predicted values into probabilities of a high yield. The model then uses a threshold value to convert the probabilities into binary predictions.

The best classifier is chosen based on performance criteria, and the best and strongest classifier is employed in the best model. The performance of the model is used to design the User Interface.

### *4.4 GRID SEARCH CV*

GridSearchCV is a method for optimizing the hyperparameters of a machine learning model. It does a thorough search across a specified hyperparameter space, cross validating each combination of hyperparameters, to find the best set of parameters for the model.

```
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import accuracy_score, classification_report

params = {
    'n_estimators':[300,400,500],
    'max_depth':[5,6,7],
    'min_samples_split':[2,5,8]
}
grid_rand = GridSearchCV(rand,params,cv=3,verbose=3,n_jobs=-1)

grid_rand.fit(x_train,y_train)

pred_rand = grid_rand.predict(x_test)

print(classification_report(y_test,pred_rand))

print('Best score : ',grid_rand.best_score_)
print('Best params : ',grid_rand.best_params_)
```

Figure 4.10 GridSearchCV.

As illustrated in Figure. 4.10, the parameter grid for a Random Forest Classifier includes the number of trees, the maximum depth of each tree, and the minimal amount of samples required to split an internal node.

## *5.RESULTS AND DISCUSSION*

### *5.1 USER INTERFACE RESULTS*

Flask is a powerful and adaptable web framework that offers a simple and intuitive interface for creating web applications in Python. Its minimalist design and ease of use make it a popular choice for developers who want to quickly create high-quality web applications.

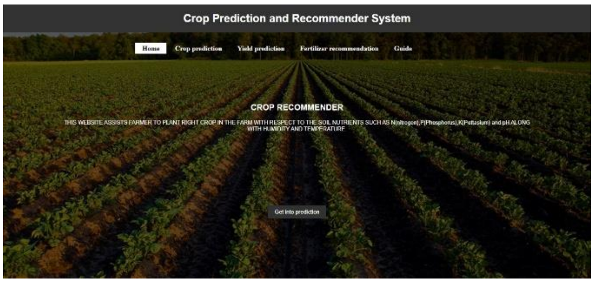


Figure 5.1 UI of System


Figure 5.2  Crop Recommender UI

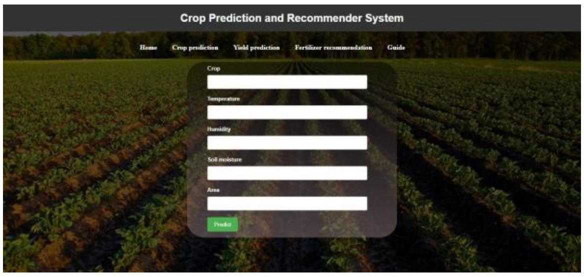


Figure 5.3 Crop Predictor UI

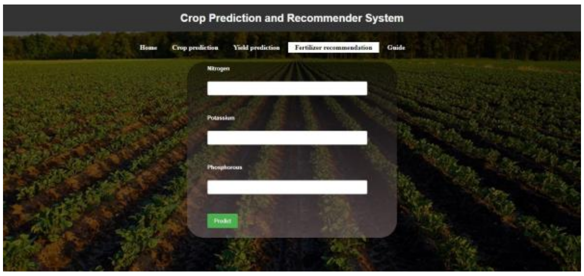


Figure 5.4 Fertilizer Recommender UI

The Home page (i.e., the landing page) of the application is shown in Figure 5.1. The Figure 5.2 depicts the User Interface of crop recommendation accepts the Soil content levels (N, P, K, pH), Humidity and Temperature. Figure 5.3 is the User Interface of yield prediction accepts the Soil content levels (N, P, K, pH), Humidity, Temperature and crop planted. The User Interface of fertilizer recommendation accepts the Soil content levels (N, P, K) is shown in Figure 5.4.

Figures 5.5, 5.6, and 5.7, respectively, show the results of crop recommendation, yield prediction, and fertilizer recommendation that take into account soil content levels (N, P, and K).


Figure 5.5 Output of Crop Recommender


Figure 5.6 Output of Yield Predictor


Figure 5.7 Output of Fertilizer Recommender

*5.2 PERFORMANCE METRICS RESULTS*

The amount of successful predictions made by the model on the test set is measured by accuracy. The three classifiers' accuracy is computed. The outcomes are displayed in Table 5.1. With high accuracy, the random forest fared better.

| Model/algorithm | Random Forest | Logistic Regression | Decision Tree |
|---|---|---|---|
| Crop Recommendation | 96.30% | 87.42% | 95.00% |
| Yield Prediction | 97.80% | 89.77% | 92.14% |
| Fertilizer Recommendation | 98.73% | 90.31% | 94.86% |

Table 5.1 Accuracy Table

Machine learning classifiers frequently employ the support and confusion matrices as classification criteria. This evaluation indicator is frequently used to offer a thorough evaluation of a model's performance.

```
              precision    recall  f1-score   support

           0       1.00      1.00      1.00        22
           1       1.00      1.00      1.00        18
           2       0.96      1.00      0.98        22
           3       1.00      1.00      1.00        15
           4       1.00      1.00      1.00        18
           5       1.00      1.00      1.00        17
           6       1.00      1.00      1.00        22
           7       1.00      1.00      1.00        29
           8       1.00      0.52      0.68        25
           9       1.00      1.00      1.00        20
          10       1.00      0.94      0.97        18
          11       1.00      1.00      1.00        20
          12       1.00      1.00      1.00        17
          13       0.88      0.96      0.92        24
          14       1.00      1.00      1.00        24
          15       1.00      1.00      1.00        26
          16       1.00      1.00      1.00        15
          17       1.00      1.00      1.00        14
          18       0.94      0.84      0.89        19
          19       1.00      1.00      1.00        23
          20       0.52      1.00      0.68        13
          21       1.00      1.00      1.00        19

    accuracy                           0.96       440
   macro avg       0.97      0.97      0.96       440
weighted avg       0.97      0.96      0.96       440

Best score :  0.9630681818181818
Best params :  {'max_depth': 7, 'min_samples_split': 5, 'n_estimators': 300}
```

Figure 5.8 Accuracy score of Crop Recommender

```
MSE train: 26944903584726.379, test: 50029668712624.312
R^2 train: 0.978, test: 0.882
```

Figure 5.9 Accuracy score of Yield Predictor

```
              precision    recall  f1-score   support

           0       1.00      1.00      1.00         2
           1       1.00      1.00      1.00         3
           2       1.00      1.00      1.00         2
           3       1.00      1.00      1.00         3
           4       1.00      1.00      1.00         2
           5       1.00      1.00      1.00         2
           6       1.00      1.00      1.00         6

    accuracy                           1.00        20
   macro avg       1.00      1.00      1.00        20
weighted avg       1.00      1.00      1.00        20

Best score :  0.9873417721518988
Best params :  {'max_depth': 5, 'min_samples_split': 2, 'n_estimators': 300}
```

Figure 5.10 Accuracy score of Fertilizer Recommender

Machine learning algorithms typically use classification metrics such as precision, recall, F1 score, and support. These evaluation criteria are frequently used in tandem to provide a complete picture of a model's performance. Figures 5.8, 5.9, and 5.10, respectively, show the performance metrics of crop recommendation, yield prediction, and fertilizer recommendation.

*6. CONCLUSION AND FUTURE WORK*

In conclusion, this project demonstrated the use of machine learning models, specifically Random Forest, Logistic Regression (LR) and Decision Tree , for crop yield prediction based on soil contents ,weather and fertilizer data. The dataset used in the project consisted of historical crop yield data, along with weather and fertilizer data, and was split into training and testing sets.


Figure 6.1 Accuracy measures of various classification algorithms

As shown in Figure 6.1, the Random Forest model outperformed the LR model in predicting crop yields, with an accuracy of 96.30% (Figure 5.8), 97.80% (Figure 5.9) and 98.73% (Figure 5.10) The input features that had the most significant impact on crop yield prediction were temperature, humidity, N, P, K and pH.

The findings of the proposed work have important implications for the agricultural sector, as more accurate crop recommendations and yield prediction along with fertilizer recommendation can help farmers make informed decisions about planting and harvesting crops. The use of machine learning models can lead to higher crop yields and increased profits for farmers, ultimately contributing to food security and economic growth.

Overall, this system demonstrates the potential of machine learning for improving agricultural practices and highlights the importance of leveraging technology to address global challenges such as food insecurity.

In Future work, Micro-nutrients from the soil contents such as Calcium, Zinc, Manganese etc. can be included for the predictions and recommendations. Along with these the rainfall can also be included for the yield predictions.

## 7. REFERENCES


[1] S. P. Raja, B. Sawicka, Z. Stamenkovic and G. Mariammal, "Crop Prediction Based on Characteristics of the Agricultural Environment Using Various Feature Selection Techniques and Classifiers," in IEEE Access, vol. 10, pp. 23625-23641, 2022, doi: 10.1109/ACCESS.2022.3154350.

[2] Rao, K. Gangadhara, Keerthi Yashwanth, and M. Sridhar Goud. "Crop Yield Prediction by using Machine Learning Techniques." Annals of the Romanian Society for Cell Biology 25.6 (2021): 2551-2557.

[3] Reddy, D. Jayanarayana, and M. Rudra Kumar. "Crop yield prediction using machine learning algorithm." 2021 5th International Conference on Intelligent Computing and Control Systems (ICICCS). IEEE, 2021.

[4] K. Ramu and K. Priyadarsini, "A Review on Crop Yield prediction Using Machine Learning Methods," 2021 2nd International Conference on Smart Electronics and Communication (ICOSEC), Trichy, India, 2021, pp. 1239-1245, doi: 10.1109/ICOSEC51865.2021.9591764.

[5] R. J, V. K. G. Kalaiselvi, A. Sheela, D. S. D and J. G, "Crop Yield Prediction Using Machine Learning Algorithm," 2021 4th International Conference on Computing and Communications Technologies (ICCCT), Chennai, India, 2021, pp. 611-616, doi: 10.1109/ICCCT53315.2021.9711853.

[6] Van Klompenburg, Thomas, Ayalew Kassahun, and Cagatay Catal. "Crop yield prediction using machine learning: A systematic literature review." Computers and Electronics in Agriculture 177 (2020): 105709.

[7] Waikar, Vrushali C., Sheetal Y. Thorat, Ashlesha A. Ghute, Priya P. Rajput, and Mahesh S. Shinde. "Crop prediction based on soil classification using machine learning with classifier ensembling." International Research Journal of Engineering and Technology (IRJET) 7, no. 05 (2020): 4857-4861.

[8] Seema Patil, Rakshitha. M. M. J, Pooja. K. C, Vaishnavi. H, Dr. H. Girisha- Crop Yield Prediction Using Machine Learning and Deep Learning (2020) ISSN 2321 3361 2020 IJESC Volume 10 Issue No.7

[9] M. Kalimuthu, P. Vaishnavi and M. Kishore, "Crop Prediction using Machine Learning," 2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT), Tirunelveli, India, 2020, pp. 926-932, doi: 10.1109/ICSSIT48917.2020.9214190.

[10] P. S. Nishant, P. Sai Venkat, B. L. Avinash and B. Jabber, "Crop Yield Prediction based on Indian Agriculture using Machine Learning," 2020 International Conference for Emerging Technology (INCET), Belgaum, India, 2020, pp. 1-4, doi: 10.1109/INCET49848.2020.9154036.

[11] F. F. Haque, A. Abdelgawad, V. P. Yanambaka and K. Yelamarthi, "Crop Yield Analysis Using Machine Learning Algorithms," 2020 IEEE 6th World Forum on Internet of Things (WF-IoT), New Orleans, LA, USA, 2020, pp. 1-2, doi: 10.1109/WF-IoT48130.2020.9221459.

[12] R. Medar, V. S. Rajpurohit and S. Shweta, "Crop Yield Prediction using Machine Learning Techniques," 2019 IEEE 5th International Conference for Convergence in Technology (I2CT), Bombay, India, 2019, pp. 1-5, doi: 10.1109/I2CT45611.2019.9033611.)

[13] A. Nigam, S. Garg, A. Agrawal and P. Agrawal, "Crop Yield Prediction Using Machine Learning Algorithms," 2019 Fifth International Conference on Image Information Processing (ICIIP), Shimla, India, 2019, pp. 125-130, doi: 10.1109/ICIIP47207.2019.8985951.

[14] S. Bhanumathi, M. Vineeth and N. Rohit, "Crop Yield Prediction and Efficient use of Fertilizers," 2019 International Conference on Communication and Signal Processing (ICCSP), Chennai, India, 2019, pp. 0769-0773, doi: 10.1109/ICCSP.2019.8698087.

[15] Rajeswari C., Sathiyabhama B., Devendiran S., Manivannan K. Bearing fault diagnosis using wavelet packet transform, hybrid PSO and support vector machine, Procedia Engineering, ,Vol.97 (1) PP:1772-1783,2014 (CSE)

[16] Usha M., Kavitha P, Anomaly based intrusion detection for 802.11 networks with optimal features using SVM classifier, Wireless Networks, Vol – 23 (8) PP: 2431-2466, DoI: 10.1007/s11276-016-1300-5, 2017

[17] Rajeswari, K. C., and M. P. Uma. "Prosody modeling techniques for text-to-speech synthesis systems–a survey." *International Journal of Computer Applications* 39.16 (2012): 8-11.

[18] Nandini, V., and P. Uma Maheswari. "Automatic assessment of descriptive answers in online examination system using semantic relational features." *The Journal of Supercomputing* 76.6 (2020): 4430-4448.

[19] Metaheuristic Based Clustering with Deep Learning Model for Big Data, R. Krishnaswamy, Kamalraj Subramaniam, V. Nandini, K. Vijayalakshmi, Seifedine Kadry and Yunyoung Nam, Computer Systems Science & Engineering, vol.44, no.1.

[20] Iot assisted biomedical monitoring sensors for healthcare in human Computer Systems Science and Engineering K. Basarikodi and V. Sumathy S. Periyanayagi, V. Nandini, vol 45, issue no: 3.

[21] Automatic assessment of descriptive answers in online examination system using semantic relational features, Uma maheswari P, Nandini V ,2018/5, Journal of supercomputing.