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***Abstract*—Of all the sectors in the Indian economy, agriculture holds a place of utmost importance, employing nearly half of the nation's workforce and contributing almost 19% to the Gross Domestic Product (GDP). However, the agricultural industry in India is currently undergoing a structural shift that has led to a crisis situation. To remedy this, we must explore every avenue to make agriculture a profitable enterprise and encourage farmers to continue crop production activities. Despite India being the world's second-largest producer of fruits and vegetables, farmers are financially distressed due to crop loss resulting from inappropriate crop selection, disease, and market saturation. By analyzing soil and environmental factors in a particular region, we can predict the best crop to cultivate for optimal yield. Our proposed machine learning model leverages this information to help farmers choose appropriate crops based on soil type, temperature, humidity, water level, soil fertility, and market demand. The web application also enables farmers to identify crop diseases and determine suitable market prices for their produce, ultimately maximizing their profits. To achieve this, we will employ various machine learning algorithms such as Support Vector Machines (SVM), Multivariate Linear Regression, KNN, ANN, Random Forest, among others, to design the most accurate model possible. The objective of this project is to develop a web application that aids farmers in maximizing their profits by performing the above-mentioned tasks.**

Keyword - Deep Neural Network, Random Forest, DenseNet, Random Forest Regression, Machine Learning, Python.

I. Introduction

Since time immemorial, agriculture has been the backbone of human survival, providing the necessary sustenance for daily life. In India, it has also been a primary occupation and a major industrial sector. Traditionally, farmers relied on their naked eye observations and avoided the use of chemicals to maintain the health of their animals and land. However, with the rapidly changing weather conditions, the food supply is depleting and insecurity is increasing. Climate uncertainty makes it challenging for farmers to decide what crops to grow and when and where to start. The use of fertilizers is also uncertain due to changes in soil, water, and air conditions, leading to a decline in crop yield rates. In recent years, the rates of agricultural products like fruits, flowers, food grains, and vegetables have fluctuated significantly due to the mismatch between demand and supply. This price variation impacts both the farmers and the consumers. Plant diseases pose a severe threat to production, and their timely prevention is essential to effectively deal with them. The lack of necessary infrastructure in many parts of the world makes rapid identification difficult. As almost 80 % of farmers come from rural areas, if the revenue from crop production goes down, their lifestyle is affected, making precision farming an important aspect to increase profits. Machine learning is a recent technological advancement that can help predict the crop with respect to atmospheric and soil parameters of the agricultural land. The unpredictable ecological conditions of today, due to globalization, make it challenging for farmers to forecast weather and crops based on climate data. The proposed system aims to build a web-based application that provides functionalities for crop prediction based on environmental factors, customer requirements, and market demand. The application also includes crop disease prediction, crop price predictor, and best time to add fertilizer forecasting. Once the crop is predicted, farmers can select the affordable crop for their land and receive a detailed analysis to understand which seeds to sow to get higher yields. The proposed system uses machine learning to predict the affordable crop for given input parameters to assist poor farmers in decision-making and suggest effective solutions for more profitable cultivation.

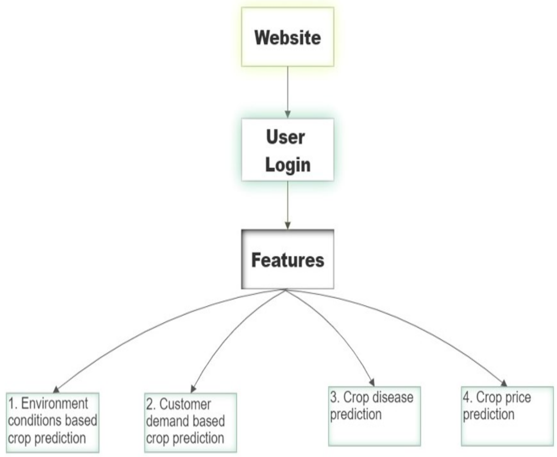

Fig. 1. Block diagram represents working of model

II. Related work

In an early study, a dedicated website was created to evaluate the impact of weather parameters on crop production in specific districts of Madhya Pradesh. The districts were selected based on the region covered by the crops, with the top five districts selected based on their maximum crop area. The selection of crops was based on the prevailing crops in these districts, which included maize, soybean, wheat, and paddy, with 20 years of yield data collected and analyzed. The established model showed a high level of accuracy, ranging from 76% to 90% for the selected crops, with an average accuracy of 82%[1].

In their study, the researchers utilized the sliding window non-linear regression technique to predict crop yield and pricing by analyzing historical data patterns. Focusing on various districts in Tamil Nadu, they developed a system that recommends optimal crop options for farmers. The system incorporated demand level classification, which accurately predicts crop demand by classifying the dataset of fluctuating market prices. Moreover, the authors incorporated a text-to-speech conversion feature in the proposed system, enhancing its accessibility for a wider audience[2].

Sanjay Jharkharia, and his co-authors, have delved into studying the feasibility of applying ARIMA models in the wholesale vegetable market to provide accurate demand forecasting of vegetables for the benefit of farmers and wholesalers alike. Their study involved the implementation of ARIMA models on the data collected for onion sales in the Ahmedabad market. The developed models were then utilized to forecast the demand for onions in the said market, resulting in a more informed and efficient decision-making process for the stakeholders involved[3].

In the research paper titled "Efficient Crop Yield Prediction Using Machine Learning Algorithms" by Arun Kumar and his colleagues, a unique approach was adopted to classify crop yields in batches based on yield productivity using Artificial Neural Networks. The results obtained defined the range of productivity, and regression was carried out to obtain the real crop yield and the expected cost. Nitin Singh and Saurabh Chaturvedi's study, "Weather Forecasting Using Machine Learning," collected historical weather data from various weather stations to forecast future weather conditions. The authors used a machine learning approach to analyze the data and make predictions, which could help farmers to plan their crops accordingly[4].

The implementation of crop yield estimation through classification techniques is a promising approach that offers great potential to predict crop yield and recommend the optimal crop for cultivation through data mining techniques. However, this system has some limitations that must be taken into consideration. For instance, it lacks feasible methods to meet the market demand and effectively communicate the recommendations to farmers. These challenges require further exploration to ensure the successful implementation of such a system[5].

Shima Ramesh, Ramchandra Hebbar, and PV Vinod proposed a novel approach to detect plant diseases using machine learning. They utilized the Random Forest algorithm to determine the health condition of the plant leaves. By using this method, they were able to accurately identify whether a leaf is diseased or healthy, enabling farmers to take timely action and prevent the spread of the disease. The authors have also tested their approach on different plant species and achieved promising results, indicating its potential as a practical solution for plant disease detection[6].

In their study, S.S. Sannakki and V. S. Rajpurohit developed a classification system for detecting pomegranate diseases using the backpropagation neural network algorithm. The approach involved segmenting the defected area and using color and texture as features for classification. To improve accuracy, the authors converted the image to the Lab color space to extract the chromaticity layers. Their system achieved a high accuracy rate of 97.30%. However, a limitation of the system is that it is only applicable to a limited number of crops[7].

In their research article, Godliver Owomugisha, John A. Quinn, Ernest Mwebaze and James Lwasa developed an automated system for diagnosing two devastating diseases of banana plants: bacterial wilt disease and black Sigatoka disease. The authors extracted color histograms from the images of banana plants and converted them from RGB to HSV, and RGB to Lab. To classify the diseases, they used various machine learning algorithms, such as nearest neighbors, decision tree, random forest, extremely randomized tree, Naïve Bayes, and support vector classifiers. Out of these seven classifiers, extremely randomized trees yielded the highest score and provided real-time information with the added flexibility to the application[8].

Ganesh Sastry Kakaraparthi and B.V.A.N.S.S. Prabhakar Rao's project addresses the challenging task of predicting crop prices accurately to ensure that farmers receive the benefits they deserve. The project adopts machine learning techniques, which have proven to be effective in providing solutions to complex problems. The proposed solution uses Decision Tree regression techniques, which leverage the power of trained data from certified datasets to predict crop values. The outcome of this project promises to revolutionize the agricultural sector by providing a reliable system that can help farmers make informed decisions about crop pricing[9].

Awanit Kumar and Shiv Kumar have proposed a novel approach for predicting crop production for the upcoming year. Their method is based on fuzzy logic, a rule-based forecasting technique that considers various factors such as land for agriculture, rainfall, and crop forecasting. The system uses K-means to analyze the incoming dataset, which is then applied to fuzzy logic-based prediction models.[10].

III. PROPOSE METHODOLOGY

Our proposed solution for farmers' problems involves a comprehensive web application that enables farmers to overcome challenges in agriculture. By utilizing GPS location, the farmers can access four functionalities that offer solutions to their farming needs. The first functionality provides a prediction of the most suitable crop to grow based on the land's soil and area, and it also suggests the right time to use fertilizers for maximum yield. This feature also predicts the crop yield. The second functionality suggests the most beneficial crop to grow based on customer demand and market needs, including alternate crops to grow if the demand for the chosen crop is not satisfactory. The third functionality allows farmers to upload images of their crops to detect anomalies, and if an anomaly is detected, the farmer will be provided with a complete solution to eliminate the disease. This feature also predicts the correct ages of the crops. Finally, the fourth functionality provides farmers with price predictions for their crops based on the current market, which can help them maximize their benefits.

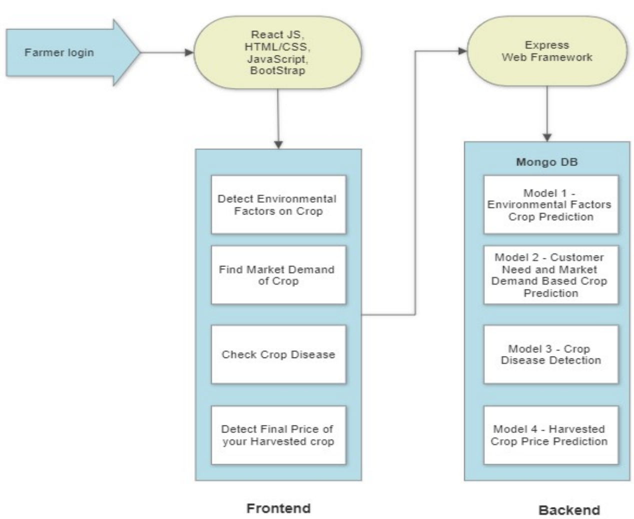

Fig. 2. The block diagram shows working of our website

A. MODEL 1 – ENVIRONMENTAL FACTORS BASED CROP PREDCITON

Our proposed solution to the problem faced by farmers is a smart and user-friendly recommender system.For our model, we utilized a dataset that included six attributes: nitrogen content, phosphorous content, potassium content, pH of the soil, and average rainfall of each state in India for every month over the past 110 years. We used preprocessing techniques, such as fuzzy matching, to obtain the desired attributes. Using this dataset, we were able to predict 22 varieties of crops, including rice, maize, coffee, coconut, papaya, orange, and apple, among others.

We tested several algorithms, including Support Vector Machine (SVM), Artificial Neural Network (ANN), Random Forest (RF), and Multivariate Linear Regression (MLR). However, the Deep Neural Networks (DNNs) algorithm provided the best results, achieving an accuracy of 97%. Our chosen DNN architecture consisted of three hidden layers with 64, 128, and 64 neurons, respectively, and an output layer with 22 neurons, each corresponding to a specific type of crop. We used SeLU as the activation function in the input and hidden layers, while the output layer used softmax. Our model was created using the PyTorch framework and trained on a dataset split into an 80:20 train-test ratio. We used categorical crossentropy as the objective (loss) function and ADAM as the optimizer. The accuracy was used as our performance metric, and we trained the model for 100 epochs.Furthermore, the system will also suggest the best time for fertilizer application to maximize the yield. This solution allows farmers to choose the most profitable crops or predict crop yields for specific regions. We collected historical data from reliable sources such as data.gov.in, kaggle.com, and indianwaterportal.com for the Maharashtra and Karnataka regions, which includes attributes such as state, district, year, season, type of crop, area under cultivation, soil, production, and more.

TABLE I
FEW INSTANCES OF OUR DATASET

N	P	K	Temp.	pH	rainfall	Result
90	42	43	20.8	6.5	200.5	Rice
78	42	42	20	7.6	262	Rice
107	34	32	26	6.7	177.7	Coffee
89	60	19	29.15	5.91	78.6	Maize
25	78	76	17.4	7.2	66.96	chickpea

Our web application has two modules: the prediction module and the fertilizer module. After registering with the app, the farmer can use these modules to predict crop yield and obtain fertilizer recommendations. In addition, the app includes a crop recommender system that suggests crops based on soil type and area, as well as a fertilizer usage service that guides farmers on the best time to apply fertilizers, taking into account rainfall predictions for the next 14 days using Open Weather API. Using a Machine Learning approach, the model learns from historical data sets and discovers patterns and correlations, allowing for more precise crop yield predictions and

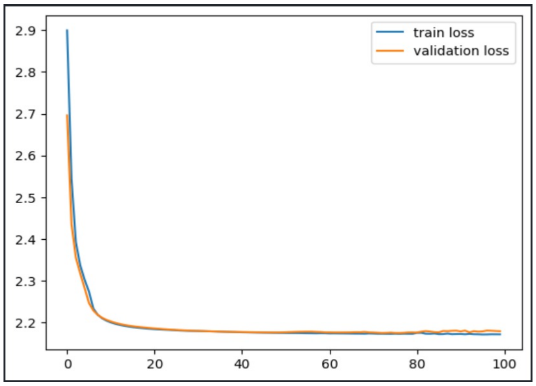

Fig. 3. Train loss v/s validation loss

more optimized resource allocation, resulting in a significant enhancement in the agricultural sector.

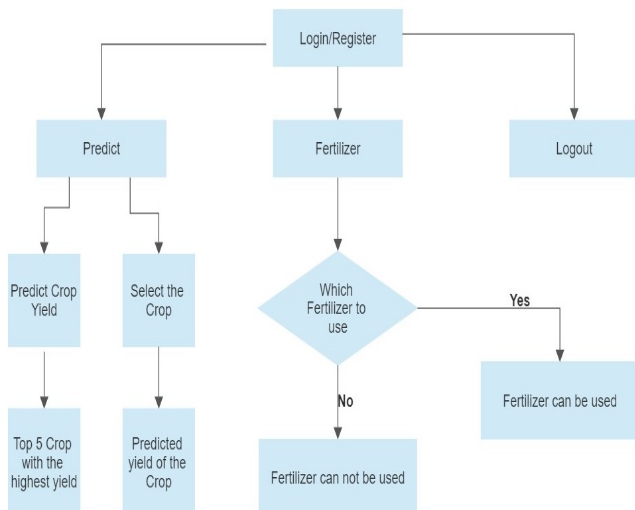

Fig. 4. Illustrate flow chart of proposed model - 1

B. MODEL 2 –YIELD PREDICTION AND MARKET DEMAND BASED CROP FORECASTING

After predicting the suitable crop, we proceeded to yield prediction and customer demand-based forecasting. Yield prediction plays a crucial role in helping states estimate the crop output in a given year, which can help control market prices. This study focuses on forecasting crop yield in advance by utilizing machine learning techniques to analyze various factors, such as location, season, and crop type, on the collected dataset available on data.gov.in. The yield prediction dataset consists of attributes such as State Name, District Name, Crop Year, Season, Crop, Area, and Production.

We employed linear regression, random forest, support vector regression, and decision tree algorithms to analyze which algorithm provided the best results for this problem. However, we found that the linear regression algorithm was not accurate for this type of prediction. Therefore, we evaluated the performance of the other algorithms and found that the random forest algorithm had a higher accuracy level, ranging from 85% to 90%. Despite its high accuracy, the random forest algorithm was relatively slow in terms of processing time.

Overall, our study highlights the importance of yield prediction for managing market prices and how machine learning techniques can be utilized to provide accurate yield predictions. By analyzing various factors, such as location, season, and crop type, this model can predict crop yields in advance, which can help farmers plan for the upcoming season and improve their overall crop output.

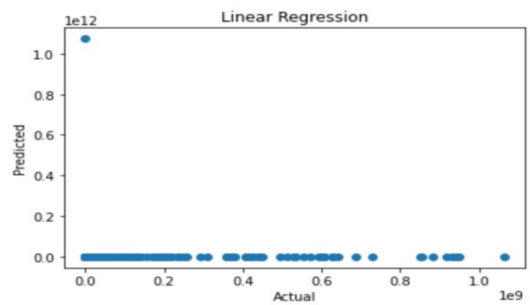

Fig. 5. Accuracy graph for linear regression

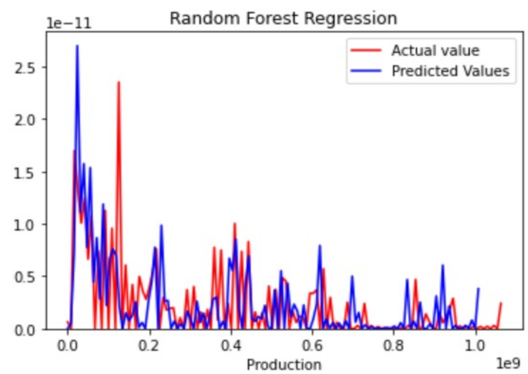

Fig. 6. Accuracy graph for random forest regression

To bridge the gap between the demand and supply of food crops, it is essential to accurately forecast the demand for various food commodities and guide the farmers accordingly. This ensures that the farmers cultivate crops that meet the actual demand of the society, thus preventing any wastage of resources and minimizing losses for both consumers and farmers. With the emergence of big data analytics, it is possible to provide effective solutions to such problems. By analyzing vast amounts of data, including weather patterns, market trends, and consumer behavior, farmers can make informed decisions about which crops to grow and when to grow them. This not only helps in reducing the mismatch in demand and supply but also ensures that the farmers maximize their profits and contribute to the overall growth of the agricultural sector. This paper presents a novel forecasting model aimed at reducing the gap between the demand and

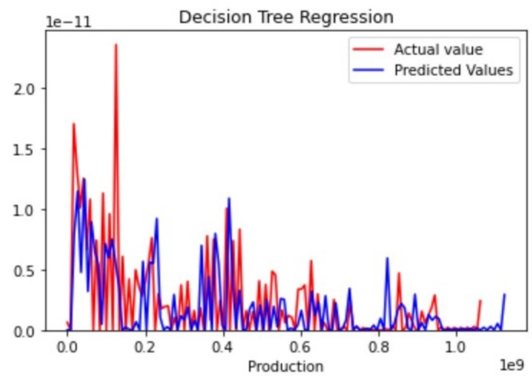

Fig. 7. Accuracy graph for decision tree regression

supply of crops. The model predicts the demand for various food commodities, providing guidance to farmers on selecting appropriate crops to satisfy the demand. By doing so, it helps reduce the mismatch between demand and supply. To develop the forecasting model, we have collected agricultural data from the previous year, which includes information on crop areas, types of crops cultivated, soil characteristics, yields, and overall crop consumption. This data is then used to predict the future demand for crops, which enables farmers to make informed decisions on crop selection and cultivation.

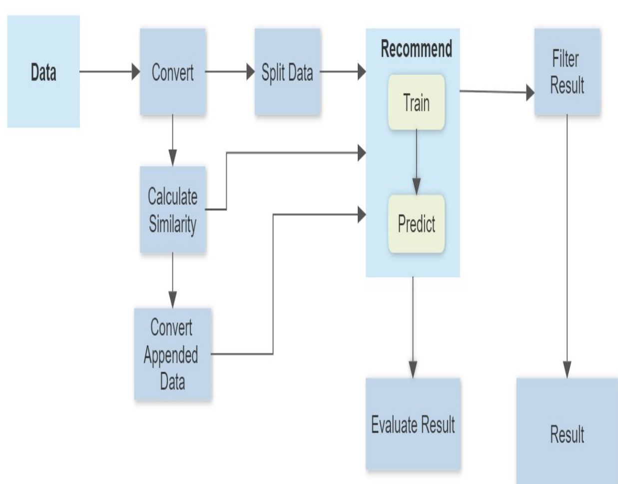

Fig. 8. Illustrate flow chart of proposed model - 2

The system applies data mining techniques to classify the collected dataset and predict the demand of crops based on changes in market prices. The dataset is classified into various categories such as high demand, moderate demand, and low demand. The system then recommends the appropriate crops to be grown to meet the demand for each category. This helps farmers to make informed decisions about crop selection and avoid overproduction of crops that have low demand in the market. By utilizing these data-driven insights, the system can help reduce the waste of resources and maximize profitability for farmers. The system classifies the data into three categories based on the change in the market prices of the crops.

The system classifies the data into three categories based on the change in the market prices of the crops.

- Category is Excess, which is characterized by a sudden decrease in the price or less consumption of the crop compared to the cultivation. This indicates that the supply of the crop is more than the demand, leading to a surplus in the market.
- Category is Scarce, which is characterized by a sudden increase in the price or less consumption of the crop compared to the cultivation. This indicates that the demand for the crop is more than the supply, leading to a shortage in the market.
- Category is Neutral, which is characterized by no change in the price and a standard price is maintained throughout. This indicates that the supply and demand of the crop are in balance, leading to a stable market. By classifying the data into these categories, the system can provide guidance to farmers in selecting and growing the appropriate crops to meet the demand and avoid the gap between demand and supply.

If the demand is low, the system suggests an alternate crop, and if it is high, the recommended crop is the one with the corresponding high demand grade. To calculate demand, the formula takes into account the outlier, which indicates a sudden increase in crop price that is not within the same price range as the other time periods. The calculated demand is based on the total crop cultivated, total crop consumed, and change in price, which is the difference between the outlier price and the sample mean price.

We have used data mining results to suggest crops for cultivation by the farmers, taking into consideration various parameters such as total cultivation of crops, area, overall consumption, and demand grade. The suggested data may contain one or more crops, but priority is given to those corresponding to the higher demand grade. This way, our system helps to inform farmers about demand and assists in cultivating the appropriate type of crops.

C. MODEL 3 – CROP DISEASE DETECTION

Crop disease detection is a critical aspect of modern agriculture, which can assist farmers in improving crop yields, reducing economic losses, and promoting sustainable farming practices. Crop diseases can have a significant impact on agriculture, leading to reduced yields, lower crop quality, and decreased profits for farmers. Early detection and accurate diagnosis of crop diseases are essential for farmers to take timely action to manage and control the spread of the disease, protecting their investment and reducing crop losses.

Furthermore, excessive use of pesticides and other chemical treatments can be costly and can have negative impacts on the environment. Early detection of crop diseases can help farmers use more targeted and effective treatments, reducing the need for excessive use of pesticides and other chemical treatments. This, in turn, promotes sustainable farming practices that prioritize environmental stewardship and reduce the negative impact of farming on the environment.

TABLE II
DETAIL OF DATASET

Class	Plant Name	Images
Potato	Healthy	152
	Light-blight	1000
	Early blight	1000
Paper Bell	Healthy	1478
	Bacterial-spot	997
Tomato	Healthy	1591
	Early blight	1000
	Yellow Leaf-Curl-Virus	3209
	Target-Spot	1404
	Two spotted spider mate	1676
	Bacterial-spot	2127
	Leaf-blight	1909
	Leaf-Mold	952
	Mosaic-virus	373
	Septoria-leaf-spot	1771

Moreover, effective crop disease detection and management can contribute to global food security by improving crop productivity and reducing crop losses due to disease. With the global population projected to reach 9.7 billion by 2050, it is crucial to ensure that crops are protected from disease and that crop yields are maximized to meet the growing demand for food.

TABLE III
DETAILS OF PREPARED DATASET

Dataset	No. of images
Dataset-1(Potato)	2152
Dataset-2(Pepper Bell)	2475
Dataset-3(Tomato)	16011

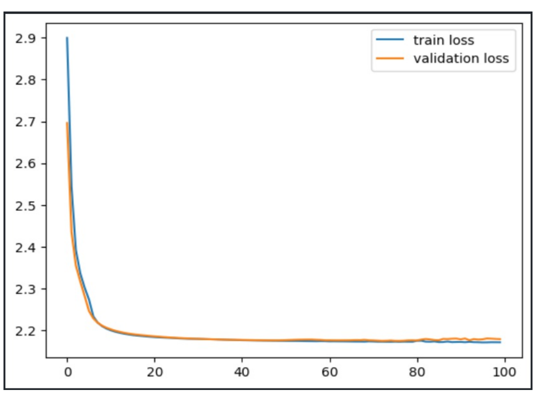

Fig. 9. Train loss v/s validation loss

The use of deep learning models such as DenseNet for plant disease detection and classification has shown promising results. The DenseNet model is trained on a preprocessed dataset using the backpropagation algorithm and an appropriate optimizer to achieve high accuracy in predicting plant diseases. The success of the prediction largely depends on the quality of the dataset and the accuracy of the model training.

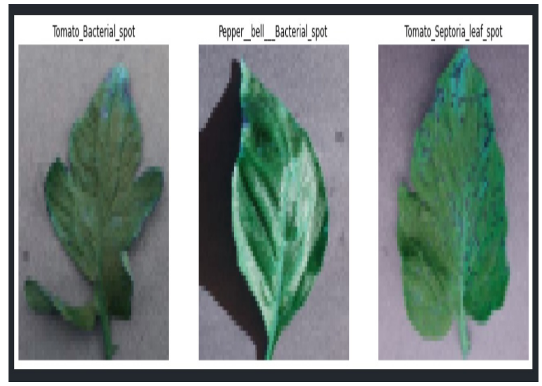

Fig. 10. Instance of dataset

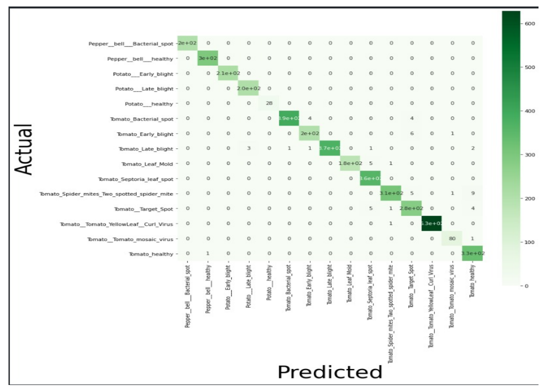

Fig. 11. confusion matrix

Therefore, it is crucial to pay attention to data collection, preprocessing, and model training to achieve high accuracy in predicting plant diseases using DenseNet.

Transfer learning is a useful technique that reduces the volume of training data, training time, and processing costs for creating deep learning models. It enables the learning from one model to be applied to another, making it possible to reuse features across layers, increasing the efficiency of the architecture's parameters, and allowing for greater variation and better performance in later layers.

The DenseNet model, which employs transfer learning to automatically extract features and leverages their weights learned on the ImageNet dataset, is a powerful tool for reducing calculation workload and enhancing model performance. The architecture of DenseNet201 allows for the construction of simple and straightforward models, which can be adapted to a wider range of plants and diseases. Nonlinear transformations such as convolution, pooling, rectified linear units, and batch normalization are implemented in each layer of the DenseNet network, making it an effective tool for crop disease detection.

In conclusion, crop disease detection is an essential component of modern agriculture that can help farmers increase crop yields, reduce economic losses, promote sustainable farming practices, and contribute to global food security. The use of deep learning models such as DenseNet and transfer learning techniques has shown promising results in crop disease detec-

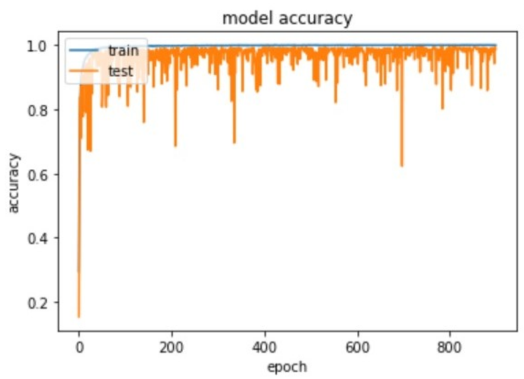

Fig. 12. Model accuracy

tion and classification. It is important for farmers to stay up-to-date with the latest crop disease detection techniques and tools to ensure healthy and productive crops for future generations. Future research can explore the use of other CNNs that have already undergone multi-classification training and update the developed tool to be more accurate in the treatment section, taking into account crop conditions and weather data for better diagnosing plant diseases, particularly in India

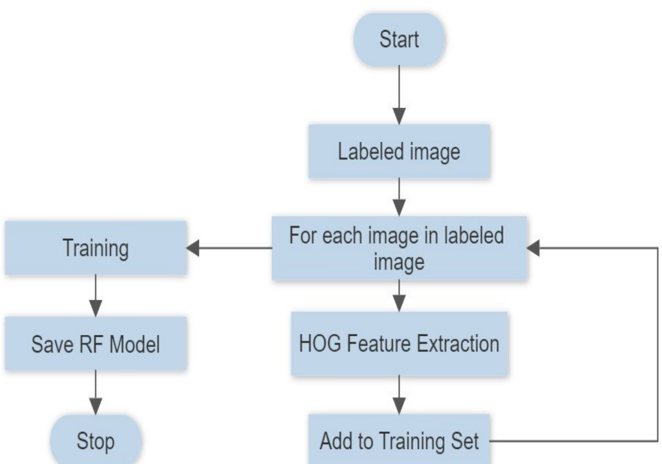

Fig. 13. Illustrate flow chart of proposed model - 4

D. MODEL 4 – HARVESTED CROP PRICE PREDICTION

Our crop price forecasting model is designed to revolutionize the way farmers predict crop prices, offering them an efficient and effective solution to ensure maximum benefits. By utilizing machine learning techniques, we have been able to generate improved results using various data sets. Our model employs Decision Tree regression techniques to predict crop values, based on trained data from certified datasets, ultimately leading to increased productivity. The model also takes into account various environmental conditions that could potentially affect crop growth. The web application provides easily accessible results for poor farmers, ultimately helping them make informed decisions. Unlike traditional technical analysis methods, our machine learning-driven price predictions offer a unique way of combining technical and fundamental analysis methods. Additionally, our approach differs in that it takes into account real-time data and incorporates non-linear relationships between variables, resulting in more accurate and reliable predictions.

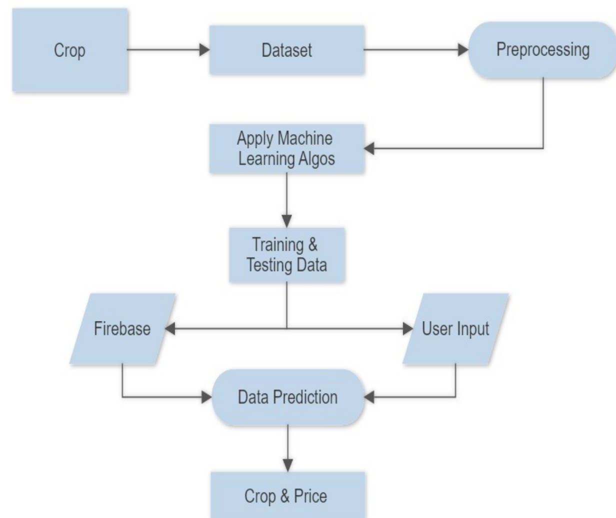

Fig. 14. Illustrate flow chart of proposed model - 4

The innovative approach of machine learning-driven price prediction offers a multitude of advantages over traditional methods. One significant advantage is its ability to account for multiple price determinants, which greatly enhances the accuracy of predictions. In addition, this approach provides localized predictions at the level of a specific region or even a farm, making them highly relevant and actionable for farmers. The combination of technical and fundamental analysis further improves accuracy by providing short-term predictions through technical analysis and long-term forecasts through fundamental analysis. This integration of both analyses offers a comprehensive understanding of external and internal factors that affect commodity prices, leading to more accurate and reliable predictions. Ultimately, this results in better decision-making and higher profits for farmers.

The dataset has been imported from kaggle(Prices for Food Crops_Commodities_2012_to_2015) .We find that our Linear regression model has an accuracy of around 25% Linear regression can be prone to underfitting the data.Hence if you build a model using linear regression and you find that both the test accuracy and the training accuracy are low then this would likely be due to underfitting.

We find that our model has an improved accuracy of around 97% with use of Random Forest Regression.Random forest works by builds multiple decision trees and merges them together.Often it's more accurate and stable in prediction . Random decision forests correct the decision tree's habit of overfitting to their training set. In Decision Trees, the process

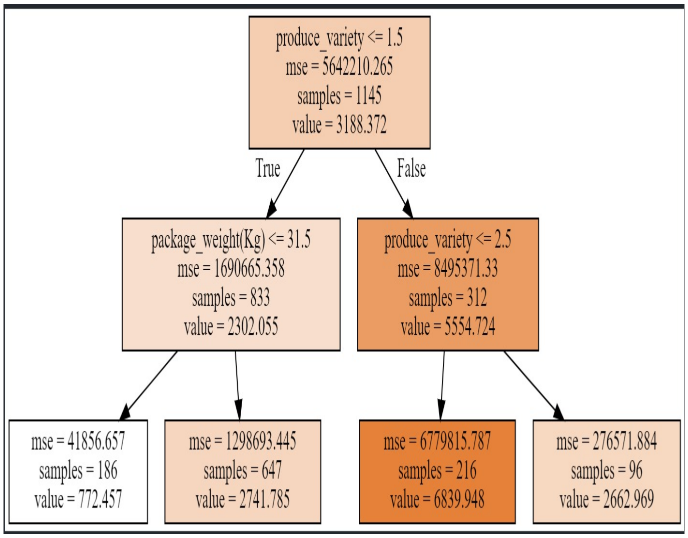

Fig. 15. Result decision tree

of predicting the record's class label begins at the top of the tree and follows a path down to the leaf nodes. At each node, the value of the record's attribute is compared to the value of the attribute used to split the data. Based on the comparison, the corresponding branch is followed to the next node until a leaf node is reached, which provides the predicted class label.

When constructing a Decision Tree, selecting the best attribute to use as the root node or at different levels of the tree can be a challenging task, especially when dealing with datasets that contain numerous attributes. Randomly selecting nodes as the root may result in poor performance and low accuracy. To overcome this, information gain is used as a criterion to evaluate the importance of attributes for classification, while the Gini index is utilized for continuous attributes.

In the case of crop price prediction, Decision Tree Regression is employed since crop prices are seasonal and vary with time. The dataset contains rainfall and WPI as the parameters for crop price prediction. By using Decision Tree Regression and considering relevant parameters, our model aims to provide accurate and reliable predictions to help farmers make informed decisions.

E. Results

TABLE IV
ACCURACY OF MODELS

Model Name	Best Algorithm from found	Accuracy
Crop Prediction	Deep Neural Network	97%
Yield Prediction	Random Forest	98.6%
Crop Disease Detection	DenseNet	95%
Crop Price Prediction	Random Forest Regression	97%

F. Comparision with Existing Work

Our crop prediction model gives an accuracy of 97 with deep nueral network compared to [11] which has accuracy of 83. Our yield prediction model gave accuarcy of 85-90% which is one of the highest in existing works.The plant disease detection model gave an accuracy of 98.6% using DenseNet compared to previous work [12] which has an accuracy of 95%.Our price prediction model for crop price prediction uses random forest regreesion to give an accuracy of 97% compared [13] which has accuracy of 80% to 91% for various model.

G. Conclusion

To improve profitability in an increasingly competitive and volatile environment, farmers need to have a deep understanding of their profit drivers and tactical management plans in place. .The main emphasis of our project is to help the farmer increase their profits. On completion of this project out model will be able to –

1. Our machine learning model takes into consideration various factors like soil quality, weather patterns, and market trends to provide farmers with accurate crop yield predictions and pricing forecasts.
2. The model can suggest optimal planting and harvesting times based on data analysis of the above-mentioned factors.
3. Our model can also recommend specific fertilizers and crop protection methods based on the analysis of soil and weather data, which helps maximize crop yield and minimize crop loss.
4. With the help of our model, farmers will be able to make informed decisions about their crops and increase their profitability and competitiveness in the market.
5. Our web application provides farmers with easy access to all of this information, making it easier for them to manage their farms and make informed decisions on the go.

Overall, our machine learning model and web application are designed to help farmers optimize their crop production and make better decisions based on accurate data analysis.

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