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Crop, Fertilizer and Pesticide Recommendation using Ensemble Method and Sequential Convolutional Neural Network

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Abstract: Agriculture is the backbone of the Indian economy, with 60% - 70% of the Indian people relying on agriculture for subsistence. Unfortunately, farmers sometimes don't have the time needed to carefully consider all important facts before making decisions. As a result, they rely on agricultural experts, who may or may not always be available. With the aid of precision agriculture, these farmers are given knowledge on the specific crops that should be grown on their property. The major objective is to develop a website which makes it simple to use by using the Machine Learning model to generate the real-time prediction that analyzes environmental and soil factors like Nitrogen (N), Potassium (K), Phosphorous (P), pH, Temperature, Humidity, Soil moisture and Rainfall which suggests the best crop to grow using Ensemble Model through Majority Voting Mechanism, fertilizer to apply using Fertilizer Dictionary and pesticide based on the image analysis of the pest using Sequential Convolutional Neural Network(CNN) from Kaggle dataset. The resulting model when given inputs on the web interface recommends the crop suitable based on soil condition hence giving best decision on what crops to grow, what fertilizer to be used and helpful for identification of the pest and prescribe the appropriate dosage of pesticide.

Keywords*: *Machine Learning, Recommendation System, K-nearest Neighbor(KNN), Support Vector Machine(SVM), Random Forest Algorithm, Sequential Convolutional Neural Network.

1. Introduction

Farmers are the foundation of our civilization. They are responsible for all of our food. As a result, whether the country is tiny or vast, its whole population is dependent on farmers and only because of them we are able to exist. Farmers are thus the most influential people in the globe. Farmers are essential to our economy. They are an essential in civilization since everyone need appropriate nourishment to survive. Also, farmers contribute about 17% of the Indian GDP. Yet, a farmer is forbidden all societal privileges. Farmers in India are in deep trouble. Every week or month, we hear about farmer suicides. Additionally, farmers have all had a difficult living in the past. They are underpaid.

Because the intermediaries obtain the majority of the money, the farmer receives nothing in cash. Furthermore, farmers lack the financial resources to send their children to school. Sometimes the situation becomes so dire that they are unable to eat. As a result, farmers are facing starvation. For crops to thrive, the right amount of sunlight and rain is necessary. Therefore, if the crops don't get it, they'll be destroyed. So, farmers commit suicide. To meet the requirement at this time, farmers cannot continue to employ their old ways. In order to meet these needs and give many individuals in this industry excellent employment prospects, several novel automation techniques are created. In all industries, such as finance, robotics, agriculture, and education, artificial intelligence has emerged as one of the most significant technological advancements. It is having a significant impact on the agriculture business and playing a very important function in that area.

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Artificial intelligence has emerged as one of the most important technologies in every industry including finance, robotics, agriculture and education. It is a vital part of agriculture and is changing the agricultural industry. AI addresses the problems of the agricultural industry, such as food security, expanding population, and climate change, employment problems in this industry and thanks to AI, modern agriculture has been raised to new heights. Artificial intelligence enables real-time harvesting, crop management, production and Marketing. To identify a number of important elements, including yield detection, weed identification, crop quality, and many others, a variety of sophisticated computer-based systems are being created.

The aim of every farmer is precision agriculture. The next significant advancement, according to experts, will include the use of ML. Perhaps never will it be able to take the position of the farmer. Farm owners nonetheless have to make difficult decisions on a regular basis, and ML applications may give them the knowledge they need to make those decisions more wisely. Farmers have access to so much information today—more information than they can handle without the aid of machine learning technologies. ML can swiftly examine enormous amounts of data. It may advise a particular course of action in light of such data. It may, for instance, advise when to plant in order to fend off pests and disease.

1.1. Problem Statement

Farmers Typically Encounter Challenges When Environmental And Soil Conditions Change Rapidly, And Yield May Suffer As A Result. This Problem Is Solved By Employing The Ensemble Model For Crop And Fertilizer Recommendation, As Well As The Sequential Convolutional Neural Network For Pesticide Recommendation.

1.2. Motivation

Agriculture accounts for around 18% of India's yearly GDP. And almost 60% of the population has always participated in it. This economy would not function properly without farmers, and survival would have been difficult because they produce our food. Farmers are unable to determine what crop to cultivate depending on the elemental composition, humidity levels, and temperature of their soil due to a lack of understanding about nutrients such as potassium, salt, and so on. If they know what to cultivate, it will help farmers financially, reduce losses, and increase the nation's GDP.

Objectives

The Objectives of the project are:

- To collect the datasets from Kaggle dataset for crop, fertilizer and pesticide recommendation
- To develop a model using Ensemble method to recommend the fertilizer and Sequential Convolutional Neural Network to recommend the pesticide for the appropriate crop.
- To develop a web interface to display the recommendations.
- To validate the developed model with respect to performance metrics such as accuracy, and precision.

Scope

The scope of this project is:

- For pesticide recommendation, accuracy depends on the quality of the input image chosen.

2. Literature Survey

The Literature Surveys That Are Used As References Are Described In This Section.

The Vast Majority Of Recent Research On Crop Prediction Systems Have Incorporated Data On The Numerous Factors Utilized, Primarily In Comparisons Of The Various Classification Algorithms Used To Predict Crops.

Gupta et al., [1] created a system that analyzes, pre-processes, and then applies the MapReduce framework to the gathered data on seed, rainfall, humidity, soil, crop production, temperature, and wind speed. In the past, comparisons of various techniques have also been made. The technique used in this case is K-means clustering. The dataset only contained the geographical regions of Maharashtra, Ahmednagar, and the Andaman & Nicobar Islands.. To assist farmers in increasing agricultural productivity, the project tends to collect, evaluate data on wind speed (in a few locations). Temperature, seed, crop production, rainfall, humidity, and soil .The relationship between the parameters are studied using scatter plots and bar graphs. In addition, a recommender system that was self-created was used to forecast the harvests and display them on a Flask-based GUI.

To balance the dataset and compare Random Forest, Naive Bayes, SVM , Bagging Methods, Decision Trees, K-Nearest Neighbor and Raja et al., [2] focuses on applying sampling techniques like ROSE, SMOTE, and MWMOT during preprocessing. Superior prediction rates are offered by algorithms like KNN, bagging, decision tree, nave bayes, RF, and SVM. As a result, these strategies are used during the prediction process. The dataset employed is real-time felin dataset comprising yields for potato tubers, dry matter, and starch.

Keerthana et al., [3] introduced an ensemble method for crop prediction that takes into account variables from the dataset including average temperature, nation, average rainfall, crop name, pesticide in tonnes, yield value and year. AdaBoost and Decision Tree Regressors were taken into account by the suggested system in order to assess the combination against other combinations .

According to productivity, season, and the state of Tamil Nadu's Vaishnavi et al., [4] provided crop recommendations for banana crop. The Tamil Nadu Agriculture Dataset had around 1,20,000 entries. It contains information such as yield, crop year, season, crop name, farmed area, and district. The users were suggested with crops that can be cultivated based on productivity of land. They just considered the crop banana, and their forecast accuracy ranges from 90 to 95 percent..

In the paper "IoT based Classification Techniques for Soil Content Analysis and Crop Yield Prediction," Reshma et al., [5] provided a strategy for predicting the soil dataset category and learning about crop choices for the given soil. Objective was to develop a suitable crop that is cultivated in the provided land. It considers variables such as groundwater level, soil type, daily and seasonal needs of the community, neighborhood population, size of the same plantation, labour resources accessible to the farmer, , and the accessibility of agricultural land in the region.

In Pande et al., [6], agricultural output is predicted for two particular regions—Maharashtra and Karnataka—using machine learning methods to anticipate crop yields for user-selected Most profitable crop is then suggested a user-friendly smart phone application, together with error rate and accuracy. The rainfall estimate for the specified area is retrieved employing a position-based identification based on GPS. This study provides a practical and understandable yield forecast strategy for farmers. Farmers are connected to the internet via a smartphone application in the suggested strategy. GPS aids in the user's location. The user specifies the location and kind of soil. To assess agricultural production, ANN, MLR, RF, SVM, and KNN are utilized. Of all, Random Forest produced 95% accuracy bagging highest. The algorithm helps to make recommendations on when to utilize fertilizers to increase yield.

To estimate the mustard crop production from soil analysis, Pandith et al., [7] used machine learning (ML) technology. The metrics recall, f-score, accuracy, specificity, and precision have been assessed. Several machine learning (ML) approaches, including Naive Bayes, K-nearest neighbour , ANN, random forest and multinomial logistic regression were used to foresee the ability mustard crop output by soil analysis. One benefit of the created model was that crop yield predictions could be made even while fertilizer was being used to assist soil analysis and allow farmers to make the appropriate decisions in cases of poor crop yield predictions. However, in a large data environment that demonstrated system complexity, crop production prediction using the established model proved challenging.

To find the crop prediction with the highest accuracy value, Kumar et al., [8] describe an approach in the agricultural sector for crop yield forecast. This approach uses variables such as crop name, pH, temperature, rainfall, humidity, and random forest algorithm.

In order to anticipate the yield, Nishant et al., [9] used complex regression techniques as Kernel Ridge, Lasso algorithms and ENet. Stacking Regression technique is used to improvise the algorithms and produce strong predictions for almost all types of crops cultivated in India. The characteristics of the data are Season, State, Area and District.

In this paper, the authors offer two classifier Deep feature extraction methods based on pre-trained CNN. In the suggested model, merge six cutting-edge convolutional neural networks and fine-tune and assess them both individually and as an ensemble on the given issue. Finally, SVM algorithm is used to determine the performance of various combinations based on the recommended models. To evaluate the validity of the suggested model [10], researchers gathered the Turkey-PlantDataset, that includes photos of 15 distinct kinds of diseased images. The model has an accuracy of 97.56% and the early fusion ensemble model has an accuracy of 96.83% .

The model [11] proposed by Feng Jiang et al. uses the rice leaf dataset comprises 1634 images of rice blast, 1678 images of rice streak leaf spot, and 1765 images of rice bacterial spot. It also contains 2274 images of healthy rice. The mean shift image segmentation technique is used here during image preprocessing. To efficiently differentiate the form features of four different types of rice leaf lesions are utilized. The optimal feature combination is chosen using 6 layers of CNNs. Subsequently, under various parameters, SVM was utilized to categorize and identify four different types of rice leaf lesions.

This study [12] presents a crop pest recognition technique that employs five widely used CNN models to detect 10 common agricultural pest species with high accuracy (ResNet50, VGG-19, GoogLeNet, ResNet152 and VGG-16)

The primary contributions of this research are the description and sharing of a manually compiled and verified agricultural pest dataset. To increase the model's overall performance, two background reduction techniques are employed prior to the training phase. Afterwards, more training data was produced through data augmentation. With superior pest classification outcomes than the original model, a modified GoogLeNet model is suggested to handle the complex backdrops offered by farming landscapes. As comparison to the cutting-edge approach, the improved GooLeNet model achieves an improvement of 6.22%.

3. Software and Hardware Requirements

3.1. Software requirements

The software requirements are :

- Coding Language: Python
- Jupyter notebook
- Tools:
- Pandas : working with csv files
- Numpy : working with arrays
- flask : app routing,web application
- heroku :cloud deployment
- pickle :saving ML model
- neural networks (keras, tensorflow, CNN):for classification and training
- PyCharm : python offline coding
- matplotlib.pyplot : plotting graphs for training and testing accuracy,plotting graphs for training and testing loss
- h5 : storing DL model
- sklearn : classifiers

3.2. Hardware requirements

The hardware specifications of our project are

- Windows10 or above
- 64-bit CPU with an Intel i3 or higher processor
- 4GB RAM or greater.

4. Proposed System

The architecture of the proposed system, the approach utilized, and the dataset used are all described here.

4.1 Architecture

Figure 1 exemplifies the suggested system model.

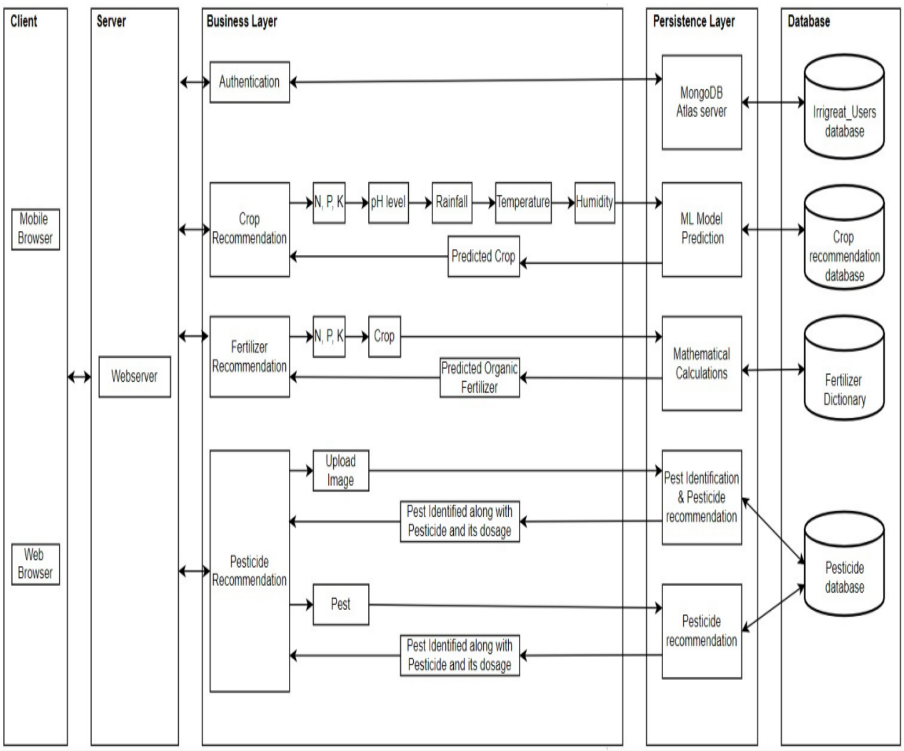


Fig 1: Proposed Architecture diagram

4.2 Process Flow Diagram

The proposed system allows the farmer to interact with the system in a simple way. The interface allows the farmer to enter the parameter values. The entered parameter values are sent to the developed machine learning model. The final output is shown on the website. Figure 2 shows that the Process Flow Diagram.

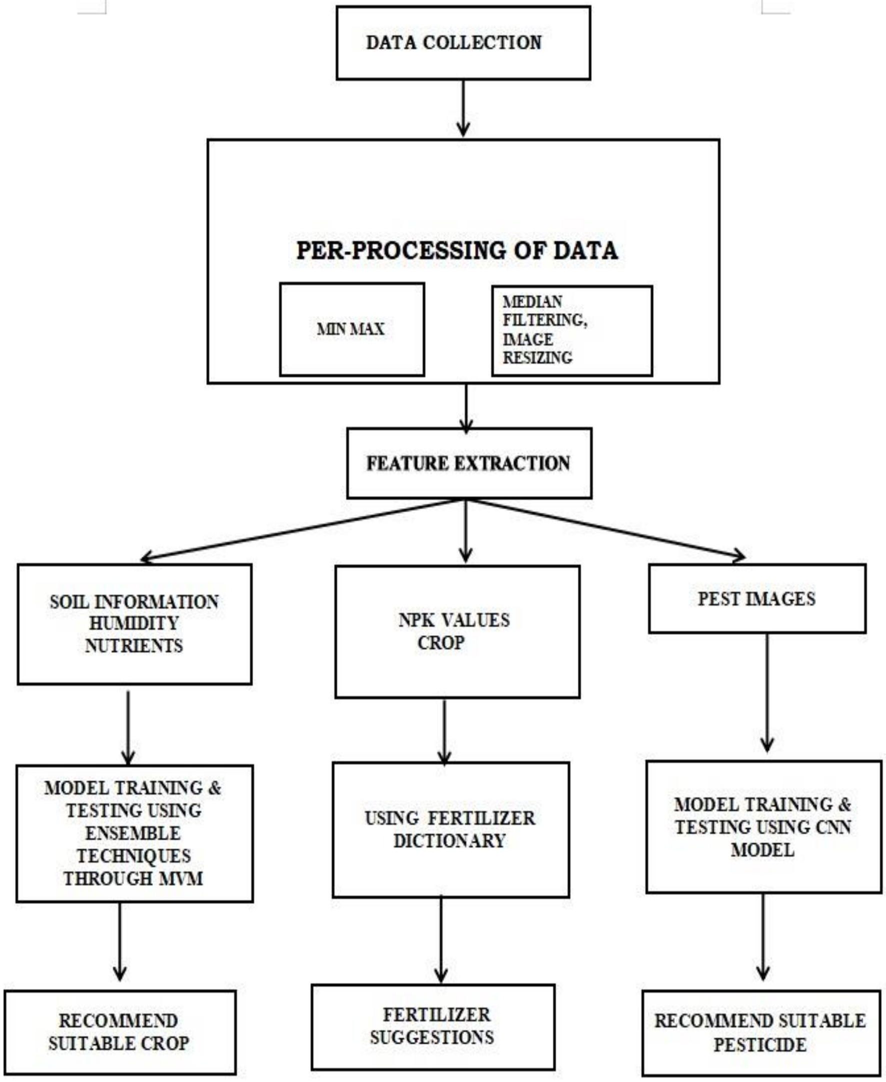


Fig 2: Process Flow Diagram

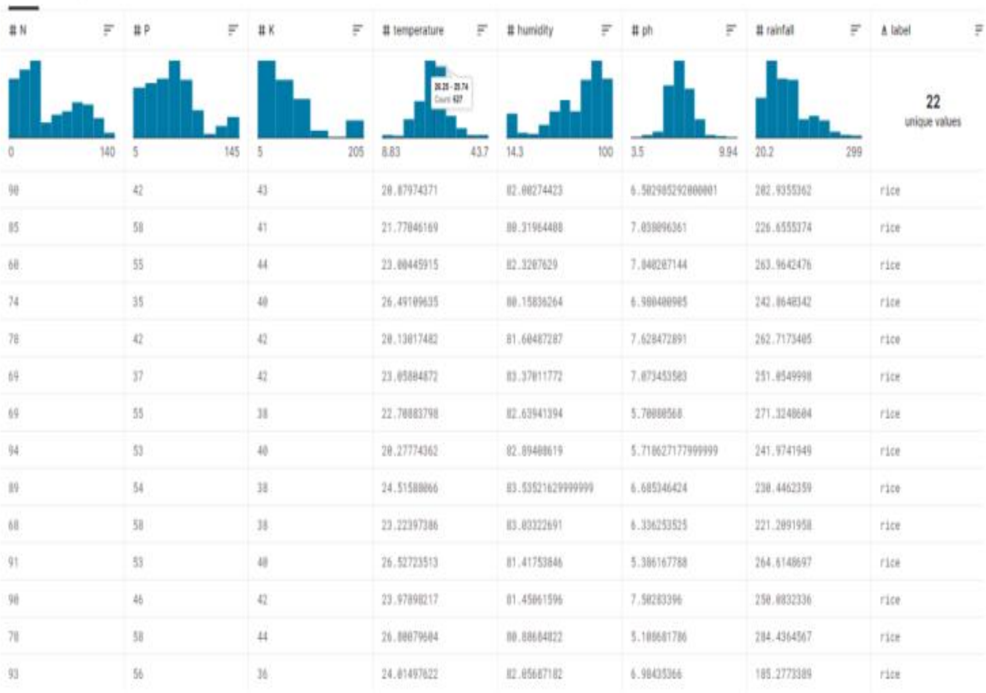
4.3 Methodology

The Methodology includes the implementation steps divided as modules. The project is divided into various modules such as:

- Data collection and pre processing
- Training and testing the samples
- Building:
- Ensemble Model
- Convolutional Neural Network Model
- Recommendation of crop , fertilizer and pesticide based on the input values

- **Data collection:**
- **Crop And Fertilizer Recommendation:**

The data collected is preprocessed by replacing missing values, removing null values and by using MinMax Scaling Technique. Input the specific parameters like: N, P, K (all of them in %), temperature (in °C), relative humidity (in %), rainfall (in mm) and pH for crop and input the specific parameters like: N, P, K (all of them in %), and crop. Figure 3 shows the dataset images used in crop and fertilizer recommendation model.



# N	# P	# K	# temperature	# humidity	# ph	# rainfall	A label
0 – 140	5 – 145	5 – 205	8.83 – 43.7	14.3 – 100	3.5 – 9.94	20.2 – 299	22 unique values
90	42	43	20.87974371	82.00274423	6.502985292000001	202.9355362	rice
85	58	41	21.77046169	80.31964408	7.038096361	226.6555374	rice
60	55	44	23.00445915	82.3207629	7.840207144	263.9642476	rice
74	35	40	26.49109635	80.15836264	6.980400905	242.8640342	rice
78	42	42	20.13017482	81.60487287	7.628472891	262.7173405	rice
69	37	42	23.05804872	83.37011772	7.073453503	251.0549998	rice
69	55	38	22.70883798	82.63941394	5.70080568	271.3248604	rice
94	53	40	20.27774362	82.89408619	5.718627177999999	241.9741949	rice
89	54	38	24.51588066	83.53521629999999	6.685346424	230.4462359	rice
68	58	38	23.22397386	83.03322691	6.336253525	221.2091958	rice
91	53	40	26.52723513	81.41753846	5.386167788	264.6148697	rice
90	46	42	23.97898217	81.45061596	7.50283396	250.0832336	rice
78	58	44	26.80079604	80.88684822	5.108681786	284.4364567	rice
93	56	36	24.01497622	82.05687182	6.98435366	185.2773389	rice

Fig 3: Crop and Fertilizer recommendation dataset

- ***Pesticide Recommendation :***

The dataset contains photos of pests such as aphids, beetles, armyworms, grasshoppers, bollworms and others. The photos are saved with the ".jpg" extension.. All the images are resized into the dimensions of 224 x 224. Figure 4 displays the dataset images used in Pesticide recommendation model.

Fig 4: Pesticide recommendation dataset

- **Training and Testing**

Integrating training from test data is the last stage in the data preparation process. A technique to gauge your model's accuracy is train/test. Since the model often needs as many data points as possible for training, the data typically tend to be distributed unevenly. According to the Pareto Principle, the dataset is divided into train and test sets in an 80:20 ratio.

- **Building Ensemble Model and Convolutional Neural Network Model**

The model is trained using four distinct base classifiers: SVM, Naive Bayes, RF and KNN. The unique fusion of these base models with the bagging approach will provide an improved model with an advantage over the current models. Using a sequential convolutional neural network, photos are processed.

- **Recommendations**

The recommendations of the model are generated accordingly to the users by the input value they enter. The crop is recommended when the input values are N, rainfall, P, humidity, , K, pH and temperature. The fertilizer is recommended when inputs are N, P, K and crop type. The pesticide is recommended when the input is an image.

4.4 Algorithms

- **Collection of the data and Pre-Processing**

Data collected from Kaggle website is used for the recommendations required for crop, pest and fertilizer.

For crop and fertilizer, the dataset is .csv file whereas for pesticide recommendation dataset is in form of images.

The data are received from many sources, but because they are collected in raw format, analysis of them is not possible

.**Step-1:** Input raw data in the form of a .csv format for the crop and fertilizer recommendation dataset and in form of images for pesticide recommendation

Step-2: Identification of null values and missing values for csv file and pre-process them my using Standard Scalertechnique

Step-3: Image normalization, image resizing techniques are used for pest dataset.

Step-4: Finally**,** the data will be in an understandable format.

- ***Ensemble Model***

The model is trained with the four different base classifiers namely Random Forest, Naive Bayes, K-Nearest Neighbor and Support Vector Machine.

- **Random Forest Algorithm:**

To apply Random Forest Algorithm for the given dataset

Step 1*:* With the 6 parameters available choose 600 records at random.

Step 2*:* Creating individual decision trees corresponding with the parameters chosen.

Step 3*:* Choosing how many decision trees should be built.

Step 4*:* Final output is considered based on determining each decision tree's predictions that consist of majority categories.

- **Support Vector Machine Algorithm:**

Input: Training dataset X and corresponding labels Y, Test dataset X_test

Output: Predicted labels for test dataset Y_test

Step 1: Standardize the training dataset X by subtracting the mean and dividing by the standard deviation

Step 2: Fit an SVM model to the standardized training data X and corresponding labels Y

Step 3: Standardize the test dataset X_test using the same mean and standard deviation from step 1

Step 4: Use the trained SVM model to predict the labels for the standardized test dataset X_test

Step 5: Output the predicted labels for the test dataset Y_test

- **K-Nearest Neighbor Algorithm:**

Input: Training set X_train = "x_i, y_i," where x_i is the i-th input and y_i is the output class label it corresponds to, and test input x

Output: Test input x's predicted output class label.

Step 1: Determine the Euclidean distance b/w every training input (x_i) and the test input (x).

Step 2: Sort the distances in ascending order and select the k nearest neighbors. The hyperparameter k is typically chosen using cross-validation.

Step 3: Classify the test input x based on the majority class of its k nearest neighbors

Step 4: Return the predicted output class label for the test input x

- **Naive Bayes Algorithm:**

Input: Training and Test data

Output: Predicted classes for test data

Step 1: Obtain the training and test datasets and prepare them.

Step 2: Extract the features from the training dataset.

Step 3*:* For each class, determine the prior probability.

Step 4: The likelihood probability for each characteristic in each class should be calculated.

Step 5*:* Normalize the likelihood probability for each class.

Step 6*:* Calculate the posterior probability for each class.

Step 7: Using the greatest posterior probability, predict the class for each instance in the test dataset.

- **Bagging Algorithm:**

Input: Training dataset, test dataset, base learner, number of base learners, bagging size.

Output: Predicted classes for test dataset

Step 1: Collect and preprocess the training and test datasets.

Step 2: Initialize an empty array of predicted classes for the test dataset.

Step 3: For each base learner:

- Randomly select a subset of the training dataset with replacement (bagging).
- Train the base learner on the selected subset.
- Predict the classes for the test dataset using the trained base learner.
- Append the predicted classes to the array of predicted classes.

Step 4: Combine the predicted classes from all base learners using majority voting

- ***Convolutional Neural Network Model***

Input: Pest Image

Output: Name of Identified pest and recommended pesticide used

Step 1: Preprocess the input data, including scaling and normalization.

Step 2: Generate training and test sets from the data.

Step 3: Defining the CNN model's architecture, including the quantity and kind of convolutional and pooling layers, as well as activation parameters like learning rate and batch size.

Step 4: Train the CNN model on the training set using backpropagation and an optimization algorithm (e.g. stochastic gradient descent).

Step 5: To avoid overfitting, monitor the model's performance on the validation data set and tweak the hyperparameter.

Step 6*:* Evaluate the model's performance on the test set to estimate its generalization performance.

Step 7: Use the trained CNN model to predict the appropriate pesticide recommendation for a new input sample by passing the sample through the model and obtain the predicted output.

Step 8: Improve performance by using transfer learning and fine-tuning.

4.5. Recommendation of crop, fertilizer and pesticide

Step 1: Users open the website and chooses what recommendation they require.

Step 2: Type of recommendation:

Step 2.1: Crop Recommendation:

- Enter the Inputs - N, P, K, pH, Temperature, Rainfall, Humidity
- Click the recommend button
- Output is the recommendation of Crop suitable for the input

Step 2.2: Fertilizer Recommendation

- Enter the Inputs - N, P, K, pH, Crop Name
- Click the recommend button
- Output is the recommendation and suggestion of Fertilizer suitable for the crop.

Step 2.3: Pesticide Recommendation.

- User uploads an image of the plant
- Click the recommend button
- Output is the recommendation of Pesticide that can be used based on the pest detected**.**

5. Results and Analysis

The outputs and findings of the suggested system are presented in this section. Here are the results:

Figure 5 represents the homepage of the website named as “Agromender” which is helpful for recommending crop, fertilizer or pesticide as per requirement.

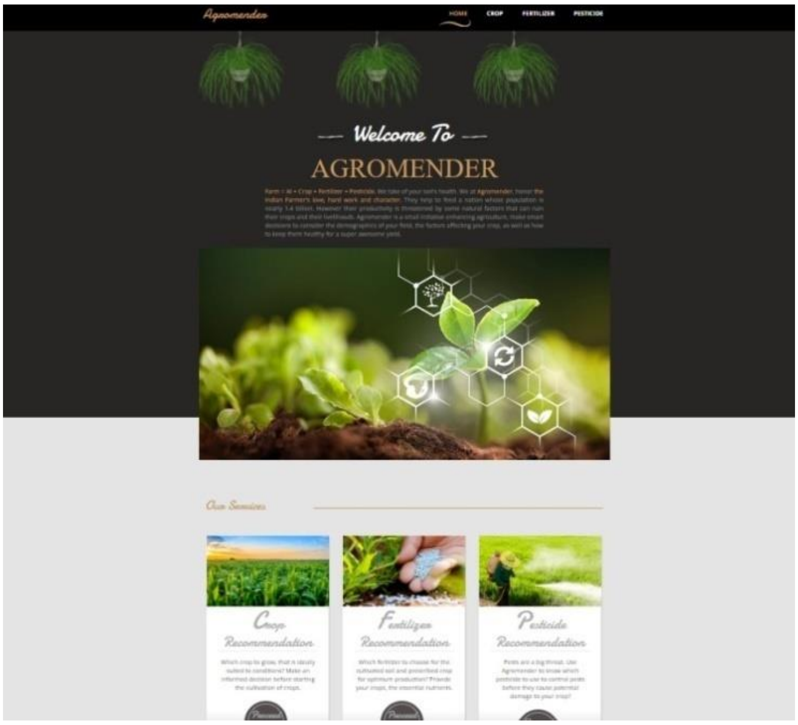


Fig 5: Homepage of the website developed

Figure 6 and Figure 7 represents the crop recommendation window. When values of parameters are entered ;Figure 6, the recommendation of crop which is suitable for soil is suggested in; Figure 7.

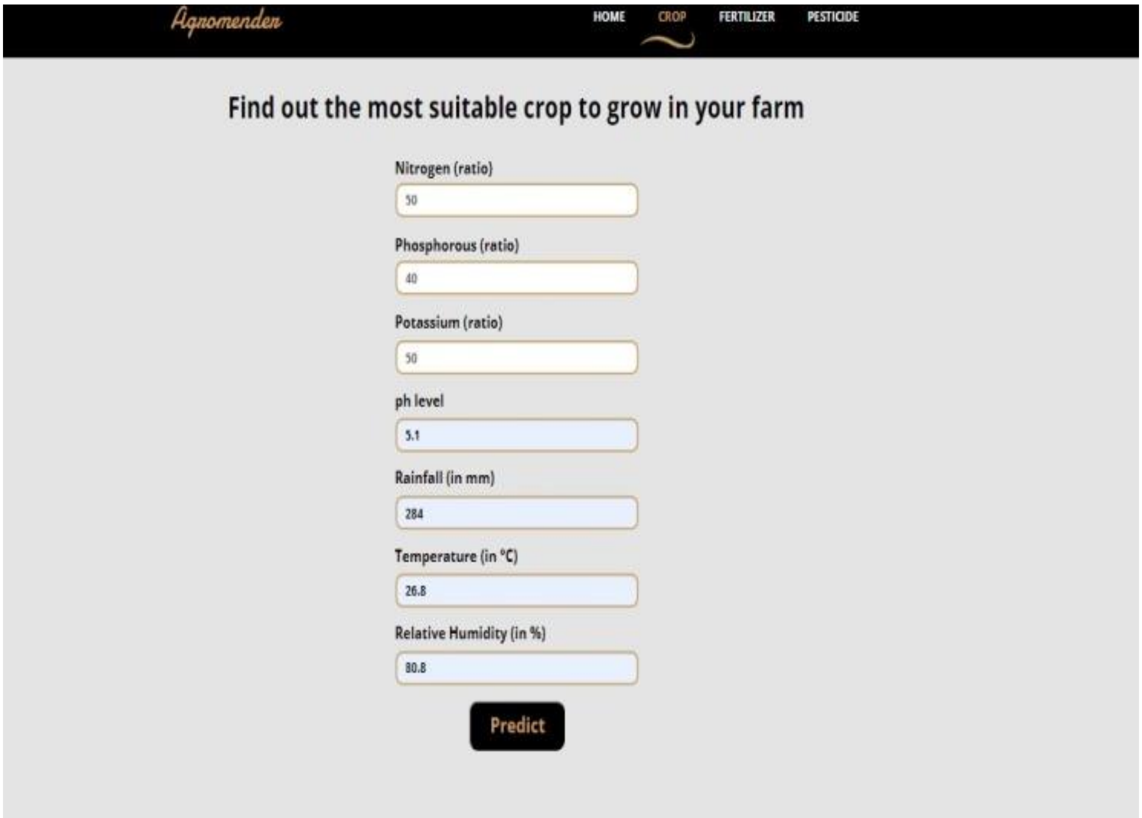


Figure 6: Crop recommendation window

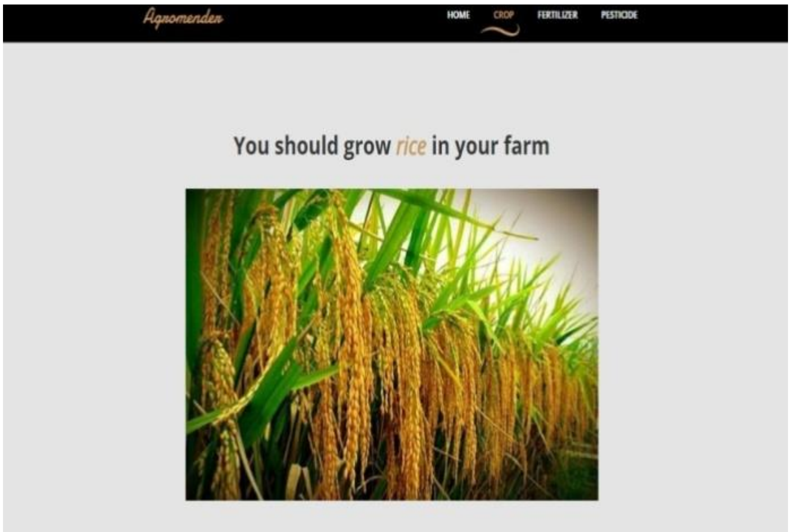


Fig 7: Recommendation of crop for entered values

Figure 8 and Figure 9 represents the fertilizer recommendation window. When values of parameters of N, P, K are entered; Figure 8, the recommendation of crop which is suitable for soil is suggested in; Figure 9.

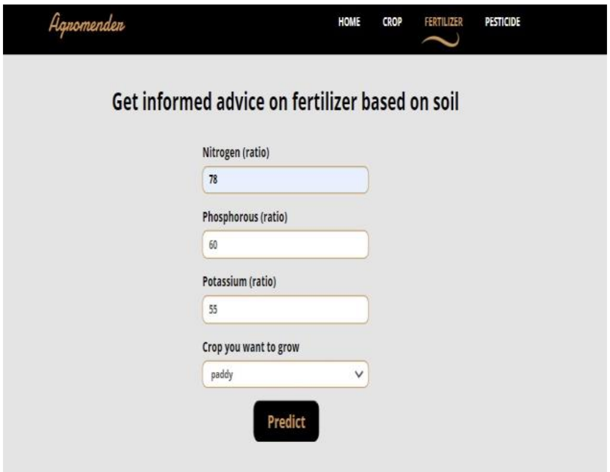


Fig 8: Fertilizer recommendation window

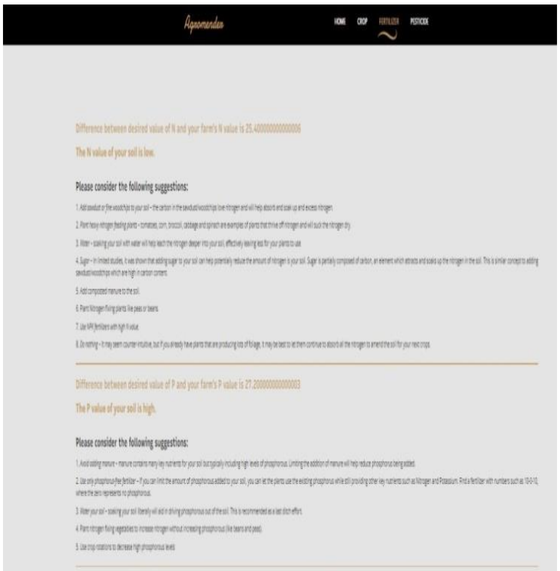


Fig 9: Recommendation of fertilizer for entered values

Figure 10 and Figure 11 represents the pesticide recommendation window. When an image is uploaded of a leaf or pest ; Figure 10, the recommendation of pesticide which is suitable for soil and the plant is suggested in; Figure 11

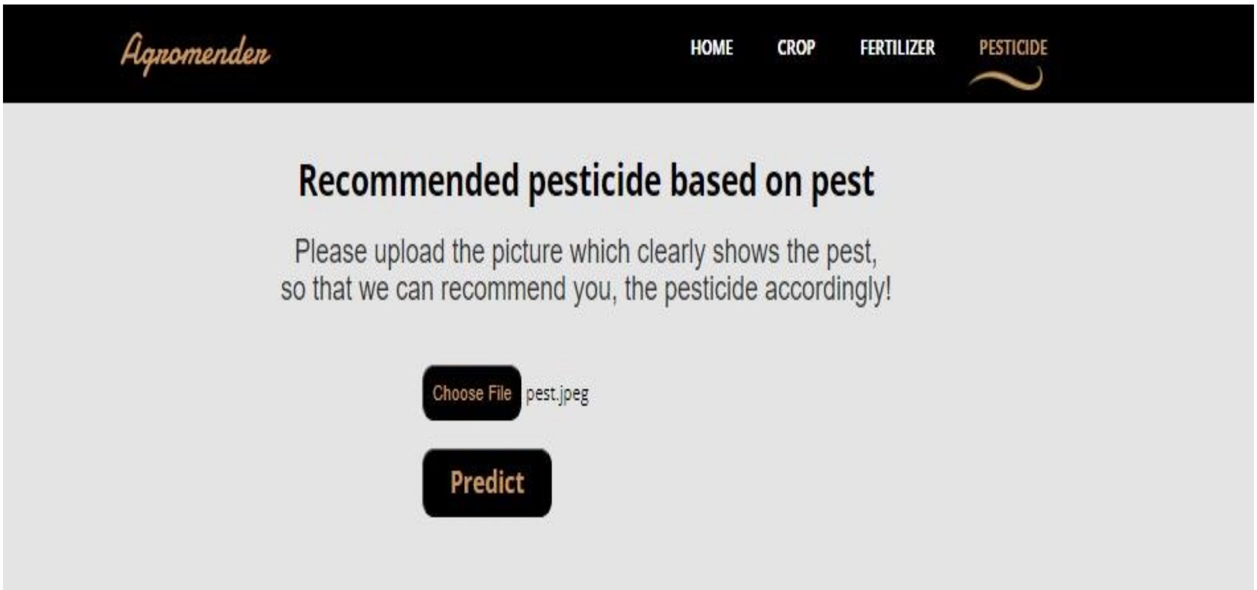


Fig 10: Pesticide recommendation window

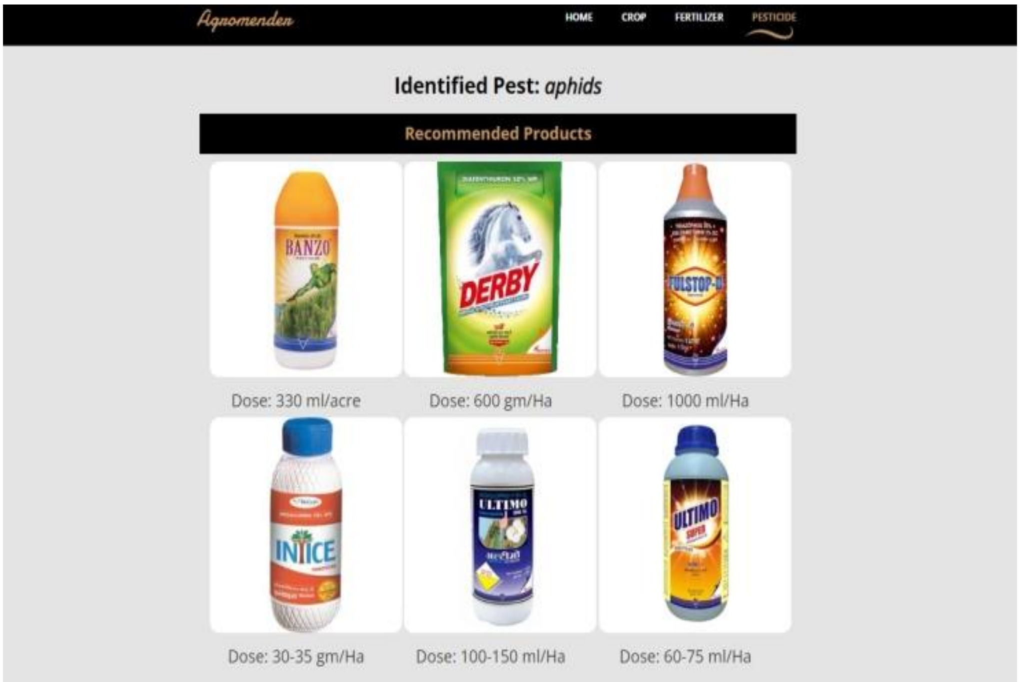


Fig 11: Recommendation of pesticide for input image

The proposed model for "Agromender" can be judged in various aspects. Firstly, for the crop recommendation, since ML model is used to predict the crop which would be best suited as per site specific parameters, so here accuracy score helps to tell about how effective the solution is. Ensemble model using majority voting technique was used. The learners are: Naive Bayes, kNN, SVM and Random Forest. Accuracy Score came out to be 96.44%. The desired accuracy was greater than or equal to 90%, but ML model is able to achieve 96.44%, hence it's appreciable. Since, Fertilizer Recommendation is simply a dictionary based solution, so it is based on research performed by the team members. Last module is Pesticide Recommendation. If the user chooses to upload an image, then pesticide would be recommended post identification of the pest and pests are identified through the DL model which is CNN.

The performance metric in this case is represented below by the training and validation accuracy and loss statistics. The Performance Metric same could be seen in Figure 12,

Figure 13 represents model accuracy versus epochs. Figure 14 represents model loss versus epochs.

	ACCURACY	LOSS
TRAINING	0.9699	0.0712
VALIDATION	0.9520	0.4681

Fig 12: Performance Metric

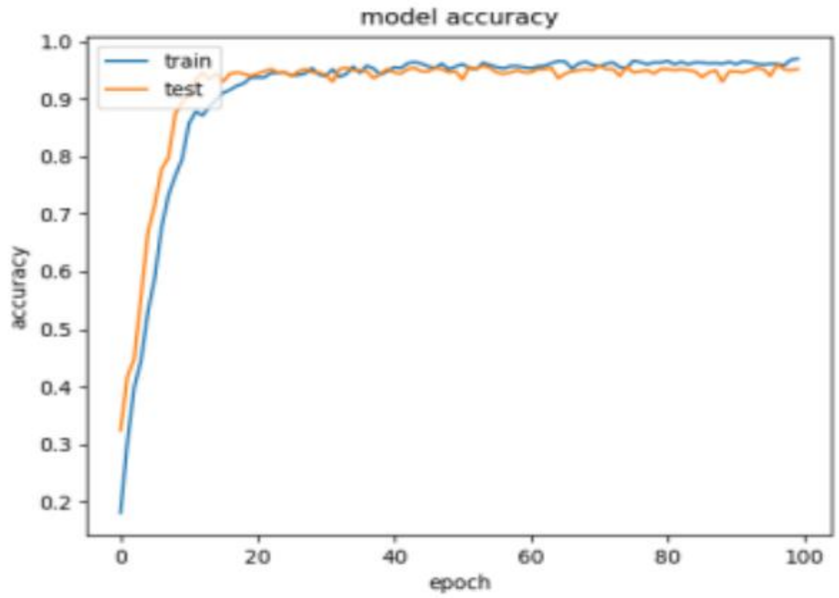


Fig 13: Accuracy versus epochs

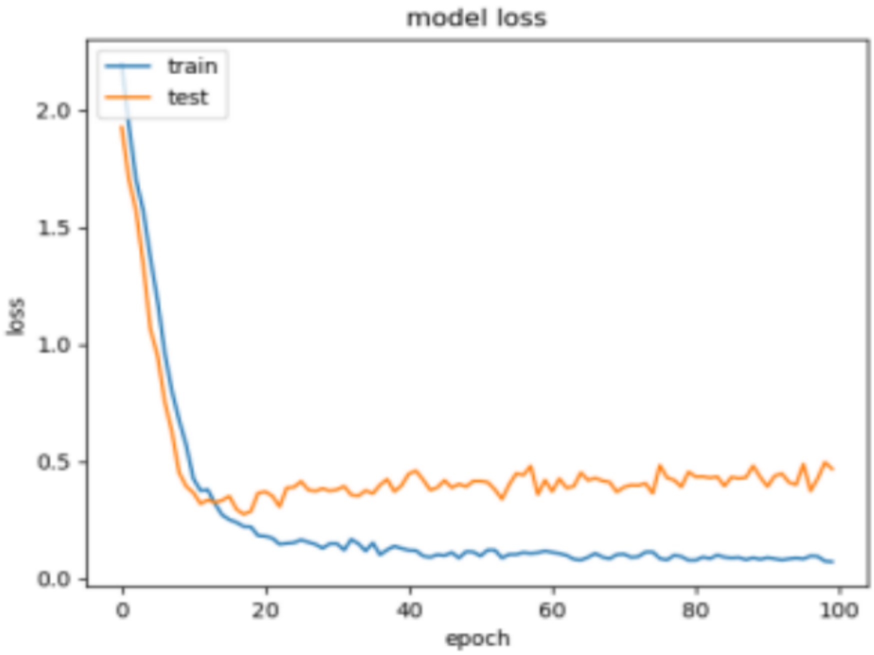


Fig 14: Model loss versus epochs

6. Conclusion and Future Work

Farmers contribute to feeding a nation with a population of roughly 1.4 billion people. Unfortunately, several natural causes endanger their production and imperil their livelihoods. As a result, the solution will assist farmers in increasing agricultural production, reducing soil degradation in cultivated areas, receiving educated advice on organic fertilizers/other fertilizers, and determining the best crop by considering many qualities. This would offer a thorough prognosis, benefiting both farmers and the environment. Not only that, but pest management would be a significant issue addressed by this initiative.

By giving the farmer information that regular farmers don't consider, with the use of this technology, crop failure is less likely, and crop productivity is increased. It also prevents them from sustaining losses. Currently, it suggests growing a crop that is highly suited for the environment by using important environmental characteristics as inputsOn a higher level, a hardware component can be integrated as a response systemThe humidity and other parameters may be adjusted to meet the needs of the farmer. Currently, the system receives input from all environmental components, but an algorithm may be used to anticipate one specific parameter using information from other two available parameters. Estimating soil pH, for example, by using soil moisture and sunshine. As a result, the sensors would be less expensive to install and maintain.

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