Technology-Enabled Agriculture Advancements

Aartee Chimate[1] Dhananjay Salunke[2] Sachin Vishwakarma[3] Dr.Prasenjit Bhavathankar[4]
[1,2,3,4]Department of Information Technology
[1,2,3,4]Sardar Patel Institute of Technology, Mumbai, India

Abstract — Machine learning techniques have the potential to revolutionize the agriculture industry by optimizing farming practices, increasing crop yield, and reducing environmental impact. Farmers can use machine learning algorithms to predict crop yield, recommend crop rotation schedules, fertilizer types and amounts, irrigation schedules, and pest and disease management options. Predicting crop yield is critical for farmers to make informed decisions about planting, fertilizing, and harvesting. Machine learning algorithms can analyze a range of data, including soil type, weather patterns, and historical yield data, to predict crop yield accurately. By optimizing their farming practices, farmers can maximize their yield, minimize their costs, and reduce their environmental impact. In addition to predicting crop yield, machine learning algorithms can recommend the optimal crop rotation schedule, fertilizer type and amount, and irrigation schedule for a particular region. By analyzing soil composition, nutrient levels, and weather patterns, farmers can maximize their yield while minimizing their costs and environ- mental impact. Machine learning can also help farmers manage pests and diseases more effectively by identifying the signs of pests and diseases based on images of crops and recommending treatment options. This information can help farmers to quickly and effectively manage pests and diseases, reducing crop damage and increasing yield. Finally, machine learning techniques can optimize the supply chain in the agriculture industry by analyzing data on crop yields, weather patterns, and consumer demand. By identifying the optimal time to plant, harvest, and transport crops, farmers can maximize their profits and minimize waste. In conclusion, machine learning techniques can help ensure a sustainable future for the agriculture industry by optimizing farming practices, increasing crop yield, and reducing environmental impact. As the world faces increasingly complex challenges, it is more important than ever that the agriculture industry embraces innovative solutions.

Keywords: Artificial Intelligence, Convolutional Neural Net- Work, Classification Algorithms

I. INTRODUCTION

In India, agriculture is crucial due to the growing population and increased food demand. However, crop yields are negatively impacted by diseases caused by bacteria, viruses, and fungi. To mitigate this, plant disease detection technology utilizing machine learning techniques can be used to identify diseases, resulting in higher yields. Additionally, recent price fluctuations and uncertain climate trends have further affected crop prices, creating a need for a system to assist farmers in achieving high-yield production and crop protection.

Farmers suffer from crop losses due to uncertainties, limited knowledge of plant diseases, and uncertain yields. They require accurate models and recommendations for required fertilizer ratios based on national air and soil parameters. India's economy is highly dependent on agriculture, but traditional approximations for crop management are still widely used by farmers, including fertilizer usage and crop selection.

Improper plant management and fertilizer use have led to sharp crop price fluctuations and increased crop damage in recent years. The purpose of the forecasting system is to assist farmers in understanding yields and managing value risks.

Using machine learning algorithms to analyze vast amounts of data and provide accurate crop yield predictions is crucial for research that contributes to food security. Precision agriculture aims to improve crop yield through the use of information technology techniques. Our system prioritizes profitability and sustainability for farmers and offers location-based crop forecasts and graphical data analysis.

The fertilizer recommendation system utilizes modern in- formation technology, soil quality assessment, and fertilization theory to improve soil nutrient management. It is designed as a fertilization model based on expert knowledge and agronomic research practices. Plant infections and diseases can be caused by living organisms and non-living factors such as soil pH, nutrient deficiencies, and weather conditions.

Plant diseases, caused by living and non-living organisms, include anthracnose, early blight, late rot, downy mildew, powdery mildew, Alternaria, leaf curl, wilt, mold, spot, rodent, and rust. This study aims to accurately identify and classify these diseases using a hybrid image processing technique.

II. RELATED WORK

There has been considerable research and constant efforts to increase crop productivity, detect fertilizer needs, and predict plant diseases by researchers in recent times. Studying their work can contribute to a better system.

1) Krishi Rakshan - A Machine Learning-based New Recommendation System to the Farmer (2022) proposed a methodology for identifying crop disorder using a picture, forecasting the most appropriate crops for the land using user- provided data on soil nutrients, rainfall, and temperature, and recommending the best fertilizer for the crop.
2) ”Agricultural Crop Recommendations Based on Productivity and Season” in 2021 proposed a methodology of data mining that plays a novel role in agriculture research. This field uses historical data to predict crop recommendations, employing techniques such as neural networks and K-nearest Neighbor. The k-means algorithm, on the other hand, does not use historical data but predicts based on computing centers of the samples and forming clusters. The accuracy of these predictions is between 90 to 95 percent, but a large dataset is still recommended to have efficient recommendations.

3) ”Healthy Harvest: Crop Prediction and Disease Detection System” in 2022 used three different algorithms for crop prediction and disease detection: Logistic regression: predicts categorical output. Random Forest: ensemble learning to improve model performance. Gaussian Naive Bayes: simple classification technique with high functionality these algorithms have high functionality and can handle high-dimensional inputs and complex classification problems. The accuracy of the system ranges from 70
4) The 2012 study ”Design of Fertilization Recommendation” proposed a methodology using a nutrient evaluation knowledge base from field experiments and a fertilizer allocation knowledge base from long-term crop management experience. These knowledge bases store information on evaluating soil nutrients and regular fertilizer arrangement and allocation for a particular crop. Machine learning algorithms are used for nutrient evaluation. The knowledge base also includes information on the times, proportion, operation approach, and special fertilization habits, such as the use of ammonium bicarbonate for early rice in Zhejiang province. The study provides calculation formulas and tables for fertilizer allocation.
5) In 2022, a study compared the performance of machine learning classifiers and neural networks for crop recommendation. Logistic regression is a supervised learning model used for classification problems. Random Forest is a classification method that constructs multiple decision trees and takes the majority of their votes for better classification. Support Vector Machine Classifiers are used for linear and non-linear data, and different kernels are used based on the type of data. Neural networks consist of different layers of nodes, including an input layer, one or more hidden layers, and an output layer, with each node connected to others with weight and bias.
6) ”Crop Yield Prediction and Efficient use of Fertilizers” in 2019 proposed the Random Forest Algorithm that fits both large and small data and provides an efficient prediction. It creates different decision trees based on the data and counts the votes to give the output. The back propagation algorithm is used for large datasets with no proper relationships between data attributes to build a habit work model by training the dataset and predicting the output.
7) The “Farming Made Easy 2021” paper proposed an algorithm that takes user input parameters such as cultivation date and location to recommend a crop. To recommend suitable fertilizers based on the crop and disease present, a dataset is used. The algorithm also displays nearby Agri-Shops using Google API and the location of recommended fertilizers. A chat function is also included by initializing the socket and establishing the connection between the client and the server.
8) The paper “A Review of Machine Learning Classification Techniques for Plant Disease Detection” in 2022 suggests using SVMClassifier, a supervised learning method in machine learning, for disease detection in various crops. The authors were able to detect three different types of diseases with smaller features using SVM classifiers with an accuracy of 90%. Additionally, the paper proposes using ANN Classifier, an Artificial Neural Network computational model for machine learning and pattern recognition, for plant disease recognition using feedback backpropagation algorithm with an accuracy of around 93%.
9) Detection of Plant Leaf-based Diseases Using Machine Learning Approach in 2022 proposed the steps” Step 1 - Input the images. Step 2 - Pre-processing: Here the size of the input image datasets are preprocessed in uniform size. Step 3 - The image Segmentation step uses the K-Means clustering method for performing the segmentation process and converts pre- processed image from RGB Color Space to L* a* b* Color Space. Step 4 - Feature Extraction: Disease leaf or healthy leaf features can be extracted by analyzing the edge-based, point-based, and line-based of the segmented leaf image. Step 5 - In this step, a support vector machine learning classification algorithm is implemented. Step 6 - Detection of plant leaf- based disease is predicted by the performance metrics like Root Mean Square Error (RMSE), Peak Signal Noise Ratio (PSNR), and disease-affected area of the leaf by using the Euclidean Distance method.”

III. Proposed System

After identifying the problem statement and the gaps in the existing systems we proposed a solution to build Machine Learning Models for Crops, fertilizers, and Plants.

In the crop recommendation application, the user can pro- vide the soil data from their side and the application will propose a crop should the user grow.

Fertilizer recommendation application, the user can input the soil data and the type of crop they are growing, and the application will predict the soil lacks or has an excess of and will recommend improvements.

Plant disease prediction application, the user can input an image of a diseased plant leaf, the application will predict what disease it is and will also give a little background about the disease and suggestions to cure it.

We have added more than 120+ Languages using NLP techniques and Google API so that the website is accessible by anyone around the globe.

A. Description

Python is used for programming in all modules, while Django is used for building the web application. The storage of data obtained from crop prediction and fertilizer prediction is done using the SQL-lite server. Matplotlib is utilized for graph visualization, while the front end of the application is built using HTML, CSS, and JavaScript.

B. Requirements

The system is a Python-based application that can be run on both laptops and personal computers. To obtain accurate predictions for crops and fertilizers, users must input their soil data and location. Additionally, if the user wishes to detect any diseases present in the plant, they can submit an image of the diseased plant to our model for diagnosis. To utilize the system, users must have a browser installed on their computer.

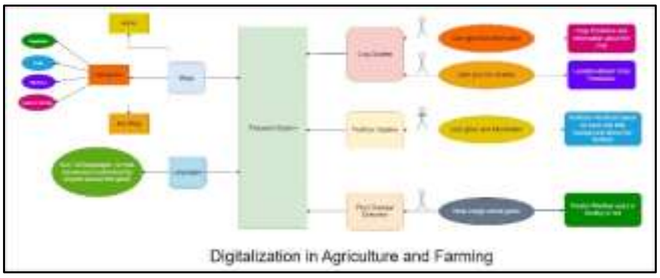

Fig. 1: Proposed System

C. Design and Methodology

In Figure 1 the proposed system contains modules:

1) Crop Recommendation System
2) Fertilizer Recommendation System
3) Plant Disease Detection System
4) Blogs
5) Languages

In crop recommendation system, the model requires soil in- formation, including Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, pH level, and rainfall, as input. By analyzing this information, the model can predict the most appropriate crop for the user. Additionally, the system offers crop recommendations that are specific to the state, district, year, and season. This feature allows the user to determine which crop is most suitable for a particular season or location. In the fertilizer recommendation system, analyzes soil information such as Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, pH level, rainfall, crop type, and soil type. By using this information, the model can recommend the most suitable fertilizer for the user.

The Plant Disease Detection System is capable of predicting the presence of diseases in plants and providing appropriate solutions for their treatment. To accomplish this, users are required to submit an image of plant leaves exhibiting symptoms of the disease.

The blog consists of articles covering various topics such as crops, fertilizers, different types of diseases, crop cultivation, livestock management, and more.

The website offers content in 120 different languages to ensure accessibility and enable everyone to comprehend the information provided on the site.

D. Algorithms and Comparison of Algorithm

1) Crop Recommendation System

For the Crop Recommendation System, we used a dataset of size 2200 x 8. This dataset contains a different field for crop recommendation. The fields of the dataset are:

- Nitrogen
- Phosphorous
- Potassium
- Temperature
- Humidity
- Ph
- Rainfall
- Crop

	N	P	K	temperature	humidity	ph	rainfall	label
0	90	42	43	20.879744	82.002744	6.502985	202.935536	rice
1	85	58	41	21.770462	80.319644	7.038096	226.655537	rice
2	60	55	44	23.004459	82.320763	7.840207	263.964248	rice
3	74	35	40	26.491096	80.158363	6.980401	242.864034	rice
4	78	42	42	20.130175	81.604873	7.628473	262.717340	rice

Fig. 2: Crop Dataset

The dataset contains 22 different types of crops like 'rice', 'maize', 'chickpea', 'kidney beans', 'pigeon peas', 'moth beans', 'mungbean', 'black gram', 'lentil', 'pomegranate', 'banana', 'mango', 'grapes', 'water- melon', 'muskmelon', 'apple', 'orange', 'papaya', 'coconut', 'cotton', 'jute', 'coffee'. Previously, crop prediction was based on farmers' past experiences. However, agricultural factors have advanced significantly, requiring the use of engineering methods in crop prediction. Rice is a major crop in the Northern region of India, and statistical methodologies have been employed to predict its production. To recommend crop yield and planting, we have used various clustering and classification techniques in major districts across India. Factors implementing crop yield were considered are:

- Rainfall, Humidity, Minimum, and Maximum Tem- perature
- PH Level
- Area factors-irrigated or cultivated

The LightGBM Model was utilized to train our dataset. This gradient-boosting framework leverages tree-based learning algorithms to achieve high levels of accuracy. Unlike other algorithms that grow trees horizontally, Light GBM grows trees vertically in a leaf-wise fashion, selecting the leaf with the maximum delta loss to grow. Compared to level-wise algorithms, a leaf- wise algorithm can minimize more loss while growing the same leaf, resulting in higher accuracy. The model demonstrates an accuracy rate ranging from 90 to 96 percent.

2) Fertilizer Recommendation System:

The fertilizer dataset contains a different field for Fertilizer recommendation. Figure 3 shows the fields of the dataset: nitrogen, phosphorous, potassium, temperature, humidity, moisture, rainfall, soil type, crop type, and fertilizer type.

The fertilizer recommendation system was implemented using a random forest classifier. This ensemble learning method comprises numerous individual decision trees. Each tree generates class predictions, and the class with the highest number of votes becomes the model's prediction. In a conventional decision tree, the algorithm considers all possible nodes when splitting a node and selects the one that maximizes the separation between observations in the left and right nodes. In contrast, each tree in a random forest can only choose from a random subset of features. This results in greater variability between trees in the model, ultimately leading to less correlation between trees and greater diversification. The random forest is a classification algorithm that uses many decision trees. The inclusion of randomness in individual trees through ingredient boosting attempts to create a forest of uncorrelated trees, thereby resulting in more accurate predictions by the committee compared to individual trees. The model demonstrates an accuracy rate between 94 to 96 percent.

	N	P	K	temperature	humidity	ph	rainfall	label
0	90	42	43	20.879744	82.002744	6.502985	202.935536	rice
1	85	58	41	21.770462	80.319644	7.038096	226.655537	rice
2	60	55	44	23.004459	82.320763	7.840207	263.964248	rice
3	74	35	40	26.491096	80.158363	6.980401	242.864034	rice
4	78	42	42	20.130175	81.604873	7.628473	262.717340	rice

Fig. 3: Fertilizer Dataset

3) Plant Disease Detection System

- Step 1: Perform image segmentation with KMeans clustering to convert the preprocessed image from RGB color space to Lab* color space. Lab* space consists of an L* luminance layer and ab chrominance layer. KMeans clustering is used to classify RGB colors mainly in the ab color space. The image is segmented into three clusters based on a distance measure like the Euclidean distance method.
- Step 2: Feature Extraction: Analyzing segmented leaves, we extract features using edge, point, and line-based images. A point-based method is used to measure disease percentage in leaf areas.
- Step 3: Classification: The next step involves implementing a support vector machine (SVM) learning classification algorithm. The SVM model is trained on a labeled dataset consisting of 70% training data and 30% test data to accurately predict outcomes.
- Step 4: Output detection and prediction.
  AlexNet CNN-based classification method was used to detect crop diseases. We use similar patterns shown in research papers. AlexNet consists of 5 Conv layers starting with an 11x11 kernel. This was the first architecture using a max pooling layer, a ReLu activation function, and three giant linear layer dropouts. This network was used for image classification with 1000 possible classes. We performed 20 epochs to train the model.

Fig. 4: Database Schema

E. Database Schema

1) Blog:

The blog section of the website covers a range of topics related to agriculture and farming, including crop cultivation, fertilizers, livestock management, and disease prevention. The blogs provide valuable information and guidance to farmers on how to efficiently grow crops, the precautions they should take, and how to prevent and manage diseases. Additionally, the blogs offer insights into the different types of crops, their uses, and the best practices for selling them.

2) CropInfo:

CropInfo contains 2 fields: Crop Name and Description. In this table, we are storing all types of crops and a little description of the crops.

3) FertilizerInfo:

FertilizerInfo contains 2 fields: Fertilizer Name and Description. In this table, we are storing all types of fertilizer and a little description of the fertilizer.

4) PreviousFertilizerPred:

PreviousFertilizerPred table contains all the previous fertilizer predictions so that whenever the next farmer visits the website he/she does not need to enter all the data again. This saves the time of the farmer as well as computation.

5) PreviousCropPred:

PreviousCropPred table contains all the previous crop predictions so that whenever the next farmer visits the website he/she does not need to enter all the data again. In this way, he/she can easily find out which crop they should grow.

6) Crop State:

The Crop State table presents location- specific information on crops, organized by state, district, year, and season. This comprehensive dataset spans from 1994 to 2015, allowing farmers to efficiently analyze large amounts of data.

IV. RESULTS AND DISCUSSION

Algorithm	Accuracy
Crop Prediction (LightGBM)	94.86
Fertilizer Prediction (Random Forest Classifier)	96
Plant Disease Prediction (AlexNet Classifier)	92.2

Table 1: shows the accuracy of different models.

Our website's homepage provides comprehensive information about our team, project, and mission. Visitors can easily navigate through different sections such as Crop, Fertilizer, Plant, and Blogs. The homepage features the most frequently used predictions, as well as information about our team. Additionally, farmers facing any issues can visit the Contact section to directly communicate with us and receive assistance in resolving their problems. In the crop section to predict the crop, we need to fill out the above form shown in Figure-5. After entering the soil information, the green box will display the recommended crop as Pomegranate. The system will also automatically update the PreviousCropPred table with this information, eliminating the need for farmers to repeatedly enter the same data on subsequent visits to the website.

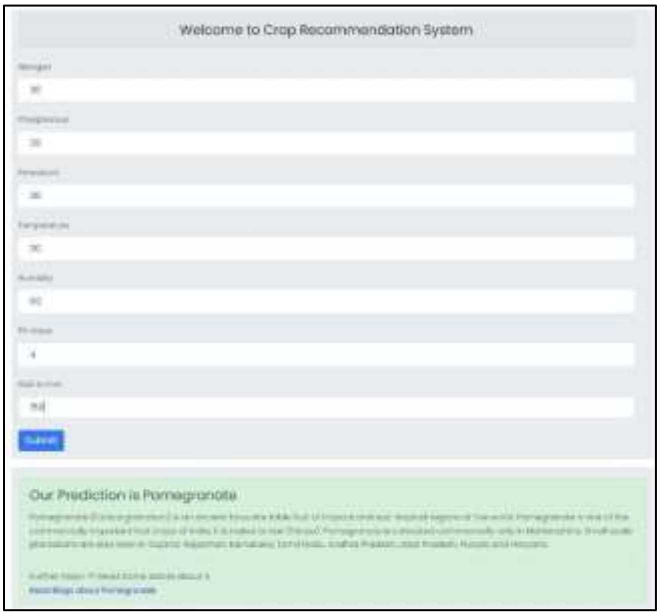

Fig. 5: Crop Prediction

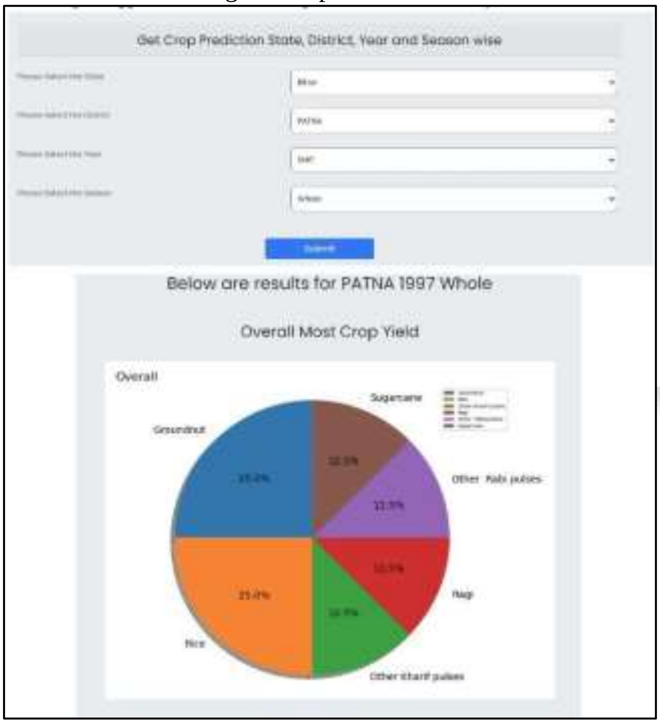

Fig. 6: Crop Location Wise

In Figure-5 our model recommends crops based on key parameters such as State, District, Year, and Season, which have been analyzed to provide insights on the most profitable crops to grow. For example, a pie chart is shown for Bihar Patna in 1997 for the entire season, displaying the yield of different crop types. This format enables farmers to efficiently analyze crop data. The model also generates a tabular format of the data below the pie chart. If only the state is provided as input, the model displays all relevant data related to that particular state.

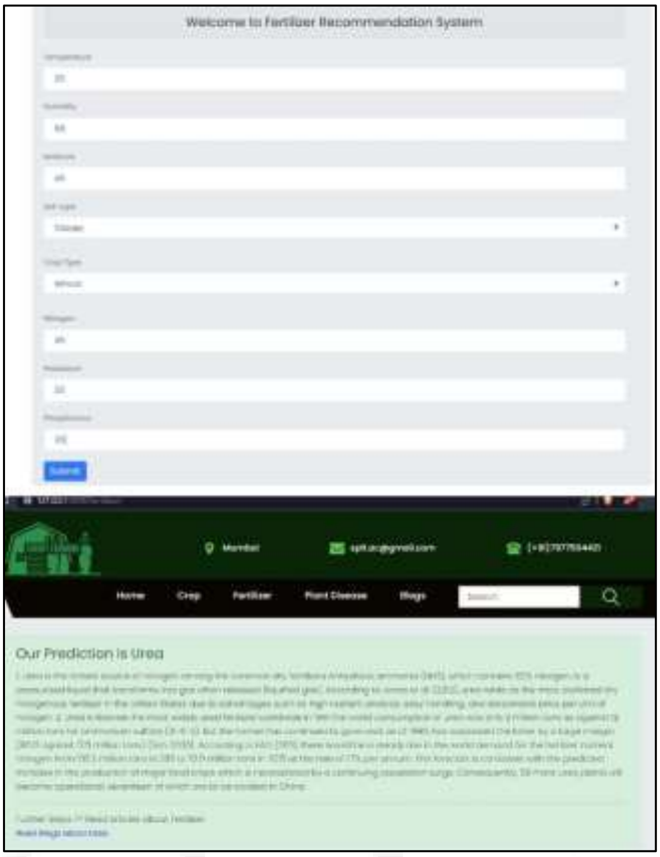

Fig. 7: Fertilizer Prediction

In the fertilizer recommendation system Figure-7, users are required to input the following information: Temperature, Humidity, Moisture, Soil Type, Crop Type, Nitrogen, Potassium, and Phosphorus. Once the user submits this information, the system will predict the appropriate fertilizer and store this information in the database. This will eliminate the need for farmers to repeatedly input the same data on subsequent visits to the website in order to receive fertilizer recommendations.

Figure-8 shows the plant disease model output is generated by submitting an image of a plant, which the system then analyzes to predict the presence of disease. The model also provides users with relevant articles to read in order to help solve the problem. For example, upon submitting the image file"CornCommonRust3.jPG," the system will predict the presence of disease in the image and provide output accordingly.

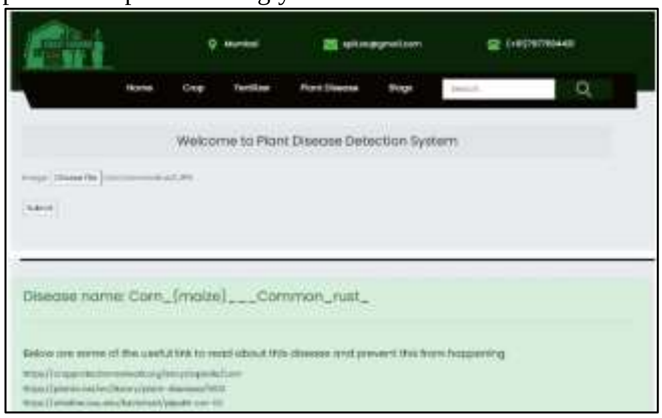

Fig. 8: Plant Prediction

V. Further work

The crop and fertilizer recommendation system is designed to simplify the work of farmers and eliminate the need for reliance on other sources of information. By entering the required parameters into the system, the recommended crop or fertilizer is delivered to the user. This results in better yields for farmers, improving their financial situation and contributing to increased production, which in turn can help address the issue of hunger in the country. Additionally, the system is equipped to detect and mitigate the impact of unexpected changes in nature, such as plant infections. Through disease detection and treatment recommendations for user-uploaded images, the system can help farmers maintain healthy crops and maximize their yields.

In addition to the existing system, there is potential to further improve farming outcomes by incorporating the Inter- net of Things (IoT). This can be done by building hardware that includes pH, precipitation, and humidity sensors, which can be installed in fields to provide real-time data about soil conditions. This data can then be directly transmitted to farm- ers' mobile phones and integrated into the recommendation systems, further enhancing the accuracy and usefulness of the system. By continually retraining the model with real-time data, the overall accuracy of the system can be improved, leading to better outcomes for farmers.

VI. Conclusion

In conclusion, the crop and fertilizer recommendation sys- tem we have developed is a valuable tool for farmers that simplifies their work and eliminates the need to rely on other sources of information. It provides a user-friendly interface that allows farmers to enter the required parameters and receive accurate recommendations for crops and fertilizers. This system has the potential to significantly increase agricultural productivity and improve the financial situation of farmers. Furthermore, we propose the integration of IoT hardware such as pH, precipitation, and humidity sensors that can provide real-time data directly to farmers' mobile phones. By incorporating this data into our recommendation system, we can improve its accuracy over time. Our research work has demonstrated the effectiveness of machine learning algorithms

References

[1] Laurens Klerkx, Emma Jakku, Pierre Labarthe', 'A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda' Wageningen University Australia, 2019.

[2] Divyanshu Varshney, Burhanuddin Babukhanwala Deepika saxsenfield- ant Disease Detection Using Machine Learning Techniques' National Institute of Technology, Kurukshetra, , July 2022.

[3] Kanaga Suba, 'Design and Implementation of Fertilizer Recommenda- tion System for Farmers' Easwari Engineering College, India, 0skip 1em plus 0.5em minus 0.4em, November 2020.

[4] Mrs. Shruthi U, Dr. Nagaveni V, Dr. Raghavendra B K, 'A Review on Machine Learning machine-learning techniques for Plant Disease Detection' 5th International Conference on Advanced Computing Com- munication Systems (ICACCS). ,, 2019.

[5] Vaishnavi.S, Shobana.M, Sabitha.R, Karthik.S, 'Agricultural Crop Rec- ommendations based on Productivity and Season', Sri Ramakrishna Engineering College, SNS College of Technology, Coimbatore, 2021 7th (ICACCS).

[6] S.Bhanumathi, M.Vineeth and N.Rohit , 'Crop Yield Prediction and Effi- cient use of Fertilizers', Sathyabama Institute of Science and Technology, Chennai, India, April 2019.

[7] Zhouqiao Ren, Xiaonan Lu, 'Design of Fertilization Recommendation Knowledge Base and Application' Institute of Digital Agriculture, Zhejiang Academy of Agricultural Sciences Hangzhou, China, 2020.,, 2020 .

[8] Punitha Kartikeyan, Gyanesh Shrivastava, 'Hybrid Feature Approach for Plant Disease Detection and Classification using Machine Learn- ing,'School of Information Technology MATS University Raipur, Chhat- tisgarh, 2022.

[9] P. Chaitanya Reddy, Rachakulla Mahesh Sarat Chandra, Vadiraj P, M. Ayyappa Reddy, Mahesh T R, Sindhu Madhuri G, 'Detection of Plant Leaf-based Diseases Using Machine Learning Approach', JAIN (Deemed-to-be University), Bengaluru, 2021.

[10] Sambhav Bhansali, Punit Shah, Jinay Shah, Priyal Vyas, 'Healthy Harvest: Crop Prediction and Disease Detection System', Universal College of Engineering Mumbai, India, Apr 07-09, 2022.

[11] D.N.V.S.L.S. Indira, M. Sobhana, A.H.L.Swaroop, Phani Kumar, "KR- ISHI RAKSHAN - A Machine Learning based New Recommendation System to the Farmer,"Gudlavalleru Engineering College, Gudlavalleru, AP, India, (ICICCS) 2020.

[12] A. Harish Kumar, B.Rajendra Naik, 'The Performance Analysis and comparison of Machine Learning Classifiers and Neural Network on Crop Recommendation', Osmania University, Hyderabad, India, 2022 8th International Conference on Advanced Computing and Communi- cation Systems (ICACCS)., 2022.

[13] Kanga suba raja subramanian, 'Design and implementation of fertilizer recommendation system for farmers', kanga suba raja publication, November 2022.

[14] Devdatta A. Bondre Mr. Santosh Mahagaonkar, 'PREDICTION OF CROP YIELD ANDFERTILIZER RECOMMENDATION USING MA- CHINE LEARNING ALGORITHMS', International Journal of Engi- neering Applied Sciences and Technology, 2019 Vol. 4, Issue 5, ISSN No. 2455-2143., september 2019.

[15] Palaniraj , Balmurugan, Durga prasad, pradeep, 'crop and fertilizer recommendation system using machine learning ', Assistant Professor, Department of Information Technology, Panimalar Institute of Technology, Chennai, India, April 2021.

