2024 International Conference on Computational Intelligence for Green and Sustainable Technologies (ICCIGST) | 979-8-3503-8188-7/24/$31.00 ©2024 IEEE | DOI: 10.1109/ICCIGST60741.2024.10717535

A Web-Based Agriculture Recommendation System using Deep Learning for Crops, Fertilizers, and Pesticides

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***Abstract*—Agriculture plays a pivotal role in the economies of developing countries like India, making a substantial contribution to their gross domestic product (GDP). However, farmers often struggle with selecting appropriate crops, fertilizers, and pesticides, frequently neglecting site-specific factors like soil type, water requirements, temperature, and regional crop profitability. These oversights can lead to reduced crop quality, yield, and profitability. To address this challenge, a recommendation system is proposed. It employs an ensemble model with a majority voting technique for crop selection based on site-specific parameters, aiming for high accuracy and efficiency. This system utilizes NPK (Nitrogen, Phosphorus, and Potassium) values, temperature, relative humidity, and pH data for real-time crop prediction. Furthermore, it includes modules for fertilizer and pesticide recommendations. For pest identification, a convolutional neural network (CNN) model is employed, allowing users to upload images of pests, with the system recommending corresponding pesticides. Developed as a web-based platform, this system aims to provide farmers with accessible tools for informed decision-making to improve crop quality, yield, and profitability.**

***Index Terms*—pest identification, fertilizer recommendation, real-time crop prediction, ensemble model, convolutional neural network**

I. Introduction

Agriculture is the backbone of the Indian economy. India is an agro-based economy, which means that many industries depend on agriculture. People living in villages depend on agriculture for their livelihood. However, many farmers are still using traditional methods, which can lead to inefficiencies, uneven yields, and excessive chemical inputs. Soil degradation and productivity loss can increase if the right crop is not selected. Traditional methods can lead to low yields, low income, excessive use of chemicals, and uncertainty in decision-making.

Technology, especially machine learning and deep learning, is bringing a new approach to the agricultural sector by providing intelligent data-driven recommendations for crop selection and fertilizer and pesticide use and management. This technology has the potential to optimize agricultural practices and improve yields.

This research paper presents a user-friendly web-based solution incorporating machine learning and deep learning to help farmers. The goal is to bridge the gap between traditional practices and modern innovations that give farmers better choices, ultimately leading to better agricultural practices and sustainability.

II. Literature Review

In this research, it was observed that crop recommendation has been extensively explored, with various systems employ ing different parameters in machine learning models such as Random Forest, Decision Tree, and Ensemble methods. However, fertilizer recommendation in artificial intelligence has not received as much attention, likely due to scattered data. Despite this, data was collected and integrated from diverse sources to create a well-organized dataset and implement a dictionary-based solution. Pesticide recommendation remains an untouched area, with researchers primarily focusing on pest detection. This work expanded this concept to include pest identification and developed a dictionary-based solution for recommending suitable pesticides in India.

Understanding the importance of agriculture as a major source of livelihood in India, and recognizing the efforts of Indian farmers in feeding the population, our project aims to serve farmers through modules for Crop Recommendation, Fertilizer Recommendation, and Pesticide Recommendation.

These efforts aim to provide valuable support to Indian farmers in optimizing their agricultural practices. The following research papers were discussed in the research:

The paper presents [1] a user-friendly yield prediction system, especially tailored for farmers in rural India. Some of the machine learning algorithms such as the Support Vector Machine, Artificial Neural Network, Random Forest, Multivariate Linear Regression, and K-Nearest Neighbor are used in predicting the yields accurately. Interestingly, the Random Forest showed an accuracy level of up to 95%, making it very promising for use in applications involving the prediction of yields with a high level of precision. The system also recommends the best time for applying the fertilizer, which will help in increasing the yield, thus solving the problem of low yields per hectare in India.

The smart farming technique mentioned in [2] combines Internet of Things (IoT) technologies with a GPS module to assess soil characteristics and determine optimal kinds and dosages of fertilizers and herbicides. Farmers can optimize pesticide and fertilizer usage for increased efficiency and sustainability by using GPS and Internet of Things (IoT) technologies to monitor crop positions and collect real-time soil condition data.

The model proposed by researchers [3] aims to maximize crop yield and recommend profitable crops for specific regions. This model predicts crop yield based on economic and environmental conditions, assisting in meeting food supply demands and determining fertilizer usage. By employing KNN and ANN algorithms, the model achieves a 65.05% accuracy rate after applying datasets from government websites and KAGGLE, further enhancing efficiency and accuracy through various parameters and algorithms.

In the study, researchers [4] employed a suite of machine learning and deep learning algorithms to forecast crop growth based on soil quality. Drawing from datasets encompassing temperature, humidity, rainfall, soil moisture, and pH levels, they train models including Decision Tree, K-Nearest Neighbor, and Random Forest. Impressively, the Random Forest model achieves a peak accuracy of 93.11 percent. Their resultant web-based software provides real-time predictions of crop growth on farmland, leveraging IoT data for enhanced precision and empowering farmers to optimize yields.

The study [5] introduces an innovative system for identifying pests that categorizes crops' beneficial and harmful pests. It outlines existing pest identification techniques and introduces a novel approach utilizing convolutional neural networks (CNN). The model is trained on a dataset consisting of 9,500 photos representing 20 pests and subsequently tested on a large dataset. Impressively, the system achieves a classification accuracy of 90%, outperforming traditional methods.

This study [6] presents a deep learning-based detection system aimed at identifying leaf diseases and pests while also recommending suitable fertilizers and pesticides. Leveraging pre-trained CNN models, the system identifies EfficientNet-Lite1 as the most accurate for leaf disease detection and ResNet50 for pest detection. The primary objective is to effectively address leaf diseases and pest infestations.

In this study [7], researchers focus on developing a specialized dataset for tomato diseases and pests. Their goal is to compile a comprehensive resource covering various diseases and pests common to tomato plants. Additionally, they optimize the Yolo V3 model to improve its accuracy in identifying disease and pest locations. This study contributes to advancing disease diagnosis and pest control strategies in tomato cultivation, providing valuable tools for researchers and practitioners in plant pathology and pest management.

In the study [8], machine learning (ML) techniques are employed to predict crop expansion, a crucial aspect of crop forecast management. Various regression methods, including random forest, linear regression, decision tree regression, polynomial regression, and support vector regression, are compared. This analysis demonstrates a 3.6% improvement over existing methods, underscoring the efficacy of ML in crop forecasting.

In their exploration of plant diseases and pest detection, researchers [9] dissect the prevailing issues, contrast conventional methodologies, and delve into the discourse on deep learning-based techniques within classification, detection, and segmentation networks. This meticulous analysis of existing studies culminates in the proposal of innovative solutions, research avenues, and prognostic insights into forthcoming trends in plant diseases and pest detection, all underpinned by deep learning methodologies.

In their study [10], researchers focus on predicting crop production based on factors such as soil composition, crop characteristics, and water availability. Their research utilizes a hybrid approach of neural networks and image processing, satellite remote sensing methods, and clustering algorithms with k-Nearest Neighbor to identify hidden patterns and predict climate data for crop production optimization.

III. Proposed Work

The proposed system is a comprehensive web-based application designed to enhance precision agriculture by providing intelligent recommendations for crops, fertilizers, and pesticides. By leveraging advanced machine learning and deeplearning techniques, this system aims to improve decision making and productivity for farmers through data-driven in sights. As in Fig. 1 the system consists of three integrated modules, each addressing a critical aspect of farming recommendations.

The first module focuses on crop recommendation, employ ing an ensemble model that integrates multiple machine learn ing algorithms such as Support Vector Machine (SVM), Ran dom Forest, Naive Bayes, and K-Nearest Neighbors (KNN). The ensemble model uses a majority voting technique to ensure robust and accurate crop suggestions. By analyzing site-specific parameters, including soil characteristics, climate conditions, and historical crop yields, the system identifies the most suitable crops for a given location. This approach aims to minimize the risk of selecting inappropriate crops, thereby enhancing productivity and profitability for farmers.

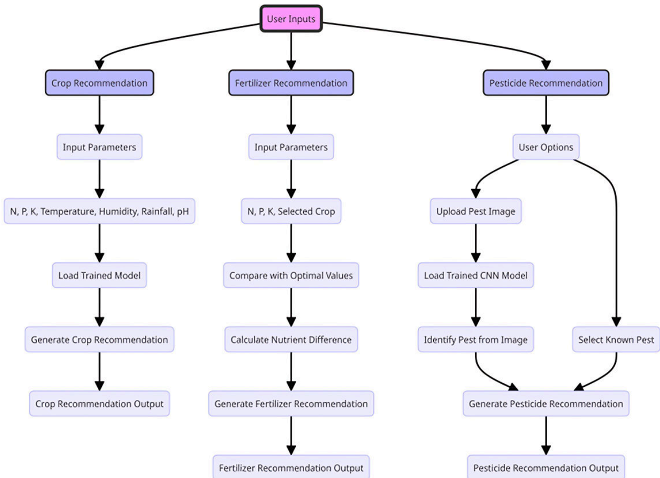

Fig. 1: Methodology Diagram

The second module provides fertilizer recommendations based on the nutrient requirements of the soil and the selected crop. The system performs an analysis of the soil's nitrogen (N), phosphorus (P), and potassium (K) levels to determine nutrient deficiencies. It then matches these deficiencies with a comprehensive dictionary of organic fertilizers, suggesting the most suitable options through a simple mathematical calcula tion. This ensures that the soil receives the optimal balance of nutrients, promoting healthy crop growth and sustainable farming practices.

The third module is dedicated to pest recognition and pesticide recommendation. Utilizing a convolutional neural network (CNN) model, the system processes images of af fected crops uploaded by farmers to identify pests accurately. The CNN model has been trained on a diverse dataset of pest images, allowing it to recognize various pests commonly found in India. Once a pest is identified, the system cross-references a database of pesticides to recommend effective treatments, considering the availability and suitability of pesticides in the Indian context. This module helps farmers quickly and accurately identify pests and choose the right pesticide, thereby minimizing crop damage and increasing yield.

The proposed system is implemented as a web application to ensure accessibility and ease of use. It features an intuitive interface that allows farmers to input data, upload images, and receive real-time recommendations. The web-based nature of the application enables access from anywhere with an internet connection, making it practical for farmers in various regions.

IV. Methodology

A. Crop Recommendation Module

The crop recommendation module in Fig. 2 is designed to assist farmers in selecting the most suitable crops for their specific site conditions. This module employs an ensemble model incorporating multiple machine learning algorithms, including Support Vector Machine (SVM), Random Forest,

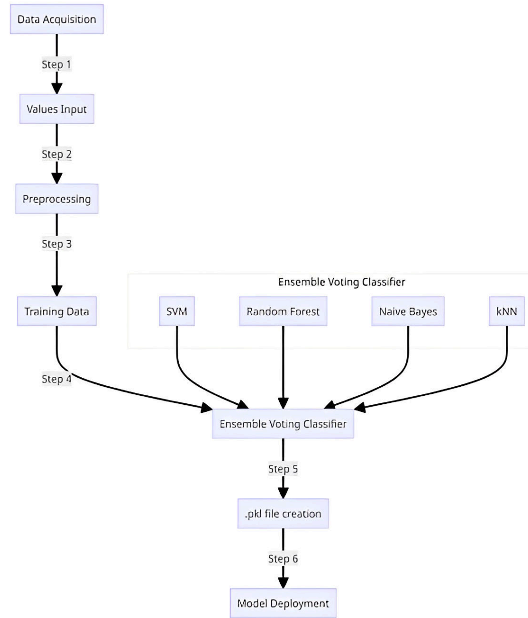

Fig. 2: Methodology Diagram for Crop Recommendation System

NaiveBayes, and K-Nearest Neighbors (KNN). Data collection and preprocessing are the first steps, involving the gathering of soil characteristics, climate conditions, and historical crop yields from the user's location. This data undergoes preprocessing to handle missing values, normalize features, and encode categor ical variables. Each of the individual models is then trained on this preprocessed dataset, leveraging their unique strengths: SVM for its robustness in high-dimensional spaces, RandomForest for handling non-linear relationships, Naive Bayes for simplicity and efficiency, and KNN for local approximations.For predictions, the module uses an Ensemble Voting Classifier with a soft voting technique. In this approach, thepredicted probabilities from each model are averaged, and the class with the highest average probability is chosen asthe final recommendation. This soft voting method enhances the accuracy and reliability of crop predictions by combining the strengths of all individual models. The ensemble model ensures that the most suitable crop is recommended, tailored to the specific soil and climatic conditions of the user's location, thereby reducing the likelihood of inappropriate crop selection and increasing productivity.

B. Fertilizer Recommendation Module

The fertilizer recommendation module in Fig. 3 focuses on optimizing soil fertility through precise nutrient management.This module starts with an analysis of the soil's nitrogen (N), phosphorus (P), and potassium (K) levels, which are critical for crop growth. The system evaluates these nutrient levels from soil test results provided by the user. It then references a comprehensive dictionary of organic fertilizers, which details the nutrient compositions of various fertilizers.

The recommendation engine employs a simple mathematical calculation to determine the required nutrient amounts based on the crop's specific needs and the existing soil nutrient levels. This calculation helps identify nutrient deficiencies and matches them with appropriate fertilizers from the dic tionary. By suggesting fertilizers that provide the optimal nutrient balance, the system promotes healthy crop growth and sustainable farming practices. This targeted approach to fertilizer recommendation ensures that the soil receives the necessary nutrients without over-application, which can be both environmentally harmful and economically inefficient.

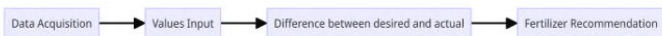

Fig. 3: Methodology Diagram for Fertilizer Recommendation System

C. Pesticide Recommendation Module

The pesticide recommendation module in Fig. 3 addresses pest management through image-based pest recognition and appropriate pesticide suggestions. This module uses a Con volutional Neural Network (CNN) model, which is highly effective for visual recognition tasks. Farmers upload images of crops showing signs of pest infestation, which are then preprocessed to enhance their quality. Preprocessing steps include resizing, normalization, and augmentation to improve the robustness of the model.

The preprocessed images are analyzed by the CNN model,trained on a diverse dataset of pest images. The model identifies the type of pest affecting the crop based on the visual features extracted from the images. Once the pest is identified,the system cross-references a database of pesticides to recommend effective treatments. These recommendations take into account the type of pest, the specific crop affected, and the availability of pesticides in India, ensuring that the suggested pesticides are both effective and accessible to the farmers. This module helps farmers quickly and accurately identify pests and choose the right pesticide, thereby minimizing crop damage and enhancing yield

Fig. 4: Methodology Diagram for Pesticide Recommendation System

V. Results

Several analyses were done on our crop recommendation model. First, we used the accuracy score for the efficacy of our machine learning algorithm in helping to foretell the best crops for specified site conditions. We use, in this work, an ensemble model that adds learners from Naive Bayes, kNN, SVM, and Random Forest. It gave a really outstanding accuracy score of 96.44%, better than the accuracy by any of the previous models, showing improvement. On the contrary, our group study has resulted in a dictionary-based approach for our fertilizer advice. Finally, when a user uploads pictures of pests with the intention of identification, the pesticide recommendation module is activated. The identification of the pest by the deep learning in the CNN model is worn. Herein, performance is evaluated by both training and validation loss together with accuracy as elaborated below.

TABLE I: The Performance through Training And Validation Accuracy as Well as Training And Validation Loss

	Accuracy	**Loss**
Training	0.9699	0.0712
Validation	0.9520	0.4681

The model's accuracy and loss metrics are depicted in graphical representations, Fig.5 and Fig.6 showcasing its performance during training and validation phases.

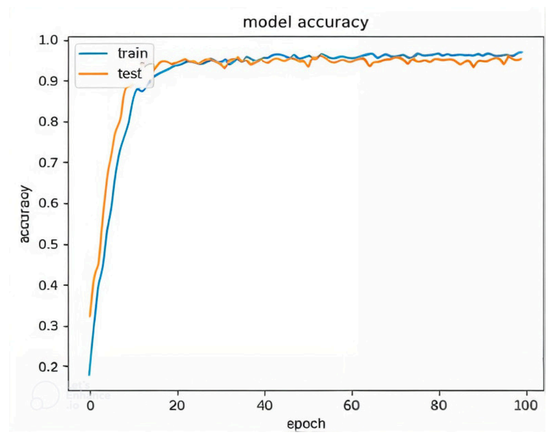

Fig. 5: Model Accuracy vs Epochs

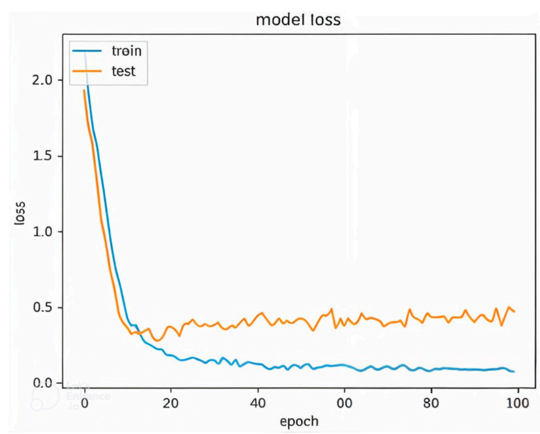

Fig. 6: Model Loss vs Epochs

The homepage of our website presents three pivotal options: crop recommendation, fertilizer recommendation, and pesti cide recommendation. Users can effortlessly select the service they need by choosing the respective option. This stream lined approach ensures easy access to essential agricultural guidance. The user will be given a choice for selecting their module, as shown in Fig. 7. Based on the requirements, the user selects the appropriate module on our website.

Fig. 7: Home Page

Let's say the user want to use the Crop Recommendation service. In order to find out what crop they need to plant on their farm, they can enter in the appropriate units for N, P, K, pH, rainfall, temperature, and relative humidity.Refer to Fig. 8 for further information.

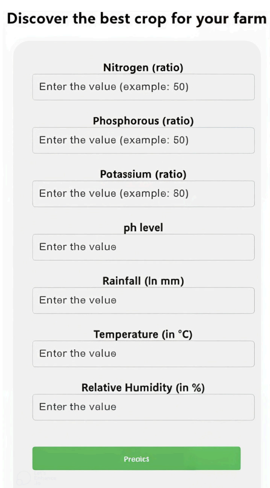

Fig. 8: Crop Recommendation (input)

Now, Fig. 9 after the user pressed the "Predict" button then the result will be shown on the screen, here in this case, it recommends "rice". Hence this is most suitable to the soil as per current weather conditions and soil conditions.

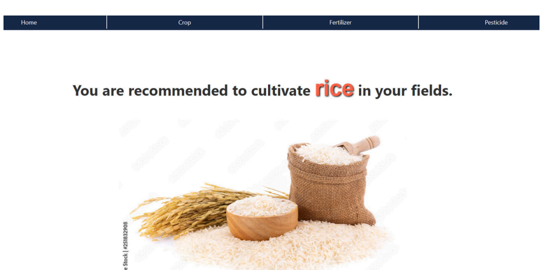

Fig. 9: Crop Recommendation (output)

Similarly, in Fig. 10 the user can access the "Fertilizer Recommendation" service by entering values for N, P, K, and the specific crop. Following this, the user will receive information about the soil's status, highlighting differences between the desired nutrient values and those present in the user's farm. Subsequently, based on the current soil condition, informed advice on suitable organic fertilizers will be provided as shown in Fig. 11

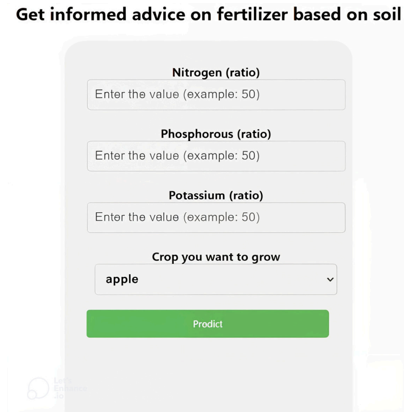

Fig. 10: Fertilizer Recommendation (input)

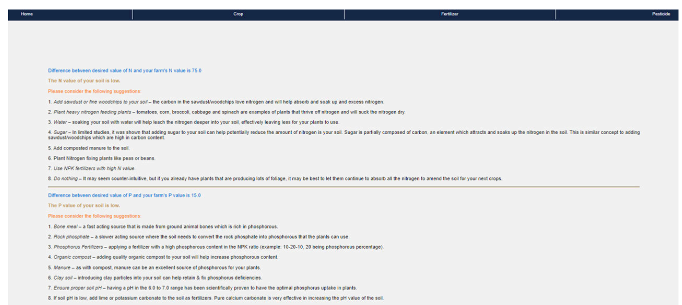

Fig. 11: Fertilizer Recommendation (output)

The Following Fig. 12 given below shows the third module "Pesticide Recommendation" where the user can upload an image of the pest that clearly shows the pest and they click the "Predict" button, initiating a rapid analysis by the machine learning algorithm.

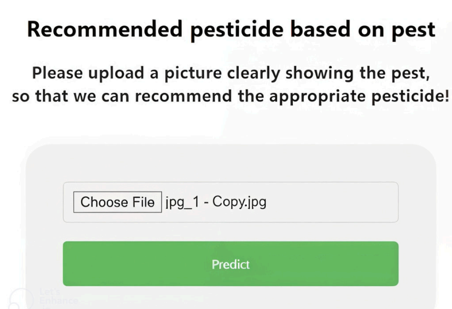

Fig. 12: Pesticide Recommendation (input)

Then our pesticide recommendation system which is employed with CNN would identify the pest and recommended the pesticides accordingly.Each suggested product will provide detailed information such as in Fig. 13 the product name, dosage, and quantity that farmers should consider acquiring.

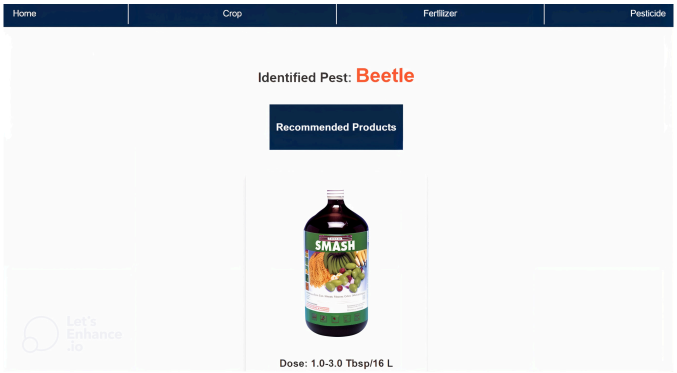

Fig. 13: Pesticide Recommendation (output)

VI. Conclusion

In conclusion, our project, titled ”A Web-Based Agriculture Recommendation System using Deep Learning for Crops, Fertilizers, and Pesticides,” effectively addresses the crucial challenge confronting farmers in selecting the right crops, fertilizers, and pesticides. By taking into consideration factors like soil type, water requirements, temperature, and regional crop profitability, our system provides real-time crop pre dictions and employs convolutional neural networks for pest identification from images. This solution aims to empower farmers with informed decisions, ultimately enhancing crop quality, yield, and profitability, while offering accessible rec ommendations.

Moving forward, we recommend expanding the system's crop and fertilizer support for easy addition of new items, enhancing the pest database, and integrating real-time weather data through weather APIs to deliver precise crop recommen dations based on current conditions.

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