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An Intelligent Crop Advisory Framework for Precision Agriculture Using Machine Learning Techniques

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Abstract: Agriculture is still the main way of earning a living for many people in developing countries like India. But small and poor farmers often struggle with choosing the right crops, dealing with poor soil nutrients, and managing plant diseases. These problems greatly affect how much they can grow and how much money they make. This research introduces a Smart Crop Advisory System that uses Machine Learning and Deep Learning to give smart advice to farmers. The system has three main parts: it suggests which crops to grow based on the soil and weather, recommends the right fertilizers based on soil type and crop needs, and detects plant diseases by analysing leaf images. The system combines smart models with a web platform so farmers can easily access the advice. The test results show that this system helps farmers make better decisions and grow more crops. This approach shows how artificial intelligence can help make farming more precise and sustainable.

Keywords: precision agriculture, crop recommendation, fertilizer recommendation, plant disease detection, machine learning, deep learning, convolutional neural network

I. INTRODUCTION

Agriculture is a key part of economic growth in many developing countries. In India, approximately 42% of the workforce depend directly or indirectly on farming through activities such as crop cultivation, food processing, and rural services. Smallholder farmers, who make up 86% of India's 146 million farming households, face numerous challenges such as poor crop choices, unpredictable weather, soil nutrient issues, incorrect fertilizer use, and harmful plant diseases that lead to 20-40% losses in crop yields each year.

Traditional farming methods rely mostly on experience and manual observation, which often result in inconsistent outcomes. These farmers usually don't have access to real-time scientific information about the best ways to match crops with soil and climate conditions, manage nutrients effectively, or detect diseases early. This lack of information leads to inefficient use of resources and ongoing issues with productivity.

Recent advancements in artificial intelligence, machine learning, and deep learning have transformed how decisions are made in agriculture. These technologies use data from multispectral soil analysis, local weather patterns, humidity and temperature levels, and crop health indicators to offer specific and practical advice that isn't possible with traditional approaches.

Precision farming uses data to make farming more efficient. Smart systems can help farmers pick the best crops, use fertilizers wisely, and catch plant diseases early. These systems can make farming more productive and sustainable.

Precision agriculture uses data to improve how resources are used and increase crop yields. Smart advisory platforms give farmers knowledge-based guidance on selecting crops, using fertilizers wisely, and identifying diseases early, helping them boost productivity while also supporting sustainable farming practices.

This paper presents a Smart Crop Advisory Framework that combines multiple machine learning techniques and convolutional neural networks to offer detailed advice on crop selection, fertilizer management, and disease detection. By using data-driven insights, the system enables these farmers to achieve higher crop yields, improving by 25-35%..

Figure 1. shows the employment distribution in the agriculture sector, highlighting the importance of agriculture as a major source of livelihood.

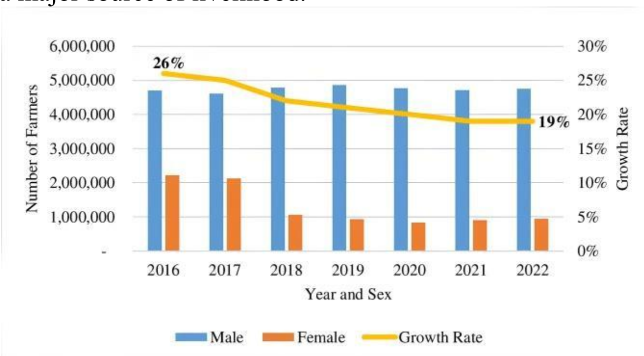

Figure 1. Employment distribution in the agriculture sector

II. LITERATURE REVIEW

Machine learning and artificial intelligence are now commonly used in modern farming to boost crop production and help farmers make better decisions. Botero-Valencia et al. [1] conducted a comprehensive review of machine learning applications in sustainable agriculture. Their study highlights how intelligent systems can improve farming efficiency and optimize resource management.

Priya and Ramesh [2] discussed the role of machine learning in precision agriculture and emphasized its importance in promoting sustainable farming practices. Their research shows that data-driven approaches can significantly increase crop productivity while reducing resource wastage.

Liakos et al. [3] provided a detailed overview of machine learning applications in agriculture, including crop monitoring, yield prediction, irrigation management, and plant disease detection. Their study demonstrates how machine learning techniques can analyze agricultural data effectively and assist farmers in making informed decisions.

Saleem et al. [4] explored the use of automation in agriculture by integrating machine learning and deep learning models. Their work highlights how the combination of intelligent technologies can enhance agricultural efficiency and productivity.

Attri et al. [5] investigated the use of machine learning techniques for crop management. They emphasized the importance of predictive models in improving agricultural productivity and demonstrated how these models can help farmers manage soil nutrients and growing conditions more effectively.

Ahmad and Nabi [6] discussed the concept of Agriculture 5.0, which integrates artificial intelligence, the Internet of Things (IoT), and machine learning to develop intelligent farming systems capable of improving agricultural sustainability and efficiency.

Sharma and Dadheech [7] focused on the role of artificial intelligence in crop yield prediction and agricultural decision support systems. Their research highlights the growing importance of intelligent technologies in modern agriculture.

Li et al. [8] examined the emerging role of foundation models in smart farming and identified several research gaps that need to be addressed in the development of advanced AIbased agricultural systems.

Even though many studies have looked at how machine learning can be used in agriculture, most of these solutions focus on single tasks like recommending crops or detecting diseases. The system we're proposing brings together several farming advisory features into one platform, offering a complete decision support system for farmers.

III. METHODOLOGY

The proposed system integrates multiple machine learning models to provide intelligent recommendations for farmers. The architecture of the system consists of three major components: crop recommendation, fertilizer recommendation, and plant disease detection. These three components work together to form a complete advisory system that helps farmers make better decisions in their agricultural practices. The system is designed to analyze different agricultural parameters such as soil nutrients, environmental conditions, and plant images in order to generate useful recommendations.

The overall system works by collecting input data from the user and processing it using trained machine learning and deep learning models. The user can provide soil parameters, crop information, or images of plant leaves through a web-based interface. The system then analyzes this information using predictive models and provides recommendations related to crop selection, fertilizer usage, and plant disease identification. By combining these modules into a single system, farmers are able to obtain multiple types of agricultural guidance through one platform.

Machine learning techniques are used because they are capable of analyzing large amounts of agricultural data and identifying useful patterns. These models learn from historical agricultural datasets and are trained to recognize relationships between soil conditions, environmental factors, crop characteristics, and plant diseases. After training, the models are able to generate predictions when new input data is provided by the user. such as poor crop choices, unpredictable weather, soil nutrient issues, incorrect fertilizer use, and harmful plant diseases that lead to 20-40% losses in crop yields each year.

A. Crop Recommendation Model

The crop recommendation model analyzes soil nutrients such as nitrogen, phosphorus, and potassium along with environmental parameters including temperature, humidity, and rainfall. These factors play an important role in determining which crops can grow successfully in a particular region. By analyzing these parameters, the system can suggest crops that are suitable for the given soil and environmental conditions.

The model uses a supervised machine learning method to determine which crops would grow best based on these inputs. During the training process, the model learns from agricultural datasets that contain information about soil conditions and suitable crop types. When a user provides the required input parameters, the trained model analyzes the values and predicts the most suitable crop for cultivation. This helps farmers avoid selecting crops that may not perform well under certain soil or climate conditions.

Table I. Input Parameters Used for Crop Recommendation

Sr. No.	*Parameter*	*Description*
1	Nitrogen (N)	Amount of nitrogen present in soil
2	Phosphorus (P)	Phosphorus nutrient level in soil
3	Potassium (K)	Potassium nutrient level in soil
4	Temperature	Average environmental temperature
5	Humidity	Atmospheric humidity level
6	Rainfall	Amount of rainfall in the region

B. Fertilizer Recommendation Model

The fertilizer recommendation component evaluates soil nutrient levels to identify deficiencies or excess nutrients. Maintaining balanced soil nutrients is essential for healthy crop growth. If the soil lacks important nutrients, crop productivity may decrease.

The system analyzes soil nutrient values along with the selected crop type to determine the fertilizer requirements. By comparing existing nutrient levels with the required levels for the selected crop, the system identifies whether certain nutrients are deficient or present in excess. Based on this analysis, the system suggests appropriate fertilizers to maintain soil fertility and improve crop productivity.

Table II. Input Parameters Used for Crop Recommendation

Soil Condition	***Recommendation***	***Soil Condition***
Low Nitrogen	Apply nitrogen-based fertilizers	Low Nitrogen
Low Phosphorus	Apply phosphorus fertilizers	Low Phosphorus
Low Potassium	Apply potassium	Low Potassium
	fertilizers	
Excess Nitrogen	Reduce nitrogen fertilizer usage	Excess Nitrogen
Balanced Nutrients	Maintain current soil management	Balanced Nutrients

C. *Plant Disease Detection*

Plant diseases can greatly lower farming output if not caught early. Early detection of plant diseases allows farmers to take timely action and prevent the disease from spreading across the crop field. Detecting diseases manually can be difficult for farmers because many plant diseases show similar visual symptoms.

This module uses a deep learning model built with convolutional neural networks to identify plant diseases by analyzing images of leaves. The model looks at the visual signs on the leaves such as color changes, spots, and irregular patterns to detect disease patterns. When a farmer uploads an image of a plant leaf, the system processes the image and sends it to the trained deep learning model for analysis. The model classifies whether the plant is healthy or affected by a disease. If a disease is detected, the system provides information about the disease and suggests possible treatments or preventive measures. This helps farmers identify plant health problems at an early stage and take the necessary steps to protect their crops.

The integration of these modules creates a comprehensive crop advisory system that supports farmers in multiple aspects of agricultural decision making. By combining crop recommendation, fertilizer management, and plant disease detection into one platform, the system provides a practical solution for improving farming efficiency and productivity.

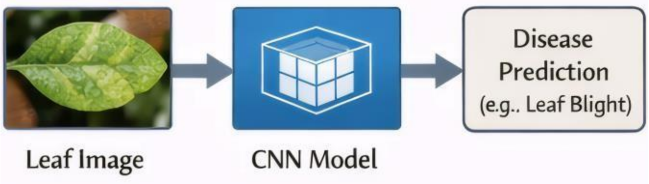

Figure 2. Plant Disease Detection using Deep Learning Model

D. *System Implementation*

The proposed crop advisory system has been developed as a web-based application designed to assist farmers in making informed agricultural decisions. The platform integrates multiple intelligent modules that allow users to access different types of agricultural recommendations through a simple and interactive interface. Farmers can input relevant information such as soil parameters, environmental conditions, or images of affected crops, and the system processes this data using machine learning and deep learning models to generate appropriate recommendations. By combining these modules into a single platform, the system provides an integrated advisory solution that supports farmers in crop selection, soil management, and disease diagnosis.

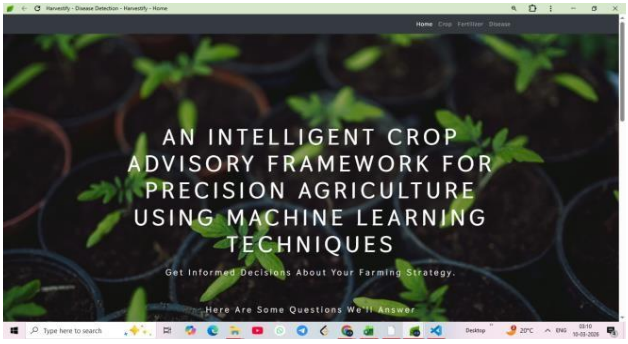

Figure 3. Homepage interface of the proposed crop advisory system

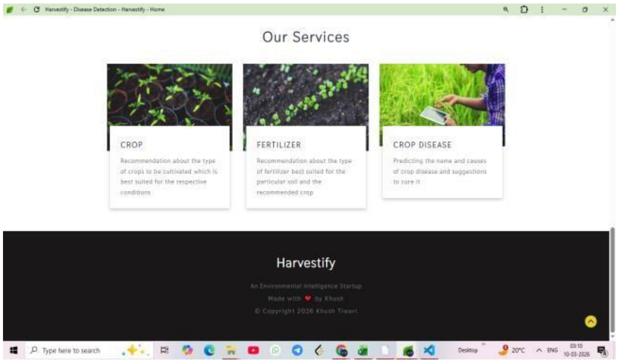

Figure 4. Services offered by the system displayed on the homepage

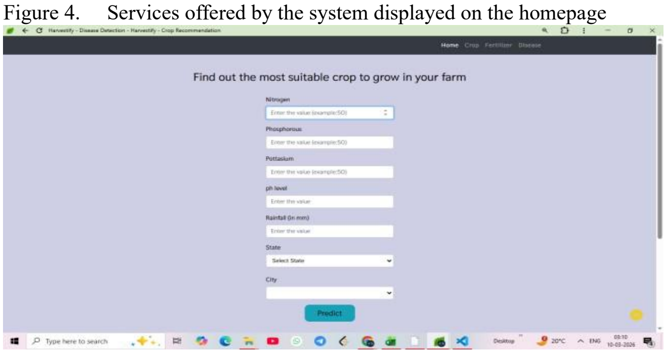

Figure 5. Crop recommendation interface where users enter soil parameters

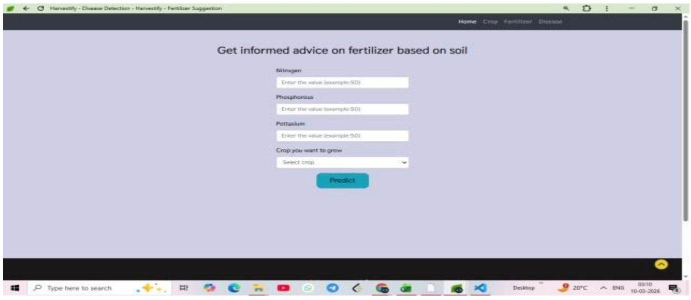

Figure 6. Fertilizer recommendation interface where users input soil nutrient

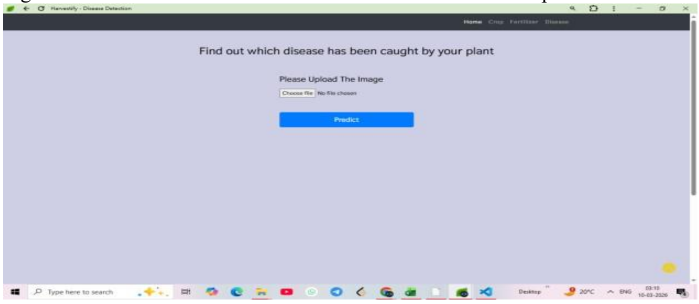

Figure 7. Plant disease detection interface where users upload leaf images for analysis

IV. RESULTS AND DISCUSSION

The proposed system was evaluated using agricultural datasets containing soil nutrient values, crop information, and plant disease images. The crop recommendation model demonstrated accurate predictions based on soil and environmental parameters.

The fertilizer recommendation system successfully identified nutrient deficiencies and suggested suitable fertilizers for improving soil health. In addition, the deep learning based disease detection model was able to classify plant diseases with high accuracy using leaf images.

The integration of these modules into a web-based platform provides a comprehensive decision support system for farmers. The system enables farmers to make informed decisions regarding crop selection, nutrient management, and plant disease treatment.

Table III. Input Parameters Used for Crop Recommendation

Sr.No.	***Module***	***Algorithm Used***
1	Crop Recommendation	Random Forest and Decision Tree
2	Fertilizer Recommendation	Rule Based and ML model
3	Disease Detection	Convolutional Neural Network

The performance of the proposed system was evaluated by comparing farming outcomes before and after using the crop advisory system.

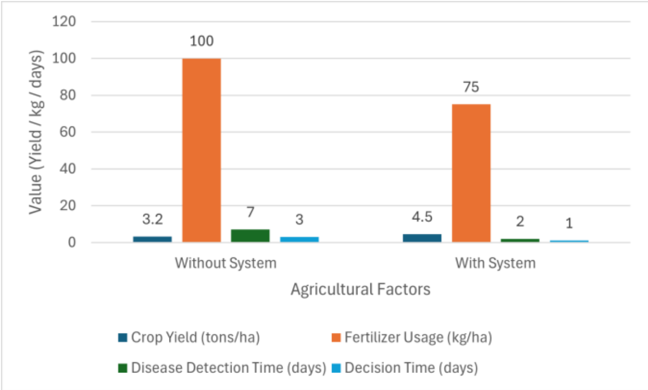

Figure 8. Comparison of farming efficiency with and without the proposed system

V. CONCLUSION AND FUTURE WORK

The proposed crop advisory system is developed as a web based application designed to assist farmers in making informed agricultural decisions. The platform integrates multiple intelligent modules that provide recommendations related to crop selection, fertilizer management, and plant disease detection through a simple and interactive interface. Farmers can enter soil parameters, environmental conditions, or upload images of plant leaves, and the system analyzes this data using machine learning and deep learning models to generate suitable suggestions.

By combining these modules into a single platform, the system offers an integrated advisory solution that helps farmers improve crop productivity and manage soil health more effectively. The user-friendly design and web-based accessibility allow farmers to easily use the system from different locations using internet-enabled devices, promoting better decision-making.

Although the proposed system provides useful recommendations for farmers, there are several opportunities for further improvement and development. In the future, the system can be enhanced by integrating real-time weather data to provide more accurate crop recommendations based on current environmental conditions. Additionally, the performance of the machine learning models can be improved by training them with larger and more diverse agricultural datasets.

Another important direction for future work is the development of a mobile application that would allow farmers to access the system more easily using their smartphones. This would make the platform more accessible, especially for farmers working in remote or rural areas. Further improvements could also include adding more agricultural services such as irrigation management, pest prediction, and yield forecasting. By expanding these features, the system can become a more comprehensive smart farming platform that helps farmers make better decisions and improve agricultural productivity.

The proposed crop advisory system shows how machine learning and deep learning can help farmers make better decisions in agriculture. By analyzing soil conditions, environmental factors, and plant images, the system provides useful suggestions for crop selection, fertilizer use, and early disease detection.

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