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Smart Fields: Enhancing Agriculture with Machine Learning

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***Abstract*—A substantial portion of the Indian population makes their livelihoods mostly from agriculture. However, there is a critical need to support our farmers with the current- state-of-the-art techniques that help to tackle the challenges posed by traditional agriculture practices Thus, the farmers can enable an increased income through monitoring the crop health, and high yield. This paper introduces a novel approach that integrates advanced computer vision and machine learning techniques for identifying diseases in crops. In addition, It also includes a smart Decision Support System (DSS) for recommending suitable fertilizers to improve productivity and crop yield. To further enhance its capabilities, we plan to utilize Internet of Things (IoT) technology for monitoring conditions that impact crop growth in time. This addition will contribute to recommendations by providing up to date insights on light conditions affecting crops. In this innovative approach, integrated sensors are utilized to gather soil parameters such as nitrogen, phosphorous, and potassium (NPK), as well as environmental factors which enables the accurate evaluation of soil and crop health. This information is then employed to predict the right crop to be grown, along with the suggestion of the optimal number of fertilizers needed to provide the necessary nutrition for a healthy crop and soil. This DSS system is designed to be user-friendly, with a mobile or web application interface. Hence the current system will be more useful for the farmers with current technology expertise.**

Keywords — ***Nitrogen, Phosphorus and Potassium (NPK), Decision Support System(DSS) , light intensity monitoring, fertilizer and Crop recommendation system***

I. INTRODUCTION

Since agriculture provides a livelihood for a sizable portion of India's population, it is essential to the nation's economic development. Nonetheless, the agricultural industry confronts complex difficulties, as farmers struggle to choose which crops are best to grow in a particular situation. Complications stem from a variety of soil properties, fluctuating weather patterns, common plant illnesses, and the continuous requirement for crop observation. This research suggests a thorough and cutting-edge strategy to assist agricultural decision-making in order to address these issues. Our suggested method makes utilises a wide variety of sophisticated ML models, such as the, XGBoost, Decision Tree approaches, Random Forest model, Support Vector Classification (SVC) based on accuracy values. Our goal is to find the best model for accurate crop detection through thorough analysis and comparison. The main objective is to increase the precision and effectiveness of selecting the best crops to grow, providing farmers with tools for data-driven decision-making.

We leverage the strength of the deep learning model ResNet, a deep learning architecture renowned for its speed and accuracy, in the field of plant disease detection. Our goal in putting this model into practice is to quickly and accurately diagnose plant diseases. By enabling prompt disease detection, this technology gives farmers the ability to prevent and manage disease outbreaks, ultimately protecting their crops.

In the future, we see Internet of Things (IoT) technology being integrated, using Bolt IoT in conjunction with an LDR sensor to determine the plant's light intensity. This real-time light condition monitoring helps to improve the accuracy of crop recommendations. In addition, we use the ESP32 platform in conjunction with an NPK sensor to ascertain the soil's values for nitrogen (N), phosphorus (P), and potassium (K). This novel method enables accurate evaluation of the soil's health and customized fertilizer recommendations based on the soil's unique nutrient needs.

In conclusion, this all-encompassing strategy leverages deep learning capabilities, integrates IoT technology, and combines advanced machine learning techniques to transform agricultural practices. Our mission is to advance India's agricultural sector, give farmers priceless insights, and promote efficient and sustainable farming practices through creative and technologically advanced solutions.

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II. LITERATURE SURVEY

[5] In this paper, the integration of IoT sensors—such as temperature, humidity, pH, and soil moisture sensors which are deployed in soil to collect data in real-time for better analysis and model training. It also suggests a prediction model for the identification of plant diseases, comparing four different algorithms to find the best one. The project intends to improve agricultural management practices by allowing timely interventions and crop protection methods via the use of advanced predictive modelling and IoT technologies.

[6] This study presents the data collected from Internet of Things (IoT) sensors embedded in soil through the development of a website. The model is mostly trained using datasets from the government. The K-Nearest Neighbors (KNN) technique is utilized for model training, allowing for the prediction of the best crop to grow in the field for a specific amount of time. The DHT11 sensor, which monitors air temperature and humidity, the MQ2 sensor, which looks for flammable materials, a soil moisture sensor, a NodeMCU for Internet communication, and a light intensity sensor for brightness measurement are the five different hardware parts used in this project.

[7] By recommending appropriate fertilizers and forecasting acceptable crops, the system seeks to assist farmers in making intelligent choices. By combining historical weather data from government websites, real-time temperature and humidity data from DHT22 sensors, and soil characteristics contributed by the farmer, it increases precision of the output. The system uses vector autoregression for predictive analysis in addition to machine learning methods including Decision Tree, K-NN, and Support Vector Machine to identify the optimal crop. It makes use of a bilingual, responsive website to promote farmer interaction. In conclusion, the system uses extensive data analysis and machine learning techniques to optimize farming operations and crop choices.

[8] Crop prediction analysis incorporates a number of soil characteristics, including pH, phosphate, potassium, sunlight, rainfall, and humidity, as well as air variables including humidity, phosphate, and nitrogen levels. In order to handle difficult agricultural problems, the suggested system makes use of Artificial Neural Network (ANN) algorithms, which replicate the neural functions of the human brain. With its input, hidden, and output layers, artificial neural network (ANN) may make accurate predictions without the need of explicit mathematical formulas. Its appeal in biological research may be attributed to its capacity to take into account a wide range of affecting elements, such as soil and environmental variables. The training phase of ANN allows it to priorities important influencing elements, which helps it provide accurate crop output projections even with the complex nature of agricultural data. By using ANN, the system helps farmers make well-informed decisions, which enhances agricultural sustainability and production by providing accurate crop output projections based on in-depth data analysis.

[9] This study investigates how susceptible plants are to a range of illnesses and infections caused by common diseases including bacterial, viral, and fungal infections as well as environmental variables. The work uses the Plant Village Dataset, which consists of over 50,000 photos divided into 38 classes, to leverage the CNN method for disease identification in plant leaves in order to overcome this difficulty. To improve the training dataset, image augmentation techniques including rotation, brightness correction, and shearing are used. The procedure entails segmenting and converting the color space of the picture, then training CNN classifiers to detect illnesses in plant leaves. An all-encompassing method for the detection and treatment of plant diseases is provided by the classifier that is used to label leaves as "healthy" if no illness is found.

[18] The study uses an enhanced model for disease identification in plant leaves that is based on the YOLOv4 algorithm. YOLOv4, a one-stage object identification model with high precision, generates bounding box coordinates and class probabilities by approaching the task as a regression issue. Targets inside each grid get predictive bounding boxes that are constructed once the input picture is partitioned into grids of uniform size. However, because of diverse backdrops, variable geometric architecture of diseased regions, and highly packed fine-grained distributions, diagnosing various illnesses in apple plants using the original YOLOv4 model is challenging. In order to overcome these problems, the study suggests improving YOLOv4 to better suit the features of the illness dataset, with the goal of improving real-time efficiency and accuracy in the detection of different apple plant diseases.

III. PROPOSED SYSTEM

This study presents a novel application that seeks to address the obstacles in crop management. The system thoroughly examines various factors such as rainfall, geographical location, temperature and soil conditions to provide precise predictions on crop suitability, akin to the expertise of an agricultural consultant. This groundbreaking solution optimizes the decision-making process for farmers, offering accurate crop recommendations tailored to their unique environmental conditions. The application provides customized fertilizer recommendations for various states, which can improve productivity and crop yield. Furthermore, the application incorporates image processing technology to aid in the identification and mitigation of plant diseases, providing farmers with a comprehensive overview of their crop's well-being. The application's holistic approach is in line with sustainable and efficient farming practices. The interface is designed to be user-friendly, and the smartphone capabilities enhance accessibility for farmers. It effectively combines precision, efficiency, and convenience in crop management.

A. Key Features and Functionalities

- Random Forest Implementation: The Random Forest algorithm considers attributes such as temperature, rainfall, geographical location, and soil conditions. It is utilized for predicting crop suitability, providing personalized fertilizer recommendations, optimizing

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crop production, and offering a user-friendly interface for easy accessibility. The algorithm handles intricate relationships between parameters, resulting in a prediction model that is more resilient and reliable. Random Forest optimizes crop production through the analysis of historical data and current conditions and enables the identification of effective strategies to enhance yield.

- Image Processing for Disease Detection: This application utilizes cutting-edge image processing technology to identify and mitigate plant diseases. The smartphone's camera is utilized to capture high-resolution images of crops, enabling a thorough analysis and identification of potential diseases. The system utilizes random forest to identify patterns, discolorations, and other visual indicators that are associated with different plant diseases. Additionally, the CNN model enables the precise

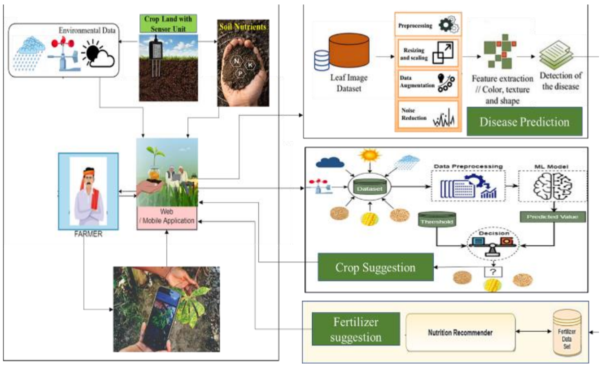

Fig. 1. Data Flow Diagram

differentiation between healthy and infected crops with exceptional accuracy. The model then processes this data in real-time, conducting a thorough analysis against a comprehensive database of known plant diseases. When a potential disease is detected, the system immediately notifies the farmer, offering crucial details about the ailment, its severity, and the recommended course of action. By adopting a proactive approach, farmers are able to promptly implement measures that minimize the negative effects of diseases on crop yield.

- Widespread Accessibility: This approach has been developed with the goal of being easily accessible to users without requiring any expensive additional hardware. The smartphone interface is designed to be user-friendly, allowing for easy navigation and utilization of the technology by a wide range of users. The application employs the standard capabilities of smartphones, eliminating the requirement for any specialized devices or equipment. The system has been carefully designed to prioritize cost-effectiveness, ensuring that it remains within the financial reach of farmers with different budget constraints.

- Convenience and Efficiency: The crop recommendation system thoroughly examines crucial agricultural parameters, delivering precise crop suitability predictions to farmers. Customized fertilizer recommendations effectively target the unique requirements of crops, resulting in enhanced productivity and higher yields. The application incorporates image processing technology to facilitate comprehensive crop health monitoring, allowing for the timely identification and mitigation of plant diseases. By taking a proactive approach, crop losses can be minimized and farming operations can be made more sustainable. The application supports sustainable farming practices by offering precise recommendations and early disease detection. This helps farmers optimize resource usage, minimize wastage, and promote environmentally friendly farming methods . IOT Implementation: In the cutting-edge landscape of smart agriculture, a transformative system emerges by seamlessly integrating the Internet of Things (IoT), soil NPK sensors, light sensors, and Bolt IoT. The IoT segment utilizes a network of sensors, such as soil NPK sensors for nutrient evaluation and light sensors for tracking light intensity essential for photosynthesis. Utilizing the capabilities of IoT, the central system receives data on temperature, humidity, soil moisture, and light conditions on real-time. Efficient connectivity and control are achieved through the integration of Bolt IoT, empowering farmers to remotely manage their agricultural operations. The abundance of data is efficiently analyzed by advanced algorithms, equipping farmers with accurate insights to make well-informed decisions. This system is characterized by tailored crop recommendations, efficient resource utilization, increased yield, and remote monitoring capabilities.

IV. Working Mechnanism

The Smart Fields web application is meant to work seamlessly by combining a variety of physical sensors, including the LDR and NPK sensors, as well as employing machine learning concepts like ResNet, Random Forest, and other related APIs. This integrated interface is designed to help farmers by making accurate and timely suggestions, optimizing resource utilization, and improving agricultural insights.

The application applies the ResNet approach to build a machine learning model capable of predicting sick plants. The model accomplishes this by identifying patterns within images, undergoing multiple epochs of training with multiple layers of input to enhance its accuracy over time.

Crop suggestions vary according to the given state and its rainfall, taking into account the soil's nitrogen, potassium, and phosphorus content. The trained algorithm makes suggestions for optimal crop selection based on the farmer's preferences. It also makes recommendations for changing the chemical composition of the soil to promote crop development.

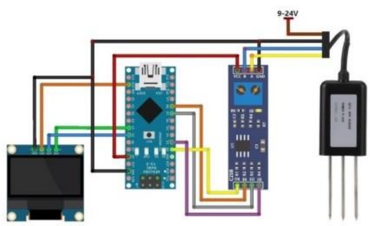

Fig. 2. ESP32 with NPK Semsor

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To simplify the procedure and decrease lab assessment expenses, NPK sensors are strategically positioned in the soil to offer real-time composition data. These values are shown via LED outputs, allowing users to simply enter the information into the appropriate models for further processing and analysis.

For focused plant care, an LDR sensor is placed in the soil, providing temperature-based monitoring. This function is especially useful for plants that require special care, since it ensures they are kept in an environment that meets their specific requirements.

In summary, the Smart Fields online application offers farmers a complete approach by combining hardware sensors, machine learning models, and real-time data to optimise agricultural methods and enhance overall crop management

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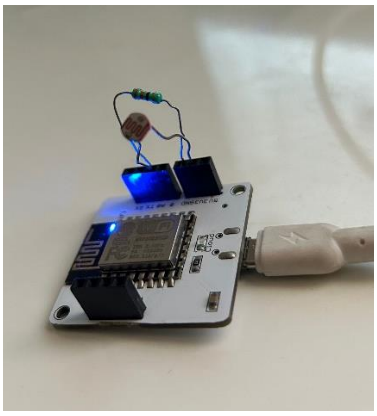

Fig. 3. Bolt IOT with LDR Sensor

V. Results And Discucssions

IoT and machine learning are used in intelligent crop selection and decision support systems to provide farmers accurate information they need to make wise decisions. These algorithms accurately detect plant illnesses and forecast the best crop choices by analyzing data from several sources, such as satellite photography and Internet of Things sensors. Their performance is improved by user input and real-world testing, which guarantees broad acceptance.

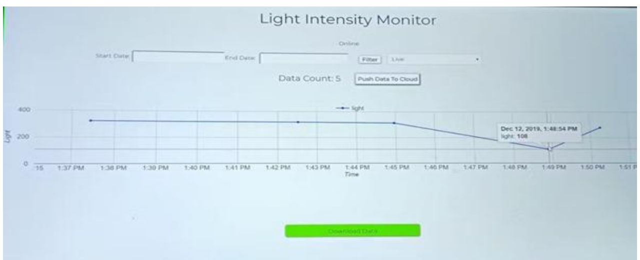

Fig. 4. Light Intensity Monitoring Graph

Smooth interaction is made possible by user-friendly interfaces. By minimizing negative effects on the environment and maximizing resource allocation, these systems support sustainable agriculture. They provide higher productivity, resource efficiency, and environmental stewardship in food production as technology advances.

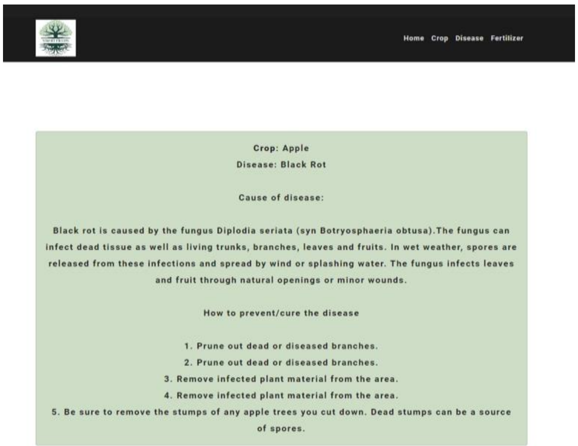

Fig. 5. Plant Disease Detection

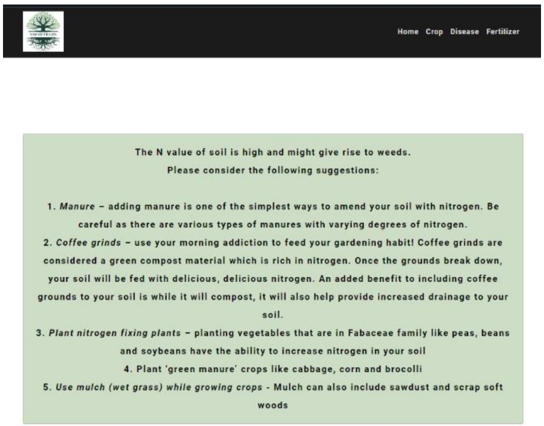

Fig. 6. Fertilizer Recommendation

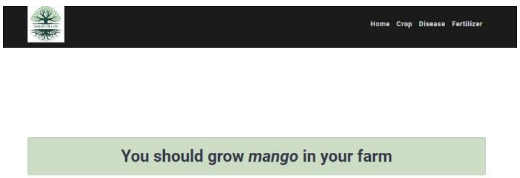

Fig. 7. Crop Suggestion

VI. Future Enhancement

A. Automated Irrigation System

Implementing an automated irrigation system optimizes water distribution by utilizing real-time sensor data. This function conserves resources, improves crop health, and assures effective water management, so contributing to sustainable and smart agriculture practices.

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B. Crop Rotation Planning

The Crop Rotation Planning function recommends rotation strategies based on historical data and soil health. Crop rotation improves soil fertility, reduces insect and disease risks, and encourages environmentally friendly farming methods. This sophisticated assistance ensures that farmers make educated decisions, maximizing productivity while conserving soil health in the long run.

C. Integration with Farm Equipment

Integrating with farm equipment, like as tractors and drones, automates critical chores like soil amendment and pest control. By synchronizing with the application's suggestions, this integration simplifies farm operations, minimizes manual work, and improves precision, resulting in more effective and resource-efficient agricultural practices.

D. Blockchain for Traceability

Blockchain technology facilitates transparent and traceable supply networks. Farmers and customers receive reliable knowledge on product provenance by documenting each step of the agricultural process, from planting to harvest. This not only fosters trust, but it also promotes sustainable and ethical agricultural practices.

VII. CONCLUSION

In conclusion, crop disease detection and recommendation systems play critical roles in providing farmers with accurate decision-making tools. The addition of a fertilizer suggestion system improves this capability by providing information on soil nutrient levels, which aids in crop selection. Furthermore, the integration of IoT sensors, including NPK sensors, provides continuous real-time data monitoring, hence decreasing the need for costly laboratory assessments. Furthermore, the integration of an LDR sensor enables specialized crop care solutions, allowing farmers to effectively meet individual growth requirements. Together, these components comprise a comprehensive and efficient agriculture management system, allowing farmers to make intelligent choices and maximize crop production in a sustainable manner.

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