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Crop Recommendation System using Machine Learning and IoT

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***Abstract*—In contemporary agriculture, optimizing crop yield while minimizing resource usage is paramount. This project addresses these challenges by presenting a Crop Recommendation System that utilizes both machine learning algorithms and the Internet of Things (IoT). Soil parameters such as nitrogen, phosphorus, potassium, pH value, and rainfall data are provided by the user, and other real-time climate data from IoT sensors including temperature and humidity, are integrated into the system. The problem at hand is the need for a personalized and data-driven approach to farmers for optimal crop selection that is best suited to their land according to soil characteristics and climate conditions. Traditional methods often fail to adapt to changing environmental conditions resulting in suboptimal crop recommendations. By training a machine learning model on a comprehensive dataset and incorporating the data provided by the user and IoT sensors, the system provides accurate and timely suggestions for optimizing crop productivity. The integration of machine learning models and IoT ensures the system's adaptability to varying environmental conditions. By considering both soil properties and climatic factors, the system outperforms traditional methods of farming, offering farmers a valuable tool for informed decision-making in crop selection. In conclusion, this project offers farmers a user-friendly crop recommendation system that holds promise for sustainable and resource-efficient agricultural production.**

***Index Terms*— Crop Recommendation System, Machine Learning, Soil Parameters, Crop Productivity, Internet of Things (IoT), Supervised Algorithms, Naïve Bayes, Random Forest, Sensor.**

I. INTRODUCTION

In today's agricultural landscape, the imperative of maximizing crop yield while minimizing resource consumption drives the adoption of advanced technologies. Precision agriculture, characterized by optimizing resource utilization and enhancing productivity, has emerged as a cornerstone in addressing agricultural challenges. This project introduces a sophisticated Crop Recommendation System that combines machine learning methodologies with Internet of Things (IoT) devices. The system addresses the complexity of aligning crop cultivation practices with soil characteristics and dynamic climate conditions. Traditional crop selection methods often struggle to adapt to the varying climatic conditions. Recognizing this gap, our project aims to provide a comprehensive and user-friendly solution. The primary objective is to offer a personalized and data-

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driven approach to crop recommendation, incorporating soil data and real-time IoT data. Farmers encounter challenges in making optimal choices for crop cultivation, considering factors such as soil composition, nutrient levels, and varying climatic conditions. The proposed Crop Recommendation System seeks to empower farmers by seamlessly integrating machine learning algorithms with user-provided soil data and real-time IoT data. The methodology entails developing a robust machine learning model trained on an extensive dataset encompassing diverse soil and climate information for various crops. By leveraging vital soil parameters and real-time IoT data, such as temperature, and humidity the system aims to deliver precise and tailored crop recommendations. This project contributes to the advancement of precision agriculture by providing farmers with a user-friendly tool for informed decision-making, harnessing the capabilities of both machine learning and IoT technologies. Subsequent sections of this project will delve into the procedural intricacies, the development and application of the machine learning model, and the compelling results positioning our Crop Recommendation System as a valuable asset in contemporary agricultural practices, integrating both machine learning and IoT advancements This holistic approach ensures not only increased crop yield but also promotes sustainability in agricultural practices, aligning with the global agenda for environmental conservation.

II. Discussion and Related Work

This research paper provides a comprehensive survey of data mining techniques applied in agriculture, outlining their applications, advantages, and challenges, aiming to provide informed decision-making in agricultural practices.[1]

This proposed model presents a crop recommendation system utilizing machine learning techniques to assist farmers in making informed decisions about crop selection based on various factors such as soil type, climate, and crop suitability, aiming to enhance agricultural productivity and sustainability.[2]

Another research offers an extensive examination of various crop recommendation systems, encompassing their techniques, applications, and future prospects, with a focus on enhancing agricultural practices through data-driven decision-making.[3]

This one presents a study on the effects of drought stress on soybean growth and yield, offering insights into the physiological and biochemical responses of soybean plants under different drought conditions, aiming to improve drought tolerance/preventive strategies in soybean cultivation.[13]

This system proposes a Crop Recommendation System using machine learning algorithms like SVM, Decision Tree, and Logistic Regression to predict suitable crops for farmers based on soil parameters and detect potential pests, aiming to improve agricultural productivity and a decrement in financial distress among farmers in India. [5]

The article presents an IoT system called SHMUs for continuous soil health monitoring, utilizing solar power and LoRaWAN technology, validated through experiments demonstrating its flexibility, wireless range, power efficiency, and solar charging capabilities for cost-effective and continuous soil property tracking in agriculture.[6]

This research investigates the impact of soil amendments, such as biochar and gypsum, on soil fertility and plant growth, highlighting their potential for improving agricultural productivity and sustainability.[7]

This model explores the synthesis and characterization of silver nanoparticles using a plant extract, highlighting their potential antimicrobial activity against various pathogens, suggesting their application in biomedical and agricultural fields for combating microbial infections.[8]

III. IOT Components Description

1) Soil moisture sensor HW-080: It is a dependable and adaptable instrument intended to precisely gauge the amount of moisture present in the soil. This sensor's corrosion-resistant electrodes guarantee long-term performance and durability even in the most demanding environmental circumstances. Because of its analog output, which offers real-time information, users can precisely monitor the moisture content of the soil. The sensor is perfect for many applications, such as gardening, agricultural, and environmental monitoring, because of its straightforward design and seamless connection with microcontrollers like Arduino. Utilizing the HW-080 soil moisture sensor in automated irrigation systems or scientific endeavors provides an effective way to maximize water use and foster robust plant development.

2) Temperature and Humidity Sensor DHT11: This device measures temperature and moisture in the air precisely by combining a thermistor with a capacitive humidity sensor. The DHT11 is a user-friendly device that may be used for home automation, weather stations, DIY projects, and environmental monitoring systems

because of its straightforward digital interface and low power consumption. Because of the sensor's accurate and dependable data, users may confidently monitor both indoor and outdoor conditions. Because of its small size and compatibility with many other microcontrollers, such as Arduino, Raspberry Pi, and ESP8266, it is a flexible option that can be used by both experts and enthusiasts. The DHT11 sensor provides an economical option for temperature and humidity sensing requirements, whether it is utilized for HVAC system control, room climate monitoring, or improving growing conditions for plants.

3) Waterproof Temperature Sensor DS18B20: This particular model of the DS18B20 sensor is housed in a waterproof casing, which makes it appropriate for use in situations where exposure to moisture or submersion in water is a problem. It offers accurate measurements across a broad temperature range (-55°C to +125°C). With this functionality, the sensor can be used in tough industrial settings, aquatic applications, and outdoor settings where traditional sensors might be susceptible to water damage.

4) NodeMCU: The NodeMCU is a powerful open-source development board based on the ESP8266 microcontroller. It is perfect for Internet of Things (IoT) projects and prototyping since it combines the Wi-Fi capabilities of the ESP8266 with the ease of use of Arduino. With its Lua-based firmware, the NodeMCU board makes programming easier and faster, enabling users to create Internet of Things applications without requiring a deep understanding of low-level programming languages. Furthermore, it has integrated Wi-Fi, allowing for easy networking with other devices and the Internet. The NodeMCU has gained popularity among makers, amateurs, and professionals for creating smart home appliances, sensor networks, and remote monitoring systems because of its small size, low cost, and wide community support.

5) Arduino UNO: The Arduino Uno is a flexible microcontroller board popular for DIY electronics and prototyping. It has a straightforward design with a large number of digital and analog ports for integrating with sensors and actuators and is equipped with the ATmega328P microprocessor. Programming is made easier by its USB connectivity and Arduino IDE compatibility, making it suitable for users of various skill levels. From simple LED blinkers to intricate robotics systems—the Arduino Uno is perfect for a variety of applications because of its affordability, robustness, and extensive community support.

It is the inevitable need for good production of the crop to have a certain amount of Nitrogen, Phosphorus, Potassium, Soil pH, Temperature, and Humidity. Different varieties of crops have different needs for these nutrients and nature's attributes. The initial dataset has been collected from online sources along with which fine machine learning algorithms have been used to give this model a boost in reliability and accuracy, empowering the users with a precise suggestion/ recommendation of the crop to be planted.

IV. Proposed Architecture and Methodology

A. Algorithms used

A particular level of nitrogen, phosphorus, potassium, soil pH, temperature, and humidity are all necessary for successful crop production. Crop varieties differ in what they require from nature in terms of these nutrients. The first dataset was gathered from internet sources, and sophisticated machine learning methods were applied to enhance the model's accuracy and dependability. This allowed the users to receive an exact proposal or recommendation for the crop that should be grown.

The following algorithms are used:

1) Random Forest: This is a reasonable decision for the model to be concerned about because of its ability to handle complex data. The Random Forest algorithm facilitates ensemble learning, combines predictions from several decision trees, manages non-linear relationships, provides insights into the value of features, and reduces overfitting. Robust and reliable crop selection assistance is made possible by its scalability and capacity to manage missing data.
2) Decision Tree: In a crop recommendation system, the decision tree algorithm simulates decision paths depending on variables such as climate and soil quality. It offers a clear framework for evaluating the significance of features, assisting farmers in choosing crops with knowledge.
3) Naive Bayes: In a crop recommendation system, the Naive Bayes algorithm evaluates the chance of crop performance in light of environmental parameters by utilizing statistical independence and probability assumptions. It effectively classifies and suggests crops according to the data at hand.
4) Support Vector: In a crop recommendation system, the Support Vector Machine (SVM) algorithm determines the best decision limits by taking into account variables like soil nutrients and meteorological characteristics like temperature and humidity. It categorizes crops, assisting farmers in selecting cultivars that are appropriate for given circumstances.

5) Logistic Regression: Using input data as a basis, this method determines the likelihood of favourable crop outcomes in a crop recommendation system. It facilitates decision-making by effectively forecasting and classifying appropriate crops for particular agricultural situations.

B. System Architecture

The suggested architecture is shown in Figure 1. Here is a step-by-step description of the architecture:

1) There is an initial dataset of 22 different crops with parameters like N, P, K, pH, temperature, rainfall and humidity.
2) An IOT database is setup which collects data from the IOT sensors placed in the field along with user inputs (if any) over time.
3) The data from initial database and IOT database is then merged to form combined data.
4) This data then undergoes "Data Pre-Processing" which is then split into "Training Data" and “Testing Data” in the ratio 80:20.
5) This “Training data” is fed to "Machine Learning Algorithms" for making recommendation models.
6) The recommendation models are then tested against the “Testing Data” to test their accuracy.
7) Finally, the recommendation system provides a "Result Prediction".

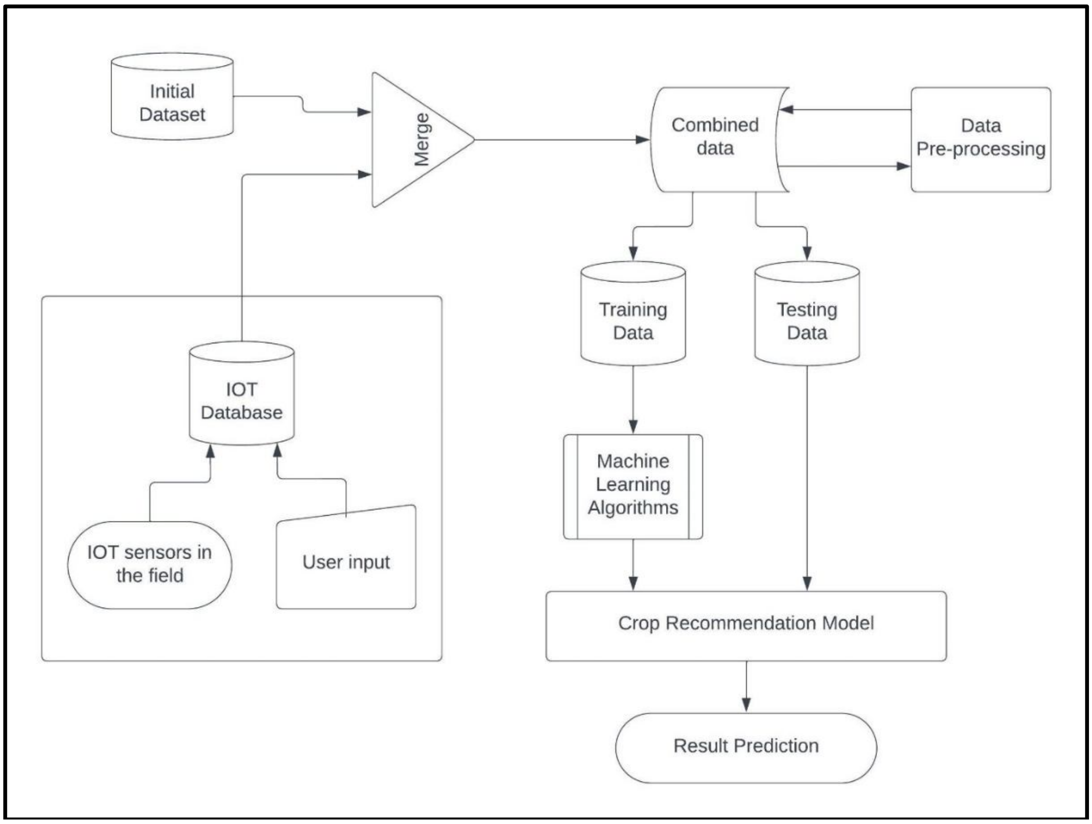

Figure 1. Architecture of the Model

C. Data pre-processing

Here's a step-by-step process for the described data pre-processing:

1) Setting Up Metadata:
   a. Assign distinct numerical codes to each crop type.
   b. Ensure no repetition of code; each crop should have a unique identifier.
2) Cleaning Raw Crop Data: Remove any missing entries, inconsistencies, or irrelevant information from the raw crop data.
3) Loading Metadata: Import the metadata that associates crop names with their respective unique numerical codes.
4) Integrating Metadata with Raw Data: Attach the metadata to the cleaned crop data by mapping the crop names to their assigned numbers.

5) Substituting Crop Names with Numerical Codes: Replace the actual crop names in the dataset with the unique numerical codes obtained from the metadata.
6) Data Segmentation into Training and Testing Sets: Divide the pre-processed data into distinct sets for training and testing purposes. The training set is employed to train the model, while the test set is utilized to evaluate its performance.

V. RESULTS AND DISCUSSION

Various machine learning algorithms such as Decision Tree, Naïve Bayes, SVM, Logistic Regression, and Random Forest were integrated with IoT devices to predict crop outcomes. This proposed model exhibited impressive accuracy rates exceeding 90 percent.

Accuracy of Logistic Regression : 96.364%

Accuracy of Naive Bayes : 99.54499999999999%

Accuracy of Support Vector Machine : 96.818%

Accuracy of Decision Tree : 98.182%

Accuracy of Random Forest : 99.318%

Figure 2. Accuracy of Algorithms Used for Crop Recommendation

Considering the data presented in Figure 3, it's evident that both the Random Forest and Naïve Bayes algorithms attained remarkable accuracy rates surpassing 99 percent. Due to the Naïve Bayes algorithm's superior accuracy, it was selected as the preferred model for predicting crop yields.

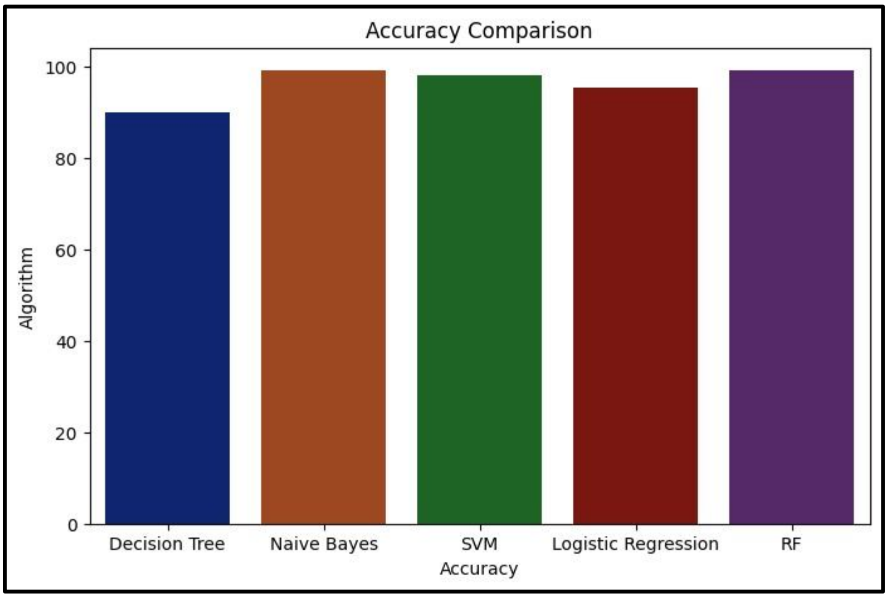

Figure 3. Graphical Representation of Accuracy of Different Algorithms

Table 1 presents a comparative analysis of our proposed study's performance against previous research in this domain. According to the findings, our final model (Naïve Bayes) attained an accuracy score of approximately 7.54% and 11.54% higher than the model outcomes reported in Ref. [15] and Ref. [19], respectively. Furthermore, as demonstrated in Table 1, we have achieved superior accuracy across all individual algorithm models compared to those in previous studies.

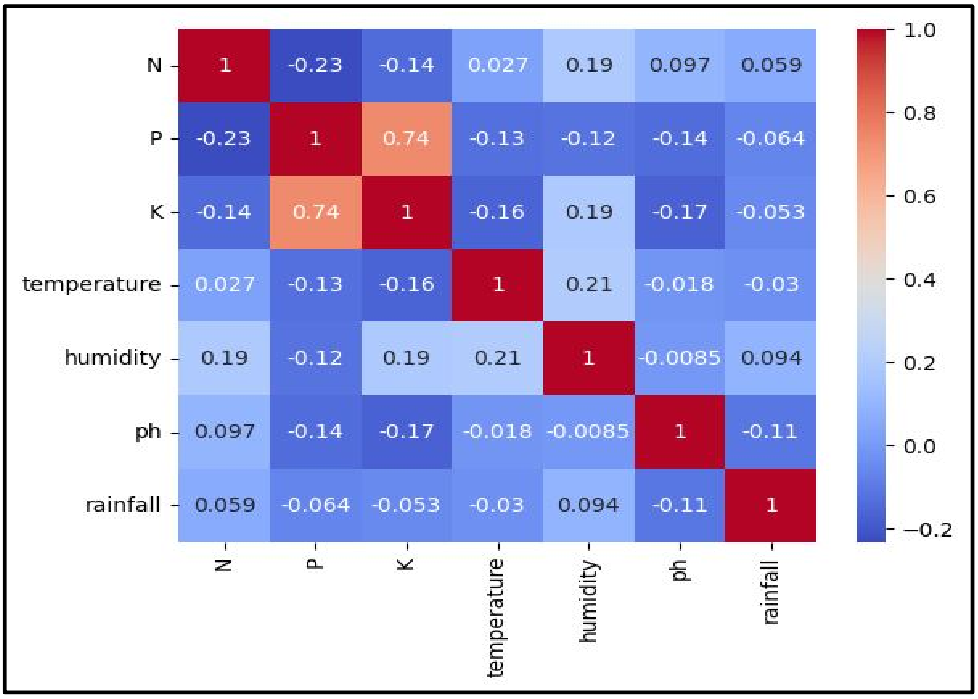

Figure 4. Heat map showing the correlation between attributes of the crop dataset

TABLE I. COMPARISON WITH PREVIOUS STUDIES

References	Sensors Used	Methodology	Accuracy
Kumar A. [19]	No	Decision Tree Naïve Bayes Random Forest Logistic Regression Support Vector Machine	86.80% 88% 88% 86.04% 89.66%
Sundaresan et al. [18]	Yes	KNN	97%
Thilakarathne et al. [4]	No	Random Forest	97.18%
Ruchirawya T.H. [15]	Yes	Naïve Bayes	92%
Proposed Model	Yes	Naïve Bayes Random Forest Decision Tree Logistic Regression Support Vector Machine	99.54% 99.31% 98.18% 96.36% 96.81%

VI. CONCLUSION

In conclusion, the development and implementation of the Crop Recommendation System signify a pivotal advancement in precision agriculture, presenting farmers with a personalized and data-driven solution for crop cultivation. By integrating machine learning algorithms trained on a comprehensive dataset and real-time IoT data, the system offers tailored recommendations based on specific soil characteristics and climatic conditions. This innovative approach enhances decision-making processes, promoting optimized resource utilization, increased crop productivity, and sustainability in agricultural practices. The system's user-friendly interface and personalized recommendations empower farmers with insights beyond traditional methods, enabling them to make informed decisions aligned with the natural attributes of their land. Through the synergy of machine learning and IoT technologies, our system fosters a more efficient and productive farming environment, contributing to the continual advancement of agricultural practices.

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