# Crop Recommendation and Irrigation system using ML with integrated IOT devices

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***Abstract—***

***In agriculture, timely and efficient irrigation is crucial to achieve maximum crop yield. However, traditional methods of irrigation are often inefficient and wasteful, leading to water scarcity and abbreviated crop productivity. To address these issues, we propose a perspicacious irrigation system that integrates IoT contrivances and machine learning algorithms to recommend the most felicitous crop for a given region and provide optimal irrigation predicated on authentic-time weather conditions and soil moisture levels. The system accumulates data on soil nutrients, temperature, and sultriness utilizing IoT sensors and uses XGBoost, a popular machine learning algorithm, to recommend the most remuneratively lucrative crop predicated on historical data. The system additionally incorporates authentic-time weather data from APIs and water level sensors to provide customized irrigation for each crop. Our system aims to improve crop productivity, minimize water waste, and avail farmers make data-driven decisions to maximize their profits.***

***Keywords—*** Crop recommendation, Irrigation scheduling, Soil moisture sensors, Machine learning, Environmental conditions, Water conservation, Crop database, Weather data, Sustainable farming, Food security

## I. INTRODUCTION

India has a vast agricultural sector, with more than 1.6 million square kilometers of land area dedicated to cultivation, making it the second-largest in the world. Given that a significant proportion of the country's population is involved in agriculture, the economy is heavily dependent on this sector. India has the potential to become a superpower in the field of agriculture, which can promote rural development and reduce poverty.

Small farms dominate the agricultural landscape in India, with more than 75% of land holdings being less than 5 acres. The majority of crops rely on rainfall for nourishment, as only around 45% of the land is irrigated. Roughly 55% of India's population is estimated to depend on farming for their livelihood.

Unfortunately, there is no universal system in place to assist farmers in agriculture. India has a rich collection of agricultural data from the past, which can be utilized for recommendations using Machine Learning, Data Mining techniques and algorithms to recommend suitable crops, irrigation and predictions.

Agricultural practices today have undergone significant changes compared to those of past decades, largely due to advancements in technology. This includes the use of sensors, devices, machines, and information technology. Contemporary agriculture relies on sophisticated technologies such as robots, temperature and moisture sensors, GPS technology, aerial images, and various complex Internet of Things (IoT) devices. The implementation of these advanced devices in agriculture enables farmers and businesses to increase profitability, efficiency, safety, and environmental sustainability. The emergence of digital agriculture and its related technologies has created numerous opportunities for data collection. Remote sensors, cameras, and other connected devices can gather data on a 24-hour basis across an entire farm or land. This information can be used to monitor plant health, soil conditions, temperature, humidity, and more. The amount of data generated by these sensors is immense, providing farmers with a better understanding of their situation on the ground through advanced technology that can inform them more accurately and quickly.

Indian agriculture is the backbone of the country's economy, employing millions of people and contributing significantly to the country's GDP. However, traditional farming practices often lead to suboptimal crop yield and inefficient irrigation, resulting in lower profits for farmers. To address these challenges, this paper proposes a Crop Recommendation and Irrigation System that leverages IoT contrivances and machine learning algorithms.

In this paper, we propose a Crop recommendation and irrigation system using IOT devices with integrated machine learning algorithms, specifically the Extreme Gradient Boosting (XGBoost) algorithm, and a weather API to forecast rain. Agriculture is a crucial sector of any country's economy, but farmers face several challenges such as unpredictable weather, inadequate irrigation, and pests and diseases. These challenges often lead to lower crop yields and reduced profits. The proposed system provides farmers with real-time data about the farm environment, crop growth, and soil moisture, enabling them to make data-driven decisions about irrigation and crop management.

The system utilizes IOT devices such as soil moisture sensors, temperature sensors, water level sensor, humidity sensors, and a weather API to collect real-time data. Adscititious, the system integrates a weather API to forecast rain, which avails optimize the irrigation system and preserve electrical energy and dihydrogen monoxide. The system provides farmers with recommendations about irrigation, crop management, and soil health, availing them to optimize crop yield and abbreviate dihydrogen monoxide utilization. The XGboost algorithm is used to analyze the collected data and provide recommendations to farmers on irrigation and crop management. The system also provides alerts to farmers when rain is detected, helping them to optimize irrigation and reduce water usage.

The system's accuracy was tested against manual recommendations, and it showed an improved accuracy rate.

The Crop recommendation and irrigation system using IOT devices with integrated machine learning algorithms presented in this paper has the potential to revolutionize the agricultural sector by providing farmers with real-time data-driven recommendations for irrigation and crop management.

Overall, the system offers a cost-effective and efficient solution to address the challenges faced by farmers and has the potential to revolutionize the agriculture sector.

## II. Literature Review

[5]Agriculture has a significant influence in the economy and jobs of India. The most prevalent issue Indian farmers have is that they do not choose their crops based on the requirements of the soil, which has a significant negative impact on their output. India is one of the countries that produces the most agricultural goods, yet its farm productivity is still quite low. So that farmers can earn more from the same plot of land with less labor, productivity needs to be raised.

[2]As is well knowledge, India has the second-largest population in the world, and the majority of its citizens work in agriculture. Farmers cultivate the same crops again and over again without experimenting with new varieties, and they apply fertiliser in arbitrary amounts without knowing how much of it is insufficient in either nutrients or quantity. Thus, this has a direct impact on crop output in addition to causing soil acidity and top layer damage.

[5] utilizes an ensemble model with majority voting techniques, random tree, CHAID, K-Nearest Neighbor, and Naive Bayes were used in this, which work together to recommend suitable crops based on soil parameters with high levels of accuracy and efficiency. Adding on to the IoT part, [22][23] delve into the application of the Internet of Things (IoT) in the agricultural industry, with a particular focus on smart irrigation mechanization. They also outline the creation of an intelligent irrigation system (IIS) for paddy crop fields, utilizing IoT technology. Incorporating sensors to track soil conditions and transmits the collected data to a web server database to calculate the optimal amount of water required. This is then controlled by a dashboard, providing an efficient and intelligent solution for irrigation in paddy crop fields. They also investigate the utilization of sensors and automation as a means of curtailing water wastage and enhancing crop yield, [24] adds on by suggesting a proficient smart irrigation system that utilizes IoT technology to reduce water wastage and aid farmers in the irrigation process. It developed the new technology which automates irrigation only when moisture and temperature levels drop below a designated threshold value, and notifies the farmer. [25] Implemented an automated water system structure based on Internet of Things (IoT) and sensor technology, aiming to provide farmers with a smart solution for regulating the temperature, moisture and pH of the soil, hence maintaining the crops yield. [26] integrated use of IoT and Wireless Sensor Network (WSN) in agriculture has the potential to enhance crop yield, decrease water usage, while improving efficiency. However, despite these benefits, [6] faced some challenges, that include high costs, insufficient technical expertise, and limited network coverage, and these must be addressed to ensure successful deployment of the system. [27] also discusses the creation of a Wireless Sensor Network (WSN) designed to track soil moisture levels in wheat crops and subsequently make decisions about irrigation. The methodology given in [27] involves a field station equipped with a sensor node that measures soil moisture and transmits the collected data wirelessly to a central node. The central node processes the data and determines the ideal time and amount of irrigation required for the crops. It provided a designed to be affordable, dependable, and user-friendly system. [28] proposes a newer recommendation system guiding suitable fruit crops based on soil requirements. The system in [28] uses Precision and Recall methods according to real data providing satisfactory accuracy, so by reducing the likelihood of selecting the wrong fruit crop, it is anticipated that the system will increase productivity. [29] explores the crop diseases by utilization of some newer ML techniques, including the support vector algorithm, C4.5 decision tree algorithm and artificial neural network. [29] also introduces a novel approach which they referred to as the Crop Selection Method (CSM), designed for the crop selection problem.

In [1] author proposes to assist farmers that use IoT in Precision Agriculture to boost crop output, "ACRIS: Agriculture Cultivation Recommender and Smart Irrigation System" has been developed. For farmers adopting precision agriculture, the module estimates soil moisture and plans irrigation to save water use and increase yield. the module titled "AMOP System: ACRIS Multiparameter Optimization Systems for Precision Agriculture". To ensure the best crop growth and water stability, the module compares the water content at various stages of plant development and incorporates IoT technology into agriculture. The suggested machine learning algorithms (SLR & K_SLR) are intelligence-based.

In [2] author proposed an irrigation system that watered plants depending on information provided by the soil moisture sensor. In addition to providing water, it updates the farmer via the App on the state of the crop. According to surveys, between 25% and 30% of the water used for irrigation is lost because of the use of these technologies. This is a significant contributor to the global water crisis. To cut down on water waste, many irrigation techniques have been used, including soil grading, artificial drainage, and seeding.

## III. Problems with the existing Methods

In traditional farming practices, farmers rely on their experience and cognizance to decide on crop management and irrigation. However, this approach often leads to suboptimal crop yield and inefficient irrigation. With the emergence of IoT contrivances and machine learning algorithms, there has been a shift toward data-driven agriculture. The proposed methodology builds upon precedent research and leverages IoT contrivances and machine learning algorithms to optimize crop yield and irrigation.

We noticed that in all the previous papers and research conducted on the same topic, the attributes that were used were humidity, temperature, rainfall and pH. There were some limitations faced due to the use of these attributes. The pH value didn't give much information about the soil and wasn't providing much help. In order to improve the accuracy and overall working of our model, we replaced the pH value with the NPK value of the soil. It improved the accuracy of our model as a whole and was a much better alternative. In [1] the author proposed the SLR algorithm which gave the accuracy of 99.75% but the algorithms' training time and testing time of the dataset is slower than the proposed XG boost algorithm. The two main reasons to use XGBoost are **execution speed and model performance**. XGBoost dominates structured or tabular datasets on classification and regression predictive modeling problems.

XGBoost is a powerful machine learning algorithm that has been widely used in many fields and has shown superior performance in terms of accuracy and speed compared to other traditional algorithms like decision trees. IOT devices with integrated Machine learning" paper incorporated the use of IoT devices like water level sensors and weather APIs for irrigation management, which was not the main focus of the other papers. This additional feature provides a more comprehensive approach to precision agriculture by not only recommending the best crops based on NPK, temperature, and humidity values but also automatically managing the irrigation process based on real-time weather and water level data.

[4] uses the Random Forest algorithm. Both algorithms are widely used in machine learning, but XGBoost has been shown to outperform Random Forest in several benchmark datasets and Kaggle competitions due to its scalability, faster computation speed, and regularization techniques to prevent overfitting. And it also focuses solely on crop recommendation without considering the irrigation aspect.
The paper [2] focuses on developing a smart irrigation system based on IoT for different types of crops. The authors have used machine learning algorithms to predict the soil moisture content and decide the irrigation schedule. They have used K-NN and decision tree algorithms to classify crops and to determine the optimal watering schedules, respectively. While this is a commendable effort, the proposed system is limited in its scope as it only addresses the irrigation problem and does not provide any recommendation for the type of crop that should be grown. However XGBoost, which has been shown to outperform K-means clustering and decision trees in various applications.

## IV. Proposed Methodology

The proposed method for the Crop recommendation and irrigation system using IOT devices with integrated Machine learning involves the collection of soil parameters such as NPK levels, humidity, temperature, and soil moisture using sensors. These sensor values are transmitted to the Arduino microcontroller, which serves as a central control unit for the system, which is connected to a relay module. Arduino which serves as a central control unit for the system. The Arduino board communicates with a relay module, which acts as an interface between the sensors and the machine learning model. The relay module is responsible for executing the crop recommendation part of our system, which is done using a Machine Learning model trained on historical crop yield data. The model makes use of the collected sensor data to suggest the best-suited crop for the current season.
The machine learning model, which uses the XGBoost algorithm, recommends the most suitable crop based on the collected soil data. The recommended crop information is then sent to the cloud for further processing. The machine learning algorithm is then applied to the collected data to recommend suitable crops for the given soil parameters.

The recommended crop data is sent to the cloud, where it is processed and returned to the relay module. Based on the recommended crop, the system determines the irrigation requirements for each stage of crop growth. To determine the irrigation requirements, our system makes use of weather APIs, such as Meteum AI, to obtain the necessary weather data. This information is then combined with the sensor data collected by the IoT devices to determine the optimal irrigation schedule and volume of water required. The weather API is used to collect real-time weather data, which is used along with the sensor data to determine if irrigation is required and the amount of water required for the crop. The irrigation process is then initiated using a motor, which is controlled by the relay module. This allows for precise control over the amount and timing of the irrigation, resulting in optimal water usage and crop yield.

The irrigation is carried out using a motor controlled by the relay module, which provides precise amounts of water to the crops at different growth stages. This system ensures that the crops receive optimal irrigation, leading to improved yields and reduced water wastage. The proposed method provides an efficient and effective solution to optimize crop growth and ensure maximum yield, thereby contributing to the improvement of agriculture in India.

The technical details of each device used is give as follows:

| | |
|---|---|
| **Input Voltage** | 3.3V - 5V |
| **Output Voltage** | Analog Signal (0-5V) |
| **Sensory Type** | Chemical Sensor |
| **Measured Parameters** | Nitrogen(N), Phosphorus(P), Potassium(K) |
| **Measuring Range** | 0-5000 ppm |
| **Accuracy** | ±10% of reading |

Fig. 1. NPK Sensor

| | |
|---|---|
| **Input Voltage** | 3.3V - 5V |
| **Output Voltage** | Digital Signal (0/1) |
| **Sensory Type** | Capacitive Sensor |
| **Measured Parameters** | Relative Humidity(RH) |
| **Measuring Range** | 0-100% RH |
| **Accuracy** | ±2-5% RH |

Fig. 2. Humidity Sensor

| | |
|---|---|
| **Input Voltage** | 3.3V - 5V |
| **Output Voltage** | Analog Signal (0-5V) |
| **Sensory Type** | Thermistor |
| **Measured Parameters** | Temperature (ºC) |
| **Measuring Range** | -55 ºC to ±125 ºC |
| **Accuracy** | ±0.5 ºC (at 25 ºC) |

Fig. 3. Temperature Sensor

| | |
|---|---|
| **Input Voltage** | 3.3V - 5V |
| **Output Voltage** | Analog Signal (0-3V) |
| **Sensory Type** | Capacitive Sensor |
| **Measured Parameters** | Soil Moisture Content |
| **Measuring Range** | 0-100% (volumetric water content) |
| **Accuracy** | ±2-5% |

Fig. 4. Soil Moisture Sensor

| | |
|---|---|
| **Input Voltage** | 7V - 12V |
| **Output Voltage** | 5V (digital pins), 3.3V (analog pins) |
| **Microcontroller** | ATmega328P |
| **Clock Speed** | 16 MHz |
| **Digital I/O Pins** | 14 |
| **Analog Input Pins** | 6 |

| | |
|---|---|
| **Communication Interfaces** | USB, UART, SPI, 12C |

Fig. 5. Arduino

| | |
|---|---|
| **Input Voltage** | 5V |
| **Output Voltage** | 5V (Control signal), 220V (load) |
| **Number of Channels** | 1-8 |
| **Max. Switching Current** | 10A |
| **Max. Switching Voltage** | 250V AC, 30V DC |
| **Communication Interfaces** | None (controlled by digital signal from Arduino |

Fig. 6. Relay Module

| | |
|---|---|
| **Input Voltage** | 220V AC |
| **Output Voltage** | 0.5-2 HP |
| **Rated Frequency** | 50 |
| **Rated Speed** | 1440-2880 RPM |
| **Type** | Induction Motor |

Fig. 7. Motor

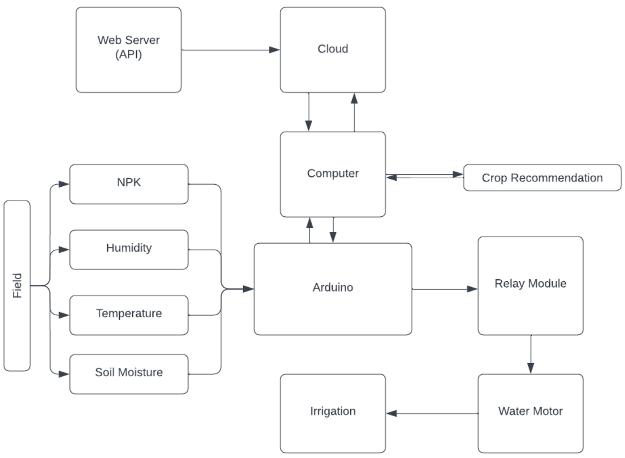



Fig. 8. Block Diagram of Crop Recommendation and irrigation

## V. Crop Recommendations Flow

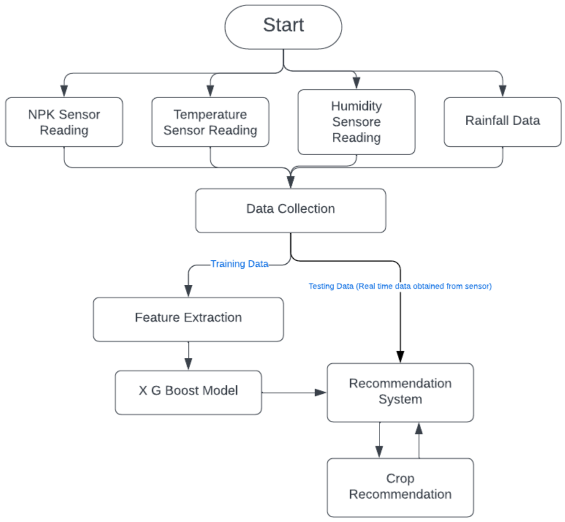



Fig. 9. Crop recommendation flow chart

The implementation of the project involves several steps, which begin with the gathering of four crucial soil values: Nitrogen, Phosphorous, Potassium (NPK), Temperature, Humidity, and Rainfall. All these Values are collected through the IoT (Internet of Things) sensors that we have inserted in the agricultural lands, then these values obtained by using IoT sensors deployed in agricultural lands collect the data and then store in the project's Dataset Collection.

The collected Dataset is then filtered and sorted according to the required needs. Then all that data is used for training and then the training data goes on for feature extraction and all the possible features and the specific values of the crops are provided in order to be improved. The Real time testing data is then obtained from our sensors and then the most suitable crop possible in the specific agricultural site is provided by the recommendation system.

We incorporate the smart recommendation system powered by the XG Boost Machine Learning algorithm to continue with our smart recommendation system, the algorithm provides with novelty and an exceptional, out of the books accuracy rate of 99.1%. This guarantees the proper functioning of our algorithm and thus makes sure that all the predictions made by it can be used in real life.

## VI. IRRIGATION FLOW

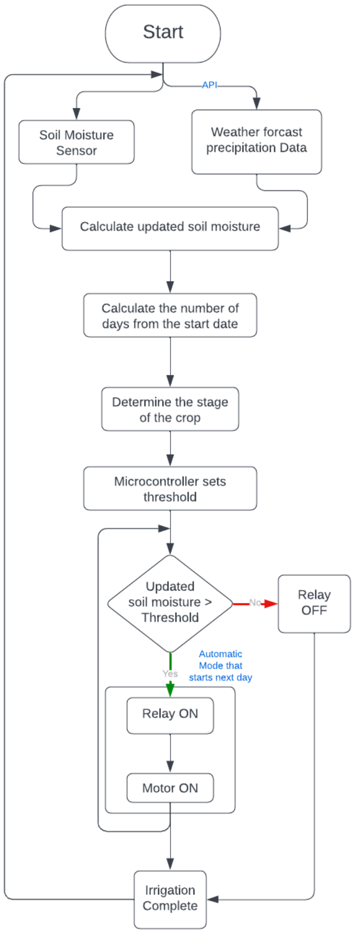



Fig. 10. Irrigation flow chart

The crop irrigation protocol commences with the use of IoT sensors deployed in agricultural lands to sense the current value of the soil moisture sensor reading, which is entirely accurate, and another factor i.e the prediction of the next-day's rainfall from newly generated APIs (Application Programming Interface). The combination of these two factors enables us to calculate and update the soil moisture levels, which are then used for further calculations. Once we receive the soil moisture level, we take input on the selected crop type as different crops have varying moisture requirements. After finalizing the crop, we calculate the number of days since it was sown in the ground, which determines the crop's current growth phase. The growth phases of crops typically comprise five stages, and the moisture requirements in each phase vary.

Once the crop type and growth phase have been determined, we select the corresponding moisture requirement value, which we have found out and stored in our dataset. The microcontroller then sets the threshold value for the crop at its current growth level.

Next, we compare the microcontroller's threshold value with the current soil moisture value. If the updated soil moisture value is higher than the threshold value determined by the microcontroller, the relay remains turned off, and no irrigation process occurs, as the soil already has sufficient moisture.

Whereas, if the Soil Moisture value is found to be less than the current threshold value then, the relay will be turned on and that will result in turning on of the water motor and start irrigating the field until the Soil moisture level reaches equal to the threshold value, and the irrigation is completed for the day.

This process will be checked on a daily basis and whatever corresponding values are found, the system protocol for irrigation will accordingly.

| **Crop (Days -->)** | **Stage 1 (1-30)** | **Stage 2 (31-60)** | **Stage 3 (61-90)** | **Stage 4 (91-120)** | **Stage 5 (121-150)** |
|---|---|---|---|---|---|
| Rice | 10% | 15% | 25% | 40% | 10% |
| Potato | 30% | 35% | 15% | 15% | 5% |
| Wheat | 20% | 40% | 20% | 10% | 10% |
| Sugar Cane | 10% | 20% | 35% | 20% | 15% |
| Corn | 20% | 25% | 40% | 10% | 5% |

Fig. 11. Amount of Irrigation required in 5 stages of crop

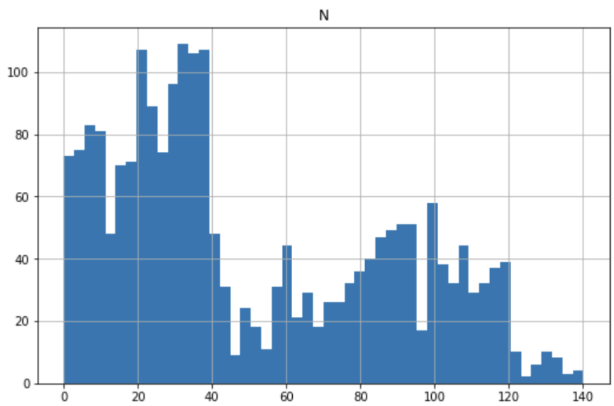
## VII. IMPLEMENTATION

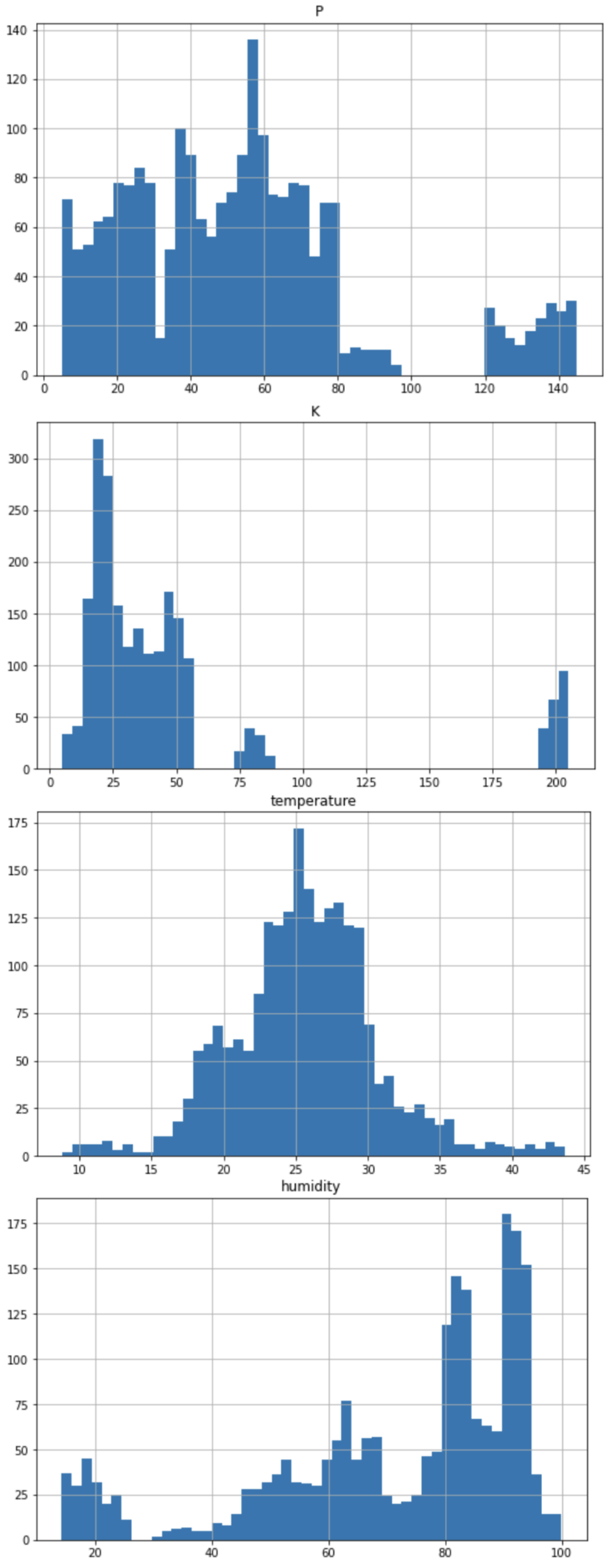
The data used for crop recommendation is collected from various sources such as soil sensors, weather API, and crop databases. The soil sensors measure the soil's nutrient levels, temperature, moisture content, and humidity, which provide information about the soil's health and suitability for different crops. The weather API provides information about the current weather conditions, forecasted weather, and historical weather data, which are used to determine the ideal growing conditions for different crops.

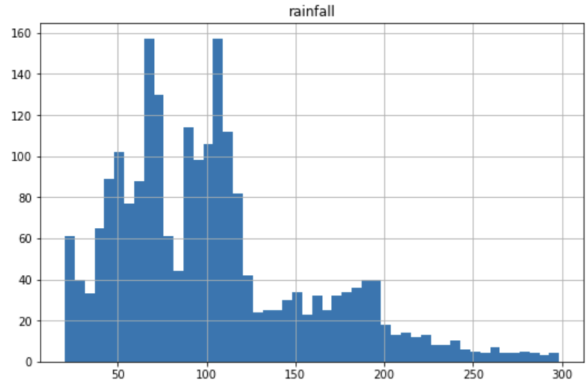
The crop databases provide information about the various crops, such as their growth requirements, disease susceptibility, yield potential, and market demand. This information is used to identify which crops are suitable for the specific soil and weather conditions and to make recommendations to the farmers.

The collected data is then fed into a machine learning model, which uses algorithms to analyze the data and make crop recommendations based on the patterns and correlations it identifies. The model considers various factors such as soil health, weather conditions, crop yields, and market demand to provide farmers with customized crop recommendations. By using this data-driven approach, farmers can make informed decisions about which crops to grow, resulting in improved yields, reduced costs, and better profits.

Here is data distribution of NPK, temperature, humidity and rainfall data.





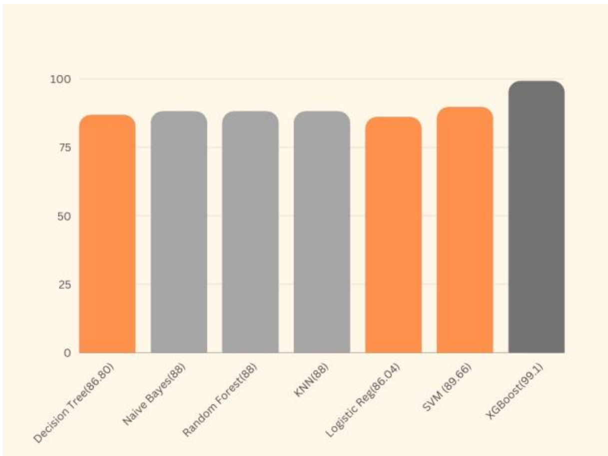




## VIII. RESULTS

Our crop recommendation and irrigation system utilizes the XGBoost algorithm to provide highly accurate crop recommendations, with a success rate of 99.1%. To determine the appropriate amount of irrigation for each crop, we use the number of days since planting to determine its growth phase. Because crops take approximately 150 days to mature, we divide this period into five distinct phases of around 30 days each. The growth phase is a critical factor in determining the necessary moisture level required for optimal crop growth.

Once we have established the current growth phase and the corresponding soil moisture requirements, we gather data on precipitation using APIs in our current latitude and longitude, which adds up with the existing moisture and determines the total moisture level in the soil. This information allows us to calculate the precise amount of irrigation needed to maintain the ideal moisture level for the crop.

Our system incorporates a water motor that starts working once the required moisture level is calculated. A soil moisture sensor placed in the ground continuously updates the moisture level, and once it reaches the optimal value, the system is notified, and the motor stops. This process is repeated daily, ensuring that the irrigation levels remain within the required parameters.




## IX. CONCLUSION

In conclusion, this paper give a solution of a cutting-edge tool that may assist farmers in making judgements regarding their crops and irrigation requirements. It integrates machine learning with IoT sensors. The system can deliver precise and prompt recommendations for crop selection and irrigation needs at various stages of growth by integrating IoT devices, such as sensors and motors, with Machine Learning algorithms and meteorological APIs.

The system can be used by both small- and large-scale farmers because it has been developed with scalability and affordability in mind. IoT device integration enables real-time monitoring and control of irrigation, which results in more effective use of water resources and less water waste. The machine learning algorithms that are employed for crop recommendation are trained on pertinent data sets and can be adjusted for various geographical locations and crop varieties.

Overall, the initiative has shown how technology has the ability to improve agriculture and help Indian farmers with some of their problems. The method has the potential to raise agricultural productivity, cut down on water use, and boost farmer profitability. To increase the system's precision and effectiveness and examine the possibility of integrating it with other technologies like blockchain for improved traceability and transparency in the agricultural supply chain, more research and development should be done.

## X. Future Scope

The utilization of IoT devices and machine learning algorithms for crop recommendation and irrigation systems has enormous potential for future developments. One possible future direction is the integration of precision agriculture techniques such as remote sensing, GIS, and drones can provide adscititious data that can be acclimated to ameliorate the precision of your system. Integration of these techniques with your subsisting system can be avail in monitoring crop magnification, disease detection, and yield prognostication.

Genuine-time monitoring and control can withal be implemented by integrating more sensors and utilizing wireless communication technologies. This will avail in making real-time decisions about irrigation, fertilization, and other crop management practices and Mobile application can withal be made. Government schemes can withal be integrated. Some other accommodations can also be integrated like nutrition suggestions and plant disease detection for crop health.

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