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Crop Recommendation and Irrigation System Using ML with Integrated IoT

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Sample Project Working Video:
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1. INTRODUCTION

1.1. THEORETICAL BACKGROUND

Crop Recommendation:

The practice of choosing the best crop or crop type to be cultivated in a specific area or under a specific set of circumstances is known as crop recommendation. It requires taking into account a number of variables, including crop compatibility, market demand, soil type, and water availability. agricultural advice aims to boost agricultural output and profitability while reducing negative effects on the environment.

Crop models that mimic crop development and production based on environmental conditions are one method of making agricultural recommendations. These models can aid in determining the best crop or crop type for a certain location and offer recommendations for the best planting times and management techniques.

Another strategy is to analyse huge databases on crop performance and environmental conditions using data-driven technologies like machine learning algorithms. With the aid of these techniques, it is possible to uncover trends and connections between environmental variables and agricultural yield, allowing for the creation of more precise crop recommendations.

Irrigation system:

A way to distribute water to crops to encourage growth and increase output is through irrigation systems. Irrigation systems come in a variety of designs, including sprinkler, drip, and surface irrigation.

Flooding the field with water during surface irrigation causes the water to seep into the soil, where it is then absorbed by the crops. This approach is straightforward and low-cost, but it may lead to unequal water distribution and water loss through evaporation and runoff.

1.2. MOTIVATION

Motivation for a project can stem from a variety of factors, including technical, economical, social, environmental, political, and demographic feasibility.

- <u>Technical feasibility:</u> A project may be motivated by the availability of new technology or the need to improve existing technology. In our project we utilised existing IOT technologies and ML algorithms and prepared a newer, better model.

- Economical feasibility: A project may be motivated by the potential for financial gain or cost savings. Our project, if taken to a much bigger level, can be utilised by the farmers all across the country, providing great profits.
- Social feasibility: A project may be motivated by the desire to meet the needs of society or improve the well-being of a community. Our project will be a huge benefit for all the farmers across the world and would also provide a great benefit to society and the agriculture of the world.
- Environmental feasibility: A project may be motivated by the need to address environmental concerns or reduce the negative impact of human activity on the environment. Our project is based on improving and helping with the various agricultural techniques and providing the best crop to be grown in a certain location, added on our smart irrigation system will be really beneficial in saving water, thus the environment.
- Political feasibility: A project may be motivated by political factors, such as government regulations or public policy. The government always supports all the scientific progress made towards the betterment in the field of agriculture and added on provide funding and supports all such ventures, and our project lies in complete boundaries of the governmental rules and regulations.
- Demographic feasibility: A project may be motivated by demographic factors, such as population growth or changing consumer preferences. The world population is ever growing and at the max it has ever been, and feeding the growing population is a really important task, at this point there is no chance for any crop yield to go to waste, so this motivated us to develop something to achieve a better crop yield.

1.3. AIM OF THE PROPOSED WORK

AIM of this paper is to develop an efficient and automated irrigation system that can recommend the appropriate crop based on the environmental and soil conditions. By using various sensors to collect data on NPK levels, humidity, temperature, and soil moisture, the system utilises machine learning algorithms to recommend the most suitable crop for the given conditions. The system then integrates weather APIs and water level sensors to determine the irrigation requirements for the recommended crop at different growth stages, ensuring that the crop receives the optimal amount of water. The project aims to optimise the yield of crops, reduce water wastage, and promote sustainable agriculture practices.

1.4. OBJECTIVES OF THE PROPOSED WORK

The primary objective of crop recommendation and irrigation system is to maximise crop yield. This can be achieved by providing crops with the right amount of water, nutrients, and other inputs necessary for their growth.

Another important objective is to minimise water usage. This can be achieved by using efficient irrigation systems that deliver water directly to the plant roots and by recommending crops that are well-suited to the local climate and soil conditions.

Crop recommendation and irrigation systems should provide timely recommendations to farmers based on real-time data, weather conditions, and other relevant factors to ensure that crops receive the right inputs at the right time.

Crop recommendation and irrigation systems should also aim to enhance soil health by recommending crops and irrigation practices that help to maintain soil fertility and minimise soil erosion.

With the help of modern technologies like IoT and machine learning, crop recommendation and irrigation systems can facilitate precision agriculture practices by providing accurate recommendations on the precise amount of water, nutrients, and other inputs required for specific crops, reducing waste and maximising efficiency.

2. LITERATURE SURVEY

2.1. SURVEY OF THE EXISTING MODELS/WORK

Numerous models and studies on irrigation systems and crop recommendations have been conducted. Here are a few instances:

Models for crop recommendations based on machine learning:

Crop recommendation models have been created using machine learning algorithms. These models use a variety of variables, including soil type, climate, and other environmental factors, to suggest the best crop for a given region. These models, as examples, include:

a) Decision Tree Model: This model makes predictions about the best crop based on input variables using decision trees.

b) An artificial neural network (ANN) model uses a sophisticated network of synthetic neurons to learn the connections between the input variables and the best harvest.

c) Support Vector Machine (SVM) Model: SVM models classify input variables into groups using a hyperplane, and then utilise those groups to predict the best crop.

Models for recommending crops based on rules:

Rule-based models suggest the best crop based on a set of rules or criteria. These models frequently draw from the expertise and experience of experts. Rule-based models include, for instance:

a) Fuzzy sets are used in fuzzy logic models to represent the input parameters and how they relate to the best crop.

b) Expert System Model: To suggest the best crop, expert system models consult a knowledge base of laws and regulations.

Sensors and actuators are used in IoT-based irrigation systems to monitor and manage the water delivery to crops. These systems have the ability to autonomously modify the water supply based on variables including temperature, weather, and soil moisture levels. IoT-based irrigation systems include the following examples:

a) WSN models use a network of wireless sensors to track the moisture content of the soil and other environmental variables. The water supply to the crops is then adjusted using this information.

b) Automated Irrigation System: Using sensors and actuators, automated irrigation systems automatically change the water supply to the crops in accordance with predetermined specifications.

c) Support Vector Machine (SVM) Model: Based on the input variables, SVM models can also be utilised to forecast crop yield.

These are only a few illustrations of the different models and research studies on irrigation systems and crop recommendations. We can anticipate seeing even more advanced models and systems in the future as technology develops.

2.2. SUMMARY/GAPS IDENTIFIED IN THE SURVEY

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 optimise 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 some papers, 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 modelling 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 regularisation 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.

3. OVERVIEW OF THE PROPOSED SYSTEM

3.1. INTRODUCTION AND RELATED CONCEPTS

In agriculture, crop suggestion and irrigation systems are two interrelated ideas that are essential for boosting crop yields and guaranteeing effective water utilisation.

Based on elements including soil type, weather patterns, and market demand, crop recommendation systems employ data and algorithms to advise the best crops to grow in a given area. These systems can aid farmers in making knowledgeable choices on the crops to plant, the best time to do so, and the best ways to care for them to maximise growth and yield.

On the other hand, irrigation systems are made to provide water to crops in a controlled and effective manner. There are many different kinds of irrigation systems, each having their own benefits and drawbacks, such as drip irrigation, sprinkler irrigation, and flood irrigation.

Irrigation systems that are well-planned and maintained can assist farmers in using water resources more effectively, minimising water waste, and ensuring that crops receive the proper amount of water for optimum growth.

Crop recommendations and irrigation systems work together to increase crop yields while using less water and fertiliser, which benefits farmers. This could improve communities all around the world's food security, sustainability, and revenues.

3.2. ARCHITECTURE

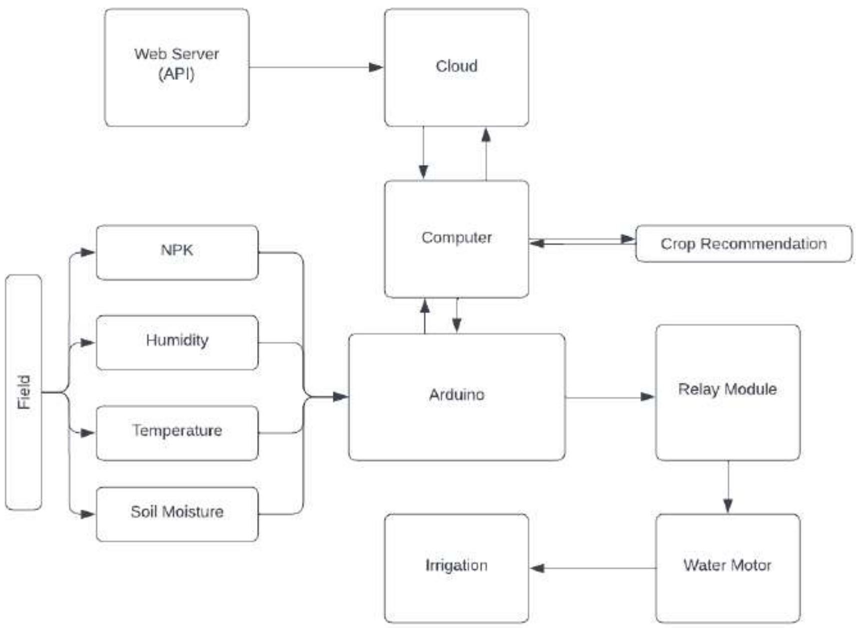


Fig. 1. Proposed Architecture

3.3. PROPOSED SYSTEM MODEL

A crop recommendation and irrigation system is a complicated system that includes data collection, processing, analysis, and decision-making, among other things. The following elements make up the suggested system model for this kind of system:

- Data collection: This step entails gathering pertinent information from numerous sources, including weather stations, soil moisture sensors, and crop growth stages. The information gathered needs to be precise, dependable, and timely.
- Data processing: It includes preparing the raw data for analysis by cleaning, verifying, and converting it into a specific format. A database should be used to hold the processed data so that it can be retrieved and edited quickly.
- Data analysis: This step entails looking at the data that has been processed to produce conclusions and suggestions. The data can be analysed using machine learning algorithms to forecast crop production, soil moisture content, and irrigation needs.
- Making decisions: This step entails selecting crops, planning irrigation, and applying fertiliser after carefully considering the insights and suggestions gleaned from data analysis.
- User interface: This part entails giving farmers a simple way to communicate with the system. The user interface needs to be simple to use, intuitive, and available on a variety of gadgets including tablets and smartphones.
- Implementation: In this step, the system's recommendations are put into practise on the farm. Other farming technology and automated irrigation systems can be used for this.

In order to give farmers accurate and timely information on crop selection, irrigation planning, and fertilisation, the suggested system model for a crop recommendation and irrigation system integrates numerous technologies and procedures. The system can assist farmers in making decisions that will improve crop production, conserve water, and raise crop yields.

4. PROPOSED SYSTEM ANALYSIS AND DESIGN

4.1. INTRODUCTION

In order to help farmers choose crops wisely and plan irrigation effectively, this study will suggest an effective crop recommendation and irrigation method. One of the largest economic sectors in the world is agriculture, and efficient use of resources like seeds, water, and land can boost agricultural productivity and profitability. This way, farmers can make the best use of their resources and increase crop output with the aid of an intelligent system that can offer crop-specific recommendations and optimise irrigation timing.

The two key parts of the proposed system are irrigation scheduling and crop recommendations. In order to suggest appropriate crop kinds, the crop recommendation component will analyse a variety of factors, including soil type, climate, and available resources. Based on numerous variables like soil moisture levels, weather, and crop water requirements, the irrigation scheduling component will offer optimised schedules for irrigation.

4.2. REQUIREMENT ANALYSIS

Understanding the needs of the system is the first stage in constructing a crop recommendation and irrigation system. The following are some essential criteria for this system:

a. Crop Data Management: The system should be able to manage and store data related to various crops, such as their growth cycle, water requirements, soil preferences, etc.

b. Soil Analysis: In order to make the best recommendations for the crops to be cultivated, the system should be able to analyse the soil's characteristics, including pH, moisture content, nutrient levels, etc.

c. Weather Analysis: For efficient irrigation management, the system should be able to retrieve weather data in order to offer real-time information regarding temperature, precipitation, humidity, etc.

d. Crop Recommendation: Based on the study of soil and weather data, the system should suggest which crops to cultivate.

e. Irrigation Recommendation: Based on a review of soil and weather data, the system should offer suggestions for how much water to apply to crops.

f. User Management: The system needs a user management module to handle users with various degrees of access, including farmers, researchers, and agronomists.

4.2.1. FUNCTIONAL REQUIREMENTS

A crop recommendation and irrigation system must meet the following functional specifications:

- Database of crops: The system should have a thorough database of crops that includes information about each crop's growth patterns, fertiliser needs, and water requirements.
- Soil analysis: The system should be able to analyse the soil composition and pH levels to determine the suitability of the soil for a particular crop.
- Climate information: To determine the best crops to grow and how much irrigation to recommend, the system should have access to weather information like temperature, humidity, and rainfall.
- Crop recommendation: The system should suggest appropriate crops to grow in the specified soil and climatic conditions based on the soil analysis and climate data.
- Recommendations for irrigation: Based on the crop's water requirements and the meteorological information, the system should also suggest suitable irrigation schedules.
- Sensor integration: To give real-time data for more precise irrigation and crop suggestions, the system should integrate with soil moisture sensors and weather stations.
- User input: To personalise the recommendations, the system should enable users to enter their own information, such as preferred crops and water availability.
- Notification and alerts: In the event of severe weather or when the watering schedule needs to be changed, the system should notify users and issue alarms.
- Data storage and analysis: The system should keep track of all the information gathered and use it to examine crop performance, spot trends, and enhance the precision of suggestions in the future.
- User interface: The system should have a user-friendly interface that allows users to easily view and understand the crop and irrigation recommendations.

4.2.1.1. PRODUCT PERSPECTIVE

The product could be comprised of several components, including:

- Hardware: This includes IoT devices such as weather stations, soil moisture sensors, and NPK,DHT 22 which collects data from the field and transmit it to a central system for analysis. The hardware may also include controllers or actuators for automated irrigation control.
- Software: The software component would encompass the machine learning algorithms that analyze the data collected from the IoT devices to provide crop recommendations and irrigation schedules. This could include data processing, pattern recognition, and predictive modeling to generate accurate recommendations and optimize irrigation scheduling.

- User Interface: The product can likely have a user-friendly interface, such as a mobile application or a web-based dashboard, that allows farmers to interact with the system, receive recommendations, and monitor and control their irrigation system remotely. The user interface would provide easy access to the analyzed data, recommendations, and alerts, enabling farmers to make informed decisions.
- Data Connectivity: The product would require connectivity to gather data from the IoT devices and transmit it to the central system for analysis. This could involve wireless connectivity options, such as Wi-Fi, cellular, or other IoT communication protocols, to enable seamless data transmission and communication between the various components of the system.
- Customization and Scalability: The product may need to be customizable and scalable to accommodate different crop types, regional variations, and farmer preferences. It could be designed to handle a wide range of crops, soil types, and weather conditions, and offer flexibility to adapt to different farming practices and requirements.
- Maintenance and Support: The product may require ongoing maintenance and support, including software updates, troubleshooting, and customer support to ensure smooth operation and address any technical issues that may arise.
- Integration and Compatibility: The product integrates with existing farm management systems, equipment, and workflows, and is compatible with different IoT devices and sensors available in the market, to ensure interoperability and ease of adoption.

4.2.1.2. PRODUCT FEATURES

- Crop Recommendation: The system may utilize machine learning algorithms to analyze various data inputs, such as weather data, soil health parameters, historical crop data, and crop-specific requirements, to provide farmers with crop recommendations.
- Irrigation Optimization: The system optimizes irrigation scheduling based on real-time data from IoT devices such as soil moisture sensors, weather stations, and evapotranspiration rates. Machine learning algorithms could analyze this data to determine the optimal irrigation schedule for each crop, taking into account factors such as crop water requirements, soil conditions, and water availability, to ensure efficient water usage and minimize water wastage.
- Data Analytics and Visualization: The system may provide farmers with data analytics and visualization tools, such as dashboards or reports, to help them understand and interpret the collected data. This could include visual representations of weather data, soil moisture levels, crop

health parameters, and other relevant information, allowing farmers to make informed decisions based on the analyzed data.

- Remote Monitoring and Control: The system may allow farmers to remotely monitor and control their irrigation system and other IoT devices through a user-friendly interface, such as a mobile application or a web-based dashboard. This could enable farmers to remotely adjust irrigation schedules, receive real-time alerts, and monitor the performance of the system, providing convenience and flexibility in managing their crops.
- Support and Maintenance: The system may include ongoing support and maintenance, such as software updates, troubleshooting assistance, and customer support, to ensure smooth operation and address any technical issues that may arise during the use of the system.

4.2.1.3. USER CHARACTERISTICS

- Farmers: The primary users of the system would be farmers, who are engaged in crop production and irrigation management. Farmers of various scales, including small-scale farmers, large-scale farmers, and commercial growers, could benefit from the system to optimize their crop management practices, improve irrigation efficiency, and enhance crop yield and quality.
- Agronomists and Crop Advisors: Agronomists, crop advisors, and agricultural consultants could also be potential users of the system. They may use the system to provide recommendations to farmers on crop varieties, planting dates, irrigation schedules, and other agronomic practices based on the data and insights generated by the system. They could also monitor and assess crop performance remotely using the system's analytics and visualization tools.
- Agricultural Researchers and Educators: Agricultural researchers and educators may use the system for field research and educational purposes. The system could provide them with real-time data on crop performance, weather conditions, and irrigation management, which could be used for research studies, teaching, and training purposes.
- Farm Managers and Operations Managers: Farm managers and operations managers may utilize the system to oversee and manage crop production and irrigation practices across multiple fields or farms. The system's remote monitoring and control features could enable them to efficiently manage and optimize irrigation scheduling, monitor crop health, and make informed decisions on crop management practices.
- Service Providers: Service providers, such as irrigation contractors, farm consultants, and agricultural technology providers, could potentially use the system as part of their services to

provide recommendations and insights to their clients. They may utilize the system's features to optimize irrigation management and provide value-added services to farmers.

- Agricultural Technology Enthusiasts: Agricultural technology enthusiasts, early adopters, and innovators who are interested in leveraging advanced technologies such as machine learning and IoT for agriculture could also be potential users of the system. They may use the system to explore new ways of optimizing crop production and irrigation management practices and stay ahead of the curve in adopting cutting-edge agricultural technologies.
- Other Stakeholders: The system may also be used by other stakeholders in the agriculture sector, such as agricultural policymakers, government agencies, and agricultural extension officers, who are involved in promoting sustainable agriculture, water resource management, and agricultural best practices. The system's data-driven recommendations and insights could support their decision-making processes and help them achieve their agricultural objectives.

4.2.1.4. ASSUMPTION AND DEPENDENCIES

- Availability and Reliability of Data: The system relies on accurate and reliable data, including weather data, soil data, crop data, and other relevant data, for generating crop recommendations and irrigation schedules.

  Assumption: Sufficient and reliable data from reliable sources would be available for the system to function effectively.
- Internet Connectivity: The system may require internet connectivity for data collection, analysis, and communication with IoT devices.

  Assumption: Reliable internet connectivity would be available at the farm or field locations where the system is deployed.
- IoT Devices and Sensors: The system may depend on IoT devices, such as soil moisture sensors, weather stations, and irrigation controllers, to collect real-time data for irrigation scheduling and crop monitoring. *Dependency*: Appropriate IoT devices and sensors would be available, functional, and properly installed to gather the required data.
- Machine Learning Algorithms: The system's crop recommendation capabilities rely on machine learning algorithms, i.e. XGBoost Algorithm that are trained on historical data to make accurate predictions. *Assumption*: The machine learning algorithms used in the system are appropriately trained and optimized for the specific crops, regions, and conditions where the system is deployed.

- Crop Database and Models: The system may rely on a comprehensive database of crop information, including crop growth models, phenology data, and agronomic practices, to generate recommendations. *Dependency*: Accurate and up-to-date crop database and models would be available to support the system's recommendations.
- System Integration: The system may require integration with existing farm management systems, irrigation systems, or other agricultural technologies for seamless data exchange and operation. *Dependency*: Integration interfaces or APIs are available and compatible with the existing systems or technologies used by the farmers.
- User Adoption and Training: The system's effectiveness relies on user adoption and proper utilization of its features.
- *Assumption*: Users are trained and willing to adopt the system as part of their crop management and irrigation practices, and are willing to follow the recommendations provided by the system.
- Regulatory Compliance: The system may need to comply with local regulations and standards related to data privacy, irrigation management, and agricultural practices.
- *Assumption*: The system is designed and developed in compliance with relevant local regulations and standards.

4.2.1.5. DOMAIN REQUIREMENTS

- Crop-Specific Recommendations: The system should is capable of providing crop-specific recommendations based on the crop types, growth stages, regional climate, and soil conditions.
- Weather Data Integration: The system should integrate real-time weather data, including temperature, precipitation, humidity, wind speed, and solar radiation, from reliable sources to accurately assess the current and future weather conditions. This data is crucial for making informed decisions on irrigation scheduling, crop management, and pest and disease management.
- Soil Data Integration: The system should incorporate soil data, such as soil moisture, soil type, and nutrient levels, to assess the soil conditions and determine the appropriate irrigation requirements for optimal crop growth. Accurate and up-to-date soil data is critical for providing customized recommendations based on the specific soil conditions of the farm or field.
- Crop Growth Models: The system should leverage crop growth models that are specific to the crops being cultivated and the region where the system is deployed. Crop growth models can provide insights into the crop growth stages, phenology, and resource requirements, which are

essential for generating accurate recommendations on irrigation, fertilization, and other crop management practices.

- Irrigation Management: The system should have the capability to manage irrigation scheduling based on crop water requirements, soil moisture levels, weather conditions, and other factors. This may involve automated control of irrigation systems, such as drip irrigation or sprinklers, based on real-time data and algorithms to optimize water use efficiency, prevent over-irrigation or under-irrigation, and ensure optimal crop growth.

4.2.1.6. USER REQUIREMENTS

- Crop Recommendation: Users may require accurate and timely recommendations on optimal crop types, planting dates, crop varieties, fertilization schedules, and other agronomic practices based on their specific farming conditions, such as location, soil type, and climate.
- Irrigation Management: Users may require an efficient and automated irrigation management system that takes into account factors such as crop water requirements, soil moisture levels, weather conditions, and irrigation infrastructure, to optimize water use efficiency and prevent over-irrigation or under-irrigation.
- Weather Monitoring: Users may require real-time weather monitoring capabilities, including temperature, precipitation, humidity, wind speed, and solar radiation, to make informed decisions on crop management practices, such as irrigation scheduling, pest and disease management, and harvesting.
- Soil Monitoring: Users may require soil monitoring features that provide information on soil moisture, nutrient levels, and soil type to assess the soil conditions and determine appropriate fertilization and irrigation requirements for optimal crop growth.
- Easy-to-Use Interface: Users may require a user-friendly interface that is easy to understand and use, with intuitive navigation and clear presentation of relevant information, such as crop recommendations, irrigation schedules, and weather forecasts.
- Customization: Users may require the ability to customize the system based on their specific farming practices, preferences, and field conditions. This may include options to input local agronomic knowledge, adjust system parameters, and receive personalized recommendations.
- Mobile Access: Users may require mobile access to the system, either through a mobile app or a responsive web interface, to conveniently access and manage their crops and irrigation schedules from anywhere, at any time.

- Data Privacy and Security: Users may require assurances of data privacy and security, with measures in place to protect their confidential information, such as farm location data, crop data, and other sensitive data, from unauthorized access or breaches.
- Support and Maintenance: Users may require ongoing support, updates, and maintenance for the system, including technical support, bug fixes, and software upgrades, to ensure smooth operation and reliability of the system.

4.2.2. NON FUNCTIONAL REQUIREMENTS

4.2.2.1. PRODUCT REQUIREMENTS

4.2.2.1.1. EFFICIENCY

The efficiency of the whole crop recommendation and irrigation system depends on various factors, including the performance of the crop recommendation model, the accuracy of the weather and precipitation data used for irrigation scheduling, the effectiveness of the soil moisture sensor, the computational resources available for data processing, and the user interface design for ease of use and quick decision-making.

Assuming the crop recommendation model is trained with high accuracy (99.1% accuracy with XG Boost algorithm), the weather and precipitation data used for irrigation scheduling is reliable and up-to-date, the soil moisture sensor provides accurate readings, and the system is deployed on appropriate computational resources with efficient data processing and storage mechanisms, the overall efficiency of the system can be high.

However, it's important to note that the efficiency of the system may also depend on other factors such as the quality of input data, system configuration, network connectivity, and user behavior. Regular monitoring, maintenance, and updates to the system may be required to ensure ongoing efficiency and performance optimization.

4.2.2.1.2. RELIABILITY

Accuracy of crop recommendations: The system provided accurate and relevant crop recommendations based on sensor data, weather data, and other inputs. The recommendations were reliable and consistent, helping farmers make informed decisions about crop selection, planting, and management practices.

Timeliness of irrigation schedules: The system generated irrigation schedules in a timely manner based on forecasted weather data, precipitation data, and soil moisture data. The schedules were reliable and timely, helping farmers optimize irrigation practices and avoid over- or under-irrigation.

System uptime and availability: The system should available and accessible to farmers as per the agreed-upon service level agreements (SLAs) without frequent downtime or disruptions. It was reliable in terms of system uptime, ensuring that farmers could access crop recommendations and irrigation schedules when needed

4.2.2.1.3. PORTABILITY

Platform independence: The system was designed and implemented in a way that allowed it to run on different hardware platforms, operating systems, or software frameworks. It was not tightly coupled to a specific platform or technology, enabling it to be easily deployed in different environments.

Compatibility with different sensor and weather data sources: The system could easily integrate with different types of sensors and weather data sources, allowing farmers to use different sensor devices or weather APIs to collect data for crop recommendation and irrigation scheduling. It had the flexibility to adapt to different data sources without requiring significant modifications to the system

4.2.2.1.4. USABILITY

User interface design: The system had a well-designed and visually appealing user interface that was intuitive and easy to navigate. It had clear and organized screens, menus, and controls, allowing farmers to easily interact with the system and input data.

System documentation: The system had comprehensive documentation, including user manuals, tutorials, and help guides, providing clear instructions on how to use the system. The documentation was written in simple and understandable language, making it accessible to users with different levels of technical expertise.

Learnability: The system had a short learning curve, allowing farmers to quickly understand how to use the system and its features effectively, even with limited technical background.

4.2.2.2. ORGANISATIONAL REQUIREMENTS

4.2.2.2.1. IMPLEMENTATION REQUIREMENTS

The implementation requirements may include:

- Hardware: The system may require specific hardware components, such as sensors for NPK, temperature, humidity, and soil moisture, as well as a reliable and stable communication network to transmit data between the sensors and the system.
- Software: The system may require specific software components, including the crop recommendation model trained with the XG Boost algorithm, a weather API for accessing forecasted weather and precipitation data, and a database to store and retrieve data related to crops, soil moisture, and irrigation schedules.
- Integration: The system may need to be integrated with other existing systems or databases, such as farm management systems, weather APIs, or irrigation systems, to exchange data and information for accurate crop recommendations and irrigation schedules.
- Security: The system may require robust security measures to protect sensitive data, prevent unauthorized access, and ensure the integrity and confidentiality of the system. This may include encryption of data, user authentication, role-based access control, and regular security audits.
- Scalability: The system may need to be scalable to handle varying amounts of data, users, and operations as the system grows over time. This may involve designing the system architecture to accommodate future expansion, optimizing database performance, and utilizing scalable technologies.
- Testing and validation: The system may require rigorous testing and validation to ensure its accuracy, reliability, and functionality. This may involve testing the crop recommendation model with different datasets, validating the irrigation schedules with actual weather and precipitation data, and conducting user acceptance testing to ensure the system meets user requirements.
- Deployment and training: The system may require proper deployment and training for end-users, such as farmers, to ensure they understand how to use the system effectively, interpret crop recommendations, and follow irrigation schedules. This may involve providing user training materials, conducting workshops, and providing ongoing support to address user questions or issues.

- Compliance: The system may need to comply with relevant regulations, standards, and guidelines, such as data privacy regulations, agricultural practices, and industry standards. This may involve ensuring data privacy, adhering to local farming practices, and complying with relevant standards and regulations related to irrigation and crop management.

4.2.2.2.2. ENGINEERING STANDARD REQUIREMENTS

Sensor standards: The system may need to comply with relevant sensor standards for NPK, temperature, humidity, and soil moisture sensors, such as ISO 17192 for soil moisture sensors, ISO 19268 for nitrogen sensors, and ISO 23081 for metadata standards for data exchange between sensors and systems.

Communication standards: The system may need to adhere to communication standards for transmitting data between sensors, system components, and external systems, such as wireless communication standards (e.g., IEEE 802.11 for Wi-Fi, LoRaWAN for long-range low-power communication), and data exchange standards (e.g., REST, MQTT, OPC-UA).

Modeling standards: The crop recommendation model may need to follow established modeling standards and best practices, such as model evaluation using cross-validation, hyperparameter tuning, and model interpretability techniques.

Database standards: The system may need to comply with established database standards, such as data normalization, data integrity, and data backup and recovery procedures, to ensure reliable and efficient data storage and retrieval.

Software development standards: The software components of the system may need to adhere to established software development standards, such as coding standards, version control, documentation, and software testing (e.g., unit testing, integration testing) to ensure high-quality and maintainable code.

Security standards: The system may need to comply with established security standards and best practices, such as data encryption, user authentication, role-based access control, and vulnerability testing, to protect sensitive data and prevent unauthorized access.

System integration standards: The system may need to follow established standards for integrating with other systems or APIs, such as API standards (e.g., REST, GraphQL), data exchange formats (e.g., JSON, XML), and authentication and authorization protocols (e.g., OAuth, JWT).

Compliance with regulations: The system may need to comply with relevant regulations, guidelines, and standards, such as data privacy regulations (e.g., GDPR, HIPAA), agricultural practices (e.g., Good Agricultural Practices), and environmental regulations (e.g., water usage regulations), as applicable to the region or industry where the system is deployed.

4.2.2.3. OPERATIONAL REQUIREMENTS

4.2.2.3.1. ECONOMIC

The economic operational requirements for a crop recommendation and irrigation system include:

Cost of equipment: The cost of the equipment required for the system, such as weather stations, soil moisture sensors, and irrigation equipment, should be reasonable and within the budget of farmers.

Cost of data collection and processing: The cost of collecting and processing data should be reasonable and not overly expensive. This can be achieved by using affordable sensors, data processing software, and cloud computing services.

Cost of maintenance and support: The cost of maintaining and supporting the system should be reasonable and not impose a significant financial burden on farmers. This can be achieved by providing adequate training and support to farmers to ensure they can use the system effectively and minimising the need for repairs.

Cost savings from improved crop yield: The system should result in increased crop yields, leading to cost savings for farmers. This can be achieved by recommending crops that are better suited to the local climate and providing optimal irrigation schedules that prevent under or overwatering, which can result in crop failure.

Return on investment (ROI): The system should provide a reasonable ROI for farmers, taking into account the costs associated with the system, such as equipment, data collection, processing, maintenance, and support, and the cost savings resulting from improved crop yields.

Affordability: The system should be affordable for small-scale farmers, as they are the most vulnerable and least able to bear high costs.

4.2.2.3.2. ENVIRONMENTAL

The environmental operational requirements for a crop recommendation and irrigation system include:

Sustainable water usage: The system should encourage sustainable water usage by recommending optimal irrigation schedules that prevent overwatering and minimise water wastage.

Efficient use of resources: The system should be designed to make efficient use of resources, such as water and energy, to minimise waste and reduce environmental impact.

Climate-resilient crops: The system should recommend crops that are better suited to the local climate and weather patterns, reducing the risk of crop failure due to extreme weather events.

Conservation of natural resources: The system should encourage conservation of natural resources, such as soil and water, by recommending crops that are suited to local soil conditions and requiring less water.

Reduction of greenhouse gas emissions: The system should be designed to reduce greenhouse gas emissions associated with crop production by recommending crop varieties that require less fertiliser, pesticide, and energy input.

Biodiversity preservation: The system should encourage biodiversity preservation by recommending crop rotation and intercropping practices that maintain soil health and reduce the need for synthetic inputs.

Use of renewable energy sources: The system should be powered by renewable energy sources, such as solar or wind power, to minimise its environmental impact.

4.2.2.3.3. SOCIAL

The social operational requirements for a crop recommendation and irrigation system include:

Accessibility: The system should be accessible to all farmers, regardless of their location or socioeconomic status.

User-friendly interface: The system should have a user-friendly interface that is easy to understand and use, even for farmers with limited technical knowledge.

Localization: The system should be designed to cater to the local context, including local weather patterns, soil types, and cultural practices.

Community involvement: The system should involve the local community, including farmers, agricultural extension workers, and local leaders, to ensure that it meets the needs and priorities of the community.

Capacity building: The system should provide capacity building opportunities, such as training and support, to farmers, to ensure that they can effectively use the system and apply its recommendations to their farm operations.

Gender sensitivity: The system should be sensitive to gender issues, including the differing roles and responsibilities of men and women in agricultural production, and should consider the needs and priorities of both men and women farmers.

Equity and inclusivity: The system should promote equity and inclusivity, including by ensuring that small-scale farmers and marginalised communities have access to the system and its benefits.

4.2.2.3.4. POLITICAL

The political operational requirements for a crop recommendation and irrigation system include:

Government support: The system should have the support of the government, including policymakers and regulators, to ensure its long-term sustainability and effectiveness.

Policy alignment: The system should be aligned with national agricultural policies and strategies to ensure that it supports the government's development goals and priorities.

Legal compliance: The system should comply with relevant laws and regulations related to agriculture, environmental protection, and data privacy and security.

Accountability and transparency: The system should be accountable and transparent, with clear mechanisms for monitoring and evaluation, and with safeguards to protect against corruption and misuse of power.

Stakeholder engagement: The system should engage with relevant stakeholders, including farmers, agricultural extension workers, civil society organisations, and private sector actors, to ensure that it is responsive to their needs and priorities.

Resource mobilisation: The system should be supported by adequate resources, including financial, human, and technological resources, to ensure its sustainability and effectiveness.

Multi-stakeholder collaboration: The system should encourage collaboration and partnerships among different stakeholders, including public and private sector actors, to promote innovation, knowledge sharing, and resource mobilisation.

4.2.2.3.5. ETHICAL

The ethical operational requirements for a crop recommendation and irrigation system include:

Data privacy and security: The system should prioritise data privacy and security, with clear policies and procedures for handling and protecting personal and sensitive data.

Fairness and equity: The system should be designed to promote fairness and equity, with no biases or discrimination based on factors such as race, gender, or socioeconomic status.

Informed consent: The system should obtain informed consent from farmers and other stakeholders, with clear information about the system's purpose, how it works, and any potential risks and benefits.

Transparency and accountability: The system should be transparent and accountable, with clear mechanisms for monitoring and evaluation, and with safeguards to protect against misuse or unethical behaviour.

Responsible use of technology: The system should be developed and used in a responsible manner, with consideration of the potential impacts on the environment, society, and human rights.

Respect for cultural values: The system should respect cultural values and traditions, with sensitivity to local customs and practices.

Ethical oversight: The system should have ethical oversight, with clear guidelines and procedures for ensuring that ethical principles are upheld in all aspects of the system's design and implementation.

4.2.2.3.6. HEALTH AND SAFETY

The health and safety operational requirements for a crop recommendation and irrigation system include:

Equipment safety: The system should be designed and maintained in a manner that ensures the safety of all equipment used in the process, including the irrigation system, soil moisture sensor, and water motor.

Hazardous materials management: Any hazardous materials used in the system, such as pesticides or fertilisers, should be managed in accordance with safety regulations to prevent harm to human health and the environment.

Personal protective equipment (PPE): Farmers and other workers should be provided with appropriate PPE, such as gloves or masks, to prevent exposure to hazards such as chemicals or dust.

Emergency response planning: The system should have a clear plan for responding to emergencies, such as equipment failure or accidents, to minimise any risks to human health and safety.

Training and education: Farmers and other workers should receive appropriate training and education on the safe use of the system, including equipment operation, chemical handling, and emergency response.

Regular maintenance and inspection: The system should undergo regular maintenance and inspection to ensure that it is in good working order and any potential hazards are identified and addressed promptly.

Health and hygiene: The system should promote good health and hygiene practices, such as handwashing and sanitation, to prevent the spread of disease and ensure the safety of farmers and workers.

4.2.2.3.7. SUSTAINABILITY

The sustainability operational requirements for a crop recommendation and irrigation system include:

Efficient use of water resources: The system should be designed to optimise the use of water resources, with efficient irrigation methods that minimise waste and reduce water consumption.

Conservation of soil health: The system should promote soil conservation practices, such as crop rotation and cover cropping, to improve soil health and reduce erosion.

Reduction of greenhouse gas emissions: The system should aim to reduce greenhouse gas emissions, such as those from energy consumption and fertiliser use, by utilising renewable energy sources and sustainable agricultural practices.

Biodiversity conservation: The system should promote biodiversity conservation, such as through the use of agroforestry and intercropping practices that promote ecosystem diversity.

Economic viability: The system should be economically viable, with cost-effective practices that promote sustainable farming practices and support the livelihoods of farmers and rural communities.

Social responsibility: The system should be socially responsible, promoting fair and equitable practices that respect the rights and dignity of farmers and workers, and contribute to the well-being of local communities.

Environmental impact assessment: The system should undergo regular environmental impact assessments to identify any potential negative impacts and implement appropriate measures to mitigate them.

4.2.2.3.8. LEGALITY

The legality operational requirements for a crop recommendation and irrigation system include:

Compliance with regulations: The system should comply with all relevant laws, regulations, and guidelines related to agricultural practices, water use, and environmental protection.

Intellectual property rights: The system should respect intellectual property rights, including any patents, copyrights, or trademarks that may apply to the technology or data used in the system.

Data privacy and security: The system should ensure the privacy and security of any data collected from farmers or other users, in compliance with applicable data protection regulations.

Liability and risk management: The system should address liability and risk management concerns, such as by providing appropriate warnings and disclaimers related to the accuracy and use of the crop recommendations.

Contractual obligations: The system should meet any contractual obligations that may apply, such as obligations to suppliers, customers, or investors.

Ethical and social responsibility: The system should promote ethical and socially responsible practices, such as fair labor practices and responsible use of resources.

Transparency and accountability: The system should be transparent and accountable, with clear communication channels for stakeholders and appropriate mechanisms for addressing any concerns or complaints.

4.2.2.3.9. INSPECTABILITY

Modularity: The system may have been designed with modular components that are easily inspectable, allowing for individual assessment and evaluation of each component's performance and functionality.

Logging and monitoring: The system may have included logging and monitoring mechanisms that captured relevant data, such as sensor readings, system events, and user interactions, which could be reviewed and analyzed for inspection purposes.

Diagnostics and debugging: The system may have included diagnostic and debugging tools that facilitated identification and resolution of issues or anomalies in the system's operation, enabling effective inspection and troubleshooting.

Documentation: The system may have been accompanied by comprehensive documentation, including system architecture, design specifications, user manuals, and maintenance procedures, which could be reviewed and referred to during inspections.

Testing and validation: The system may have undergone rigorous testing and validation procedures during development and deployment, which included inspections to verify the system's performance, functionality, and compliance with requirements.

4.2.2.4. SYSTEM REQUIREMENTS

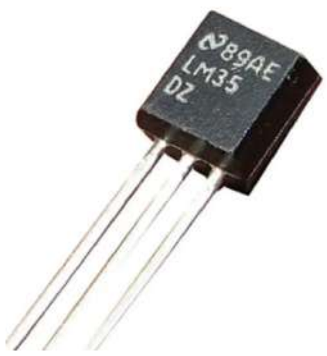
4.2.2.4.1. HARDWARE REQUIREMENTS

NPK sensors: Sensors to measure nitrogen, phosphorus, and potassium levels in the soil.

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

NPK Sensor

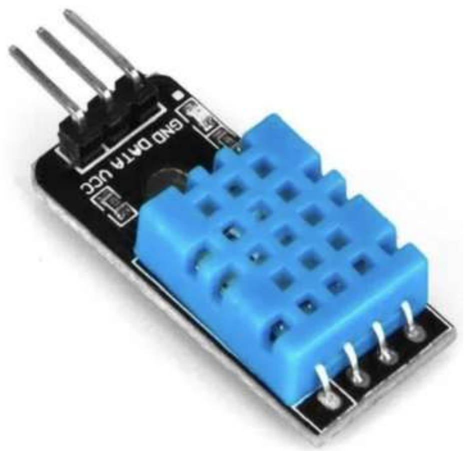
Temperature sensors: Sensors to measure temperature of the air, soil, or water.



Input Voltage	3.3V - 5V
Output Voltage	Analog Signal (0-5V)
Sensory Type	Thermistor
Measured Parameters	Temperature (^{o}C)
Measuring Range	-55 ^{o}C to ±125 ^{o}C
Accuracy	±0.5 ^{o}C (at 25 ^{o}C)

Temperature Sensor

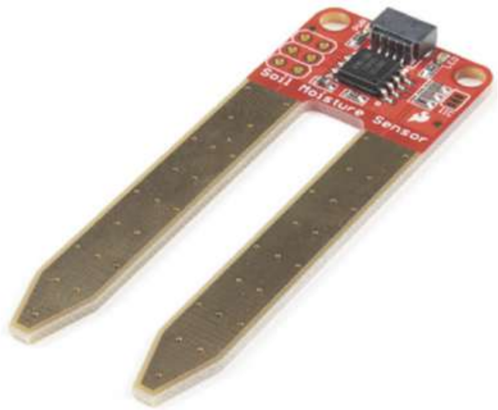
Humidity sensors: Sensors to measure relative humidity or moisture content in the air, soil, or plants.



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%

Soil Moisture Sensor

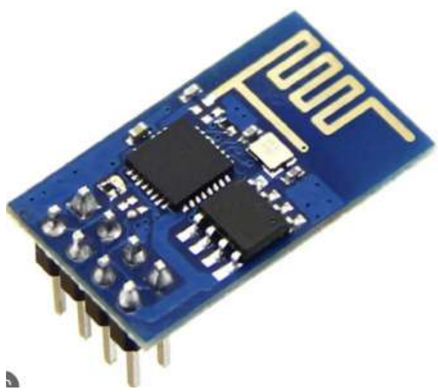
Soil moisture sensors: Sensors to measure moisture content in the soil.



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

Humidity Sensor

Wireless modules or IoT gateways: Communication devices to transmit sensor data to the central processing unit or cloud-based servers.(eg: Node MCU, ESP 8266)



Servers, edge devices, or embedded systems: Computing equipment to process and analyze sensor data, run machine learning algorithms, and generate irrigation schedules.

Storage devices: Hard drives, cloud storage, or other storage solutions to store sensor data, historical crop data, machine learning models, and other system-related information.

Power supply: Electrical power sources or backup power solutions, such as batteries or generators, to ensure continuous operation of hardware components.(Eg: Arduino Uno Microcontroller)

Mounting structures, enclosures, or weather protection measures: Physical infrastructure to install and protect sensor devices, communication devices, computing equipment, and other hardware components.

Compliance with environmental and safety standards: Waterproofing, temperature tolerance, or electromagnetic interference (EMI) compliance measures to ensure proper and safe operation of the system.

Arduino: Arduino is an open-source platform used for building electronics projects. It consists of a microcontroller board and a software development environment, which allows users to write and upload code to the board to control various components and sensors.

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

Arduino

Relay Module: A relay module is an electronic component used to control high-power devices with low-power signals. It consists of a relay switch and a circuit board, which allows it to control devices such as motors, lights, and heaters. The relay module is controlled by a low-power signal from an Arduino board, which activates the relay switch, allowing the high-power device to be turned on or off.

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

Relay Module

Motor: A motor is a device that converts electrical energy into mechanical energy. It is commonly used in robotics and automation projects to control the movement of various parts.

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

Motor

4.2.2.4.2. SOFTWARE REQUIREMENTS

Machine Learning Library: The system would have required a machine learning library, such as scikit-learn, TensorFlow, or PyTorch, for developing and training the crop recommendation model using the XGBoost algorithm with a 99.1% accuracy .

Database Management System: The system uses a database management system, such as MySQL, PostgreSQL, or MongoDB, JSon, CSV files for storing and managing data related to crop recommendations, sensor readings, weather forecasts, and irrigation schedules and extracts data from Kaggle.

Weather API Integration: The system integrates with weather API services, such as OpenWeatherMap or Weather Underground, to retrieve forecasted weather and precipitation data for determining irrigation schedules. We have used the Meteum API.

IoT Communication Protocol: The system utilized IoT communication protocols, such as MQTT, CoAP, or HTTP, for communication between IoT sensors, gateways, and the central system for data transmission and control commands.

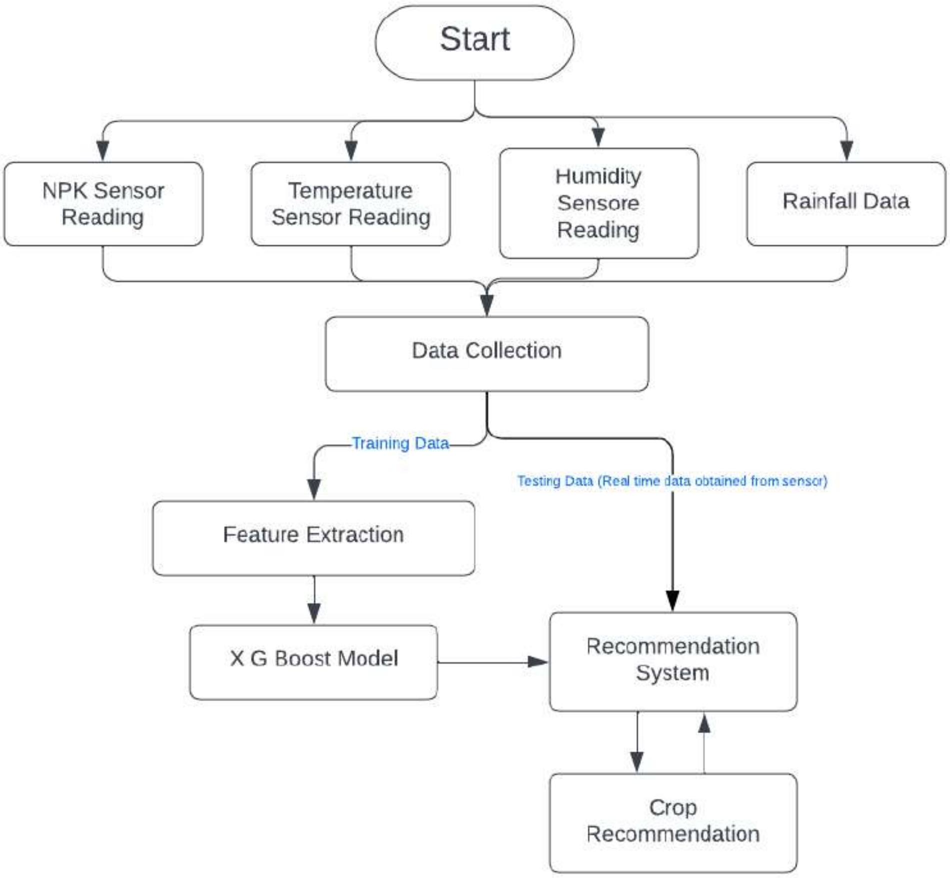
User Interface (UI) and User Experience (UX) Design: The system required a user-friendly and intuitive UI/UX design for farmers or users to interact with the system, view recommendations, monitor sensor readings, and manage irrigation schedules.

Data Processing and Analysis: The system implemented data processing and analysis algorithms or modules for cleaning, filtering, and analyzing sensor data, weather data, and other relevant data to generate crop recommendations and determine irrigation schedules.

System Integration: The system may have required integration of various software components, APIs, and protocols for seamless communication and coordination between different parts of the system, such as the crop recommendation module, sensor module, weather API module, and irrigation scheduling module.

Security Measures: The system may have implemented security measures, such as data encryption, authentication, and authorization, to protect sensitive data and ensure secure communication between different components of the system

5. IMPLEMENTATION



Flow Diagram for crop recommendation

In the proposed system, the sensor data collected from the soil, including NPK values, humidity, temperature, and soil moisture, is sent to the Arduino board. The collected data is then processed using machine learning models to recommend the most suitable crops for cultivation in that particular soil. The cloud server returns the recommended crop list to the relay module, which further sends signals to the motor to start the irrigation process. The irrigation system is controlled using data collected from the weather API and water level sensors. The system recommends the appropriate amount of irrigation required for different stages of crop growth, such as nursery, transplanting, vegetative, reproductive, and ripening stages. By incorporating IoT and machine learning, this system provides a highly efficient and accurate method for crop selection and irrigation, ultimately improving crop yields and increasing profitability for farmers. Generally the flow chart describe these following points

After the crop is recommended then the irrigation part starts.

Crop irrigation is a crucial factor in ensuring successful crop growth and yield. The irrigation requirements of a crop vary at different stages of its growth cycle. In general, crops can be divided into five stages of irrigation:

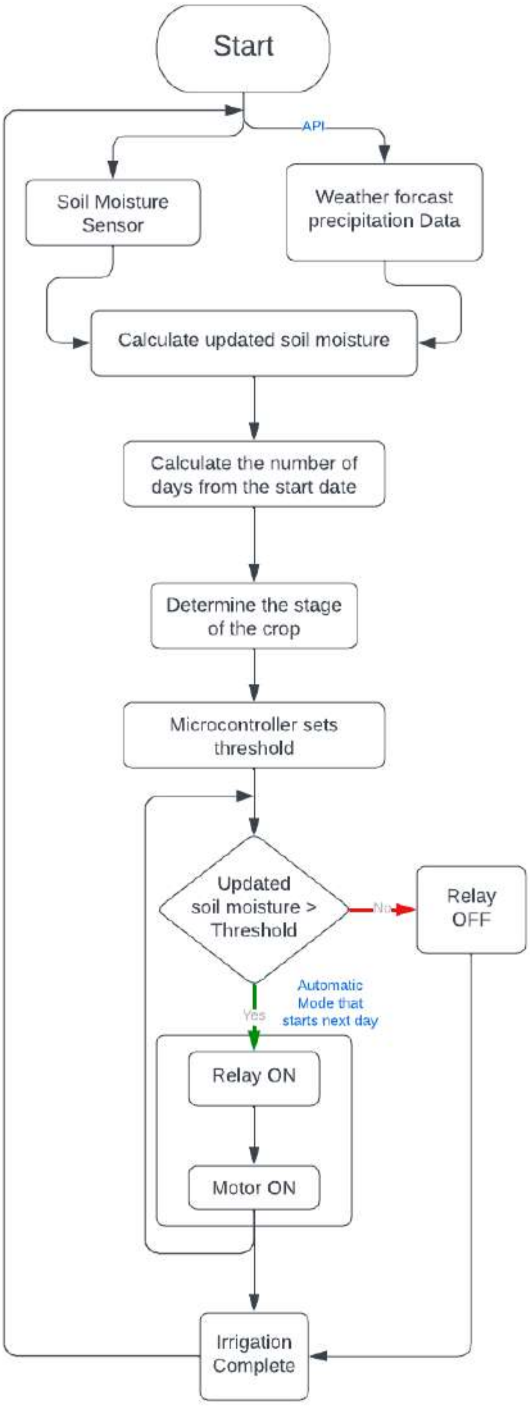
1. Nursery stage: This stage is when the crop is still in the nursery and requires careful watering. The soil should be kept moist but not overwatered, as this can lead to root rot. The duration of this stage varies depending on the crop.
2. Transplanting stage: This stage is when the crop is transplanted into the field. The soil should be thoroughly watered to ensure that the plants establish their roots. The duration of this stage is usually short.
3. Vegetative stage: This stage is when the plant grows vegetatively, producing leaves and stems. During this stage, the crop requires regular watering to ensure that the soil stays moist. The duration of this stage varies depending on the crop.
4. Reproductive stage: This stage is when the plant produces flowers and fruits. During this stage, the crop requires more water to support the growth of the flowers and fruits. The duration of this stage varies depending on the crop.
5. Ripening stage: This stage is when the crop matures and is ready for harvest. During this stage, the crop requires less water as the fruits or grains are already matured. The duration of this stage varies depending on the crop.

By understanding the irrigation requirements of a crop at each of these stages, farmers can ensure that the crop receives the right amount of water at the right time, leading to better growth and yield. The use of IoT devices and machine learning algorithms can further optimize the irrigation process and provide more accurate crop recommendations, resulting in improved crop productivity and resource efficiency.

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%

Amount of Irrigation required in 5 stages of crop

After these stages is determined then irrigation is started. Below flow diagram explains the process of irrigation after the crop is determined. Irrigation flow is as follows:

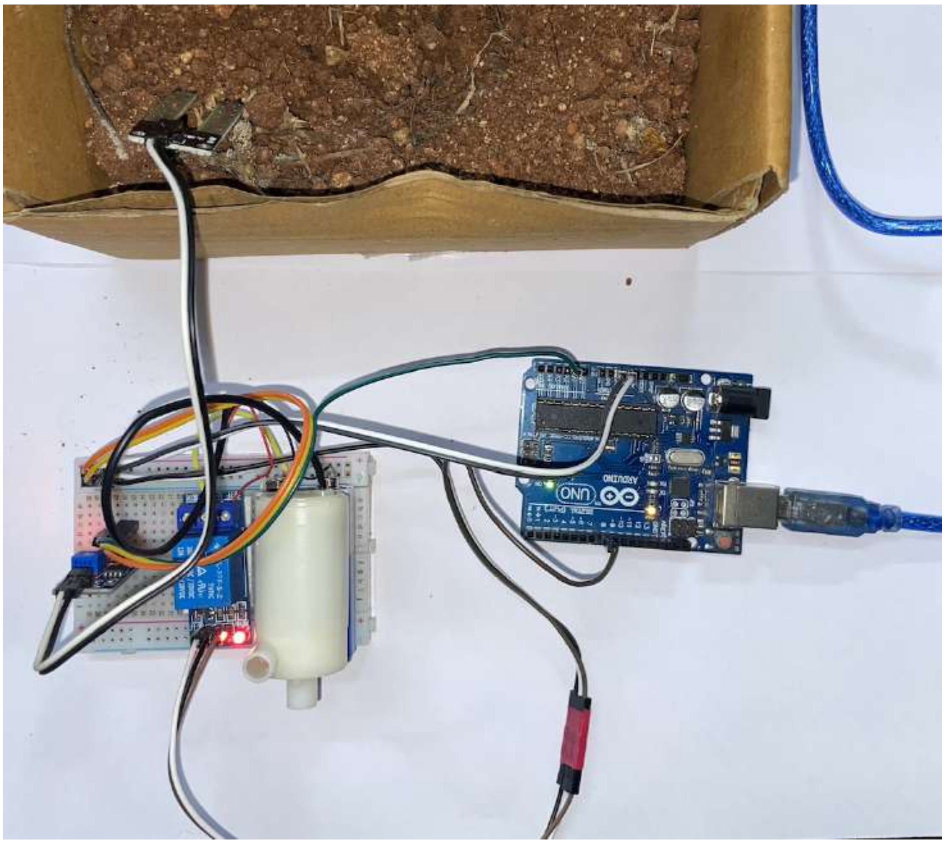


Flow diagram of irrigation system

1. Collect data from soil sensors: The first step is to collect data from the NPK, humidity, temperature, and soil moisture sensors installed in the field. These sensors will measure the current condition of the soil and send the data to the Arduino board.
2. Send data to the Arduino board: The data collected by the sensors is then sent to the Arduino board for processing. The Arduino board will read the data and use it to make decisions about whether or not to irrigate the field.

3. Decide on irrigation requirements: Based on the data collected by the sensors, the Arduino board will decide whether the field needs to be irrigated or not. If the soil moisture level is too low, the board will determine how much irrigation is needed and when.
4. Retrieve weather data: To determine the correct amount and timing of irrigation, the Arduino board will retrieve weather data from the Meteum AI weather API. This data will provide information about rainfall, humidity, temperature, and other weather conditions that will affect the irrigation needs of the field.
5. Control the relay module: Once the Arduino board has decided on the correct amount and timing of irrigation, it will send a signal to the relay module. The relay module will then control the motor that powers the irrigation system.
6. Water the crops: With the relay module controlling the motor, the irrigation system will be activated and water will be delivered to the crops at the appropriate time and in the correct amount.
7. Repeat the process: This process will repeat periodically based on the current conditions of the field, the weather forecast, and the growth stage of the crops.

Below image shows the implementation of IoT components :



Here is how motor turns on, first the crop stage is determined and then the soil moisture is check. If the soil moisture is less then the required threshold then the motor turns on.

When the soil moisture reaches the required threshold then the motor turns off.

```
[33]: print("Crop Stage : " , i)
      print("Day : " , cal_day)
      Prec_mm = sum(new1["prec_mm"]/10)
      Soil_Moisture_Tomorrow = sum(new1["soil_moisture"]/24)
      Soil_Moisture_Total = Soil_Moisture_Tomorrow + Prec_mm
      print("Soil Moisture  : " , Soil_Moisture_Tomorrow)
      print("Precipitaion Tomorrow : " , Prec_mm)
      print("Total Soil Moisture : " , Soil_Moisture_Total)
      print("Ideal Soil Moisture : " , new["Soil_Moisture"][i-1])
```

```
Crop Stage :  3
Day :  85
Soil Moisture  :  0.13
Precipitaion Tomorrow :  0.0
Total Soil Moisture :  0.13
Ideal Soil Moisture :  0.2569893695358871
```

Crop stage determined

```
[34]: if(new["Soil_Moisture"][i-1]>Soil_Moisture_Total):
          print(1)
      else :
          print(0)
```

Soil Moisture found low the required

```
1
```

[35]:

```python
import serial as s
import time as t
ser = s.Serial('COM5', 9600, timeout=0)   # check your com port
t.sleep(2)
print(ser.name,"connected")
if(new["Soil_Moisture"][i-1]<=Soil_Moisture_Total):
    ser.write(b'0')
    print ("MOTOR OFF")
elif(new["Soil_Moisture"][i-1]>Soil_Moisture_Total):
    ser.write(b'1')
    print ("MOTOR ON")
    t.sleep(20)
else:
    ser.close()
```

Motor Turns ON

```
COM5 connected
MOTOR ON
```

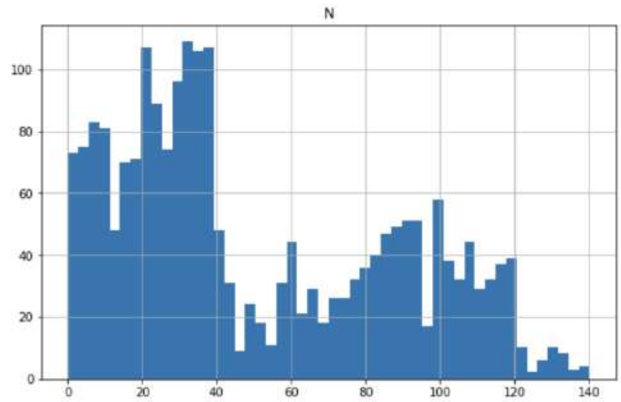
```
Moisture Percentage = 3.71%
Moisture Percentage = 3.81%
Moisture Percentage = 3.91%
Moisture Percentage = 3.91%
Moisture Percentage = 3.81%
Moisture Percentage = 3.62%
Moisture Percentage = 52.49%
0.2569893695358871  = % Ideal Moisture reached, turning off motor
```

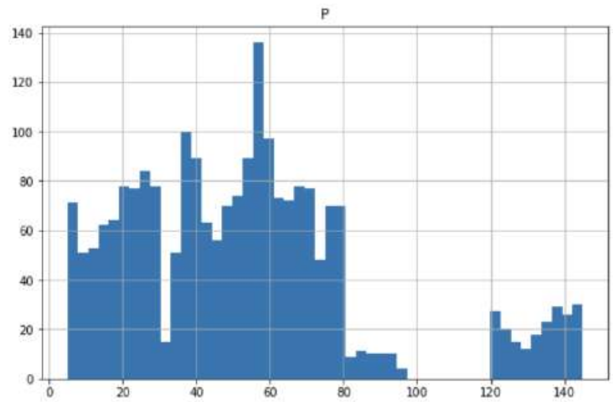
Soil Moisture exceed required threshold, so Motor turns OFF

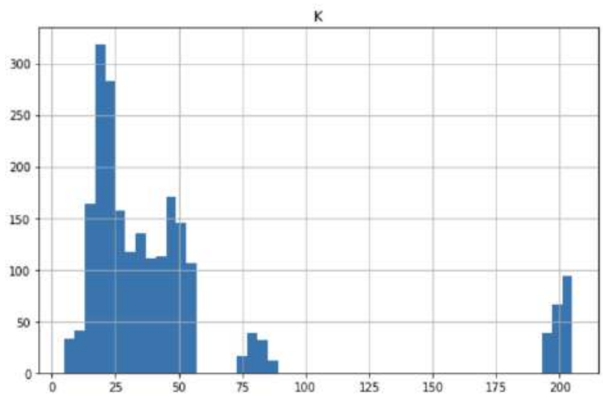
DATA:

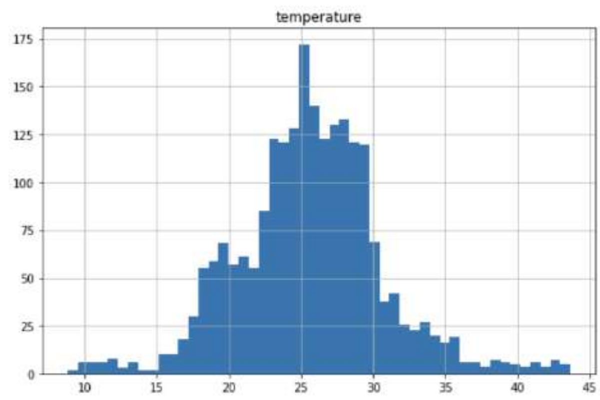
The data used for crop recommendation is collected from various sources such as soil sensors, weather API, and crop databases. The soil sensors measure the soil's nutrient levels, temperature, moisture content, and humidity, which provide information about the soil's health and suitability for different 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.

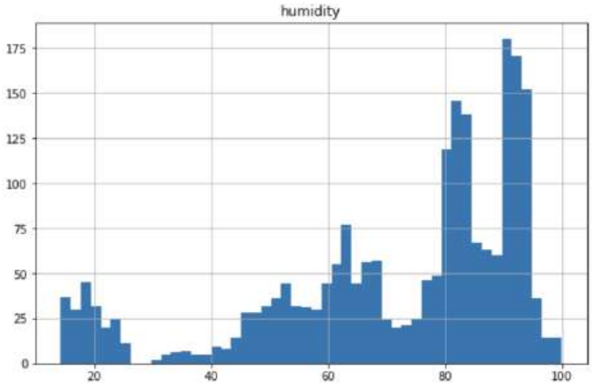
Here is data distribution of NPK, temperature, humidity and rainfall data.

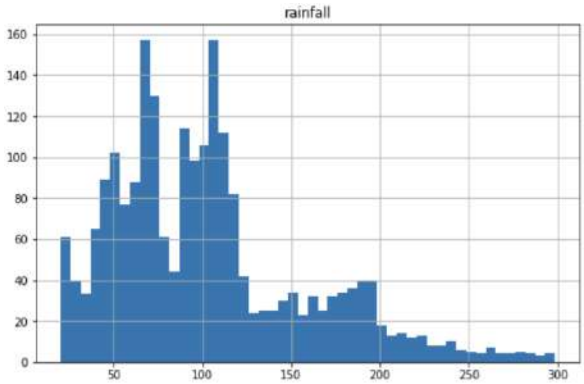









humidity
175
150
125
100
75
50
25
0
20
40
60
80
100


rainfall
160
140
120
100
80
60
40
20
0
50
100
150
200
250
300

6. **PSEUDOCODE**

Recommendation

```
# Import required libraries
import serial
import time
import requests
import json
import pandas
# Set Meteum API access key
# Make API request to Meteum API to fetch forecast data for specific latitude and longitude

# Parse JSON response and store in 'data' variable

# Print JSON data with indentation for readability

# Get current date and store in 'today' variable

# Print 'forecasts' key from 'data' dictionary

# Initialize empty dictionary 'dici'

# Loop through 'hours' data in 'forecasts' dictionary:
for each hour in forecasts:
    # Store relevant information (soil temperature, soil moisture, precipitation amount, precipitation probability, precipitation period) in 'dici' dictionary with hour as key

# Convert 'dici' dictionary to pandas DataFrame '…
```

Irrigation

```
# Import required libraries
from numpy import loadtxt
from xgboost import XGBClassifier
from sklearn.model_selection import train_test_split
```

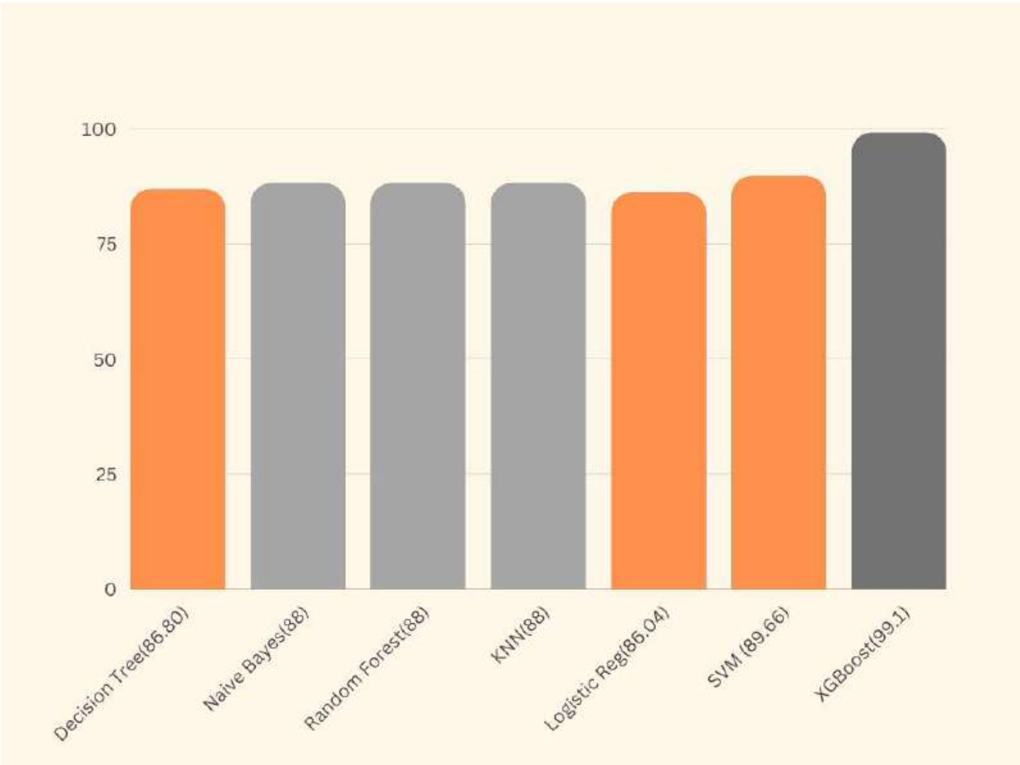
```
from sklearn.metrics import accuracy_score
import pandas as pd

# Load dataset from CSV file
dataset = pd.read_csv('Downloads/Crop_recommendation.csv')

# Extract features (X) and labels (Y) from dataset
X = dataset[["N", "P", "K", "temperature", "humidity", "ph", "rainfall"]]
Y = dataset[["label"]]

# Replace labels with numerical values
a = Y['label'].unique()
i = 0
for x in a:
    Y.replace(x, i, inplace=True)
    i += 1

# Split data into training and testing sets
seed = 7
test_size = 0.2
X_train, X_test, y_train, y_test = train_test_split(X, Y, test_size=test_size, random_state=seed)

# Initialize and fit XGBoost classifier model
model = XGBClassifier()
model.fit(X_train, y_train)

# Make predictions for test data
y_pred = model.predict(X_test)
predictions = [round(value) for value in y_pred]

# Evaluate predictions using accuracy score
accuracy = accuracy_score(y_test, predictions)
print("Accuracy: %.2f%%" % (accuracy * 100.0))
```

7. RESULTS AND DISCUSSION

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.



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