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The Smart Agriculture System Using IOT and ML

Abstract: - Numerous countries have abundant resources, including land, rivers, groundwater, the environment, with agriculture serving as the primary source of income for many people in country. Nonetheless, resource shortage has grown in recent decades, particularly for groundwater and river water, so remote control smart irrigation system is developed to avoid access use and loss of water in the agriculture. A lack of information about the best use of available resources leads to increased resource consumption and worse crop yields. Choosing crops that are unsuited for the soil or climate reduces both quality and quantity of crop. As a result, system that recommends appropriate crops and fertilizers based on soil NPK values, soil colour, Season, PH, Rainfall, temperature etc has been developed. Fires are one of the most destructive global disasters, thus early detection is necessary to avoid the damages in agriculture. To reduce losses, an automated system capable of early fire detection through alarm systems and prompt extinguishing procedures through the roof structure pipeline in the farm is developed. Another use of that same pipeline is for spraying the pesticides and fertilizers. A potential resolution to address all these challenges involves the development and implementation of an intelligent agricultural system integrating Internet of Things (IOT) and Machine Learning technologies.

Keywords: Identification of soil nutrients, Crop Recommendation, Nitrogen Phosphorus Potassium (NPK), Internet of Things (IOT), Machine Learning (ML), Random Forest (RF), Fertilizer Recommendation.

I. INTRODUCTION

A United Nations study predicts that by 2050, there will be close to 10 billion people on Earth, could potentially reach 11 billion by around 2100. The need to produce more food for this rapidly expanding population has led to a surge in the adoption of intensive agricultural methods [4]. Human livelihood is mainly depends on agriculture, which is the world's primary source of food and economic growth. Important issues facing India's agriculture industry includes soil health, inadequate irrigation, disasters such as fire in farm and poor seed quality etc.[7].

Our project primarily aims to automate land irrigation without human involvement, [15] prevent disasters in agriculture such as fires, and analyze soil NPK values to suggest suitable crops and fertilizers to the farmers. Designing an automated system requires the integration of Machine Learning and IOT principles [11]. An Internet of Things (IOT) network is a network of interconnected devices that are able to exchange and collect data from the environment without human intervention [14]. Particularly in countries like India, efficient water management is essential where agriculture serves as the backbone. [13].So our primary aim is to prevent water wastage by automating the irrigation system using IOT sensors and android application. Building an automated system requires the combining of IOT concepts with various sensor data, processing it according to user requirement [11], and ensuring automated water distribution throughout the entire field for irrigation [15]. Inadequate or excessive water

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supply can cause plant water stress and hinder plant growth. Automating crop watering offers a significant benefit in optimizing water consumption and increase productivity [10].

Another serious problem in agriculture is the occurrence of fires, which frequently occurs due to the burning of materials, flammable gases, electrical circuits, etc. Currently, cost effective fire alert systems or automation for agriculture are less [6]. In order to avoid such disasters, we are designing a smart fire detection system using IOT. Sensors will detect fires in the farm, transmitting signals to an Arduino system, which will activate a motor and use a roof-mounted pipeline system for both watering and extinguishing fires. This same pipeline system will also be utilized for spraying fertilizers and pesticides on the crops.

Additionally, utilizing machine learning (ML) as a technology can revolutionize traditional farming practices. Tasks such as tilling the soil, selecting suitable crops based on soil conditions, ensuring adequate fertilizer application, and managing pests are integral agricultural practices. However, recent natural disasters have presented serious difficulties for farmers. [5].The choice of inappropriate crops profoundly impacts farmers, depleting available resources like seed cost and fertilizers [17]. It is essential to check the soil to determine the availability of nutrients in soil for plant growth before applying fertilizer. [4]. Inadequate soil nutrients cause various plant disorders and lower yields. Hence, having detailed information about nutrient quality of their soil is highly valuable to farmers. Their profitability significantly increases when they understand which crops grow well in particular soils and when to apply fertilizers[1].Addressing these challenges we designed smart, user-friendly recommender application for farmers using machine learning [16]. This system would suggest suitable fertilizers and crops based on different values such as soil colour, Season, PH, Rainfall, temperature etc. and the NPK values obtained using an NPK sensor.

II. LITERATURE REVIEW

This study aims to introduce an innovative and cost-efficient irrigation system that incorporates real-time monitoring, remote control functionality, and cloud-based data processing. Its main objective is to combine these elements such that they function according to predetermined thresholds for parameters. The system's actions, such as switching motor on and off, are depends upon these predefined parameter values. Furthermore, the research enhances user interaction through a mobile application, making the system easier to use. This resource aids users in assessing the suitability of their environment for their intended agricultural practices [11].

The study highlights how crucial agriculture is to maintaining human survival. To optimize fertilizer recommendations and to predict crop yields, various machine learning techniques are used. Farmers provide soil properties as input data to the application. An agriculturally-dependent country's economic stability, significantly influences land productivity, which is influenced by seasonal, economic, and organic factors. The primary goal is to gather, store, and analyze data that is essential to forecasting agricultural productivity. The goal is to enable farmers to choose most suitable crops for their specific needs. The study's insights will help farmers to choose crops with more knowledge, taking into account aspects like cost and reducing possible losses in particular regions[18].This research will be enhance by also suggesting fertilizers for soil depends on various soil constraints.

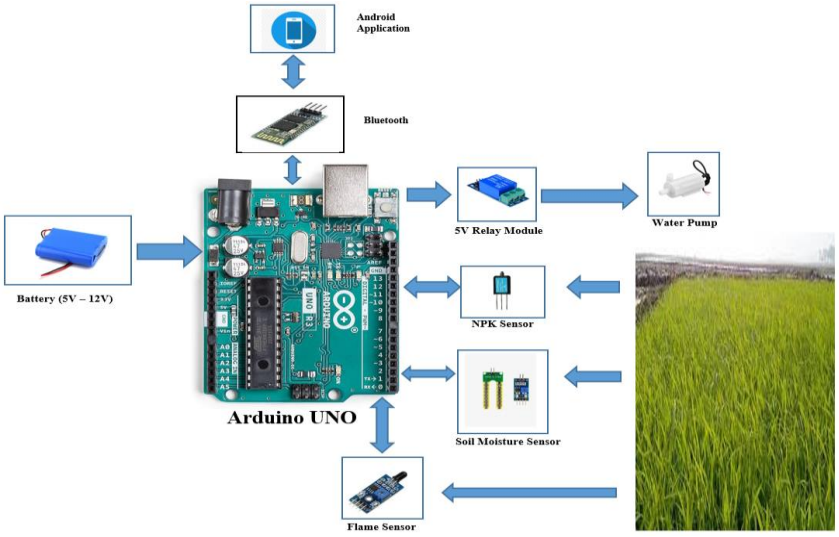
In India, agriculture is a vital industry that employs and sustains 70% of the country's workforce, making it the foundation of the national economy. Key factors that are impacting agriculture include soil quality and climatic conditions. Crop mismatching with inappropriate soil or climate conditions not only reduces the quality and quantity of the crop yield but also affects the overall agricultural output. In order to deal with this, the current study aims to develop a system that can both recommend crops and evaluate the condition of the soil. This study aims to predict which fertilizers will be needed for certain crops. Using machine learning algorithms, this research intends to increase the accuracy of recommendations based on soil attributes such as nutrient composition, moisture levels, and rainfall patterns, thereby, we implemented a suggested paradigm in our own project for real-world use. [2].

Timely identification of fire, recognized as one of the most catastrophic events globally, is crucial to prevent significant damage to the environment and living organisms. Studies suggest that 75-80 percent of fire-related casualties could have been averted if prompt action had been taken. To mitigate such losses, there is a pressing need for an automated system capable of early fire detection through various alarm systems. This study delves into the current advancements and applications of the Internet of Things (IOT) in the fire fighting industry, highlighting its potential momentum. Furthermore, it provides a summary of a survey conducted to identify research trends and challenges in fire-related projects. The IOT for fire management aims to interconnect diverse objects within fire-related organizations. The paper elucidates the development of a fire detection system utilizing Arduino, integrated with smoke and temperature sensors, triggering a buzzer alarm upon detection of fire-related indications[3].

The productivity of agriculture is dependent on various soil elements such as temperature, pH, phosphorus (P), potassium (K), and nitrogen (N) and moisture. Accurate measurement of these factors and timely fertilizer application are crucial for maximum yields during the appropriate seasons. However, limited knowledge and improper fertilizer usage hamper farmers' crop potential. Traditional techniques for evaluating soil nutrients require collection and transportation to laboratories for testing, which is an expensive and subjective procedure. This study suggests an effective method that combines machine learning-driven crop recommendations with IOT-based soil nutrient monitoring. Using a variety of sensors system continuously gathers field data and sends it to a cloud-based database using a wireless sensor network. By analyzing parameters like (N, P, K, temperature, pH, humidity, and rainfall), the machine learning algorithm finds ideal crop varieties for improved productivity. Using machine learning in agriculture improves crop selection, lowers the need for needless fertilizer, decreases manual labour, and increases yield overall. By integrating IOT-based soil nutrient monitoring with machine learning algorithms, this system recommends suitable crops for particular lands, contributing to increased agricultural yeild and national economic growth [1].

III. PROPOSED SYSTEM

The concept of smart agriculture is gaining popularity, supported by Machine Learning and Internet of Things sensors that collect information from agricultural areas and respond to human inputs. Smart farming systems that use remote sensing can increase production, reduce waste, and efficiently manage a wider range of resources. [8]. The development of Smart Agriculture Systems using IOT and ML not only helps to improve the farming quality but also saves farmer's lot of time. In our system this will be accomplish with the use of soil moisture, NPK and Flame detection sensors which are connected to Arduino Uno. This project's primary goals are to reduce accidents, improve old agricultural methods, and protect farmers from fertilizer-related infections.

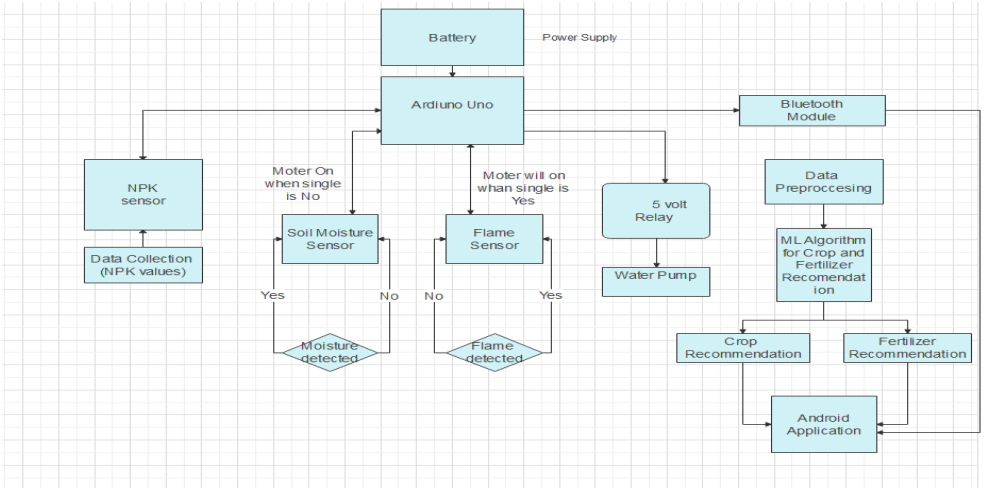


A soil moisture sensor in our system monitors the moisture level in the soil. If the soil's water level drops below the necessary amount, a signal is transmitted to the Arduino and arduino transmits signal to the relay module, starting the motor automatically and water will get supplied through the roof structure pipeline in the farm. When the water level reaches the required threshold, the motor will be deactivate automatically.

The NPK sensor collects Nitrogen, Phosphorus, and Potassium values from the soil. Based on these values, and some additional values such as soil color, season, PH, rainfall, temperature, etc., our user-friendly mobile application recommends specific fertilizers and crops for the soil. This recommendation process is carried out by using machine learning model trained with appropriate machine learning algorithms.

When flame detection sensor detects a fire in the farm, the flame detection sensor transfers a signal to the arduino, which in turn relays it to the relay module. This activates both a buzzer for an audible alert and a motor automatically. A roof structure pipeline is setup in the farm, providing a dual purpose. In case of a fire, this pipeline is used to sprinkle water to extinguish the fire in the farm. Also the same pipeline is used for spraying pesticides and fertilizers onto the crops using the motor. Thus, the roof structure pipeline provides both as a fire extinguishing system as well as mechanism for spraying pesticides and fertilizers.

IV. SYSTEM FLOW DIGRAM



The flow of system is shown in above flowchart.

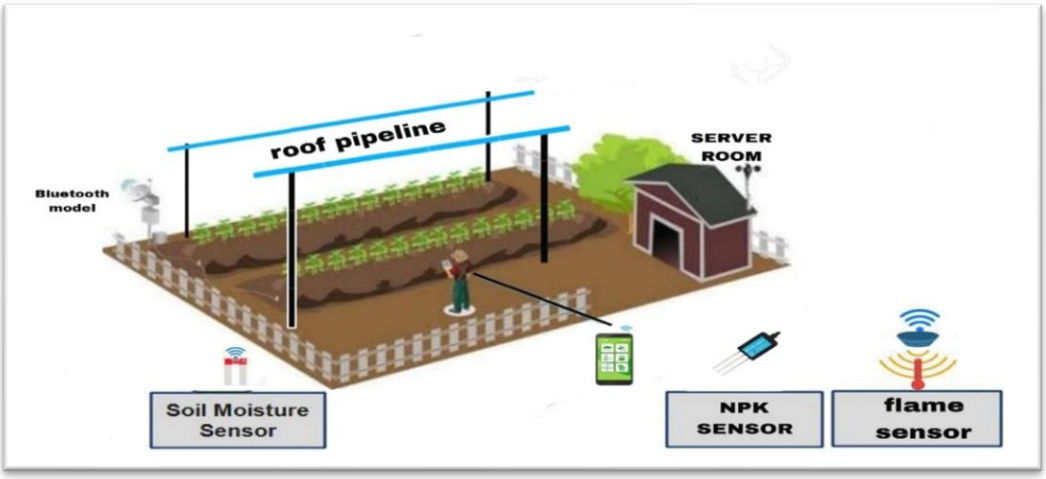
All sensors, such as soil moisture sensor, flame sensor, NPK sensor and relay module, Bluetooth module, are connected to a central board known as the arduino Uno.

The NPK sensor will find out soil NPK values and transmits them to the arduino. These values are used as inputs for the crop and fertilizer recommendation system. The recommendation process will be carried out through a machine learning model trained with appropriate machine learning algorithms. This model suggests appropriate crops and fertilizers by considering NPK values and some other parameters such as soil color, season, PH, rainfall, temperature, etc. within an Android mobile application. The application is linked to the arduino via Bluetooth module.

The soil moisture sensor analyzes the soil's moisture level. If the moisture of soil falls below the required limit, the sensor notifies the arduino, which send signal to the relay module to activate the water pump. The water pump will get activated, ensuring that the farm gets required amount of water. The sensor continuously analyzes moisture levels and transmits data to the Arduino. Once the farm gets the required moisture level, the water pump automatically switches off.

The flame sensor detects flames within the farm, serving as a safeguard against accidents. When the sensor detects a fire, it notifies the Arduino, which in turn, sends a signal to the relay module. As a result, the water pump is activated, leading to the sprinkling of water on the farm to extinguish the fire. The motor automatically turn off in one minute after successfully extinguishing the fire.

V. ARCHITECTURAL SETUP



All the sensors, including the Soil Moisture Sensor, Flame Detection Sensor, and NPK Sensor, are securely positioned in the farm. The Relay module, Bluetooth module, and all above mentioned sensors are connected to the central board known as the arduino Uno, where all the arduino setup is fixed in the server room. The Soil Moisture Sensor tracks the moisture content in the soil, based on this detected values motor automatically activates

or deactivates. Also, the motor can be manually controlled by an Android application remote connected to the arduino via the Bluetooth module.

When a fire breaks out, the Flame Detection Sensor sends the signals to start the motor, activating the sprinkling of water from the roof structure pipeline to extinguish the fire. This pipeline, which is set on top of the farm, fulfils the dual functions of supplying water and spraying pesticides and fertilizers. The NPK sensor fetches NPK values from the soil, and based on these values, crop and fertilizer recommendations are provided to the farmer through our Android application.

VI. METHODOLOGY

A. Arduino Module

The Arduino UNO R3, serving as a microcontroller board, is tasked with overseeing and managing system operations. This board, based on ATmega328, incorporates a range of features:

This device includes 14 digital I/O pins with six PWM outputs. Additionally It also includes a reset button, a power jack, an ICSP header, a USB port, six analog inputs, and a crystal oscillator operating at 16 MHz. It comes pre-equipped with all the necessary components in order to help the microcontroller. You can easily connect it to a computer through USB or supply power it through an AC-to-DC adapter, or even initiate its operations using a battery.

The ATmega328 boasts a memory capacity of 32 KB, with SRAM and EEPROM capacities of 2 KB and 1 KB, respectively. The powering of arduino can be done either through a USB connection or an external power supply, automatically choosing the suitable power source. The external power supply may take the form of an adapter, typically an AC-to-DC converter, or batteries.

The arduino provides connectivity to a range of communication devices, including computers, other Arduino boards, or additional microcontrollers. The ATmega328 facilitates UART TTL (5V) serial communication through digital pins 0 (RX) and 1 (TX). Furthermore, an integrated ATmega16U2 on the board handles serial communication through USB, presenting itself as a virtual COM port for software on the PC [21].

B. NPK sensor

The soil NPK sensor is a valuable tool for assessing soil fertility by detecting the quantities of nitrogen (N), phosphorus (P), and potassium (K).

The sensor evaluates NPK levels based on soil electrical conductivity. The electrical conductivity of soil varies due to differences in nitrogen, phosphate, and potassium concentrations. The sensor determines nutritional levels by sensing conductivity.

C. Soil Moisture Sensor

A Soil Moisture Sensor is accost effective electronic sensor used to monitor soil moisture levels. This sensor is capable of measuring the amount of water in the soil. The Sensing Probes and the Sensor Module are the two important parts of this sensor. The probes of sensor allow the current to travel through the soil, while the resistance value is determined by the moisture content of the soil. The sensor module receives data from the sensor probes, convert it into an analog or digital output after processing.

D. Flame detection Sensor

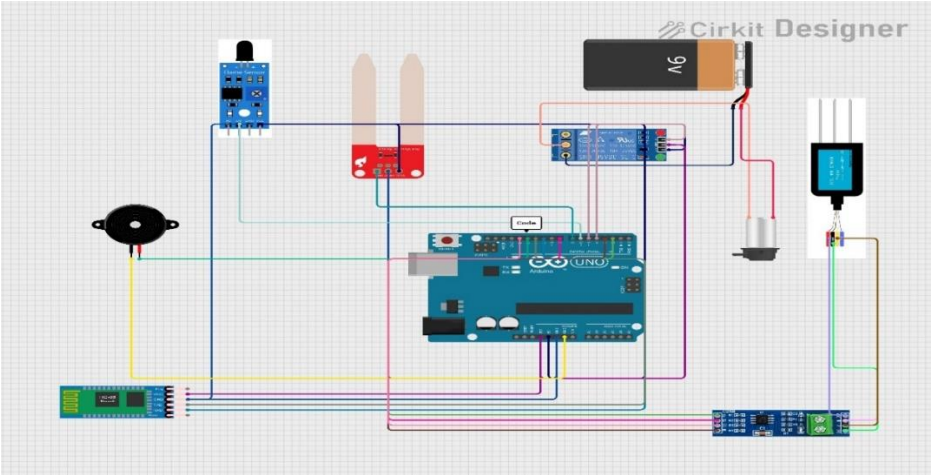
A flame sensor constitutes a form of detector specifically designed to identify and react to the presence of a fire or flame.

E. Random Forest Algorithm

We are using Random Forest algorithm of machine learning for implementing crop and fertilizer recommendation system. Random forest is used in supervised learning techniques for classification and regression. The classification technique will be used to determine the crop that will best suited for a particular land according to soil constraints and the fertilizer that is required for soil. Any classification algorithm may be used, but in our implementation, we primarily chose random forest because of its ability to deliver high[22].

VII. RESULTS AND DISCUSSION

1. IOT Setup



Soil moisture sensor has four pins VCC, GND, A0 and D0. VCC is connected to 5v of arduino Uno, GND is connected to GND of arduino Uno. A0(analog output) generates analog output voltage proportional to the soil moisture level and A0 is connected to the pin mode 7 of arduino Uno. Flame Detection Sensor has three pins VCC,GND and D0 .VCC is connected to 5v of arduino Uno, GND is connected to GND of arduino Uno and D0(Digital output) pin is connected to the pin mode 6 of arduino Uno. It outputs high or low based on flame detection. Buzzer is an audio signalling device contains two pins namely positive and negative. Positive pin is connected to pin mode 12 of arduino Uno and negative is connected to GND of arduino Uno. NPK sensor has four pins VCC, GND, A and B. A and B of NPK sensor is connected to A and B of RS485 module.RS485 converts electrical signals into digital data module contains 8pins VCC,GND,A,B,DI,DE, RE,R0 where VCC and GND is connected to NPK sensor's VCC and GND. A and B of RS485 module is connected to A and B of NPK sensor. DI pin is connected to pin mode 3 of arduino Uno.DE pin is connected to pin mode 13 of arduino Uno. RE pin is connected to pin mode 8 of arduino Uno. R0 pin is connected to pin mode 2 of arduino uno. Relay module is used to switch system on and off it contains total six pins VCC,GND,IN,NC,COM,N0. VCC is connected to 5v of arduino Uno, GND is connected to GND of arduino Uno. IN is connected to pin mode 5 and pin mode 4 of arduino Uno.N0 and COM is connected to water pump. Bluetooth module is used for wireless connectivity between smartphones, computers, IOT devices. It contains total 6 pins out of that we use 4 pins that are VCC,GND,TXD,RXD. VCC is connected to 5v of arduino Uno, GND is connected to GND of arduino Uno. RXD is connected to pin mode 10 of arduino Uno and TXD is connected to pin mode 11 of arduino Uno.

2. ML Model

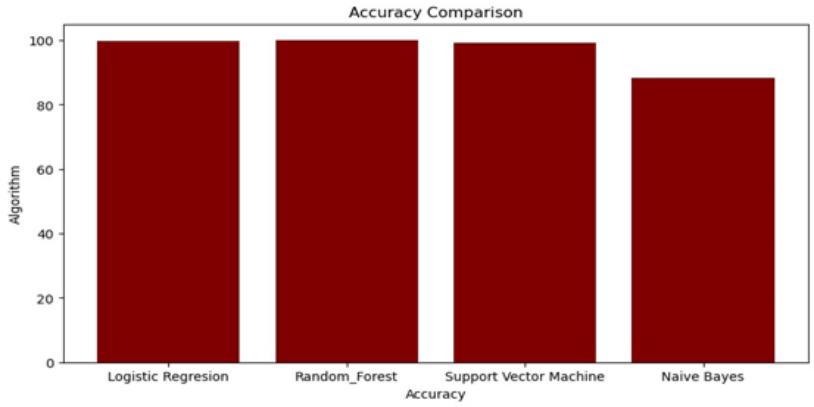
The primary objective of our ML model is to suggest the crops and fertilizers, so we tried for the highest level of accuracy in our model. We trained the ML model using SVM (Support Vector Machine), Naïve Bayes, Logistic Regression, and Random Forest algorithms, in order to determine which algorithm produced the highest accurate prediction and compared the results. As the Random Forest algorithm has an accuracy of 100% for crop recommendation and 93.90% for fertilizer recommendation hence we built our ML model using it. The below table lists the algorithms that were used and their corresponding accuracy. [20].

a. Crop Recommendation

The crop recommendation system's dataset contains four thousand five hundred and twelve samples. The dataset's attributes are Nitrogen, phosphorus, potassium, soil colour, Season, PH, Rainfall, temperature. The label column contains sixteen different types of crops. The dataset was represented as a graph at the visualisation stage. The pre-processing stage of the data includes searching for missing values and, if any are identified, eliminating them by using missing value treatment.

Table-I- Algorithm and Accuracy

Algorithm	Accuracy
Logistic Regression	99.77%
Random Forest	100%
Support Vector Machine	99.11%
Naïve Bayes	88.37%

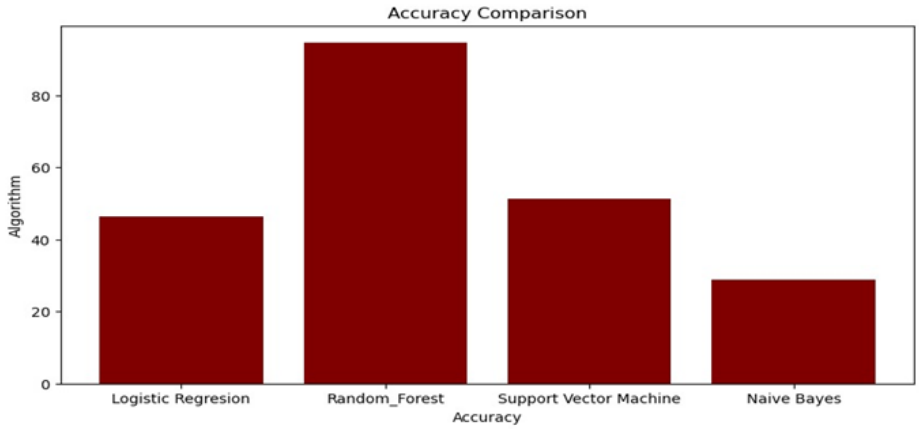


b. Fertilizer Recommendation

The fertilizer recommendation system's dataset contains four thousand five hundred and twelve samples. The dataset's attributes are Nitrogen, phosphorus, potassium, soil colour PH, Rainfall, temperature, crop. The label column contains eighteen unique fertilizers. The dataset was represented as a graph at the visualisation stage. The pre-processing stage of the data includes searching for missing values and, if any are identified, eliminating them by using missing value treatment.

Table-II-Algorithm and Accuracy

Algorithm	Accuracy
Logistic Regression	46.40%
Random Forest	93.90%
Support Vector Machine	51.38%
Naïve Bayes	28.79%



3. Mobile Application for Monitoring and Controlling:

In android application there is one main page contains three buttons-
Water Pump Control
Crop Recommendation
Fertilizer Recommendation

Figure-Android App- Farm Controller Tab

In water pump controller tab we can turn motor on and off using on/off button and message will be displayed accordingly.

Figure-Android App- Water Pump Control Tab

In crop recommendation tab we have to entered the values such as Nitrogen, phosphorus, potassium, district name, soil colour, Season, PH, Rainfall, temperature and clicking on recommend crop button it will display crops that are suitable for soil .

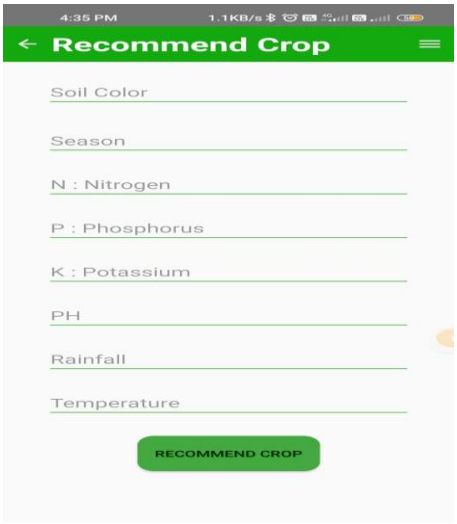


Figure-Android App- Crop Recommendation Tab

In fertilizer recommendation tab we have to enter the values such as Nitrogen, phosphorus, potassium, district name, soil colour PH, Rainfall, temperature, crop and clicking on recommend fertilizer button it will display the required fertilizers.

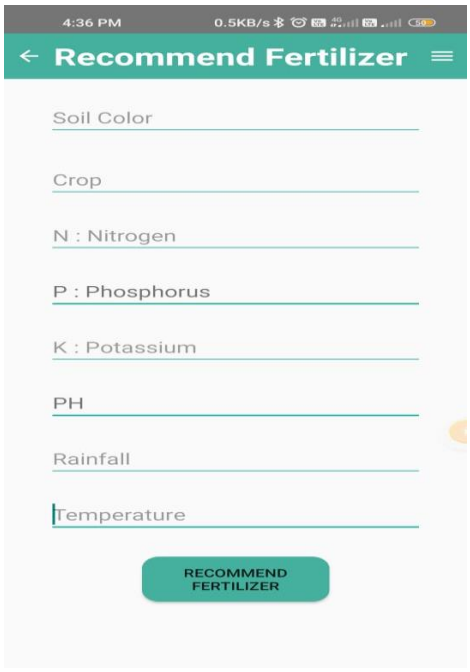


Figure-Android App- Fertilizer Recommendation Tab

VIII. CONCLUSION

Using sensor networks and machine learning, our system offers a full smart agricultural system which monitors and manages crops. The system is made up of Internet of Things devices that monitor several environmental factors and a mobile application that enables users to control irrigation system, sensors in real time also helps the farmer managing natural disasters like agricultural fires. Additionally, the system uses machine learning models that suggest the best crops and fertilizers according to soil constraints and some other environmental factors. Through the integration of Internet of Things and machine learning, this system may assist farmers to make their decisions effectively, save their time, prevent accidents and overcome the traditional way of farming, also helps the farmer to avoid infections from fertilizer, improve crop yields, while reducing environmental effect and resource use.

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