**SMART AGRICULTURE USING ENSEMBLE MACHINE LEARNING TECHNIQUE IN IoT ENVIRONMENT**

**METHODOLOGY**

**Sensors:** In the smart agriculture system, sensors play a vital role as the primary data acquisition units. These electronic devices are embedded in the soil or placed in the agricultural environment to capture critical real-time environmental parameters. In our project, we have specifically used a DHT11 sensor for measuring ambient temperature and relative humidity, and a soil moisture sensor to determine the volumetric water content in the soil. These sensors are inexpensive, efficient, and easy to interface with microcontrollers, making them ideal for small to medium-scale smart farming solutions. The data collected by these sensors reflects the immediate condition of the farmland, helping assess the suitability of the environment for various crops. This raw sensor data serves as the foundation for intelligent decision-making, enabling precision agriculture practices like optimized irrigation scheduling, fertilization timing, and selection of suitable crops. Accurate environmental sensing is vital for reducing resource wastage, improving crop yield, and mitigating the effects of climate variability.

**ESP32 Microcontroller:** Once the environmental parameters are captured by the sensors, they are transmitted to the ESP32 microcontroller, which serves as the central processing and communication hub of the system. The ESP32 is a powerful and energy-efficient microcontroller that features integrated Wi-Fi and Bluetooth capabilities, making it ideal for IoT-based applications. In this project, the ESP32 reads the analog and digital signals from the connected sensors, processes the data, and formats it for cloud transmission. It also handles real-time data acquisition tasks and ensures that the sensor readings are continuously collected without delay. The microcontroller is programmed to perform initial data filtering or conversion (such as converting analog moisture levels into readable percentages), which ensures the integrity and usability of the data before it is uploaded. The seamless interfacing of ESP32 with sensors and the ThingSpeak platform is a testament to its versatility, making it the backbone of the entire automation framework in the smart agriculture system.

**ThingSpeak:** ThingSpeak is a cloud-based IoT analytics platform that enables the collection, storage, and analysis of sensor data over the internet. Once the ESP32 gathers and processes the sensor data, it uploads the readings to ThingSpeak in real-time via Wi-Fi. ThingSpeak acts as a middleware between the data-generating hardware and the data-analyzing software, MATLAB in our case. It stores the incoming data in time-series format and allows visualization through dynamic charts and graphs, helping researchers and farmers observe trends and variations in environmental conditions over time. One of the key features of ThingSpeak is its compatibility with MATLAB for advanced analysis. In our system, ThingSpeak is configured with MATLAB analytics for further data processing and crop prediction. Moreover, its RESTful API architecture ensures seamless communication between the cloud and embedded devices. This cloud integration facilitates remote monitoring and control, making the system highly scalable and suitable for real-world agricultural deployment.

**MATLAB (Data Analysis + Machine Learning):** The most intensive part of the system occurs in MATLAB, where the real power of machine learning is applied to the sensor data. The MATLAB environment receives the uploaded data from ThingSpeak and conducts data preprocessing, feature extraction, and model prediction tasks. In our project, we have utilized an ensemble machine learning model(Random Forest, XGBoost, Decision Tree), which combines the predictions of multiple classifiers to enhance the accuracy and robustness of the crop prediction. The environmental parameters like temperature, humidity, and soil moisture are input into the trained model, which compares them against a dataset of crop requirements. Based on the similarity and statistical patterns, the model predicts the most suitable crop for the current environmental conditions. MATLAB not only serves as a platform for implementing machine learning but also provides visualization tools that help in understanding model accuracy, error analysis, and decision boundaries. The ensemble method ensures a balanced and unbiased prediction by mitigating the limitations of individual classifiers, making this approach highly reliable for smart agriculture applications.

**Displaying Predicted Crop in MATLAB:** The final step in the system workflow is the display of the predicted crop within MATLAB. Once the ensemble model processes the environmental data and identifies the optimal crop, the result is displayed through MATLAB’s GUI or console. This prediction gives actionable insight to farmers, allowing them to plan sowing, irrigation, and crop care more efficiently. The output display is user-friendly and can be extended to mobile or web applications for ease of access. The visibility of the predicted crop ensures that the decision-making process remains transparent and can be validated by domain experts or agricultural scientists. Moreover, the real-time update capability means that any change in environmental parameters can result in a new prediction almost instantly. This interactive and responsive system closes the loop between data sensing and decision-making, fulfilling the vision of smart agriculture. By integrating IoT and machine learning into a coherent system, the project not only demonstrates technical innovation but also showcases how digital tools can be leveraged to transform agriculture.