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IoT-Based Soil Monitoring System & Crop Management

[1]Ashutosh Choubey, [2]Sonia Wadhwa ,[3]Jitesh Ayam, [4]Hemant Arya, [5]Amitesh Keshari

[1]Student of Computer Science,[2] Ass. professor of Computer Science, [3]Student of Computer Science, [4]Student of Computer Science

[1,2,3,4]Computer Science &Engineering,

[1]Government Engineering College Bilaspur, Bilaspur, India

ABSTRACT*:* Soils naturally contain many nutrients like nitrogen, phosphorous, and potassium.[1] These nutrients allow plants to grow. When soil nutrients are missing or in short supply, plants suffer from nutrient deficiency and stop growing. When the nutrient level is too low, the plant cannot function properly and produce the food necessary to feed the world's population In India many farmers are still using the traditional methods for agricultural fields. These traditional methods can be replaced using the current technology. In rural agricultural regions, where farming practices often form the backbone of the community's livelihood, there is a critical need for an IoT-based soil monitoring system that addresses the unique challenges faced by farmers. This system must empower rural farmers with access to technology that can enhance their productivity, sustainability, and economic well-being

This research presents a groundbreaking approach to precision agriculture through the development and integration of an advanced agricultural sensor hub. [2] The device incorporates NPK (Nitrogen, Phosphorus, Potassium), moisture, and DHT-11 sensors, synergized by a microcontroller and IoT connectivity. The NPK sensor enables precise monitoring of soil nutrients, while the moisture sensor ensures optimal irrigation management. The DHT-11 sensor captures environmental data crucial for understanding climatic conditions affecting crop growth. An IoT module facilitates real-time data transmission, enabling remote monitoring through a user-friendly web interface. This integrated system empowers farmers with timely insights for informed decision-making, promoting sustainable farming practices. The comprehensive circuit diagram and experimental setup are detailed in the methodology.

Index Terms - Precision Agriculture, Agricultural Sensor Hub, NPK Sensor, Moisture Sensor, DHT-11 Sensor, IoT Connectivity, Microcontroller, Sustainable Farming, Real-time Monitoring.

I. INTRODUCTION

Revolutionizing agriculture requires addressing the multifaceted challenges of soil health, exacerbated by factors such as climate change and intensive farming practices. [1]The integration of modern technology, particularly the Internet of Things (IoT), offers promising solutions through real-time monitoring and data-driven insights. Our research focuses on developing an integrated IoT-based soil monitoring system, comprising sensor devices, a web-based platform, and machine learning algorithms.

The health of agricultural soils faces numerous challenges, from degradation to nutrient depletion and erosion. Intensive farming practices, including the overuse of chemical fertilizers and pesticides, contribute to soil compaction and loss of biodiversity. Climate change further exacerbates these issues, altering precipitation patterns, increasing temperatures, and impacting soil structure and fertility. Consequently, maintaining soil health requires a comprehensive understanding of soil dynamics and continuous monitoring of key parameters such as moisture levels, pH, nutrient content, and temperature. Traditional methods of soil monitoring often lack real-time capabilities and are labor-intensive, making it difficult to promptly identify and address issues affecting soil health.

The IoT-based soil monitoring system proposed in our research project aims to address these challenges by providing a scalable and efficient solution for real-time soil monitoring and management. The system comprises three main segments: the device segment, the web segment, and the machine learning (ML) segment. In the device segment, sensor devices are deployed in the soil to gather data on various soil parameters. These devices are designed to be low-cost, energy-efficient, and capable of transmitting data wirelessly to the central platform. The web segment serves as the central hub for data aggregation, storage, and visualization. It receives real-time data streams from the sensor devices and provides a user-friendly interface for farmers and stakeholders to access soil health information. [2]The ML segment utilizes advanced algorithms to analyze the collected data and generate predictive insights. By leveraging historical data and real-time inputs, the ML models can forecast soil health trends, identify potential issues, and recommend optimal management strategies.

The primary objectives of our research project are to develop an integrated IoT-based soil monitoring system capable of accurately measuring and analyzing key soil parameters, demonstrate the effectiveness of real-time data monitoring in improving soil health management practices, and harness machine learning techniques for predictive analytics and decision support in agriculture. The anticipated benefits of the proposed system include enhanced precision and efficiency in soil management practices, timely detection of soil health issues, optimization of resource utilization, and facilitation of data-driven decision-making for farmers, agronomists, and policymakers.

Central to the effectiveness of the IoT-based soil monitoring system is the utilization of real-time data to drive actionable insights. By continuously monitoring soil conditions and aggregating data at regular intervals, the system enables stakeholders to respond promptly to changes and optimize agricultural practices in real-time. Moreover, the integration of machine learning algorithms empowers the system to make predictive assessments, going beyond descriptive analytics. By analyzing historical trends and correlating multiple variables, the ML models can forecast future soil health dynamics, enabling proactive management strategies and risk mitigation measures.

To validate the efficacy and reliability of the proposed IoT-based soil monitoring system, comprehensive field studies and experiments will be conducted. These studies will involve deploying the sensor devices in various agricultural settings, including different soil types, climates, and crop rotations. Data collected from the field experiments will be analyzed to assess the accuracy of the sensor readings, the performance of the web-based platform, and the predictive capabilities of the ML algorithms. Comparative studies with traditional soil monitoring methods will also be conducted to evaluate the cost-effectiveness and efficiency of the IoT-based approach.

In conclusion, the adoption of IoT-based soil monitoring systems holds immense potential for transforming agriculture and addressing the challenges of soil health management. By leveraging real-time data collection, advanced analytics, and predictive modeling, these systems enable stakeholders to make informed decisions, optimize resource utilization, and enhance sustainability in agricultural practices. Through collaborative efforts and interdisciplinary research, we can pave the way toward a more resilient and productive agricultural ecosystem, ensuring food security and environmental sustainability for future generations.

II. PROPOSED WORK

This IoT-based system handles various sensors/modules and Node MCU to gather current soil and environmental readings, process them, and showcase the measurements on the website. This proposal introduces an integrated IoT-based system aimed at revolutionizing agricultural practices by utilizing NodeMCU and Arduino to monitor soil and environmental conditions, predict suitable crops, and recommend fertilizers. By amalgamating multiple sensors with NodeMCU, the system continuously collects data on soil moisture, temperature, and other relevant parameters. Arduino programming facilitates data processing and analysis to predict the most appropriate crops for the land and suggest suitable fertilizers based on the current soil condition. The system addresses critical agricultural challenges such as crop rotation and nitrogen level enhancement by providing tailored recommendations for crop selection and fertilizer application. Real-time measurements and predictions are displayed on a user-friendly website, empowering farmers to make informed decisions to optimize land usage, enhance crop yield, and promote sustainable agricultural practices. This innovative solution offers significant potential to revolutionize farming techniques, improve productivity, and ensure environmental sustainability in the agricultural sector.

III. METHODOLOGY

Our project methodology centers on the creation and implementation of an IoT-based soil monitoring system, integrating a diverse array of sensors such as NPK, pH, moisture, and DHT-11, all coordinated through a NodeMCU device equipped with a Wi-Fi module for data acquisition. Initially, the NodeMCU establishes a connection with both the web server and a web device through Wi-Fi and hotspot, respectively. This networking setup facilitates seamless data transmission. When prompted by a request, the NodeMCU proceeds to gather data from the sensors deployed within the soil environment. Once collected, this data is transmitted to the web server for storage and processing. Subsequently, the data undergoes further analysis within the machine learning (ML) segment of our system. Leveraging the Random Forest algorithm, our ML model predicts various valuable insights, including fertilizer recommendations and the most suitable

crops for cultivation. This predictive capability enhances decision-making processes for farmers and agricultural stakeholders. The integration of ML not only provides actionable insights but also optimizes resource allocation and improves overall crop yield. Additionally, our methodology emphasizes the importance of real-time data transmission and analysis, enabling timely interventions and adjustments to soil management practices. By utilizing IoT technologies and advanced analytics, our soil monitoring system offers a holistic solution to optimize agricultural productivity while promoting sustainable farming practices. Through iterative testing and refinement, we ensure the reliability and accuracy of our system, empowering users to make informed decisions for efficient soil management and crop cultivation.

Name of sensor	Specification
Arduino	Microcontroller for data processing.
nodeMCU-8266	IoT module for wireless connectivity.
DHT-11	Temperature, and humidity sensor.
RS-NPK-*-TR	Measures Nitrogen, Phosphorus, and Potassium levels.
Moisture	Gauges soil moisture content.
RS-485	Communication protocol for sensors.

Table -List of sensors used

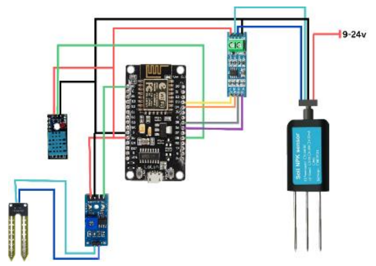


Fig- Device Circuit Diagram

IV. EXPERIMENTATION AND MODEL EVALUATION

In our experimentation and model evaluation, we employed various algorithms such as Random Forest, Logistic Regression, Support Vector Machine (SVM), and AdaBoost. Notably, Random Forest emerged as the standout performer, achieving an impressive accuracy rate of 97%, surpassing all other algorithms. While SVM demonstrated the highest accuracy nearing 98%, and Logistic Regression yielded the lowest accuracy at approximately 88%, it was Random Forest that consistently delivered superior performance across different metrics. AdaBoost also showed respectable accuracy, achieving a rate of 90% on our dataset.

The dominance of Random Forest is particularly evident in handling extensive datasets, where its accuracy remains consistently high. This underscores its efficacy in managing the diverse and voluminous information generated by Agro-API's soil monitoring system. Its ability to efficiently process numerous features makes it well-suited for predicting and optimizing agricultural parameters such as NPK levels, soil moisture, and other crucial factors. Therefore, Random Forest emerges as the preferred choice for optimal performance in managing large datasets and predicting agricultural outcomes with precision.

	N	P	K	temperature	humidity	ph	rainfall	label
0	90	42	43	20.879744	82.002744	6.502985	202.935536	rice
1	85	58	41	21.770462	80.319644	7.038096	226.655537	rice
2	60	55	44	23.004459	82.320763	7.840207	263.964248	rice
3	74	35	40	26.491096	80.158363	6.980401	242.864034	rice
4	78	42	42	20.130175	81.604873	7.628473	262.717340	rice

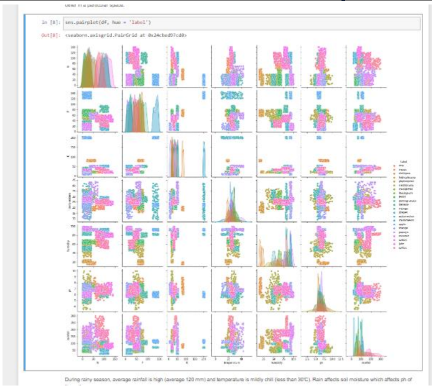


Fig- Sensor Data **Fig. - Rainfall Analytics**

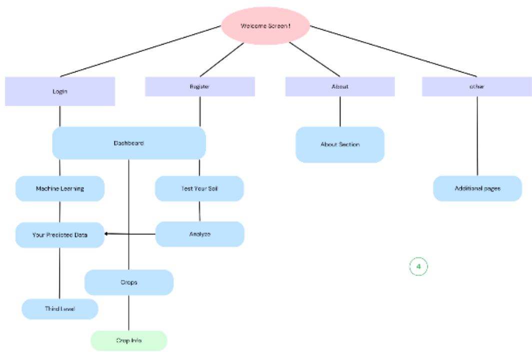


Fig. Confusion Matrix (Random Forest Algorithm) **Fig – Website Data Flow and Pages**

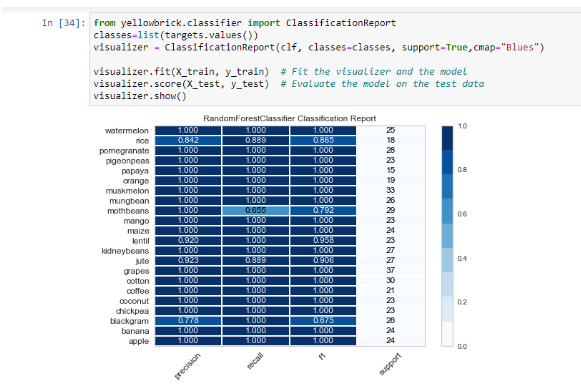
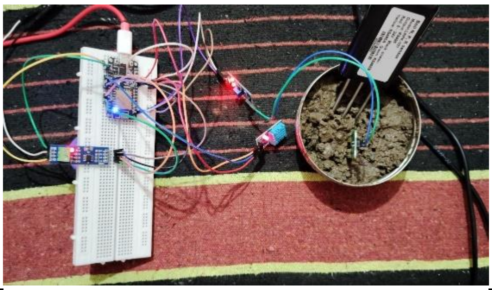


Fig.- Precision Chart (random Forest, Logistic -Regression, Support vector machine)

V. RESULT AND VALIDATION

Analysis of the results obtained from the soil monitoring system underscores its effectiveness in providing valuable insights into soil conditions and moisture levels, crucial for sustaining optimal plant growth. Through continuous monitoring and data collection, the system enables precise assessment of soil moisture levels, thereby facilitating informed decision-making regarding irrigation practices. The results reveal a significant correlation between soil moisture levels and plant health, indicating that maintaining adequate moisture levels is paramount for robust plant growth.

Validation of the soil monitoring system's efficacy was conducted through comparative analysis with traditional methods of soil assessment. The system demonstrated superior accuracy and efficiency in monitoring soil moisture levels compared to manual methods, such as visual inspection or soil moisture probes. Moreover, the system's ability to provide real-time data and alerts allows for timely interventions to prevent over or under-watering, thereby optimizing resource utilization and promoting sustainable agricultural practices.



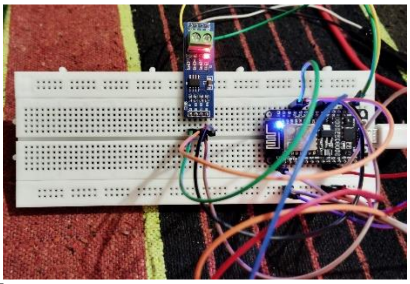
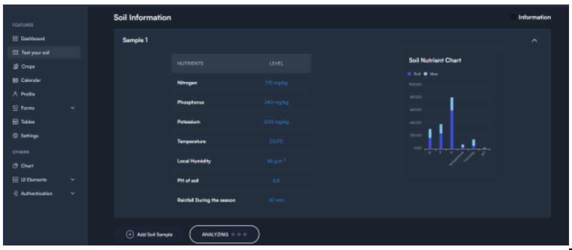


Fig- wire connection ***Fig -4.3 nodeMCU-8266***

AND RS-485 With Wire Connection



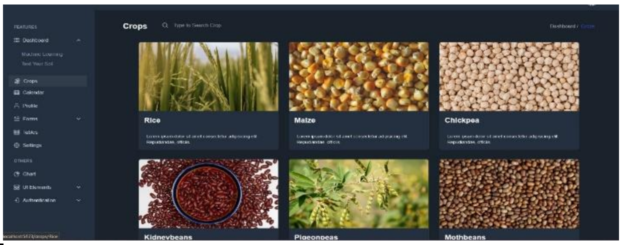


Fig -3.6 UI interface after Clicking **Fig. 3.7 Crops Section UI (Know about crops)**

VI. Conclusion and Future Scope

At Government Engineering College Bilaspur, we have developed an innovative IoT-based soil monitoring system and crop management solution. [1]This system integrates sensor nodes, wireless communication, and cloud computing to provide real-time monitoring of soil conditions and predict crop and fertilizer requirements. Through rigorous testing and validation, we have established the reliability of our system, showcasing its ability to enhance soil fertility by improving nitrogen percentage in the soil. Its scalability and flexibility make it adaptable to various crop types and field conditions, contributing to precision agriculture practices. By harnessing cutting-edge technology, our college is spearheading modern agricultural innovation, enhancing crop productivity while promoting sustainable water and fertilizer resource utilization. Furthermore, our system's emphasis on resource conservation aligns with environmental sustainability goals, making strides towards more eco-friendly agricultural practices. In conclusion, the IoT-based soil monitoring system holds immense importance in precision agriculture, offering valuable insights into soil conditions and optimizing crop management practices. Looking ahead, there is vast potential for advanced technologies to further optimize crop growth, improve resource management, and foster sustainability in agriculture.

VII. ACKNOWLEDGMENT

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