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Crop Suggestive System through Soil Property Characterization using IoT

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Abstract: *The emergence of Internet of Things (IoT) technology has brought about a significant transformation in multiple sectors, including agriculture, by facilitating data- driven decision-making and real-time monitoring. In this work, we present a novel Internet of Things (IoT) agricultural suggestion system that uses soil property characterization to enable accurate crop management and selection. Our technology seeks to help farmers optimize agricultural yields while minimizing resource usage and environmental impact by combining IoT sensors with modern data analytics.*
Our system's primary feature is the installation of Internet of Things (IoT) sensors throughout fields to continuously collect data on important soil attributes. These characteristics include salinity, pH values, temperature, moisture content, nutrient concentrations, and organic matter content. This data is wirelessly transmitted by the sensors to a cloud platform or centralized database, where it is thoroughly analyzed.
One of the many difficulties facing modern agriculture is choosing crops optimally to maximize yields while minimizing environmental effect. Conventional crop selection techniques sometimes rely on manual soil testing or broad suggestions, which produces less than ideal results and inefficiencies. A novel method using the Internet of Things (IoT) is suggested to address this: a Crop Suggestive System using Soil Property Characterization (CSS-SPC). Using Internet of Things sensors, this system continuously monitors and analyzes soil parameters in real-time, giving farmers customized crop recommendations depending on the unique conditions of their property.
Crop rotations, soil amendments, and irrigation schedule optimization are made possible for farmers through smooth planning and decision-making that ismade possible by integration with current farm management systems. Farmers' ongoing input on the effectiveness ofsuggested crops guarantees the system's accuracy and continued applicability.

Keywords: Internet of Things

I. INTRODUCTION

In recent years, the agricultural landscape has witnessed a transformative shift towards precision farming practices, fueled by technological advancements like the Internet of Things (IoT). This synopsis introduces a novel agricultural innovation - the Crop Suggestive System - which leverages IoT technology to characterize soil properties. This pioneering system holds the potential to revolutionize modern agriculture, enabling farmers to make data-driven decisions that optimize crop yield while conserving resources.
Technology is revolutionizing modern agriculture, especially with the help of the Internet of Things (IoT). A major obstacle that farmers around the world must overcome is optimizing crop selection in order to increase yields, profitability, and sustainability. Conventional crop selection techniques frequently depend on broad guidelines or time-consuming soil testing, which may not take into consideration the subtle variations in soil characteristics among farms. A novel method utilizing Internet of Things technology is suggested to close this gap: a Crop Suggestive System through Soil Property Characterization (CSS-SPC). Using real-time data and an integrated network of Internet of Things sensors, this system offers farmers customized crop recommendations by continuously monitoring and analyzing soil parameters.

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Real-time soil condition monitoring is made possible by the incorporation of IoT technology, which enables crop suggestions that are dynamic and adaptive. In contrast to conventional techniques that depend on recurring soil testing, the CSS-SPC system gives farmers access to current data on soil fertility and health, allowing them to make better decisions all during the growing season.

II. LITERATURE SURVEY

Crop recommendation using IoT and machine learning is a growing field of research, with several studies investigating its potential applications and benefits. Some keys are:

[1] A study published in the Journal of Agricultural Science and Technology suggested that using machine learning algorithms to analyses data from soil sensors can significantly improve crop yield and reduce water usage. The study found that a crop recommendation system basedon machine learning algorithms could increase crop yield by up to 28% while reducing water usage by up to 37%.

[2] Another study published in the International Journal of Agricultural and Biological Engineering explored the use of a crop recommendation system based on IoT sensors and machine learning algorithms to optimize nitrogen fertilizer application. The study found that the system could reduce nitrogen fertilizer usage by up to 44% while increasing crop yield by up to 27%.

[3] A review article published in the Computers and Electronics in Agriculture journal highlighted the potential of using IoT sensors and machine learning algorithms to optimize crop management practices. The review noted that such systems can improve the efficiency of resource utilization, reduce waste, and increase sustainability in agriculture.

[4] A study published in the Journal of Intelligent Systems reported the development of a crop recommendation system based on IoT sensors and machine learning algorithms for maize cultivation. The system was able to predict maize yield with an accuracy of 96.87% and recommend the optimal planting time and amount of fertilizer and water required for maximum yield.

[5] A research article published in the Journal of Applied Remote Sensing explored the use ofremote sensing technology to collect data on crop health and soil moisture for a crop recommendation system based on machine learning algorithms. The study found that the system could accurately predict crop yield and recommend the optimal irrigation and fertilization techniques for maximum yield.

III. METHODOLOGY

The process of implementing IoT sensors forreal- time soil data collection, preprocessing the data for accuracy, analyzing it using machine learning algorithms, and producing customized crop recommendations is known as the Crop Suggestive System through Soil Property Characterization (CSS-SPC) using IoT methodology. This procedure entails determining the suitability of a crop based on the characteristics of the soil, integrating it with farm management systems, testing and validating it, and deploying it along with continuousmaintenance. CSS-SPC facilitates data-driven decision-making in agriculture by maximizing resource consumption, boosting production, and encouraging sustainability and resilience in farming operations through iterative improvement and stakeholder participation.

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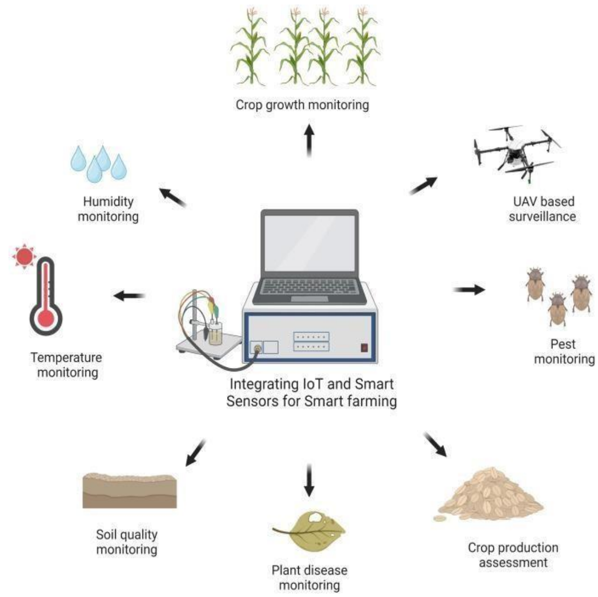


IV. DESCRIPTION OF HARDWARE AND SOFTWARE

Hardware used

- Esp8266
- Aurduino
- Soil moisture sensor
- NPK soil sensor
- Breadboard
- Connecting wires
- 7.12v adaptor

Software used

- Kaggle

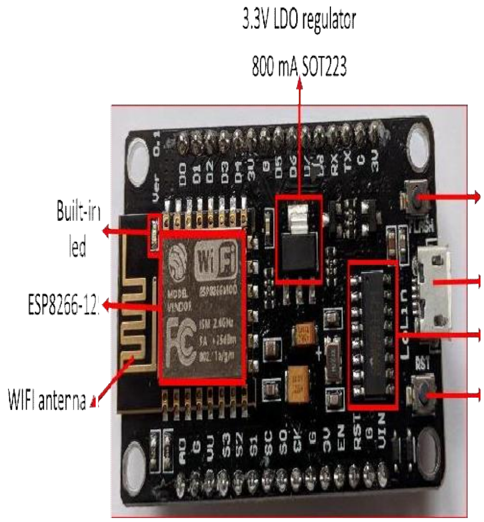
Kaggle: Kaggle is a powerful platform for data science and machine learning, offering a rich environment for processing datasets using various machine learning algorithms. It provides users with access to a vast collection of public datasets and a collaborative Jupyter notebook interface forcode development and execution. Kaggle'sintegrated development environment supports Python and R, and includes essential libraries like TensorFlow, scikit-learn, and pandas. The platformalso features robust tools for data visualization,model training, and evaluation, making it ideal for prototyping and developing machine learning solutions. Additionally, Kaggle hosts competitionsthat enable users to test their models against real- world problems, fostering a vibrant community of data scientists and researchers.

ML Algorithm:

Random Forest:

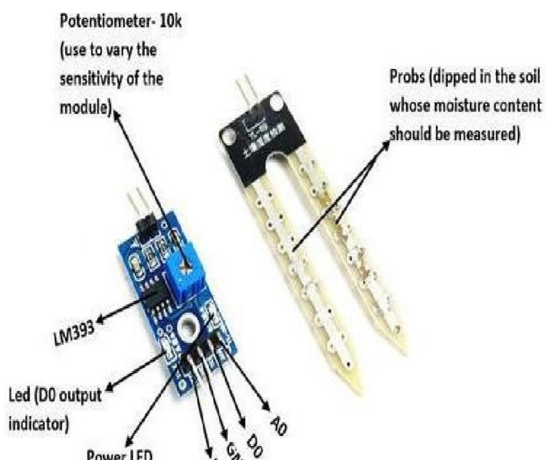
The Random Forest is an ensemble machine learning model that combines multiple decisiontrees to improve accuracy and robustness. Each tree in the forest is trained on a random subset of the data and a random subset of features, promoting diversity among the trees. The model aggregates thepredictions of all the trees, typically through majority voting for classification or averaging for regression, to produce the final output. This approach helps to reduce overfitting and enhance generalization to new data. Random Forests are highly versatile and effective for a wide range of tasks, including classification, regression, andfeature selection.

Esp 8266: Microcontrollers can connect to IEEE 802.11 bgn-enabled 2.4 GHz Wi-Fi by means of the ESP8266 module. It can be used as a self- sufficient MCU by running an RTOS-based SDK, or it can be utilized with ESP-AT firmwareto offerWi-Fi connectivity to external host MCUs.

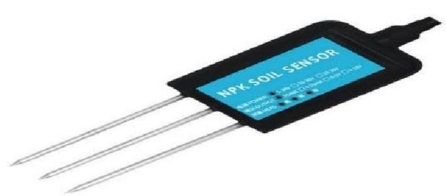


Soil moisture sensor: The amount of water in the soil is measured by a soil moisture sensor (SMS), which is also used to control irrigation systems.

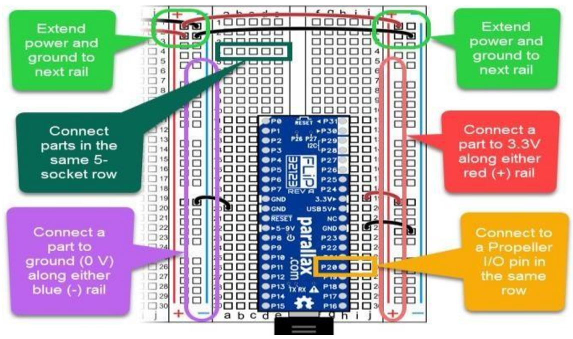
SMSs can be positioned areas of a field and can beeither stationary or moveable. Before every planned watering event, an SMS may measure the amount of moisture in the root zone when it is connected to an irrigation system controller.



NPK soil sensor: The soil NPK sensor can be used to measure the amounts of potassium, phosphorus, and nitrogen in the soil as well as determine the fertility of the soil by measuring these elements' concentrations

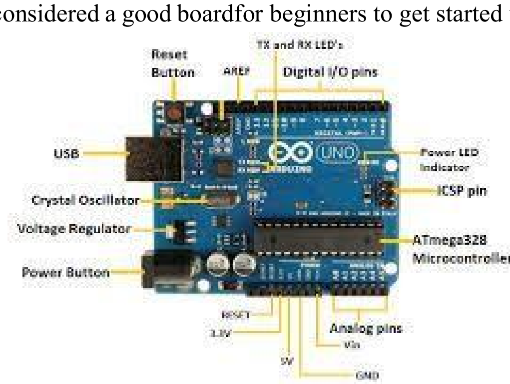


Breadboard: Although they have certain drawbacks, breadboards are appropriate for low- current and low-frequency applications. For instance, they need more physical space for simple circuits, and when there are several connections, the circuit may get jumbled. Moreover, breadboards aren't ideal for high- speed designs since connecting and unplugging them can interfere with other connections.



Connecting wires: An electrical circuit's connecting wires are essential because they enable the flow of electricity between its various electricalcomponents. They create electrical conductivity between two devices by means of flexible metal strands. Connecting wires, for instance, enables electricity to move from a cell.

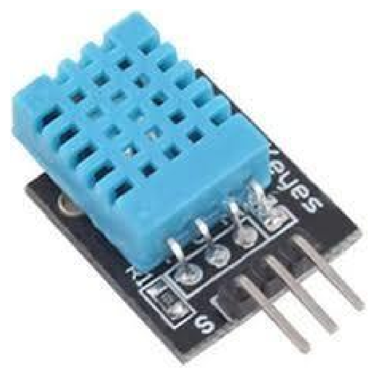
Arduino uno: The Arduino Uno is a microcontroller board designed by Arduino.cc in Italy. It's a pocket-sized computer that can be programmed to control circuits and interact with the outside world through sensors, LEDs, motors,and speakers. The Uno is considered a good boardfor beginners to get started with electronics and coding.



12V Adaptor: An adapter made specifically to give a device precisely 12 Volts of direct currentis called a 12V DC power supply. The voltage that is delivered needs to be exactly the same as what the equipment needs.

DHT11:

DHT11 is a low-cost digital sensor for sensing temperature and humidity. This sensor can be easily interfaced with any micro-controller such as Arduino, Raspberry Pi etc., to measure humidity and temperature instantaneously. DHT11 humidity and temperature sensor is available as a sensor and as a module.



FIELD SURVEY

The system's target crops and the territories that have been assigned for its implementation have been identified. We actively engaged farmers, agricultural specialists, and other stakeholders in stakeholder meetings to clarify and define the project's unique requirements. The collaborative sessions were documented, and visual representations, captured in accompanying images, providevaluable insights into the interactions withkey participants

Figure1: Farm visit

Figure2: Farmer 1

Figure3:Discussion on the Farm

Figure4: Farmer 2

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V. WORKING

Through the seamless integration of real-time soil data analysis and customized recommendations,the Crop Suggestive System through Soil Property Characterization (CSS- SPC), which uses Internet of Things technology, orchestrates a transformative process in modern agriculture enhancing crop selection and management. This novel system functions via a painstakingly planned workflow that takes place in a sequence of linked phases.

The initial phase of the CSS-SPC is the installationof IoT sensors throughout the fields. These sensorscarefully detect vital characteristics like pH levels, moisture content, temperature, nutritional composition, salinity, and organic matter content. They are positioned strategically to record the spatial diversity of soil conditions. By ensuring thorough coverage, the deployment offers a full picture of soil dynamics throughout the whole agricultural terrain.

Consequently, the IoT sensors' ongoing acquisition of data on soil properties starts the information flow that is necessary for makingwell-informed decisions. With the meticulouscollection of data at predetermined intervals, these sensors provide an understanding of soil conditions in real time. By use of wireless transmission, enabled by communication protocolssuch as Wi-Fi or cellular networks, thegathered data is transferred without difficulty to a centraldatabase or cloud platform, where it is awaitinginterpretation and analysis.

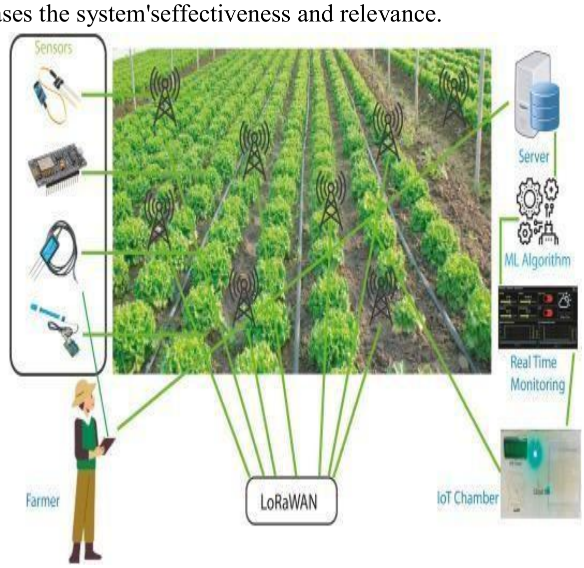
Strict analysis is performed on the processed soilproperty data using expert systems or sophisticated machine learning methods.

Using the data that has been examined, the CSS-SPC system begins evaluating whether crops are suitable to grow in different regions of the farmland. The method matches these parameters with the reported soil properties by accounting for subtle elements such crop salinity tolerance, Temperature & Humidity moisture requirements, and nutrient availability. The foundation for creating customized crop recommendations intended to maximize yields and promote sustainable agriculture practices is laid by this comprehensive evaluation.

The final product of the working process is the creation of customized crop recommendations based on the needs of each farmer. These carefully chosen suggestions, which are based onthe evaluated compatibility of the crops and the current soil conditions, offer practical guidance for crop selection, planting densities, and the besttimes to plant.

The iterative methodology of the CSS-SPC system, which emphasizes feedback and ongoingimprovement, is one of its main features. To aid in the continual improvement of prediction

models and recommendation algorithms, farmers are urged to share information about the yield of crops that have been suggested. By maintaining the system's adaptability and responsiveness to changing agricultural dynamics, this feedback loop gradually increases the system'seffectiveness and relevance.



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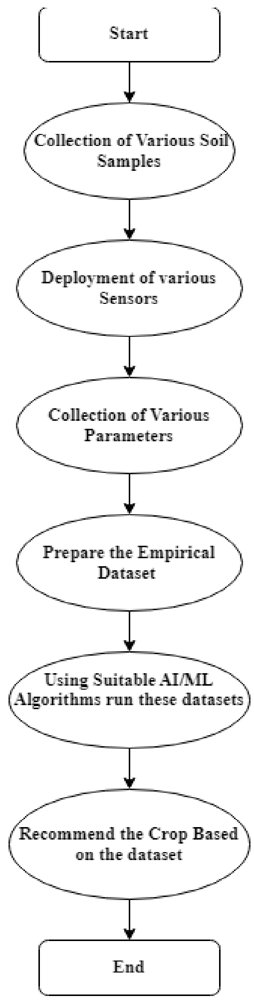
VI. IMPLEMENTATION:

Data Collection and Preparation:

- **Identify Relevant Soil Properties:** Based onyour target crops and local conditions, determine the crucial soil properties to be measured.Common choices include: Soil Moisture, NPK Sensor
- **Sensor Selection:** Choose appropriate sensors for each property, considering factors like: Accuracy and measurement range, Power consumption (for battery life in the field), Cost and ease of deployment.
- **Data Acquisition System Setup:** Select a WIFI Module (e.g., ESP8266) to collect sensor data. Program the device to read sensor values at specified intervals and perform initial data processing (e.g., filtering noise).
- **Data Storage and Management:** Choose a cloud storage platform (e.g., Thingspeak) to securely store sensor data. Develop a system for data logging and organization, ensuring traceability and ease of access



Machine Learning Model Development:

Dataset Preparation: Gather historical datalinking soil properties to suitable crops for your target region. This data can come from agricultural research or local farm records. Ensure the data is accurate, complete, and representative of the crops and soil conditions you are interested in. Pre-process the data tohandle missing values, outliers, and normalize features for the chosen machine learning algorithm.

Model Selection and Training: Select a suitable machine learning algorithm based on data size, complexity, and desired outcome. Common choices include: Decision Trees – Easyto interpret and implement, good for smaller datasets. Support Vector Machines (SVMs) –Effective for high dimensional data. K-Nearest

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Neighbours (KNN) – Efficient for smaller datasets. Train the model on the prepared dataset,splitting it into training and testing sets for evaluation. Fine-tune hyperparameters of the model to optimize its performance.

Model Evaluation and Improvement: Evaluate the model's accuracy using metrics like precision. Analyse model errors and identify areas for improvement. This may involve collecting additional data, refining feature selection, or trying

VII. RESULTS

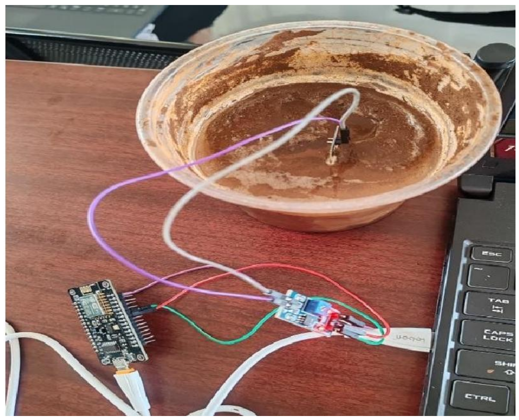

Figure: Soil moisture interfacing with ESP8266

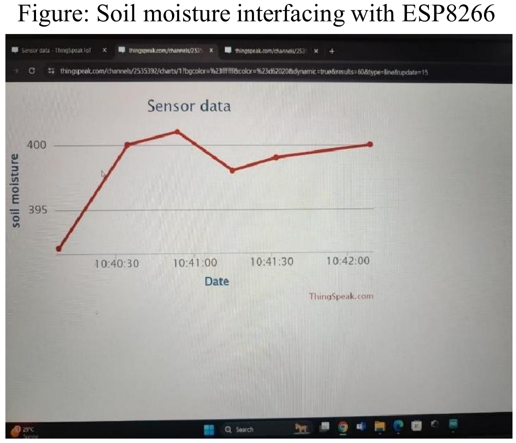

Figure: Soil moisture value

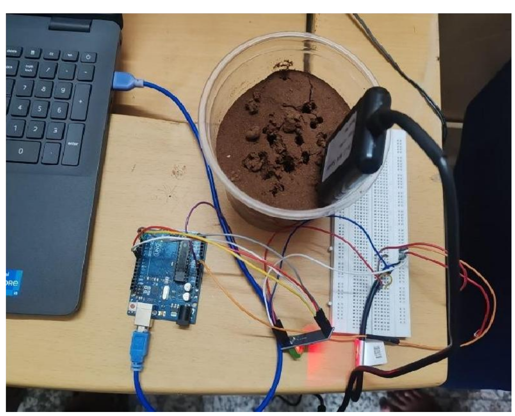

Figure: Measure of NPK values

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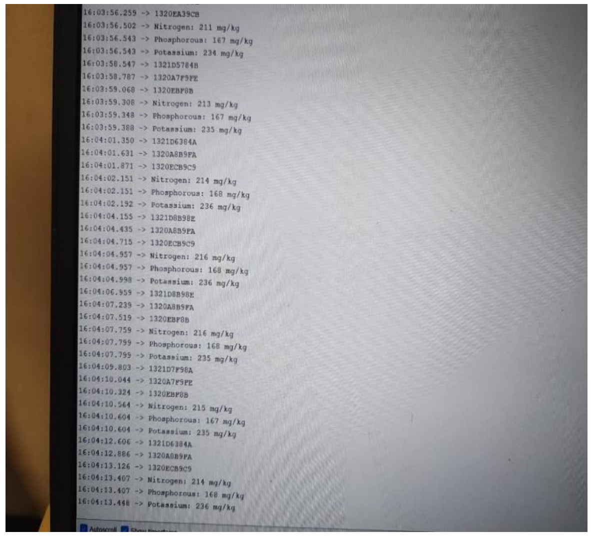

Figure: output of NPK values

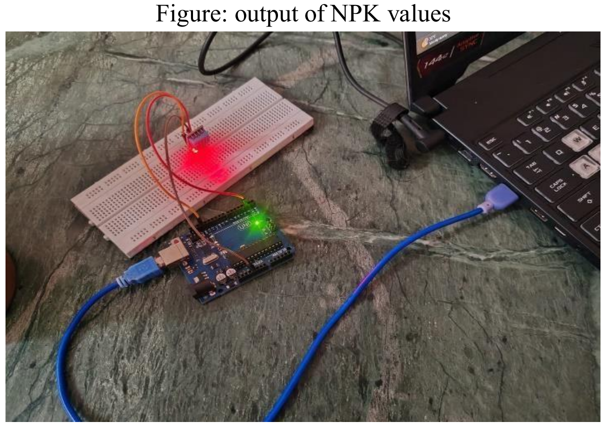

Figure: DHT11 sensor with Arduino

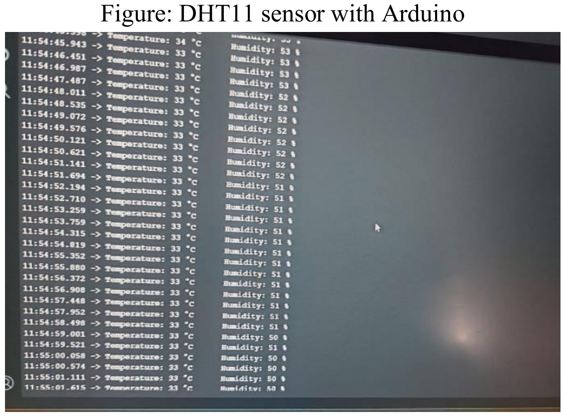

Figure: Display of Sensor Values

The ML Algorithm used in this project is Random Forest, which gives the utmost accuracy among the various other algorithms and predicts the most suitable crop.

The results of the crops predicated by the Algorithmafter analyzing the given standard dataset as follows:

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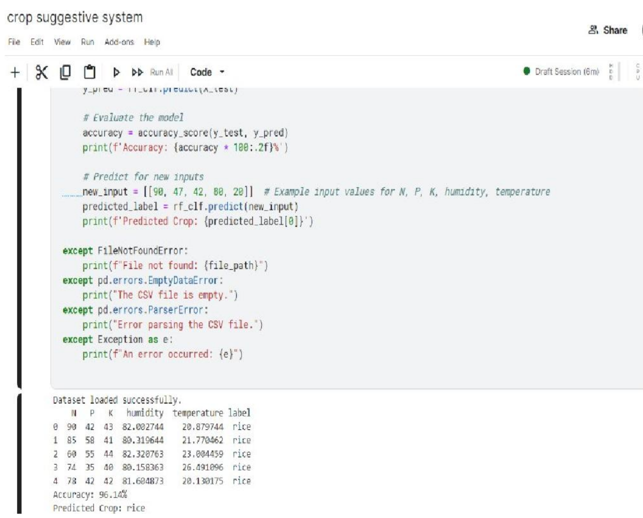
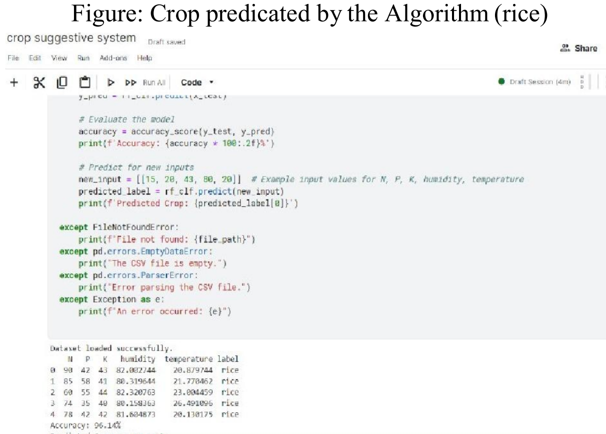
```
    y = data['label']

    # Split the dataset into training and testing sets
    X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

    # Initialize the Random Forest Classifier
    rf_clf = RandomForestClassifier(n_estimators=100, random_state=42)

    # Train the model
    rf_clf.fit(X_train, y_train)

    # Predict on the test set
    y_pred = rf_clf.predict(X_test)

    # Evaluate the model
    accuracy = accuracy_score(y_test, y_pred)
    print(f'Accuracy: {accuracy * 100:.2f}%')

    # Predict for new inputs
    new_input = [[45, 26, 45 ,45, 18]]  # Example input values for N, P, K, humidity, temperature
    predicted_label = rf_clf.predict(new_input)
    print(f'Predicted Crop: {predicted_label[0]}')

except FileNotFoundError:
    print(f"File not found: {file_path}")
except pd.errors.EmptyDataError:
    print("The CSV file is empty.")
except pd.errors.ParserError:
    print("Error parsing the CSV file.")
except Exception as e:
    print(f"An error occurred: {e}")

Dataset loaded successfully.
    N   P   K   humidity  temperature label
0  90  42  43  82.002744    20.879744  rice
1  85  58  41  80.319644    21.770462  rice
2  60  55  44  82.320763    23.004459  rice
3  74  35  40  80.158363    26.491096  rice
4  78  42  42  81.604873    20.130175  rice
Accuracy: 96.14%
Predicted Crop: mango
```

Figure: Crop predicated by the Algorithm (mango)




```
    # Evaluate the model
    accuracy = accuracy_score(y_test, y_pred)
    print(f'Accuracy: {accuracy * 100:.2f}%')

    # Predict for new inputs
    new_input = [[90, 47, 42, 80, 20]]  # Example input values for N, P, K, humidity, temperature
    predicted_label = rf_clf.predict(new_input)
    print(f'Predicted Crop: {predicted_label[0]}')

except FileNotFoundError:
    print(f"File not found: {file_path}")
except pd.errors.EmptyDataError:
    print("The CSV file is empty.")
except pd.errors.ParserError:
    print("Error parsing the CSV file.")
except Exception as e:
    print(f"An error occurred: {e}")

Dataset loaded successfully.
    N   P   K   humidity  temperature label
0  90  42  43  82.002744    20.879744  rice
1  85  58  41  80.319644    21.770462  rice
2  60  55  44  82.320763    23.004459  rice
3  74  35  40  80.158363    26.491096  rice
4  78  42  42  81.604873    20.130175  rice
Accuracy: 96.14%
Predicted Crop: rice
```

Figure: Crop predicated by the Algorithm (rice)




```
    # Evaluate the model
    accuracy = accuracy_score(y_test, y_pred)
    print(f'Accuracy: {accuracy * 100:.2f}%')

    # Predict for new inputs
    new_input = [[15, 20, 43, 80, 20]]  # Example input values for N, P, K, humidity, temperature
    predicted_label = rf_clf.predict(new_input)
    print(f'Predicted Crop: {predicted_label[0]}')

except FileNotFoundError:
    print(f"File not found: {file_path}")
except pd.errors.EmptyDataError:
    print("The CSV file is empty.")
except pd.errors.ParserError:
    print("Error parsing the CSV file.")
except Exception as e:
    print(f"An error occurred: {e}")

Dataset loaded successfully.
    N   P   K   humidity  temperature label
0  90  42  43  82.002744    20.879744  rice
1  85  58  41  80.319644    21.770462  rice
2  60  55  44  82.320763    23.004459  rice
3  74  35  40  80.158363    26.491096  rice
4  78  42  42  81.604873    20.130175  rice
Accuracy: 96.14%
Predicted Crop: pomogranate
```

Figure: Crop predicated by the Algorithm(pomogrante)

THE CORRELATION MATRIX: The below figure shows a correlation matric dissipating the relationship between various soil parameters like N,P,K, temperature & Humidity. The matrix has arange of +1 to -1. With +1 being

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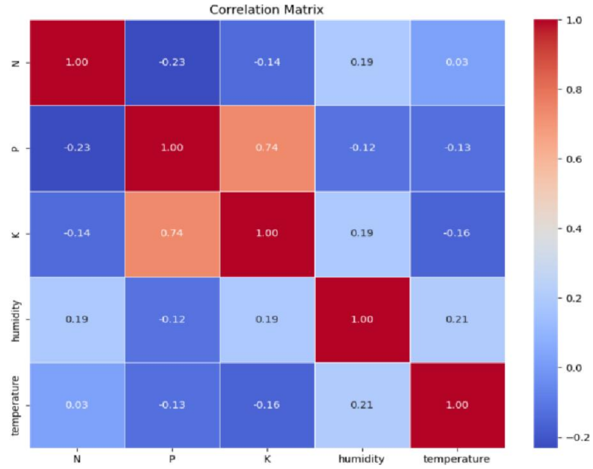
Highly corelatedto negative values indicated the parameters are notcorelated. As observed from above figure, Amongthe given parameters, Phosphorous(P), and Potassium(K) are highly corelated compared toother parameters.



VIII. APPLICATIONS

With the use of Internet of Things technology, theCrop Suggestive System through Soil PropertyCharacterization (CSS-SPC) finds applications in decision support systems, precision agriculture,crop selection and management, soil health monitoring, water and nutrient management, disease and pest management, and climate resilience. Agronomists, farmers, and agricultural consultants can make well-informed decisions by using CSS-SPC, which minimizes environmental impact, maximizes crop yields, and provides real- time insights into soil conditions.

IX. ADVANTAGES

Benefits of the Crop Suggestive System through Soil Property Characterization (CSS-SPC) employing IoT include improved agricultural productivity, resource efficiency, and crop selection that is maximized. Precision farming is made possible, soil health monitoring is enhanced, water and nutrient management is made easier, disease and pest control is improved, climate resilience is encouraged, and useful decision assistance is given. Through the use of sophisticated analytics and real-time soil data, CSS- SPC gives farmers the capacity to make well- informed decisions, reduce input costs, raise yields,and promote sustainable agricultural practices—allof which eventually boost profitability and environmental stewardship.

- Accurate Farming
- Enhanced Output
- Efficiency of Resources
- Ecological Farming Methods
- Knowledge-Based Decision-Making
- Flexibility
- Improved Quality of Crops

X. DISADVANTAGES

While the Crop Suggestive System through Soil Property Characterization (CSS-SPC) using IoT offers significant advantages, it also presents some potential disadvantages. These may include initial setup costs, technological complexity requiring specialized expertise, reliance on consistent internet connectivity for data transmission, and susceptibility to sensor malfunctions or inaccuracies. Additionally, the system may face challenges related to data privacy and security concerns, as well as the need for ongoing maintenance and updates.

- Complexity of Technology
- Dependency on Networking

- Sensor Errors
- Data Security and Privacy Issues
- Over-reliance on Technology
- Algorithm Bias Potential
- Integration's Complexity

XI. CONCLUSION

In conclusion, a potential development in contemporary agriculture is the Crop Suggestive System through Soil Property Characterization (CSS-SPC) using Internet of Things technology. Through the integration of tailored crop suggestions and real-time soil data analysis, CSS- SPC provides farmers with useful information to enhance their crop selection, resource management, and decision-making procedures. Although CSS-SPC has the potential to improve productivity, sustainability, and profitability, it also has drawbacks, including startup costs, technological complexity, and potential Dependability problems. Stakeholder cooperation, continued improvement and appropriate implementation can lessen these difficulties, nevertheless. In the future, CSS-SPC might transform crop management techniques, provide farmers with useful information, and support the development of a more productive, resilient, and sustainable agriculture industry. Adopting CSS- SPC is an essential first step in using technology to address.

X. FUTURE SCOPE

Future developments in agriculture could greatly benefit from the Crop Suggestive System through Soil Property Characterization (CSS-SPC) employing Internet of Things. Improvements like the addition of sophisticated sensors for more thorough soil monitoring, better machine learning algorithms for better predictive modeling, and the integration of satellite imagery and remote sensing data for wider spatial coverage can all be beneficial to CSS-SPC as technology develops. Furthermore, CSS-SPC may find use in areas other than conventional crop management, such as the adaptation to climate change, sustainable intensification, and circular agriculture.

Additionally, cooperation with researchers, legislators, technology developers, among other stakeholders along the agricultural value chain, can promote interdisciplinary methods and hasten CSS-SPC's global adoption. By seizing these chances for creativity.

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