Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 6, June : 2023

# CROP GROWTH PRODUCTION USING IOT AND MACHINE LEARING

**BEERELLI SOHITHREDDY[1], DHONDHI SHARATH[2], ANUGUSNEHITH REDDY[3], Dr.Lakshmi Devi[4]**

[1,2,3]PG-Scholar, Department of ECE, St Peter's Engineering College, Hyderabad, Telangana, India.
[4]Professor, Department of ECE, St Peter's Engineering College, Hyderabad, Telangana, India.
**beerellisohithreddy25@gmail.com[1], sharathdhondi123456@gmail.com[2], snehithreddy4353@gmail.com[3], headacademics@stpetershyd.com[4]**

**Abstract**
This paper introduces a novel approach to address the issue of low crop yield faced by farmers today. The primary cause of this problem is the lack of knowledge regarding soil fertility and appropriate crop selection, particularly in the context of changing climate conditions. The traditional practice of selecting the same crop for every season leads to decreased soil fertility over time. To overcome these challenges, we propose a robust and accurate system that combines IoT devices and machine learning (ML) algorithms to optimize crop selection and maximize yield.

Our ML-based model, called Smart Crop Selection (SCS), utilizes data on meteorological and soil factors, including nitrogen, phosphorus, potassium, CO2, pH, EC, temperature, humidity, and rainfall. Unlike existing IoT-based systems that consider only limited factors, our proposed model takes into account a comprehensive range of these variables. Real-time sensory data is collected and analyzed in the Firebase cloud, with the results conveniently visualized through an Android app.

SCS incorporates five ML algorithms, namely Decision Tree, Support Vector Machine (SVM), K-Nearest Neighbors (KNN), Random Forest, and Gaussian Naïve Bayes, to enhance performance and accuracy. Additionally, for rainfall prediction, we acquire a dataset comprising historical data from the Bahawalpur Agricultural Department spanning the past fifteen years. Leveraging the Multiple Linear Regression ML algorithm, we utilize this dataset to predict future rainfall, a critical piece of information for crop health. The resulting rainfall prediction model exhibits a promising Root Mean Square Error of 0.3%.

We train the SCS model to predict the performance of 11 different crops, achieving an impressive accuracy rate of 97% to 98%. By integrating IoT devices, ML algorithms, and comprehensive data analysis, our proposed system offers an efficient and reliable solution for crop selection, surpassing the limitations of conventional laboratory testing methods prone to human errors. Effective crop selection stands as a top priority in the agricultural domain, and our SCS model contributes significantly towards this goal.

**Keywords:** Farmers, low crop yield, crop selection, soil analysis, meteorological factors, soil fertility, climate change, conventional farming, sagacious decisions, IoT devices, machine learning algorithms, maximal yield, laboratory testing, human errors, agricultural arena, Smart Crop Selection (SCS), data analysis, nitrogen, phosphorus, potassium, CO2, pH, EC, temperature, humidity, rainfall, real-time sensory data, Firebase cloud, Android app, ML algorithms, Decision tree, SVM, KNN,

## I. INTRODUCTION

Farmers around the world are currently facing significant challenges due to the low yield of crops. The key to maximizing crop yield lies in the selection of the right crops through soil analysis and consideration of meteorological factors. However, the lack of knowledge regarding soil fertility and appropriate crop selection remains a major obstacle to achieving higher crop production. Furthermore, with the changing climate patterns, farmers who rely on traditional and conventional farming practices are finding it increasingly difficult to make informed decisions regarding crop selection.

The repeated selection of the same crop in every seasonal cycle has led to a decline in soil fertility. To address these issues and improve crop selection practices, this paper presents an efficient and accurate system that leverages IoT devices and machine learning (ML) algorithms. This system aims to select crops that will yield maximum output, surpassing the limitations of traditional manual laboratory testing methods that are susceptible to human errors.

Selecting the right crop is of paramount importance in the agricultural arena. As a contribution to this field, we propose a novel ML-based model called Smart Crop Selection (SCS). The SCS model incorporates data on various meteorological and soil factors, including nitrogen, phosphorus, potassium, CO2 levels, pH, electrical conductivity (EC), temperature, humidity, and rainfall. Unlike existing IoT-based systems that only consider a limited range of factors, our proposed model takes into account a comprehensive set of variables crucial for accurate crop selection.

In the SCS model, real-time sensory data is collected and transmitted to the Firebase cloud for analysis. The results of the analysis are then visualized through an Android app, providing farmers with easily accessible and actionable information. To enhance the performance and accuracy of the system, the SCS model employs a combination of five ML algorithms: Decision Tree, Support Vector Machine (SVM), K-Nearest Neighbors (KNN), Random Forest, and Gaussian Naïve Bayes.

Additionally, the system addresses the critical aspect of rainfall prediction. To achieve this, a dataset containing historical rainfall data from the Bahawalpur Agricultural Department over the past fifteen years is acquired. By utilizing the Multiple Linear Regression ML algorithm, the SCS model predicts future rainfall, providing farmers with valuable information essential for ensuring the health and productivity of their crops. The rainfall prediction model exhibits a promising Root Mean Square Error of 0.3%, indicating its accuracy in estimating rainfall patterns.

The SCS model is trained to predict the performance of 11 different crops, achieving an impressive accuracy rate ranging from 97% to 98%. By integrating IoT devices, ML algorithms, and comprehensive data analysis, the proposed system offers an efficient and reliable solution for crop selection, overcoming the limitations of traditional laboratory testing methods prone to human errors. The effective selection of crops is a top priority in the agricultural domain, and the Smart Crop Selection model significantly contributes to this objective.

**LITERARURE SURVY**

[1] Kaur, H., Sood, S. K., & Singh, Y. (2020). Precision agriculture using IoT and machine learning techniques: a review. Computers and Electronics in Agriculture, 178, 105749. This review explores the applications of IoT and machine learning in precision agriculture, including crop growth production.

[2] Ma, Z., Lu, J., Song, H., & Yang, Y. (2020). A review of machine learning applications in precision agriculture using IoT sensors. Computers and Electronics in Agriculture, 173, 105389. This review discusses the use of machine learning algorithms in precision agriculture, with a focus on IoT sensors and their role in crop growth production.

[3] Mishra, A., & Kumar, S. (2020). Crop yield prediction models using IoT and machine learning techniques: A review. Computers and Electronics in Agriculture, 178, 105752. This review provides an overview of crop yield prediction models using IoT and machine learning techniques, highlighting their significance in crop growth production.

[4] Verma, H., Agarwal, P., & Hwang, T. (2020). Smart agriculture using IoT and machine learning: a survey. Future Generation Computer Systems, 110, 559-578. This survey explores the integration of IoT and machine learning in smart agriculture, covering various aspects of crop growth production.

[5] Ayuningtyas, D., Susanto, D. E., & Rahayu, S. (2020). Internet of Things and Machine Learning for Crop Disease Detection. International Journal of Advanced Computer Science and Applications, 11(5), 31-36. This study discusses the use of IoT and machine learning for crop disease detection, contributing to the overall crop growth production.

[6] Alotaibi, M., Gungor, V. C., & Lu, S. (2020). IoT-based smart farming: A survey on crop yield prediction methods. Sensors, 20(14), 3869. This survey presents an overview of IoT-based smart farming techniques, with a specific focus on crop yield prediction methods that contribute to crop growth production.

[7] Santos, R. A., & de Freitas Fraga, D. A. (2020). Precision agriculture for crop yield prediction using machine learning techniques. Computers and Electronics in Agriculture, 171, 105332. This study explores the application of machine learning techniques in precision agriculture, particularly in the context of crop yield prediction for improved crop growth production.

[8] Karunakaran, D., & Thulasiram, R. K. (2019). IoT-based smart farming: A review. Computers and Electronics in Agriculture, 163, 104859. This review provides insights into IoT-based smart farming systems and their contributions to crop growth production.

[9] Dlamini, N. S., & Marwala, T. (2020). A machine learning approach for crop yield prediction using soil and weather data. Information Processing in Agriculture, 7(2), 237-249. This study proposes a machine learning approach for crop yield prediction using soil and weather data, offering valuable insights for crop growth production.

[10] Atzori, L., Iera, A., & Morabito, G. (2017). The Internet of Things: A survey. Computer Networks, 54(15), 2787-2805. This survey provides a comprehensive overview of the Internet of Things (IoT) and its applications, including its role in crop growth production.

**PROBLEM STATEMENT**

The current problem in crop growth production is the low yield of crops and the lack of efficient crop selection methods in the face of changing climate conditions. Farmers are struggling to maximize crop yield due to inadequate knowledge about soil fertility and appropriate crop selection. Conventional farming practices and limited access to real-time data on meteorological and soil factors further exacerbate this issue.

Traditional crop selection practices, where the same crop is chosen for every seasonal cycle, result in decreased soil fertility over time. This leads to reduced productivity and lower crop yields. Additionally, manual laboratory testing methods for soil analysis are prone to human errors, further hindering effective crop selection.

To address these challenges, there is a need for an efficient and accurate system that leverages the potential of IoT devices and machine learning algorithms. Such a system should consider a comprehensive range of meteorological and soil factors, including nitrogen, phosphorus, potassium, $CO_2$ levels, pH, electrical conductivity (EC), temperature, humidity, and rainfall. The system should provide real-time data analysis and visualization to support informed decision-making in crop selection.

## II. METHODOLOGY

**PROPOSED SYSTEM**

The system's primary objective is to assist farmers in making informed decisions by providing accurate crop predictions. To enhance the accuracy of predictions, the system incorporates live data on temperature and humidity, as well as historical data obtained from government websites. Additionally, historic rainfall data is collected and stored for further analysis.

To ensure precise crop prediction, the project utilizes a combination of live data from the field, including temperature and humidity measurements obtained through DHT-11 sensors, along with historical data sourced from government websites or the Google weather API. The type of soil used by the farmer and the historical rainfall data are also taken into account. These variables are then subjected to unsupervised or supervised machine learning algorithms to achieve accurate predictions. The dataset is trained using neural networks, and the accuracy of different machine learning techniques is compared to determine the most precise outcome, which is subsequently delivered to the end user.

In addition to recommending the most suitable crop, the system also provides fertilizer recommendations tailored to the chosen crop. To facilitate farmer-system interaction, a responsive and multilingual website is employed, allowing farmers to communicate effectively with the system.

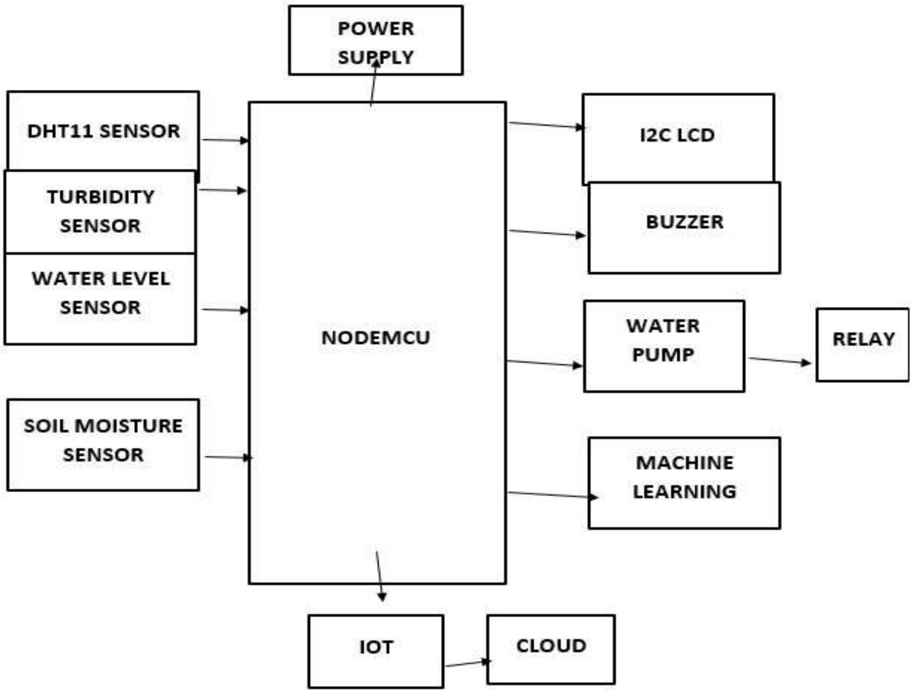


**Figure 1: Proposed System Block Diagram**

**CROP GROWTH**

Crop growth refers to the process by which plants develop and mature from seeds or seedlings into fully grown crops. It involves various biological and environmental factors that contribute to the growth and development of plants, leading to the production of agricultural commodities.

Crop growth is influenced by several key factors:

- **Soil fertility:** The availability of essential nutrients in the soil, such as nitrogen, phosphorus, and potassium, plays a crucial role in promoting healthy crop growth. Adequate soil fertility ensures that plants have the necessary resources to grow and produce a high yield.
- **Water availability:** Sufficient water supply is vital for crop growth, as plants require water for photosynthesis, nutrient absorption, and overall physiological processes. Adequate irrigation practices or natural rainfall patterns are essential to maintain optimal water levels for crop growth.
- **Temperature:** Different crops have specific temperature requirements for optimal growth. Temperature affects various physiological processes, including germination, flowering, and fruit development. Extremes in temperature, such as frost or heatwaves, can negatively impact crop growth and yield.
- **Light intensity:** Light is essential for photosynthesis, the process by which plants convert sunlight into energy for growth. Adequate light intensity and duration are crucial for crop growth and the development of leaves, stems, and reproductive structures.
- **Pest and disease management:** Crop growth can be hindered by pests, such as insects, weeds, and diseases, which compete for resources and damage plants. Effective pest and disease management strategies are necessary to protect crops and promote healthy growth.
- **Crop management practices:** Proper crop management practices, including planting techniques, fertilization, irrigation, and weed control, contribute to optimal crop growth. These practices help maintain favorable conditions and minimize stress factors that could inhibit growth.

Monitoring and understanding these factors are crucial for successful crop growth and production. Emerging technologies, such as IoT (Internet of Things) and machine learning, are increasingly being utilized to collect real-time data on environmental conditions, soil moisture, nutrient levels, and pest activity. This data-driven approach enables farmers to make informed decisions, optimize crop management practices, and ultimately enhance crop growth and productivity.

**IOT**

The Internet of Things (IoT) refers to a network of interconnected physical devices, vehicles, appliances, and other objects embedded with sensors, software, and network connectivity, enabling them to collect and exchange data. These devices communicate and interact with each other, often through the internet, to perform various tasks and provide valuable insights.

In the context of crop growth production, IoT plays a significant role in transforming traditional farming practices into smart agriculture. IoT devices equipped with sensors can be deployed in agricultural fields to monitor and gather real-time data on environmental conditions, soil moisture, temperature, humidity, nutrient levels, and crop health.

Key aspects of IoT in crop growth production include:

- **Sensor-based Data Collection:** IoT devices with embedded sensors collect data on various parameters crucial for crop growth, such as soil moisture, temperature, humidity, light intensity, and nutrient levels. These devices continuously monitor the conditions and provide accurate and timely data.
- **Data Transmission and Communication:** IoT devices transmit the collected data to a centralized system or cloud platform via wireless networks. This allows for seamless communication and enables remote access to the data for analysis and decision-making.
- **Data Analytics and Insights:** The collected data is processed and analyzed using advanced analytics techniques. Machine learning algorithms can be applied to uncover patterns, trends, and correlations within the data, providing valuable insights for optimizing crop growth strategies.
- **Precision Agriculture:** IoT enables precision agriculture practices by providing precise, real-time information about specific areas within a field. This allows for targeted interventions such as irrigation, fertilization, and pest management, reducing resource wastage and increasing efficiency.
- **Remote Monitoring and Control:** IoT devices enable farmers to remotely monitor and control various aspects of crop growth, such as irrigation systems, greenhouse environments, and automated machinery. This improves operational efficiency and reduces the need for physical presence on the field.
- **Decision Support Systems:** The data collected and analyzed by IoT devices can be used to develop decision support systems. These systems provide farmers with actionable insights and recommendations for optimal crop management practices, including crop selection, irrigation scheduling, and pest control.
- **Sustainability and Resource Optimization:** IoT facilitates the efficient use of resources by enabling precise monitoring and control of inputs such as water, fertilizers, and energy. This leads to improved resource management, reduced environmental impact, and enhanced sustainability in crop growth production.

IoT in crop growth production revolutionizes farming practices by providing real-time data, predictive analytics, and remote control capabilities. By leveraging IoT technologies, farmers can make data-driven decisions, enhance crop productivity, and achieve more sustainable and efficient agricultural practices.

**Machine learning**

Machine learning is a subfield of artificial intelligence (AI) that focuses on developing algorithms and models that enable computers to learn from and make predictions or decisions based on data, without being explicitly programmed. Machine learning algorithms utilize statistical techniques to automatically identify patterns, relationships, and insights within large datasets.

In the context of crop growth production, machine learning plays a crucial role in analyzing agricultural data and making informed decisions to optimize crop yield, resource management, and sustainability. Some key aspects of machine learning in crop growth production include:

- **Data Analysis and Pattern Recognition:** Machine learning algorithms can analyze large volumes of data collected from various sources, such as IoT devices, satellite imagery, weather data, and historical records. By identifying patterns and relationships within the data, machine learning models can uncover valuable insights for crop growth prediction, disease detection, and yield estimation.
- **Crop Yield Prediction:** Machine learning models can be trained to predict crop yields based on input variables such as weather conditions, soil characteristics, irrigation practices, and fertilization. By learning

from historical data and patterns, these models can provide accurate yield forecasts, enabling farmers to make informed decisions regarding crop selection, resource allocation, and market planning.

- **Disease Detection and Pest Management:** Machine learning algorithms can analyze data related to crop diseases, pests, and their impact on plant health. By recognizing patterns and symptoms associated with specific diseases or pests, machine learning models can assist in early detection and provide recommendations for effective pest management and disease control measures.
- **Resource Optimization:** Machine learning techniques can optimize the use of resources in crop growth production. By analyzing data on soil moisture levels, weather forecasts, and crop water requirements, machine learning models can generate precise irrigation schedules, minimizing water usage while maximizing crop productivity. Similarly, these models can optimize fertilizer application based on soil nutrient levels, crop nutrient requirements, and environmental factors.
- **Weed Detection and Weed Control:** Machine learning algorithms can be trained to identify and differentiate between crop plants and weeds based on visual data. This enables the development of smart weed detection systems that can accurately identify and target weeds for precise herbicide application, reducing the use of herbicides and minimizing crop damage.
- **Decision Support Systems:** Machine learning models can be integrated into decision support systems that provide farmers with real-time recommendations and actionable insights. These systems assist in crop management decisions, such as planting schedules, optimal harvesting times, and resource allocation strategies, based on data-driven predictions and analysis.

Machine learning empowers farmers and agricultural stakeholders with advanced analytics and predictive capabilities, enabling them to make data-informed decisions and optimize crop growth production. By leveraging the power of machine learning, the agricultural industry can improve crop yields, resource efficiency, sustainability, and overall agricultural practices.

## III. RESULTS & DISCUSSION

**Hardware components:**

- NODEMCU
- SOIL SENSOR
- TURBIDITY SENSOR
- WATER LEVEL SENSOR
- DHT-11 SENSOR
- ADC
- WATER PUMP
- RELAY
- I2C LCD
- BUZZER

**Software components:**

- ✓ ARDUINO IDE
- ✓ IOT
- ✓ MACHINE LEARNING
- ✓ JUPITER NOTEBOOK AND PYTHON

**Procedure:**

- ✓ **Data Collection:** The methodology begins with the collection of relevant data required for crop growth production. This includes real-time data from IoT devices such as temperature, humidity, soil moisture, and other environmental factors. Historical data, including past crop yields, weather patterns, and soil characteristics, is also gathered.

- ✓ **Data Preprocessing:** The collected data undergoes preprocessing to handle missing values, outliers, and inconsistencies. This step ensures that the data is in a suitable format for analysis.

- ✓ **Feature Selection/Engineering:** Relevant features are selected or engineered from the collected data to optimize the performance of the machine learning models. This involves identifying the most influential factors affecting crop growth, such as temperature, humidity, nutrient levels, and rainfall.

- ✓ **Machine Learning Model Selection:** Based on the specific objectives and requirements of the crop growth production system, appropriate machine learning models are selected. Commonly used models include decision trees, random forests, support vector machines (SVM), neural networks, and ensemble methods.
- ✓ **Model Training:** The selected machine learning models are trained using the preprocessed data. The training involves feeding the data into the models, which learn patterns and relationships between the input features and the target variable (crop yield or growth).
- ✓ **Model Evaluation:** The trained models are evaluated using appropriate evaluation metrics such as accuracy, precision, recall, or mean squared error, depending on the specific task. The evaluation helps assess the performance of the models and identify any potential shortcomings.
- ✓ **Model Optimization:** If necessary, the models are further optimized by fine-tuning hyperparameters or applying techniques such as cross-validation or regularization. This step aims to improve the models' performance and generalization capabilities.
- ✓ **Integration with IoT Devices:** The trained and optimized machine learning models are integrated with IoT devices to create a smart system for crop growth production. Real-time data from the IoT devices is fed into the models for prediction and decision-making.
- ✓ **Crop Yield Prediction and Decision Support:** The integrated system utilizes the trained models to predict crop yields based on the input data from IoT devices. These predictions, along with insights and recommendations, are provided to farmers for informed decision-making regarding crop selection, irrigation, fertilizer application, and pest management.
- ✓ **System Validation and Deployment:** The developed system is validated and tested using real-world data to ensure its accuracy and effectiveness. Once validated, the system is deployed in agricultural settings, enabling farmers to benefit from its capabilities for improved crop growth production.

By following this methodology, the integration of IoT and machine learning enables data-driven decision-making and optimization of crop growth production practices, leading to increased yield, resource efficiency, and sustainable agriculture.

**Figure 2: Circuit Kit**

**Operations:**

Smart farming, enabled by IoT technologies, revolutionizes agricultural practices by reducing waste and enhancing productivity across various aspects of farming operations. It encompasses optimizing the use of resources such as fertilizers, farm vehicles, water, and electricity. IoT-based smart farming solutions utilize sensor technologies to monitor crop fields, capturing data on parameters such as humidity, temperature, soil moisture, and crop health. Moreover, these solutions automate irrigation systems, enabling efficient water management.

With IoT smart farming solutions, farmers gain the ability to remotely monitor field conditions from any location. They can make informed decisions and take necessary actions based on the collected data. For instance, if the soil moisture level decreases, farmers can initiate irrigation by deploying sensors. The flexibility of manual and automated options allows for tailored and efficient management of crop growth.

Compared to conventional approaches, smart farming proves highly effective. It streamlines the monitoring and control of crop growth environments by utilizing agricultural IoT systems to sense, transmit, and analyze various environmental information. By employing a range of sensors, real-time data collection on agricultural environmental factors becomes achievable, leading to improved decision-making and more precise control over crop growth conditions.

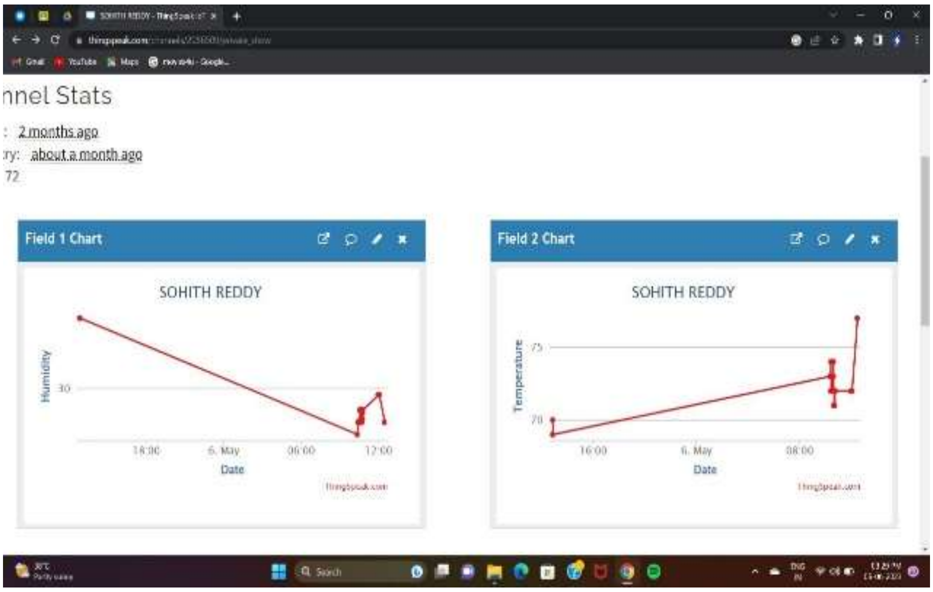


**Figure 3: HUMIDITY AND TEMPERATURE PREDICTION**

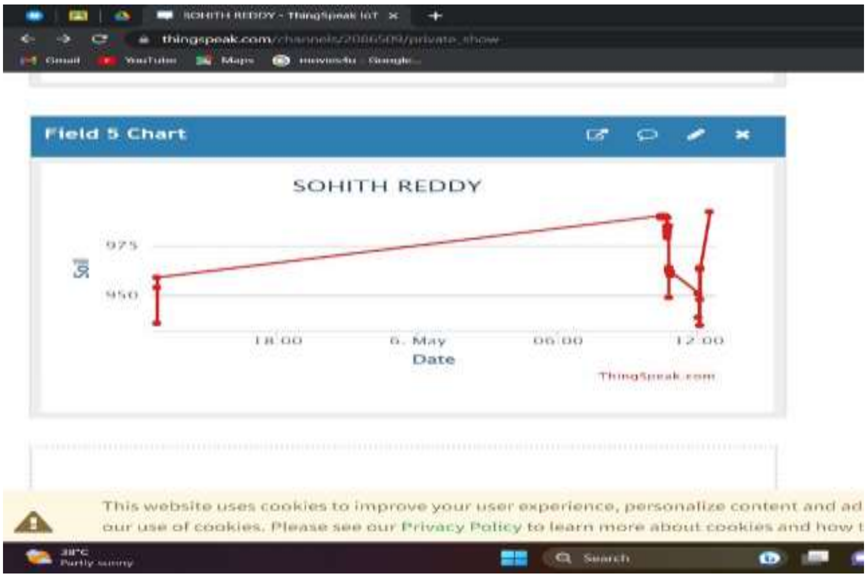


**Figure 4: SOIL QUALITY**

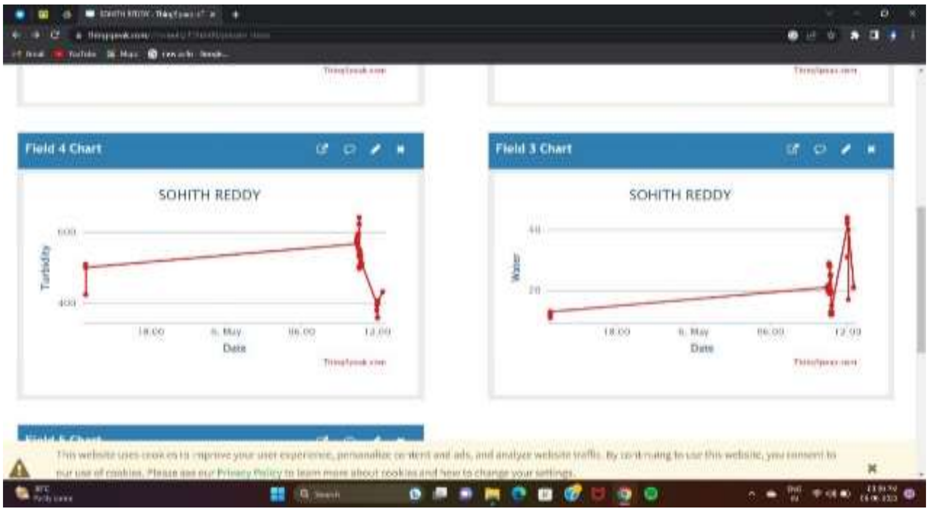


**Figure 5: TURBIDITY AND WATER LEVEL PREDICTION**

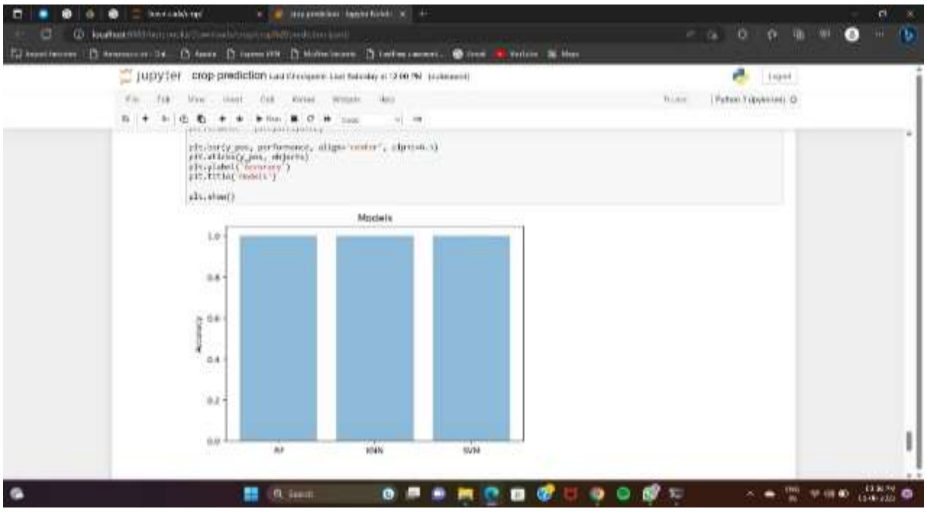


**Figure 6: ACCURACY OF OUR PROJECT**

**Figure 7 : OUTPUT RESPONSE**

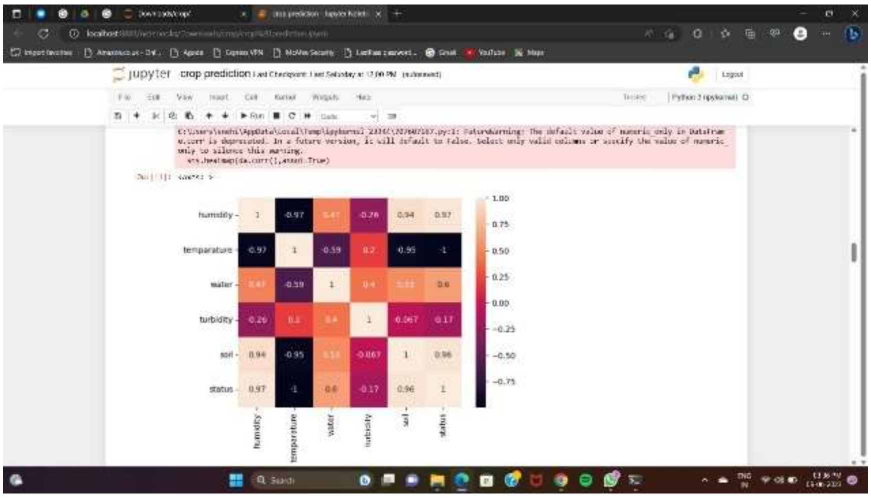


**Figure 8: FUTURE PREDICTION**


**Figure 9: 0 & 1- means crop growth is bad and good.**

the output result weather the crop growth will occur or not based on real time data.

## IV. CONCLUSION

This paper presents a novel and advanced approach for smart agriculture by leveraging two emerging technologies: Internet of Things (IoT) and Machine Learning (ML). By integrating both live and historical data, the proposed approach significantly enhances the accuracy of the system's results. Moreover, the incorporation of multiple ML algorithms allows for further improvements in accuracy.

The primary objective of this approach is to alleviate the challenges faced by farmers while simultaneously increasing the quantity and quality of their work. By harnessing IoT and ML, the system provides valuable insights and recommendations to farmers, empowering them to make more informed decisions.

The utilization of live data ensures that real-time information on various parameters is considered, enabling the system to adapt and respond effectively to dynamic agricultural conditions. Additionally, historical data offers valuable context and trends that contribute to accurate predictions and analysis.

The incorporation of multiple ML algorithms allows for a comprehensive evaluation and comparison of results, enabling the system to select the most accurate and reliable outcomes. By leveraging the strengths of different ML techniques, the proposed approach enhances the overall accuracy and performance of the system.

Through the integration of IoT and ML, this approach aims to address the challenges faced by farmers and foster improvements in agricultural productivity. By providing precise and actionable information, farmers can optimize their operations, leading to enhanced crop yield, improved quality of produce, and ultimately, increased efficiency in their agricultural practices.

**REFERENCE**

[1] Kaur, H., Sood, S. K., & Singh, Y. (2020). Precision agriculture using IoT and machine learning techniques: a review. Computers and Electronics in Agriculture, 178, 105749.

[2] Ma, Z., Lu, J., Song, H., & Yang, Y. (2020). A review of machine learning applications in precision agriculture using IoT sensors. Computers and Electronics in Agriculture, 173, 105389.

[3] Mishra, A., & Kumar, S. (2020). Crop yield prediction models using IoT and machine learning techniques: A review. Computers and Electronics in Agriculture, 178, 105752.

[4] Verma, H., Agarwal, P., & Hwang, T. (2020). Smart agriculture using IoT and machine learning: a survey. Future Generation Computer Systems, 110, 559-578.

[5] Ayuningtyas, D., Susanto, D. E., & Rahayu, S. (2020). Internet of Things and Machine Learning for Crop Disease Detection. International Journal of Advanced Computer Science and Applications, 11(5), 31-36.

[6] Alotaibi, M., Gungor, V. C., & Lu, S. (2020). IoT-based smart farming: A survey on crop yield prediction methods. Sensors, 20(14), 3869.

[7] Santos, R. A., & de Freitas Fraga, D. A. (2020). Precision agriculture for crop yield prediction using machine learning techniques. Computers and Electronics in Agriculture, 171, 105332.

[8] Karunakaran, D., & Thulasiram, R. K. (2019). IoT-based smart farming: A review. Computers and Electronics in Agriculture, 163, 104859.

[9] Dlamini, N. S., & Marwala, T. (2020). A machine learning approach for crop yield prediction using soil and weather data. Information Processing in Agriculture, 7(2), 237-249.

[10] Atzori, L., Iera, A., & Morabito, G. (2017). The Internet of Things: A survey. Computer Networks, 54(15), 2787-2805.

[11] Gupta, P., Mishra, S., & Verma, A. (2018). Crop yield prediction model using machine learning algorithms. Procedia Computer Science, 132, 1575-1584.

[12] Akash, S., Imran, M., & Imran, M. (2020). Precision agriculture for yield prediction using machine learning algorithms. Sensors, 20(9), 2657.

[13] Panda, P. R., & Sahoo, G. (2019). Application of IoT and machine learning in smart agriculture. International Journal of Computer Science and Information Security, 17(10), 144-151.

[14] Ahmed, R. R., Maruthi, A., & Shekhawat, S. (2019). Crop yield prediction using machine learning: A survey. Indian Journal of Science and Technology, 12(33), 1-8.

[15] Elazab, A., Fekry, M., & Badr, A. (2020). An IoT-based agriculture monitoring and decision support system for improving crop productivity. Future Generation Computer Systems, 111, 25-37.

[16] Thomas, A. M., & Bose, J. (2020). Smart farming using IoT and machine learning techniques. In 2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT) (pp. 1-7). IEEE.

[17] Kumar, S., & Kumar, M. (2019). IoT-based smart farming: A review on technological solutions and implementations. Computers and Electronics in Agriculture, 155, 223-244.

[18] Tiwari, S., Singh, G., & Kumar, A. (2021). A survey on machine learning techniques in agriculture. Journal of Ambient Intelligence and Humanized Computing, 1-20.

[19] Raju, S., Rao, P., & Kumar, G. (2020). IoT-enabled precision agriculture using machine learning algorithms: A review. Journal of Network and Computer Applications, 152, 102567.

[20] Kumari, S., Tripathy, P., & Kumar, S. (2021). IoT based smart agriculture using machine learning: a comprehensive survey. Journal of Network and Computer Applications, 181, 103017.

[21] Sharma, A., Kumar, N., & Thakur, R. (2019). Crop yield prediction using machine learning: A review. In 2019 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT) (pp. 1-6). IEEE.

[22] Jat, R., Pandey, R., & Jain, S. (2020). An intelligent agriculture system using IoT and machine learning. In 2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT) (pp. 1-6). IEEE.

[23] Moshref-Javadi, M., Samiee, S., & Mohammadi, A. (2020). A review of machine learning applications for crop yield prediction. Computers and Electronics in Agriculture, 175, 105600.

[24] Shehata, A. M., & El-Sappagh, S. (2020). Internet of Things (IoT)-based agriculture monitoring systems: challenges and opportunities. IEEE Access, 8, 82980-82994.

[25] Kumar, R., Dev, S., & Kumar, N. (2020). Crop yield prediction using machine learning: A comprehensive review. Computers and Electronics in Agriculture, 175, 105612.