AGRIFUTURA : Intelligent Crop Selection for a Sustainable Tomorrow

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Abstract*—Knowing the changes in climate issues and the depletion of resources on the planet is ever-growing, a balanced approach to sustainability within agricultural practices needs to be done. This article presents an integrated IoT-based crop recommendation and management system, with an associated mobile application. The system enables real-time monitoring of soil parameters, including tds , turbidity ,rainfall, soil mositure along with temperature and humidity. These values are measured and gathered through IoT sensors, which, combined with the current moisture content of the soil, aid in formulating real-time critical data on climate. All of this is captured and stored on a Firebase cloud, and the mobile application is synced to offer the end-user a list of pre-approved crops. Thus, the optimal cultivation model supported by IoT demonstrates agriculture technology's ability to maximize profits and reduce environmental impact and traditional farming's shortcomings. All empirical tests proved the system's accuracy and functional performance. Indeed, the recommendations are offered with greater precision and reliability due to the application of machine learning and especially, K-Nearest neighbors (K.N.N)

Keywords—Precision Agriculture, IoT, KNN, Machine Learning, Crop recommendation, Firebase Cloud, Mobile Application, Soil Parameter, Real-time Monitoring.

I. INTRODUCTION

Changes are beginning to take place as advanced technologies such as IoT and machine learning are being adopted in agriculture. This is happening simultaneously with challenges such as climate change, limited resources, and the ever-growing demand for sustainability. History holds examples of poor farming systems that turned inefficient, leading to low productivity even with a changing environment. However, the coupling of IoT and machine learning seems to be a real-time solution for monitoring soil's moisture content, temperature, and humidity. This review presents a novel system that merges IoT data collection and machine learning with the goal of allowing farmers make better decisions. The system focusing on the qualities of soil and climatic conditions aids in maximizing resources will greatly increase yields while maintaining sustainable farming principles. The simpler approach look for optimized agricultural systems that improves the productivity of farmers and at the same time integrating environmental protection within the new complexities of life.

II. LITERATURE SURVEY

The method used in this paper for crop yield prediction is based on Gaussian Naive Bayes. This proposed system consists of several new ideas regarding IoT data and weather forecasting platforms collected from the IoT sensors while choosing various parameters that are specifically responsible for yield while analyzing all the environmental and climatic factors affecting yield. A lot of data processing would probably be required to cement consensus for the predictions in order to maximize production and bring uniformity to the decision-making process of farmers.[1]

This paper presents AgriCloud, which integrates several artificial intelligence techniques, such as Random forest and XGBoost, into crop recommendation and yield prediction. Using soil and weather parameters as well as market trend data allows for providing yield predictions based on a 94% overall accuracy. The combination of cloud computing ensures the efficient management of data and its accessibility as a scalable tool in improving agricultural practices and decision-making processes.[2]

This report shows a smart farming system that is totally based on a three-layer fund that includes Cloud Computing, the Internet of Things, and Machine Learning. Also, it gathers data on the cloud in real time, and ML is used with associated algorithms for visualization and decision-making. The outcome of this smart farming solution is precision in farming operations, resource-efficient practices, and sustainability decisions.[3]

To get into the details, this paper will take a closer look at how well traditional machine-learning methods like Random Forest and Support Vector Machines (SVM) work when it comes to predicting crop yields. The main goal is to make better use of resources to help with decision-making showing how tech can boost precise farming and eco-friendly ways of growing crops.[4]

This paper describes the role of big data analytics in precision agriculture, particularly an analysis of weather pattern variations, soil conditions, and market trends. The results stress how big data, in this regard, would empower farmers to select crops that are both profitable and sustainable to address resource shortages and climate variability. The study emphasizes that emergence of agriculture is nowhere as impressive as given a look to data-oriented decision-making.[5]

III. WORKING

This new system proposes to utilize IoT and machine learning for assisting farmers in choosing crops to plant, depending on the climate and soil conditions. The ESP32 microcontroller is the processing unit that collects data from different sensors such as TDS (Total Dissolved Solids), turbidity, soil moisture, temperature, humidity, and rainfall. The sensors monitor soil and climate conditions continuously, providing real-time accurate data.

The gathered data is forwarded via a Wi-Fi module to the Firebase Cloud, where it is stored for later analysis. The mobile application acts as a user interface, giving farmers and agricultural specialists information on real-time sensor readings, thereby enabling farmers and experts to make decisions based on the conditions of the soil and the type of suitable crops. The system provides a machine learning model to study soil characteristics before fertilizing and after fertilizing, giving suggestions about the soil's health and suitable crop pairing.

By combining data analytics and IoT, the system enhances the accuracy of farming practices. The machine learning module analyzes the data obtained and estimates the best crops to plant depending on soil quality, weather, and resource availability. The sole remaining thing is to display the result on the mobile app for the user to get access and provide farming decisions with an informed mind.

Thereafter, the system gives an additional capability for a farmer to monitor the status of weather and soil from any place through a mobile application. This cuts down on manual intervention, foretells soil corruption in time, and enables effective management of a farm for higher agricultural productivity.

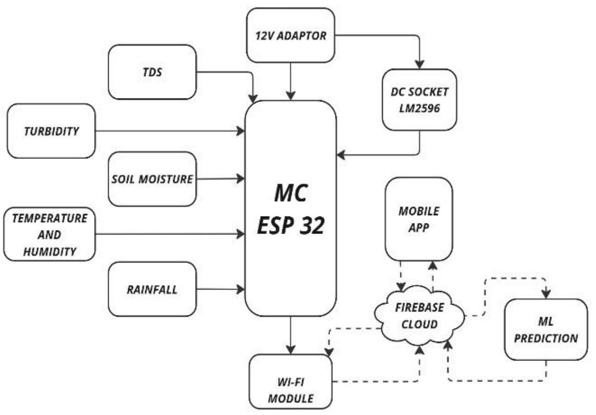


Fig. 1. Block diagram of crop selection for smart agriculture

Fig 1 The block diagram displays the proposed smart monitoring system which integrates various types of sensor modules, an ESP32 controller, a Wi-Fi module, and a mobile app that grants people access to information in real-time. Aimed at monitoring key environmental and soil parameters required for precision agriculture, the ESP32 microcontroller comprises the system's heart, obtaining data from the sensors and sending it wirelessly to a Firebase Cloud database, which then relays the data to an end-user mobile app. The system further includes a machine learning module that gives predictive information based on the collected data.Sensor Modules and Their Roles

There exist various sensors interfaced with the ESP32 that focus on measuring environmental and soil parameters of utmost priority.

TDS Sensor: This measures the overall dissolved solids in water that reflect the ecology of water quality and nutrient content within the soil. Farmers use TDS to determine whether irrigation water is safe to use by their crops.

Turbidity Sensor: A turbidity sensor basically measures the suspended particles in water for irrigation to assess water transparency. High turbidity levels are indicative of possible contamination, eventually harming soil and plant health.

Soil Moisture Sensor: This sensor measures the amount of water in the soil to provide proper water supply to crops for optimum growth. Data from this device would assist farmers in optimal irrigation management, consequently saving water.

Temperature & Humidity Sensor: The DHT11 sensor detects the atmospheric balancing of temperature and humidity at which plants grow and diseases. It gives useful data for said control of the environment.

Rainfall Sensor: The sensor, depending on the amount of rainfall, helps in planning irrigation. If adequate rainfall occurs, it saves on irrigation water and in the process preserves resources.

Power Supply and Voltage Regulation

The device gets its power supply from a 12V adapter to ensure a stable mains supply. Other components get appropriate operating voltages from a DC output supplied through an LM2596 voltage regulator. This prevents damage to the ESP32 board and attached sensors while optimizing functionality.

For Data Communication and Mobile App Compatibility

It sends the real-time readings from the sensor to Firebase Cloud Instance, where the data is stored, thanks to its built-in Wi-Fi. Firebase is only used as a data storage and retrieval system rather than as another computing cloud about heavy data processing taking place on faraway servers. The mobile app then retrieves the information from the cloud and provides users with a simple interface for tracking environmental parameters from a distance.

Machine Learning for Predictions

This machine learning (ML)-based system is implemented to provide informed responses to decision-making. This information is utilized to validate irrigation schedules, expected risks (overwatering or under-watering), and the recommended crops chosen in the decision-making process. The predictions are refreshed at certain intervals of time based on new sensor data, and this allows for targeted operative decision-making to happen in agriculture with minimum possible human input.

Overall Utilities

The real-time IoT-based monitoring system monitors while optimizing water use, soil health assessment, and crop productivity; this benefits the management of farmers. By stopping continuous manual monitoring, it enforces efficient and sustainable farming. From mobile-based monitoring to wireless connectivity to machine learning-based forecasting, this system is a smart agricultural solution that aids in decision-making and resource management to boost crop yields.

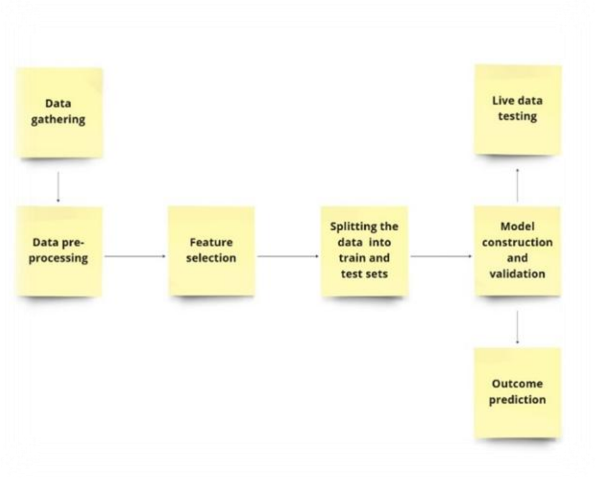


Fig. 2. ML based crop selection system

Fig 2 The first one is data collation, here abundant data is collected from different sources. The next one preprocessing which basically means cleaning, transforming and feature engineering on the data before there is any analytical work. This is the first step of feature selection, which provides us to treat the most important features to better the performance and efficiency issues on the model. Then data is divided into two parts: training and testing. Training data set is used to construct models and the test data set works as a validation to predict the performance of the model. Among various algorithms explored, the K-Nearest Neighbors (KNN) model emerged as the most effective, demonstrating superior accuracy in classification tasks. which is a most straightforward technique that does classify a point of data on the basis of the value among its neighboring points. The model which performed best shall undergo a real-life environment test. From there on, we shall constantly monitor its effectiveness and keep retraining it on the latest available system capabilities based on up-to-date data to make it best suited under any scenario; henceforth using this model to create predictions in actuality, in the realms of serving as feedback in an effective and predictive way for acting as an enhanced decision-making one that will provide insights and predict the new data.

SOFTWARE DESCRIPTION

Four state-of-the-art machine learning models were used in this project to make a robust and portable crop selection system. The responsible for analyzing the high-level environmental and soil data into more precise recommendations for farmers, these models are created by K-Nearest Neighbours (KNN), AdaBoosting, Logistic Regression as well as Support Vector Machine (SVM).

K-Nearest Neighbors (KNN) is a simple classification algorithm that uses votes from the k-alclose neighbors for classification of new instance based on distance. The closer neighbor points are together, the more they will be similar; so KNN is best for pattern recognition. KNN is a type of non-parametric model that does not assume anything from the data distribution hence it can fit pretty much many datasets. KNN: KNN really does excel for very small to midsize datasets where sane decision boundaries are not a grave concern and on the other end of spectrum seems to be performing pretty good at Multiclass classification more often than not. In this case, the KNN outperformed all the other models with an accuracy of 97.05% and can be seen as able classifying data points correctly.

A Support Vector Machine (SVM) is a supervised learning algorithm that finds the best hyperplane to classify data points by mapping them in a higher dimension so that we can separate classes with maximum margin making minimum misclassification. Especially Efficient for higher dimensional data and performs great when you have a distinct region to separate each class from each other The model works exceptionally well when the data aligns to a patterned manner. In the current study, SVM performed reasonably with an accuracy of 96.81% comparatively less than that of KNN. But it made few more errors so it appears that the Boolean classifier is strong, but not as versatile for the dataset as KNN.

Logistic Regression (LR) is the statistical model for predicting probabilities, it works on binary classification problem but it can be extended for the multi class classification. It works on linear decision boundary and uses the sigmoid function that maps outputs between 0 to 1. LR assumes a linear relationship between input features and the class labels, which will not work for datasets with non-linear decision boundaries. LR when in this case gave over 91.82% accuracy which was much less than what we got for KNN and SVM. The low accuracy shows that the data had complex patterns that logistic regression failed to learn really well.

AdaBoost is an ensemble learning approach, which improves prediction by combining multiple weak classifiers into a single strong classifier by labeling misclassified data points more weight on each iteration. Its especially helpful for classes of imbalanced data sets (when normally all targets are even) and the purpose of improving classification is accuracy over time. In this study, however ada boost perform badly with an accuracy of only 9.55%, which stated that dataset not well suited for boosting techniques.It indicates that AdaBoost either overfitting or underfitting because of its weak learners which made it useless in this case.

Consolidated Model Performance

The tested algorithms of which KNN turned out to be the best performer by achieving 97.05% accuracy clearly showing its aptitude in handling such complex decision boundaries. At 96.81%, SVM came very close, showing that it is not a strong competitor but is performing dissonantly with significantly more wrong classification. Logistic Regression: Although in numbers 91.82% accuracy, it was beaten because it relies on linear decision boundaries = bad (ie. not suited for non-linear data) The MLP classifier had some performance issues, probably caused by bad hyperparameters even though it seemed quite promising in nature. AdaBoost failed completely with 9.55 % accuracy indicating that boosting did not work with the dataset. This suggests KNN remains the most sane algorithm for this case, surpassing SVM, LR, MLP and AdaBoost in classification accuracy.

IV. CONCLUSION AND RESULTS

The amalgamation of IoT and machine learning in agriculture has disrupted traditional farming by standing as a frontier to precision and sustainability. In this new agricultural scheme, ESP32 microcontrollers and various sensors that monitor soil moisture, temperature, and humidity have been employed for real-time data monitoring; with machine learning algorithms-k-NN these systems provide accurate crop recommendations and utilize resources optimally. The successful results stand with high performance and reliability, effective predictiveness in crop classification, and thus automation in various irrigation systems to significantly reduce water wastage and enhance productivity. This hybrid system provides farmers with valuable insights into labor-saving, high crop yield, and sustainable farming solutions that are beneficial to the environment in the context of changing conditions.

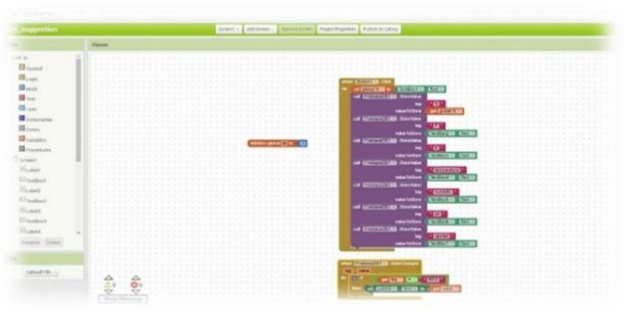
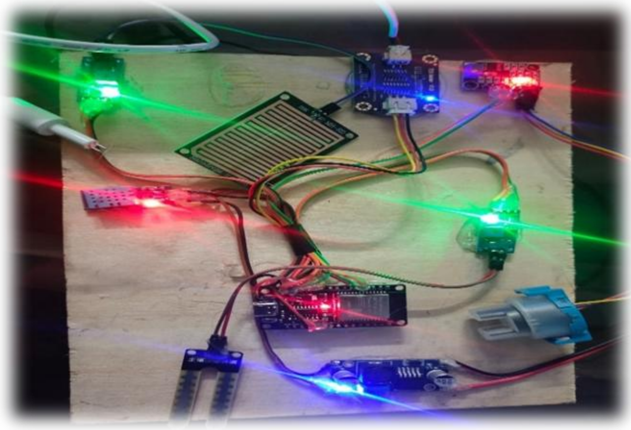


Fig. 3. Proposed crop selection using MIT AI2 App

Fig 3 The MIT AI2 Companion App, developed using MIT App Inventor, is used to create a mobile application for displaying the output of the crop recommendation system. This app allows users to view the predicted results and recommendations directly on their mobile devices, providing a user-friendly and accessible interface. The app enhances the usability of system by enabling the real-time interaction and display of results, making it convenient for end-users, especially those in agricultural sectors.

Fig. 4. Recommends the suitable crop based on the inputs

Fig 4 All collected data – soil, TDS, turbidity, temperature, humidity, and rainfall will be displayed on the mobile app in real-time. This enables easy monitoring and informed decision-making for better environmental and agricultural management.



V. FUTURE WORKS

Improved application of precision technology is in sight, with systems complete with appliances that surpass human vision, camera technology that is tuned to perfection, and accurate weather forecasting such that a less disruptible farmer's schedule can be planned ahead of time. Since these systems will indeed require fast-speed connections in areas of remoteness all the way to the security of data, such development facilitated through cutting-edge use of blockchain technology. Artificial intelligence (AI) could be a catalyst in rhizophobic pest and weed detection, consequently, being the method of control for the pests and weeds. Other systems will also aim to combine the crops they intend to plant, appearing as companion systems, while maximizing space utilization and enhancing soil health. These kinds of systems will use green sources of energy, such as solar power, and will be easy to operate by farmers worldwide, irrespective of their language, safety being unfortunately the last-and at that-the consideration of paramount importance within the systems that will store their scientific information.

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