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IoT Enabled Smart Agriculture using Digital Dashboard

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Abstract

Objectives: To develop an IoT-based smart device to retrieve soil and water parameters by collecting and storing sensor-based data and to make crop recommendations. The primary goal of this work is to create a link between farmers and their farms. **Methods:** This work produces a smart device to predict suitable crop based on several parameters using a technical approach that makes use of the Internet of Things, Machine learning algorithms, and Sensor Networks. The Gaussian Naive Bayes algorithm is used in the Prediction module to predict suitable crop types. Several components are used to make an IoT system like Raspberry Pi, DHT11 sensor, soil moisture sensor, pH sensor, LDR sensor, Ultrasonic sensor, NPK sensor, and other components to collect data related to soil properties and weather conditions. Soil samples were collected from different fields and tested by switching the IoT kit and the message will be passed to the field owner. Dataset is used from the Kaggle database to train the model for crop prediction. Seven parameters have been taken in the trained dataset such as pH, N, P, K, temperature, humidity, and rainfall. All these values were collected through soil properties sensors and weather condition sensors. Existing traditional methods like soil testing laboratories involve lengthy and costly procedures for soil testing and crop prediction. The proposed system will produce results faster at a lesser cost while making digital data available on the cloud server. **Findings:** The proposed system performs efficiently when compared to the previous report with 99.3% accuracy over 97.18%. The existing approach for lab-based soil testing takes approximately 5 – 8 days; whereas the proposed system using an IoT kit can perform n number of soil tests on a single device and the results can be viewed instantly. **Novelty:** Most of the existing systems like smart agriculture system and smart irrigation system use Arduino Uno for soil test which doesn't support high-end sensors and works only with desktop computer traditional programs. The existing system for nutrient identification uses a soil Ec sensor and color sensor to find N, P, and K values which include multi-steps and are time-consuming. The proposed system uses Raspberry Pi for soil tests which are more compatible with implementing the latest machine-level algorithms. In this system, the NPK sensor is used instead of soil Ec sensor and color sensor which will give the N, P, and K values directly. In the existing system, accuracy is 95% with the Random Forest algorithm but the proposed system will give 99.3% with the Gaussian Naïve Bayes algorithm.

Keywords: Internet of Things(IoT); Smart Agriculture; Raspberry Pi; Sensors

1 Introduction

In the Indian economy, agriculture is an important factor that will feed the whole population. It connects all the country's related organizations. In Indian agriculture, farmers follow traditional procedures that affect crop growth and yield of a crop. The financial failures they face are commonly due to the wrong selection of crops. Technology is not implemented in agriculture industries because of the economic condition of most Indian farmers[(1)] . To deal with these problems, the Internet of Things and Machine learning techniques are highly required. Recommend suitable crops and mapping this classification technique is a big task[(2)]. Factors impacting the recommendation of crops are mainly soil characteristics, macro-nutrient composition, micronutrient composition, pH value, humidity, rainfall, temperature, and many such[(3)],[(4)]. Nowadays Machine Learning is capable enough to execute multi-class classification, multi-label classification, multivariate regression, and many such advanced tasks. Many classification algorithms exist like decision trees, k-nearest neighbors, logistic regression, support vector machines, AdaBoost, XGBoost, and many such which can proficiently perform multi-class classification. There exist few optimum values for each parameter to predict the suitable crop[(5)]. This paper focuses on crop recommendations based on 22 types of crops that are being recommended. Thus, a multiclass classification approach is used to solve the problem. Further, the proposed model presents a generalized approach to use ensembling using the majority voting technique to perform recommendation tasks. This paper initially presents a few research works in this domain, and it gives a framework for crop recommendation.

Dash et al.[(6)] presented the inevitability of micronutrients, macro-nutrients, and weather conditions in predicting the suitable crop that can be grown on that soil. The authors used support vector machines and decision tree classifiers to predict the suitable crop. Also, the authors with the assistance of curve fitting and regression analysis presented the prediction of crops. Further, the paper entailed an android-based framework to leverage IoT-based smart agriculture systems. Certain correlation patterns were plotted to identify features that contribute less towards classification. Further, the relation between the nutrients i.e., nitrogen (N), phosphorus (P), and potassium (K) were presented diagrammatically. The authors also visualized the user interface of the android based IoT smart agriculture application. The highest accuracy was obtained with the use of a support vector machine integrated with the kernel i.e., 92%. The predicted crops included rice, wheat, and sugarcane.

Khushi Kumar et al.[(7)] proposed a tool for a crop prediction system for a particular soil type. Rainfall, pH, temperature, moisture, humidity, NPK, and other variables can all be monitored using Internet of Things sensors. Real-time data is taken each hour and stored on the cloud. Crops will be predicted using an API that has been trained using algorithms. Since random Forest has the highest accuracy, it is utilized to estimate the crop here. For farm soil analysis, Automatic Soil-Testing for Agriculture was developed. The kind of soil affects humidity, moisture content, pH values, and temperature. The soil parameters are compared to data from the Department of Agriculture that has been stored previously. The model also includes information on crops that are best suited to specific soil types. One limitation is Arduino Uno is used, instead of that, we can use the latest devices.

Navod Neranjan et al[(8)] compared five predictive ML algorithms— K-Nearest Neighbors (KNN), Decision Tree (DT), Random Forest (RF), Extreme Gradient

Boosting (XGBoost), and Support Vector Machine (SVM)—to identify the best-performing ML algorithm on which to build crop recommendation platform as a cloud-based service to offer precision farming solutions that are free and open source, as will lead to the growth and adoption of precision farming solutions in the long run. The proposed system is a web application-based system. Once the web application is ready, deployment of a system using the local Flask web server and testing its functionality, and whether it was accepting user input with appropriate validations and giving the output as expected. Demonstrated the integration of ML into precision farming, as well as other enabling technologies, like the cloud, and showcased all the steps involved in designing a cloud-hosted ML-powered crop recommendation platform that can help farmers in deciding which crops to harvest according to the local environmental conditions.

2 Methodology

In the proposed system DHT11 sensor, Rain Detection sensor, NPK sensor, Ultrasonic sensor, Soil Moisture sensor, and LDR sensor are connected to the Raspberry Pi with the help of jumper wires. Program written and executed in Python programming language. Raspberry Pi is connected to the ThingSpeak cloud server. Data that is received through the sensors will be stored in the ThingSpeak cloud server. The web application is implemented using the Django framework. All the values collected through the sensors which are stored in the ThingSpeak cloud will be fetched, using the Gaussian Naive Bayes algorithm crop recommendation will be given to the field owner in the form of a text message. Environmental condition analysis has been done based on temperature and humidity values.

2.1 Architecture

2.1.1 Block diagram

The concept described in Figure 1 is explained in detail regarding connections of an IoT system. The essential sensors are integrated into a Raspberry Pi and put all the sensors in a soil sample. The DHT11 sensor, LDR sensor, water level detecting sensor, and pH sensor, NPK sensor, rain detection sensor, soil moisture sensor was connected to the Raspberry Pi to make an IoT system. The Raspberry Pi delivers the data to the cloud (Thingspeak) which was collected through the sensors. Gaussian Naive Bayes algorithm will apply for the sensor data which is fetched from the ThingSpeak cloud to give crop recommendations and text messages will be forward to the farmer. Opportunity is given to the farmer to monitor their crop on regular basis using weather condition data collected through the and can take appropriate action.

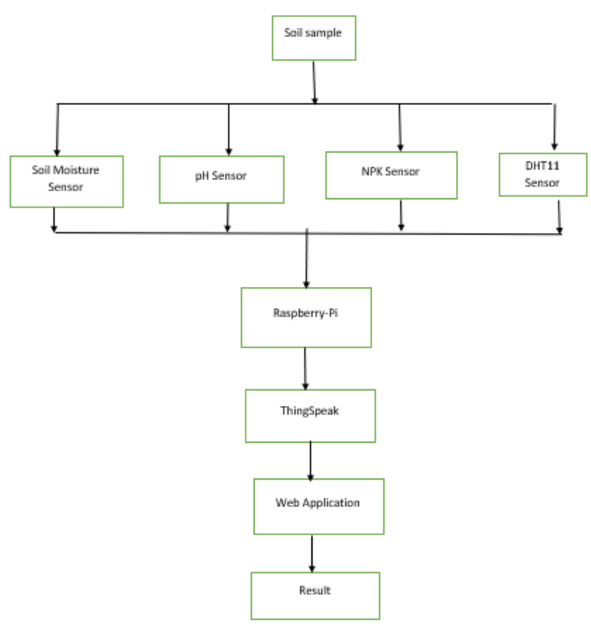


Fig 1. Block Diagram: IoT based smart agriculture using digital dashboard

2.1.2 Flowchart

The concept is described shown in Figure 2. Is a flowchart of an IoT system. The Raspberry PI delivers the data to the cloud (ThingSpeak) which was derived from the sensors. Data from sensors is compared to the crop's criteria, and the farmer is allowed to monitor the crop regularly so that they are aware of any changes in conditions and can take appropriate action. Subsequently, through the web application, live values will be collected from the cloud, and the Gaussian Naïve Bayes algorithm will be used to predict the type of crop suitable for the crop.

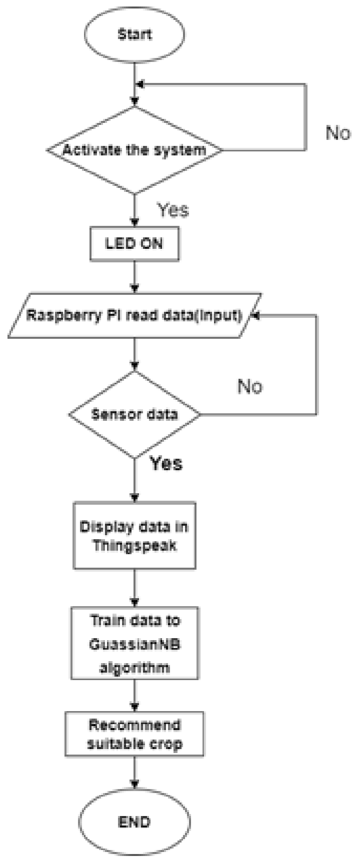


Fig 2. Flowchart

2.2 Module Description

2.2.1 Weather prediction system

The working model is to monitor weather conditions in a particular spot, which includes ambient temperature and rainfall detection. IoT has been the new technology used for measurement, gathering, supervising, and integrating the framework towards the rest of the globe, and it's a quite sophisticated and scalable workable alternative for unlocking data over the web.

The climatic conditions estimation algorithm might well forecast the wind conditions depending on environmental parameters such as temperature, humidity, and rainfall. For predicting weather information, the system employs a humidity and temperature sensor. The integrated sensor data are made available to a Thingspeak cloud platform using an RPi. Personal information is also represented in a monitoring device.

2.2.2 Crop recommendation

Crop recommendation is an important factor for the farmers to get good crop yield. The proposed system will give suggestions to the farmer as to which crop is suitable for the soil. Gaussian Naïve Bayes algorithm is used to crop recommendation shown in Figure 3.

2.2.2.1 Gaussian Naïve Bayes.

The Naïve Bayesian methodology is a technique for determining order in binary and multi-class problems. The Naïve Bayesian technique is extremely simple to use when estimated values are tried to present in symmetric or explanatory form. The idea of a single component in a class, according to a Bayesian Classifier, has nothing to do with the presence of any other element. Naive Bayes employs Statistical models, which are useful when the shape of the data well springs is high. When combined with content-based filtering, Naïve Bayes can be used to make some serious predictions, determine the outcome of many lessons of target attributes, filter spam, and aid in the development of recommendation engines. Naive Bayes can be extended to real-valued attributes by assuming a Gaussian distribution. Gaussian Naïve Bayes classifier is an extended form of principal Component analysis (pca. Other capabilities can then be used to assess the distribution of data, but the Gaussian (or Normal) proportion is the easiest to use because it only requires you to evaluate the summary statistics from having a good training phase.

```
df=pd.read_csv('crop_recommendation.csv')

# Remove outliers
Q1= df.quantile(0.25)
Q3= df.quantile(0.75)
IQR= Q3-Q1
Df_out= df[~((df<(Q1-1.5*IQR)) | (df>(Q3+1.5
IQR)).any(axis=1)]

# Split Data to Training and validation set
Target='label'
X_train.X_test, Y_train,
Y_test=read_in_and_split_data(df,target)
#Train model
Pipeline = make_pipeline(StandardScaler(), GaussianNB())
Model = pipeline.fit(X_train,Y_train)
Y_pred=model.predict(X_test)
Conf_matrix=confusion_matrix(Y_test,Y_pred)
Classification_metrics(pipeline, conf_matrix)
```

Fig 3. Crop Recommendation module

2.2.3 ThingSpeak cloud

ThingSpeak is a platform for IoT analytics tool for aggregating, visualizing, and analyzing live data streams. ThingSpeak allows you to send data from your devices, generate real-time visualizations of live data, and set alarms.

1. **Cloud Setup**

   (a) Configure ThingSpeak
   (b) Create a free Math Works account or login with an existing account to use ThingSpeak.
   (c) Choose the ThingSpeak channel where you want your data to be sent. To learn how to create a new channel, see Collect Data in a New Channel.
   (d) For the specified channel, record the following:
   (e) The ID of the channel can be found at the top of the channel display.
   (f) Write your API key, which you can find under the API Key your channel view.

2. **Create a connection on the Internet of Things (IoT).**

   (a) Go to your application in the Things Network Console and select Integrations>Add an Integration >ThingSpeak.
   (b) In the Authorization area, type your write API key, and in the Channel ID field, type your channel ID.

Pictorial Representation of ThingSpeak cloud has shown in Figures 4 and 5.

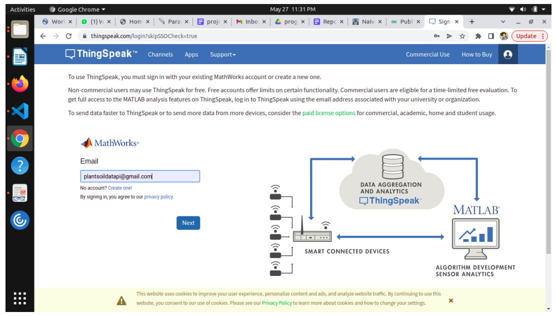


Fig 4. ThingSpeak Login

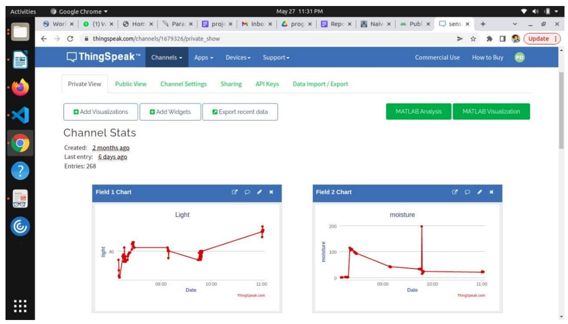


Fig 5. LDR and Soil moisture analysis

2.2.4 Django setup

Django is an elevated Scripting language configuration file that tries to encourage rapid expansion and straightforward, serve a specific purpose. It was created by experienced programmers to all most of the others related to internet progression, allowing you to focus on establishing your app. It is transparent and totally independent.

The MVT design pattern is followed by Django (Model View Template).

- Model-The information you want to display, which is commonly data from a database.
- View-A request handler that, in response to the user's request, returns the appropriate template and content.
- A text file (like an HTML file) that contains the layout of the webpage, as well as logic on how to show the data.

2.2.5 System hardware setup

The connection of Raspberry Pi with sensors is shown in Figure 6. The pH sensor, soil moisture sensor, and DHT11 sensor are connected to Raspberry Pi through the GPIO pins. Male-male, female-female, and male-female jumper wires are used to make the connections.

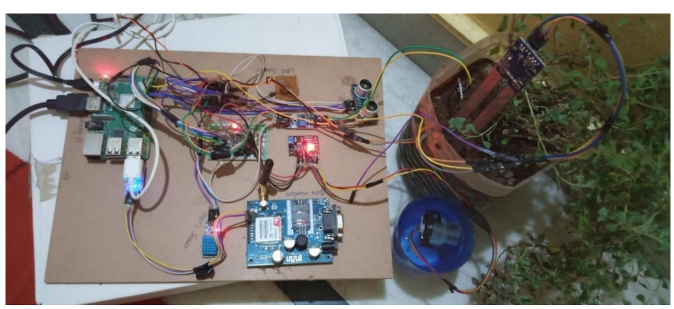


Fig 6. Hardware setup

This microprocessor-sensor setup in turn is connected to the monitor with an HDMI cable through the HDMI out port. The keyboard and mouse are connected to Raspberry Pi through the two USB-A- Ports. The SD Card for the Raspbian OS is inserted in the micro-SD card slot. Internet or Wi-Fi connection is supplied to the microprocessor through an Ethernet Out port. Finally, the power supply is provided with the USB charging cable through a 5V Micro USB Power port. Dataset Description. This data set was created by combining data from India's rainfall, climate, and fertilizer datasets.

2.2.5.1 Information about attributes and Dataset.

N - Nitrogen content in soil P - Phosphorus content in soil K - Potassium content in Soil Temperature is the measurement of the temperature in degrees Celsius, pH-soil pH value Humidity-relative humidity in percent Humidity-relative humidity in percent Humidity relative humidity in percent Humidity - relative humidity in percent Humidity are the attribute sin dataset shown in figure. The format of the dataset is in .CSV file format and size of the dataset is 141KB. Total 22 types of crops present in the database. Total number of rows in the dataset is 2200 in Figure 8 . Total 12,752 downloads are there for this dataset. Authenticity proof image shown in below Figure 7.

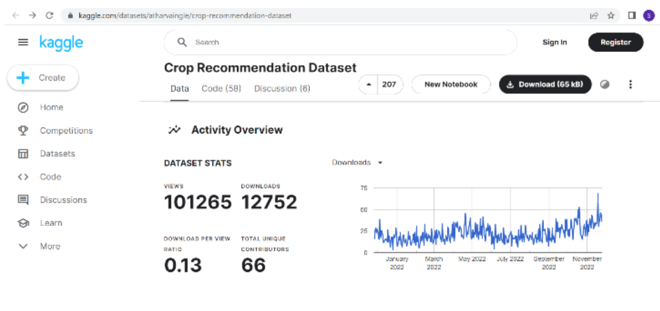
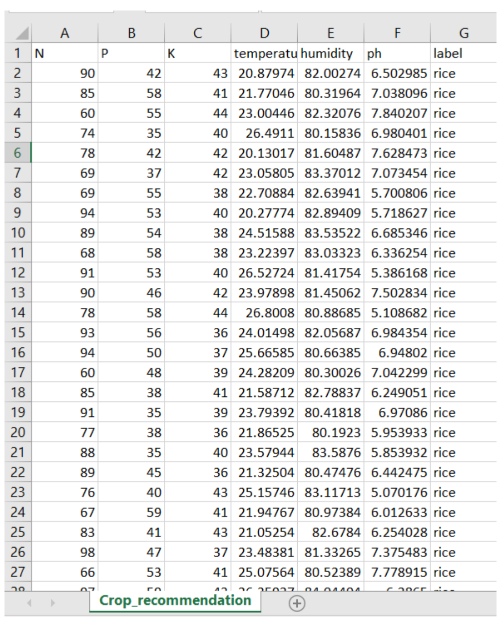


Fig 7. Crop recommendation dataset proof



	N	P	K	temperatu	humidity	ph	label
2	90	42	43	20.87974	82.00274	6.502985	rice
3	85	58	41	21.77046	80.31964	7.038096	rice
4	60	55	44	23.00446	82.32076	7.840207	rice
5	74	35	40	26.4911	80.15836	6.980401	rice
6	78	42	42	20.13017	81.60487	7.628473	rice
7	69	37	42	23.05805	83.37012	7.073454	rice
8	69	55	38	22.70884	82.63941	5.700806	rice
9	94	53	40	20.27774	82.89409	5.718627	rice
10	89	54	38	24.51588	83.53522	6.685346	rice
11	68	58	38	23.22397	83.03323	6.336254	rice
12	91	53	40	26.52724	81.41754	5.386168	rice
13	90	46	42	23.97898	81.45062	7.502834	rice
14	78	58	44	26.8008	80.88685	5.108682	rice
15	93	56	36	24.01498	82.05687	6.984354	rice
16	94	50	37	25.66585	80.66385	6.94802	rice
17	60	48	39	24.28209	80.30026	7.042299	rice
18	85	38	41	21.58712	82.78837	6.249051	rice
19	91	35	39	23.79392	80.41818	6.97086	rice
20	77	38	36	21.86525	80.1923	5.953933	rice
21	88	35	40	23.57944	83.5876	5.853932	rice
22	89	45	36	21.32504	80.47476	6.442475	rice
23	76	40	43	25.15746	83.11713	5.070176	rice
24	67	59	41	21.94767	80.97384	6.012633	rice
25	83	41	43	21.05254	82.6784	6.254028	rice
26	98	47	37	23.48381	81.33265	7.375483	rice
27	66	53	41	25.07564	80.52389	7.778915	rice

Crop_recommendation

Fig 8. Dataset

3 Results and Discussion

According to [9] this paper the accuracy of crop yield prediction is compared for each of the algorithms. With a 95 percent accuracy, the Random Forest method was shown to be the best for the provided dataset with 95%.

Evaluation of Performance-80% of the data set will be used for training, while 20% will be used for validation. Validation and Gaussian NB outperform other classification models like Random Forest 97.5, Support Vector Machine 95.9, Logistic Regression 95.45 and etc. [7] in terms of accuracy. NB Gaussian (99 percent accuracy score) Performance Outcomes Score for training: 99.5 percent Score for Validation: 99.3% shown in Figure 9.

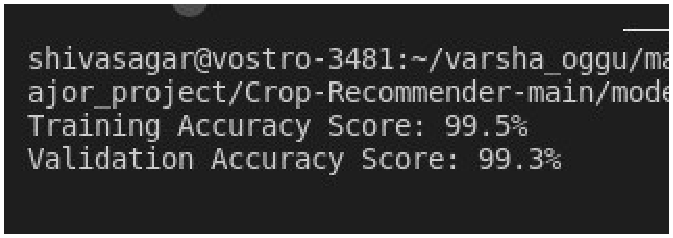


Fig 9. Crop prediction accuracy

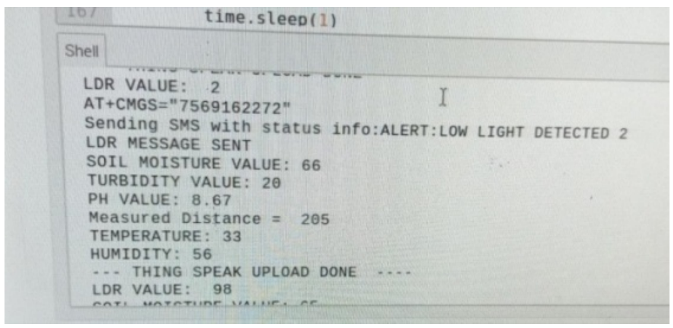


Fig 10. Sensor Data

Data collected through the sensors from field will be uploaded on the ThingSpeak cloud and it will give message to the farmer shown in Figure 13.

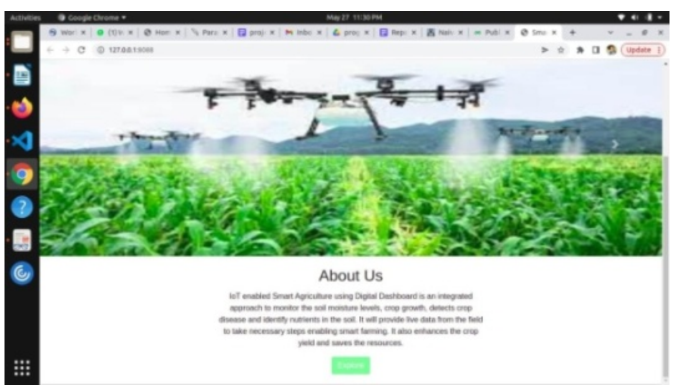


Fig 11. Front page

Figure 11 shows front page and Figure 12 shows the explore page with 3 modules. There is a link that directs to the data set used for the prediction of crops and directs to the crop monitoring and prediction of disease.

This system collects data through NPK sensor, temperature and humidity sensors and pH sensor shown in Figure 10. Gaussian Naive Bayes algorithm will be applied for the above-mentioned parameters and crop recommendation will be given.

Analysis of pH, temperature, and humidity: Based upon the values collected through sensors analysis has done for pH, temperature, and humidity values shown in Figure 14.

SMS notification: The GSM module sends an SMS notification to the mobile number after the sensor data reached a certain threshold and it alters the user with the live value. Figure 15 shows the SMS notification on the user's phone.

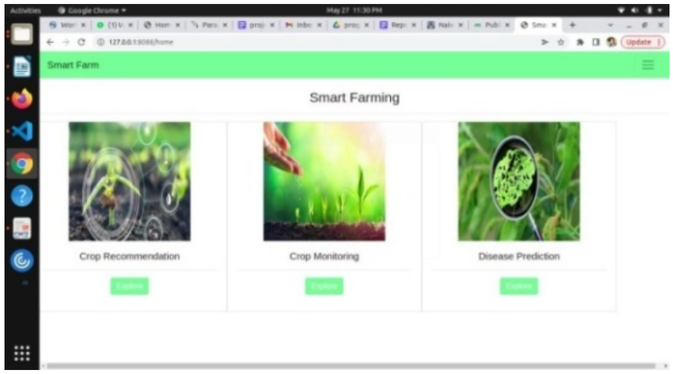


Fig 12. Explore page

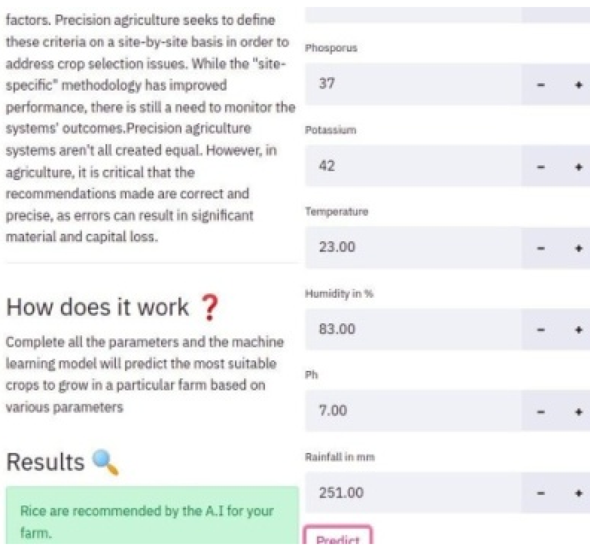


Fig 13. Crop recommendation page

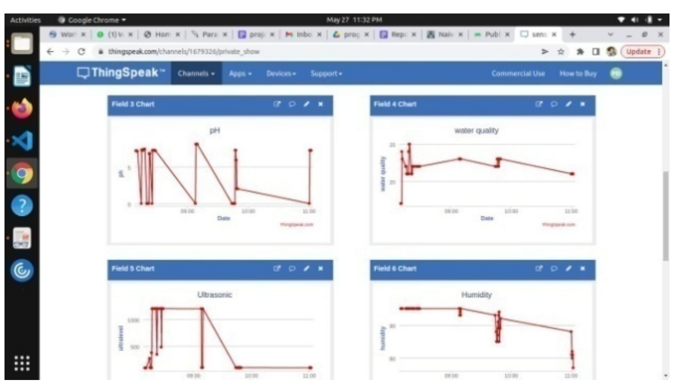


Fig 14. Analysis of pH, water quality, Ultrasonic and Humidity

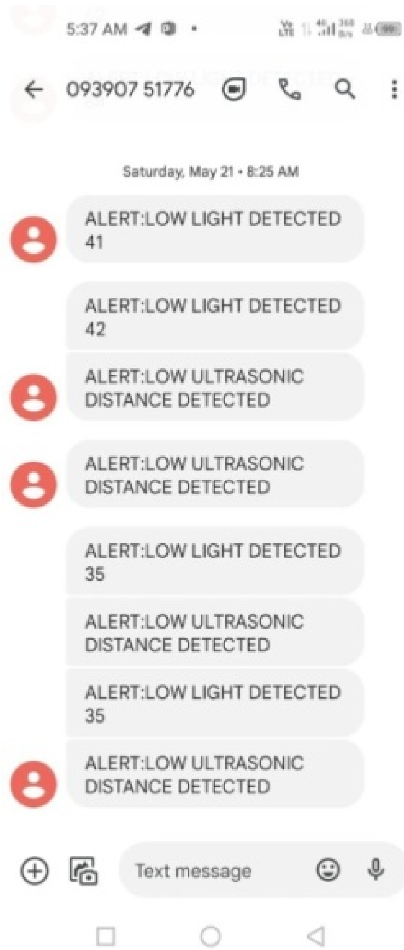


Fig 15. SMS notification

This work is done to give crop recommendations and crop growth in one system which is not there in the previously implemented work like IoT Enabled Crop Detection Systems using Soil Analysis. In previously implemented systems, mostly Arduino Uno and Node MCU devices were used to develop a system like a Crop Recommendation system using IoT and Machine Learning. In the proposed work IoT system is developed using Raspberry Pi and various sensors whose values are necessary to estimate the conditions of the crop.

4 Conclusion

This study reports on a smart agricultural device consisting of Raspberry Pi and various sensors whose values are necessary to estimate the conditions of the crop. The Gaussian Naïve Bayes algorithm is used to recommend the crop and make a suitable choice by comparing each set of data with the trained data using any kind of distance function and further classifying it into one cluster. This system has the potential to assist farmers in reducing such losses. Instead of creating favorable conditions for the crop, we can use a reverse ideology and choose crops based on the resources we have.

The limitation of this work is that it is a single entity user since it can only send the result to a single user at a time. This work can be extended with the implementation of Mobile Applications with multiple users.

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