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Agriculture Cyber Physical System for Crop Recommendation

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Abstract: ***Agriculture plays a significant role in the Indian economy. Agriculture employs more than 60% of India's population, and agriculture generates one-third of the country's revenue. As a result, it plays a vital part in the country's development. A variety of agricultural difficulties continue to hamper the country's progress. Choosing modern agriculture that integrates modern styles could be one solution to these issues. As a result, Agriculture Cyber Physical Systems, which combine IoT with other technologies such as Artificial Intelligence and Machine Learning, can make agriculture smarter.***
The Agriculture Cyber Physical System can help in increasing crop yields, reducing water waste, and reducing fertilizers overuse, among other things. This study is different in that it measures variety of aspects of the agricultural field that have a direct impact on crop choices. Second, it sends this information to a server, which then uses it to forecast farm-ready yields.
Keywords: Agriculture Cyber Physical System, IOT, Artificial Intelligence, Machine Learning., etc.

I. INTRODUCTION

In this advanced world, the majority of farmer have absence of legitimate information in regards to cultivating and horticulture making it difficult. Most piece of cultivating and farming related exercises depend on expectation and anticipation. At the point when it fails, farmer needs to bear huge losses. With depleting resources, reducing land sizes and increase in input and labour costs, combined with the uncertainty of various factors like weather, market prices etc., agriculture in India has become a profession which is full of risks. The advancements in technology must be worked upon across various disciplines and it's already shown dramatic improvements in many fields. Agriculture, on the other hand, has not got the benefit of such innovations. Our intention from this project is to at least one part of agriculture processes, that is selection of best crop for the farm. Traditionally farmers select the crop based on various factors such as market demand, and for the convenience farmers select the crop which gives most profit and requires less investment, this results to a problem of monoculture. Monoculture is that the agricultural practice of growing one plant species across a huge acreage. Instead of growing a spread of crops, as farmers have done throughout most of human history, they instead tend to land that produces only one type of crop.

A. Agriculture Cyber Physical System

In its most basic form, a Cyber Physical System (CPS) is a platform that consists of a mechanical system controlled by computer algorithms and is strongly connected with the Internet and its networked users. The platform's physical-mechanical components, which are represented by smart sensors and actuators, and software components, which are represented by computer and networking devices, are inextricably linked. Agriculture cyber-physical systems (ACPSs), or CPSs built and used in agriculture, may collect fundamental and timely information with high granularity on the climate, soil, and crops, allowing for more accurate agricultural management systems.

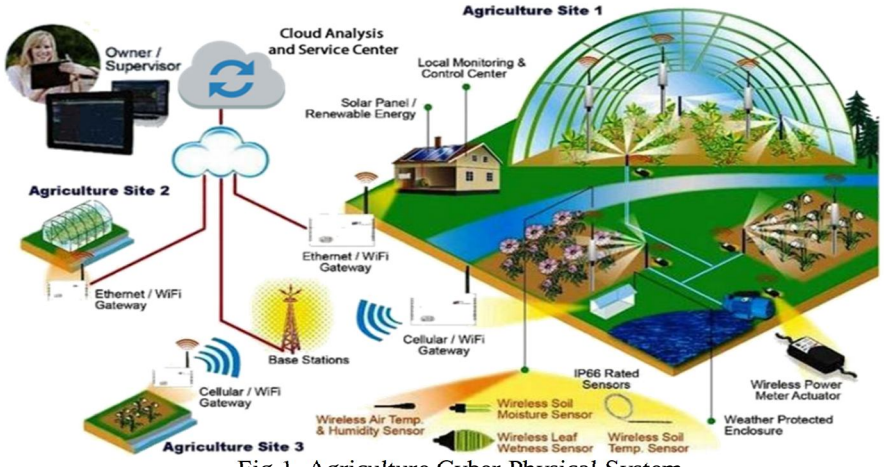


Fig 1. Agriculture Cyber Physical System

B. Internet of Things (IOT)

The Internet of Things (IoT) is the networking of physical items with electronics built in their architecture that allow them to communicate and interact with one another and with the outside world. IoT-based technology will deliver advanced levels of services in the next years, effectively changing how people live their lives. Medicine, energy, gene therapies, smart cities, and smart homes are just a few of the category examples where IoT is well-established. The Internet of Things (IoT) revolutionized every aspect of the average man's life by making everything smart and intelligent. The Internet of Things (IoT) is a self-configuring network of things.



Fig. 2. IOT Application in Agriculture

C. Artificial Intelligence

Artificial Intelligence or AI which stands for intelligence refers to systems or machines that mimic human intelligence to perform tasks and can iteratively improve themselves based on the information they collect. AI manifests in a number of forms. Artificial intelligence technology is supporting different sectors to boost productivity and efficiency. AI solutions are assisting to overcome the traditional challenges in every field. Likewise. AI in agriculture is helping farmers to improve their efficiency and reduce environmental hostile impacts. The agriculture industry strongly and openly embraced AI into their practice to change the overall outcome. AI is shifting the way our food is produced where the agricultural sector's emissions have decreased by 20%. Adapting AI technology is helping to control and manage any uninvited natural condition



Fig. 3. Artificial Intelligence and Machine Learning in Agriculture

D. Machine Learning

Machine learning is the branch of computer science which is used to construct algorithms which exhibit self-learning property i.e., learning which is done by the machine itself hence the term "Machine Learning". It is considered to be one of the major areas under Artificial Intelligence. For a machine to become intelligent like a human mind, it has to first think and learn like a human. Human mind learns from past data and experiences that it is exposed to and based on that it takes decisions in future.

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E. Problem Statement

Monoculture farming has become more common over the last few decades, and while it often helps improve a farmer's yields initially, it is causing great harm to the local environment, as well as the world as a whole. To eliminate the problems associated with monoculture like hinger use of pesticides, excessive use of fertilizers, soil degradation, loss of fertility, Overuse of Water. etc., we are going to develop a solution using the technologies like IOT, Artificial Intelligence and Machine Learning etc.

F. Objectives

1) Update Farmers with the new technology and to avoid the reliance on anticipation and to avoid manual labour.
2) To meet the difficulties such as severe weather conditions and advancing climate change, and environmental consequences resulting from intensive farming practices.
3) Making the process of measuring the properties of soil and atmosphere using the techniques of IOT and Wireless sensor network.
4) To reduce wastage of water and enhance productivity of crops by providing them ideal crop and ideal condition.
5) Design a system which connects the farm with a platform where farmer can easily determine suitable crop for the planting.

G. Methodology

1) Research and Study of Literatures and Research papers related to the project topic.
2) Analysis of the findings from literature review and finalizing the workflow of the project.
3) Collection of all the hardware and software components required for the project.
4) Designing and Assembling the Sensors and other hardware components for making complete IOT System.
5) Building the Machine Learning Model using training dataset, and checking the accuracy of model using testing data.
6) Integrating IOT system and ML Model inside one graphical user interface by which we can monitor the collected data form farm and use this data to predict the best suitable crop.
7) Testing the whole system, and correction if any.

II. LITERATURE REVIEW

1) "Enhancing precision agriculture by internet of thing and cyber physical systems. Authors: Roberto Fresco, Gianluigi Ferrari, Published in 2018"

This paper explores all the cutting-edge challenges and solutions required to implement the digital agriculture framework, intended as the evolution from Precision Farming to connected, knowledge-based farm production systems, in a context where digital technologies are first-class elements for the automation of sustainable processes in agriculture.

2) S. Siva Chandran, K. Balakrishnan, and K. Navin's "Real Time Embedded Based Soil Analyzer"

In this paper, Real time embedded based soil analyzer is used to do analysis of various soil nutrients parameters with the help of the pH value and the, soils Electrical Conductivity (EC). Depends on the pH value, The availability of various nutrients is calculated, adding today's technology towards agricultural fields, a cost-effective Real Time Embedded Based Soil Analyzer is to be designed with a rapid and dependable automated system that uses the pH value to analyses various soil nutrients.

3) "Farmer's Handbook on Basic Agriculture, A holistic perspective of scientific agriculture by Dr. P. Chandra Shekara, Dr. N. Balasubramani, Dr. Ajit Kumar, Bakul C. Chaudhary, Dr. Rajeev Sharma"

An Organization of Ministry of Agriculture, Government of India brought this paper Farmer's Handbook on Basic Agriculture out to impart technical knowledge on Basic Agriculture to farmers to provide holistic perspective of scientific Agriculture. The first chapter, "General circumstances for crop cultivation," discusses the basic needs of farmers and the farming industry by offering basic information of Good Agricultural Practices (GAP) and raising farmers' awareness of essential elements in crop choices and cropping patterns.

4) Ciprian-Radu Rad, Olimpiu Hancu, Ioana-Alexandra Takacs, and Gheorghe Olteanu, "Smart Monitoring of Potato Crop: A Cyber-Physical System Architecture Model in the Field of Precision Agriculture."

In this paper authors have presented a precision agricultural management integrated system architecture for monitoring vegetation condition of potato crop based on Cyber Physical System architecture and design technologies. The proposed system allows farmers to follow the evolution of certain parameters of interest and take appropriate decisions in order to increase agricultural productivity. Finally, the concept presented in this paper have represented the start for others researchers like us in the field of precision agriculture

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5) *"Smart Farming Prediction Using Machine Learning by S.R. Rajeswari, Parth Khunteta, Subham Kumar, Amrit Raj Singh, Vaibhav Pandey, Published on 7 May, 2019"*

In this paper, authors explored the machine learning concepts that can help in improving agriculture. This paper studies various machine learning algorithms which can be used for agriculture data

6) *"Artificial Intelligence in Agriculture by, Arka Bagchi Associate Consultant, Mindtree"*

In this article, it is discussed that how AI can change the agriculture landscape, the application of drone-based image processing techniques, precision farming landscape, the future of agriculture and the challenges ahead. AI-powered solutions will not only allow farmers to do more with less, but they will also increase crop quality and speed up the time it takes for products to reach market.

III. REQUIREMENTS ANALYSIS

A. *Input Parameters*

We are collecting the following data because there are numerous elements that influence the decision of choosing the best crop for the farm.

1) *Temperature:* The intensity of heat energy is measured by temperature. Most agricultural plants require a temperature range of 15 to 40oC for best growth. dispersion of crop plants and vegetation Temperature has a significant impact on crop germination, growth, and development.
2) *Humidity:* Water is present in the atmosphere in the form of water vapour, which is commonly referred to as humidity. The ratio of the amount of moisture present in the air to the saturation capacity of the air at a certain temperature is known as relative humidity.
3) *Soil Moisture:* Water is a key component of a growing plant that it takes from the soil. Photosynthesis requires the presence of water. Plants can use the moisture range between field capacity and permanent wilting point. Clay soil will have more available moisture than sandy soil. Soil water aids in a variety of chemical and biological processes in the soil, including mineralization.
4) *Soil Minerals and Organic Matter:* Soil mineral content is formed through the weathering of rocks and minerals as different-sized particles. These are the sources of plant nutrients, such as calcium, magnesium, sulphur, manganese, iron, potassium, phosphorus, and nitrogen. It provides crops with all major, minor, and micronutrients. It improves the soil's texture.
5) *Soil pH Concentration:* The pH (hydrogen ion concentration) of the soil determines the soil reaction. Crop growth is influenced by soil pH, and neutral soils with a pH of 7.0 are optimum for most crops. Acidic soils are possible (7.0). Plants are harmed by low pH soils due to the high toxicity of Fe and Al. The availability of other plant nutrients is also hampered by low pH.

B. *Soil Health Card*

Soil health card is a printed report that shows the status of his soil in terms of 12 parameters, including Nitrogen (N), Phosphors (P), Potassium (K), Macro-nutrients like Sulphur (S), Secondary-nutrients like Zink (Zn), Iron (Fe), Copper (Cu), Manganese (Mn), Boron (Bo) (Micro-nutrients), Potential Hydrogen (pH), Electrical Conductivity (EC), Organic Carbon ((Physical parameters). The Soil Health Card will next make fertiliser and soil amendment recommendations for the farm based on this information. N, P, K, and pH are among the characteristics necessary for the project, for which a Soil Health Card is required.

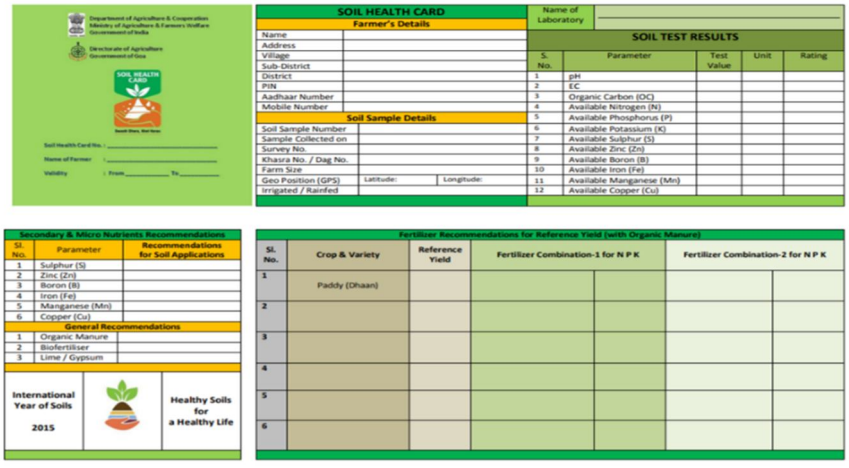


Fig. 4. Soil Health Card

C. Hardware Requirements

1) Arduino UNO: The Arduino Uno is a microcontroller board that uses the ATmega328 microcontroller (datasheet). It contains 14 digital input/output pins, 6 analogue inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

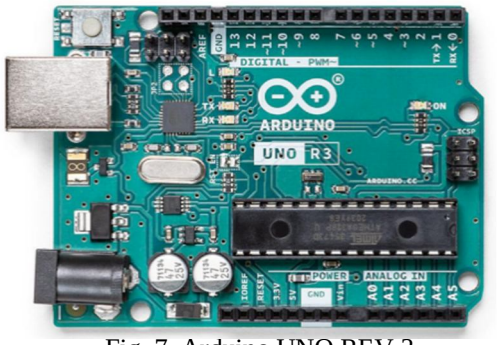


Fig. 7. Arduino UNO REV 3

2) DHT11 Sensor: This sensor is a digital humidity and temperature sensor with a low cost. Despite the use of an ADC, this sensor produces digital output and may thus be directly attached to the data pins of a microcontroller. It also has an eight-bit microprocessor for serial data transmission of temperature and humidity information.

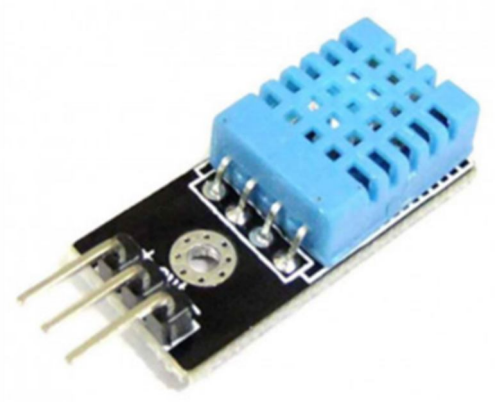


Fig. 8. DHT 11 Sensor

3) Soil Moisture Sensor: The moisture sensor has three pins: one for voltage, one for ground, and one for analogue input. This sensor measures the moisture content of the soil (in volume percent). Because moisture content is measured in percentages, the analogue value must be mapped to a range of 0-100. The electrical resistance of the soil is the attribute exploited by this sensor. This sensor has two probes that allow the current to travel through the soil.

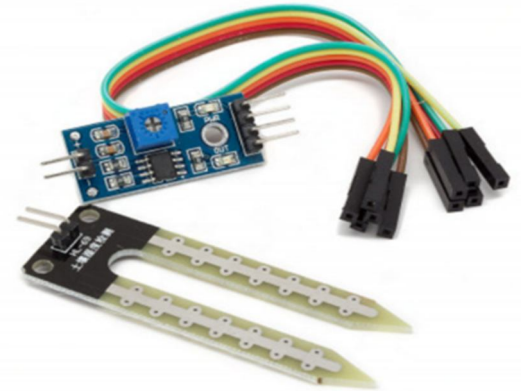


Fig. 9. Soil Moisture Sensor

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4) *Wi-Fi Module:* The ESP8266 Wi-Fi Module is a self-contained SOC with an integrated TCP/IP protocol stack that can provide access to your Wi-Fi network to any microcontroller. The ESP8266 may either host an application or offload all Wi-Fi networking functionality to a separate application processor.

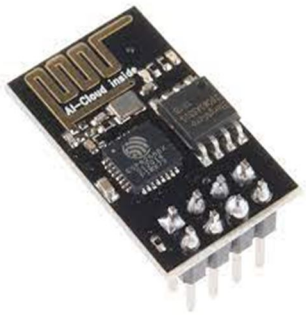


Fig. 10. ESP8266 Wi-Fi Module

D. Software Requirements

1) *Arduino IDE:* Arduino IDE is an open-source programming environment that is used to write and compile code for the Arduino module. It primarily consists of a text editor for writing code, a text console, a message area, and a toolbar with buttons for common functions. The programmes produced using this software are referred to as sketches. This software mostly uses C/C++ functions for coding.

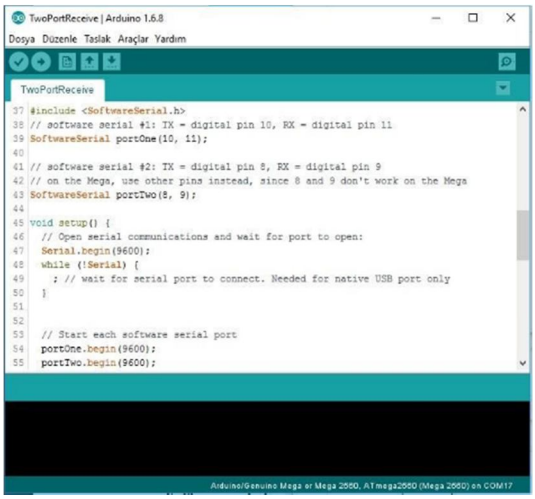


Fig. 11. Arduino IDE

2) *Thingspeak Cloud Server:* It's a free and open-source programme. This platform offers services for visualising, analysing, and aggregating live data flowing on a cloud server. It provides real-time visualisations of data submitted to this cloud server by various devices. It has the ability to run MATLAB code, so we can evaluate and process statistics as they occur in real time. Prototyping is a common application for it.

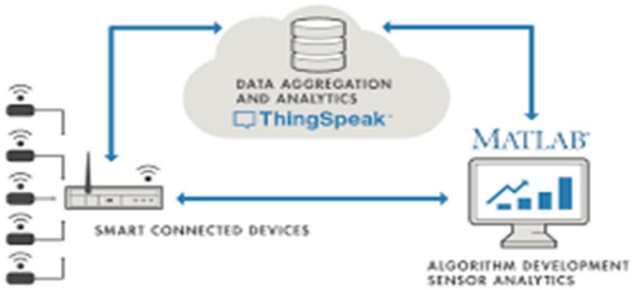


Fig. 12. Thingspeak Cloud Server

3) *Jupyter Notebook:* Jupyter Notebook is a free and open-source web software that lets you create and share documents with live code, equations, visualisations, and narrative text. Data cleaning and transformation, numerical simulation, statistical modelling, data visualisation, machine learning, and other applications are only a few examples. Python is one of the more than 40 programming languages supported by Jupyter.

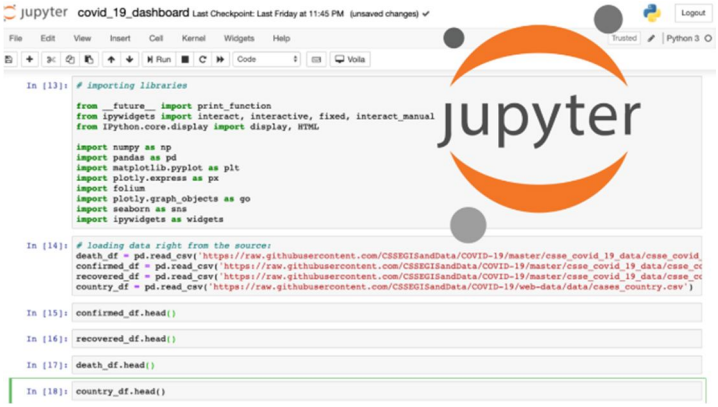


Fig. 13. Jupyter Notebook

4) *Python Programming Language:* Python is a high-level, general-purpose programming language that is interpreted. The use of considerable indentation in its design philosophy emphasises code readability. Python has recently established itself as the backbone of Machine Learning. In comparison to other object-oriented languages, it is a simple to learn programming language.

IV. SYSTEM DEVELOPEMENT

The whole system is the combination of various technologies like, IOT for sensing information, Machine Learning for Prediction, and Web technologies such as Front-End User Interface and Back End.

A. *Flow of Project*

The project is divided into four major sections as shown figure:

1) Collection of data from IOT System through Sensors and Lab Tested data through Soil Health Card.
2) Building Machine Learning models using training dataset as shown in table no 1.
3) Making Web Application using Front End Technologies such as HTML,CSS,Bootstrap and Back End Technologies such as Python Flask
4) Testing the Application for the Collected data

B. *Block Diagram of Proposed System*

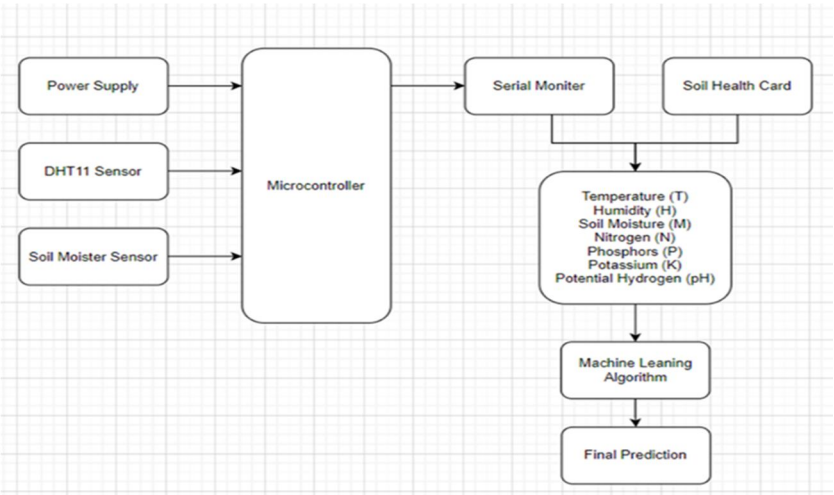


Fig. 5. Block Diagram of Cyber Physical System for Crop Prediction.

C. Experimental IOT Setup

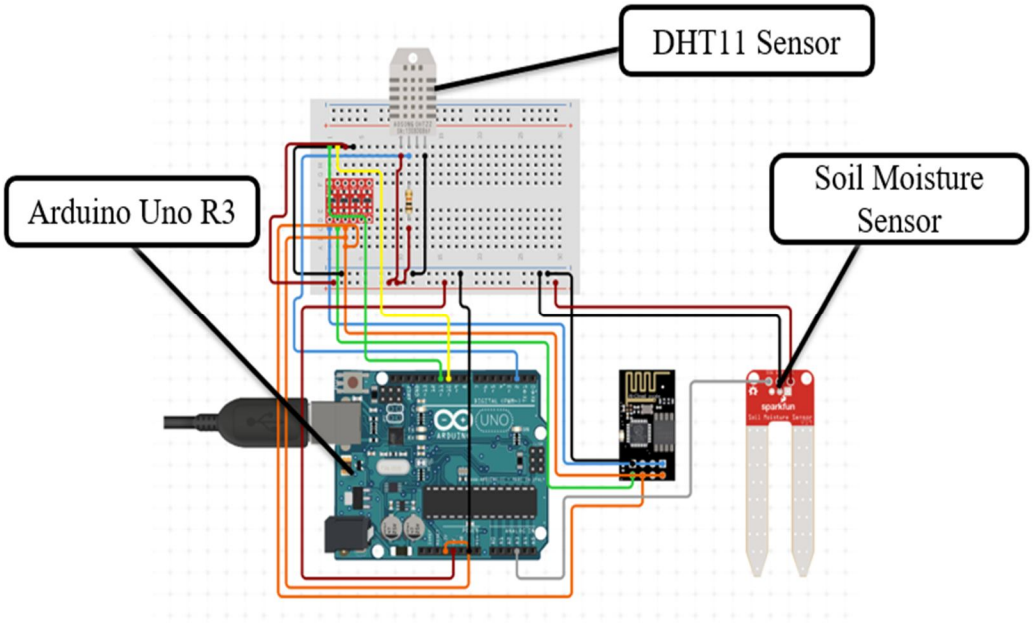


Figure 6: Iot System

The Figure 6 shows the experimental setup of IOT system for data collection. The setup contains Microcontroller that is Arduino Uno Rev 3, then sensors they are soil moisture, DHT11, and GPS module . In this Uno Rev 3 gives base for live streaming of temperature, humidity, soil moisture and sending the sensor information to the server using ESP8266 Wi-Fi to Think Speak Server.

D. Machine Learning Algorithms and Data Set

Dataset used for building predictive machine learning models is shown in table no 1, the dataset was built by augmenting datasets of rainfall, climate and fertilizer available for India,

1) Data Fields

a) N - Nitrogen content in soil
b) P - Phosphorous content in soil
c) K - Potassium content in soil
d) Temperature - temperature in degree Celsius
e) Humidity - relative humidity in %
f) pH - ph value of the soil
g) Rainfall - rainfall in mm

Sr. No	N	P	K	temperature	humidity	ph	rainfall	label
1148	38	15	27	33.74627	48.50388	6.777788	92.26439	mango
1853	24	27	34	28.87863	95.1132	6.203377	145.0583	coconut
1918	123	39	24	25.00755	78.17952	7.453106	86.06412	cotton
731	25	65	21	33.86351	68.59232	6.880246	69.24464	blackgram
1615	9	11	8	24.85903	94.39	6.559237	111.7804	orange
1635	0	12	7	20.18432	90.65458	6.96925	116.8131	orange
1073	111	88	55	29.44795	78.34972	5.505394	96.45043	banana
352	35	69	23	16.78792	24.96882	5.57841	75.45328	kidneybeans
2018	82	35	44	26.96656	78.21048	6.239011	169.8391	jute
758	34	60	16	31.35731	64.24992	7.322555	63.85669	blackgram

Table no 1: Dataset for Machine Learning

2) *Machine Learning Models:* Classification Machine learning technique for dataset classification is useful, according to the examination of datasets. The Classification algorithm is a Supervised Learning technique that determines the category of new observations using training data. Classification is the process of a machine learning from a dataset or observations and then classifying fresh observations into one of several classes or groupings. The following machine learning models are used in the project, and they are discussed below.

a) *Decision Tree Classifier:* The Decision Tree algorithm is one of the supervised learning algorithms family. The decision tree approach, unlike other supervised learning algorithms, can also be used to solve regression and classification issues. By learning simple decision rules inferred from past data, the purpose of employing a Decision Tree is to develop a training model that can be used to predict the class or value of the target variable (training data).

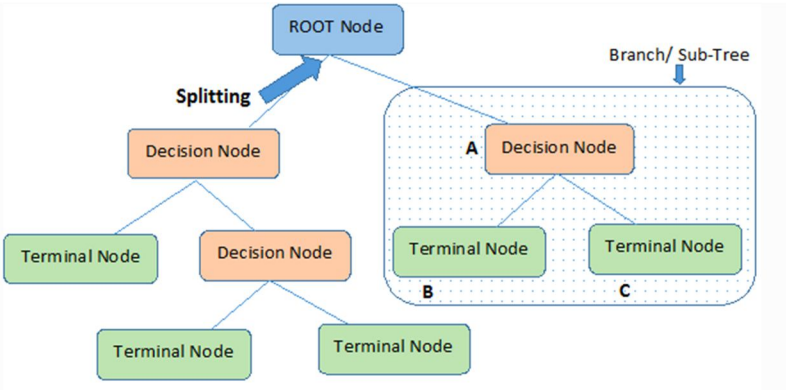


Figure 7 : Decision Tree Classifier

b) *Naïve Bays Classifier:* Naive Bayes classifiers are a group of classification algorithms that use Bayes' Theorem as its foundation. It is a family of algorithms that share a similar idea, namely that each pair of features being classified is independent of the others. The Bayes' Theorem calculates the probability of an event occurring given the probability of a previous event. The following equation expresses Bayes' theorem mathematically:

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

$P(B) \neq 0$, where A and B are events.

c) *Support Vector Classifier:* The Support Vector Machine (SVM) is a common Supervised Learning tool for solving classification and regression problems. However, it is mostly utilised in Machine Learning for Classification difficulties. The SVM algorithm's purpose is to find the optimum line or decision boundary for categorising n-dimensional space into classes so that additional data points can be readily placed in the correct category in the future

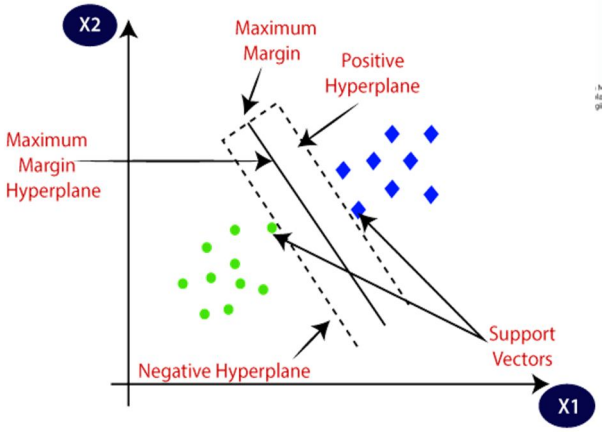


Figure 8: Support Vector Classifier

d) Random Forest Classifier: Random Forest is a well-known machine learning algorithm that uses the supervised learning method. In machine learning, it can be utilised for both classification and regression issues. " According to the name, "Random Forest" is a classifier that "contains a number of decision trees on various subsets of a given dataset and takes the average to improve the dataset's projected accuracy. Instead, then relying on a single decision tree, the random forest collects the forecasts from each tree and predicts the final output based on the majority votes of predictions.

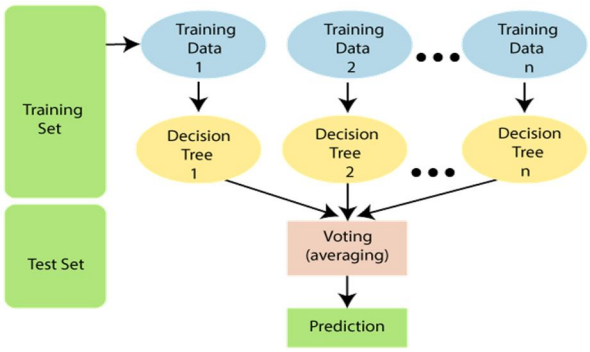


Figure 9: Random Forest Classifier

E. Web Application for Crop Recommendation System

Website is made using following web technologies

1) Front End : HTML, CSS, and Bootstrap

2) Backend : Python Flask

a) Running Web Application using Anaconda Power shell

Anaconda PowerShell is use to make the virtual environment to run the web application, it is as shown in figure 10.

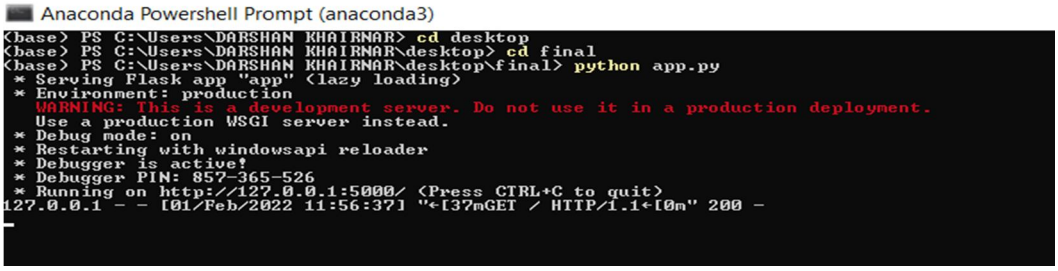


Figure 10: Anaconda PowerShell

b) Home Page of Web Application

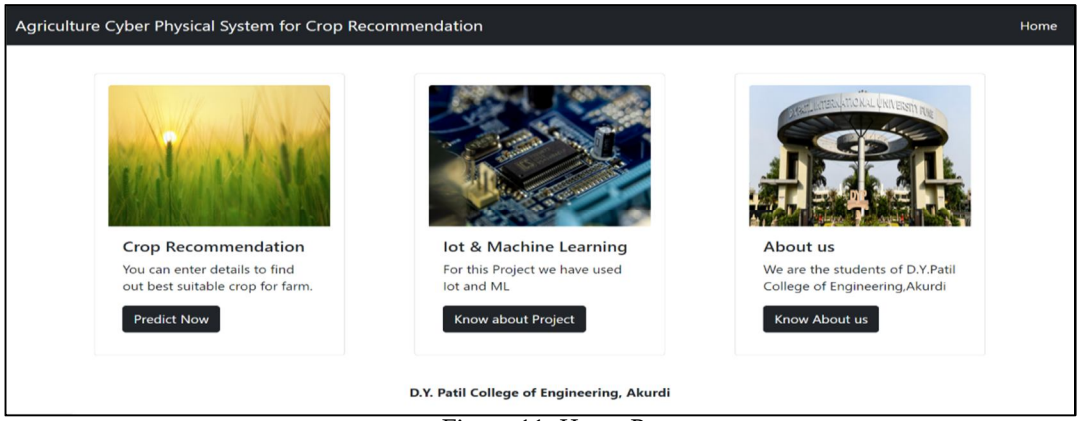


Figure 11: Home Page

Home page of the web application a card of Crop Recommendation, after clicking predict now, we can go to page where we can find out the suitable crop.

c) Crop Recommendation System page

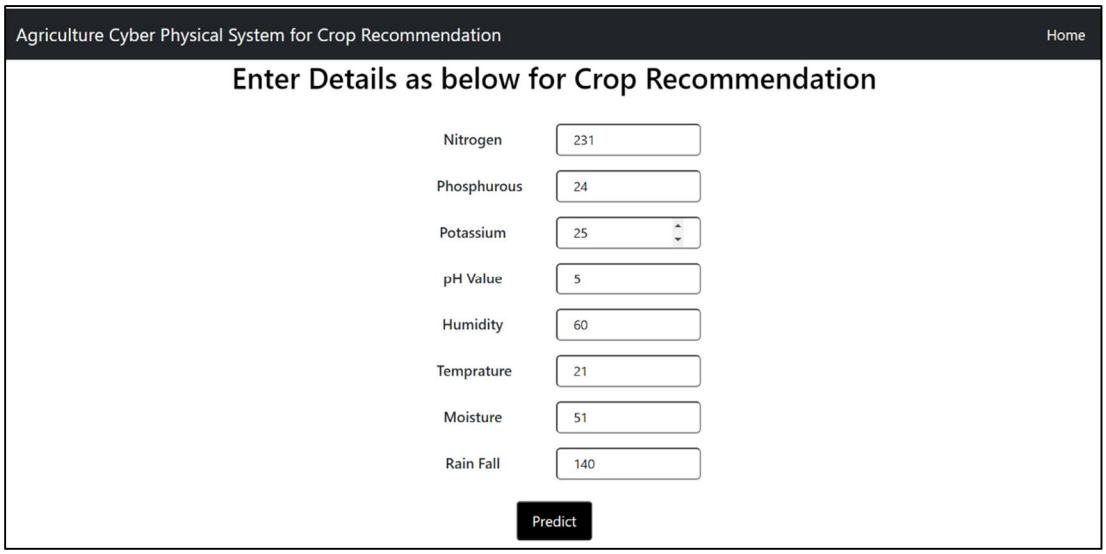


Figure 11: Crop Recommendation System Page

As shown below figure, we can enter the collected data in the respective fields and click on predict button to finally find out the best suitable crop to plant in farm.

d) Result Page

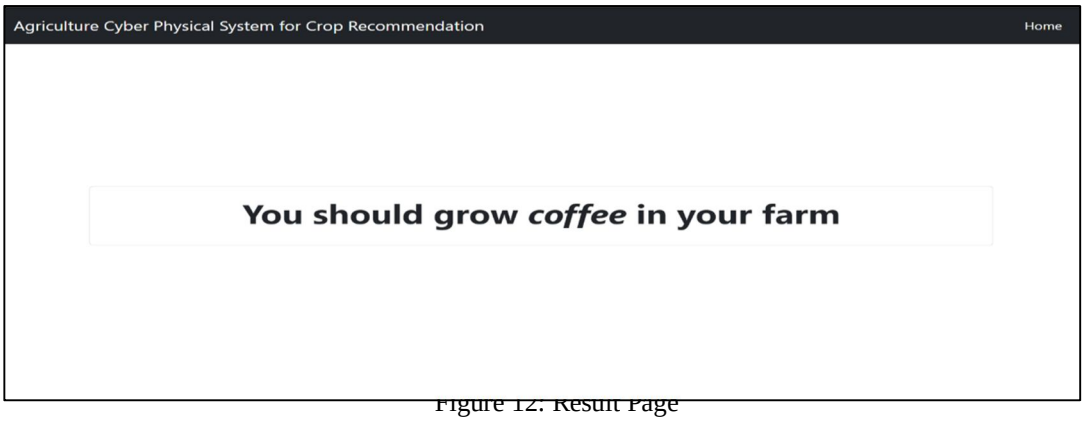


Figure 12: Result Page

After clicking on predict button we get the suggestion for the best crop to plant depending on the entered details

V. FUTURE SCOPE

A. The project has a very vast scope in future. This project can be implemented on a large scale in future. Project can be upgrade in near future as and when requirement for the same arises, as it is very adaptable in terms of expansion. As the population is growing rapidly and many new technologies are emerging during the years it is important that the, agricultural sector also should move forward in that direction.

B. In this project is limited only up to prediction of crop on the basic of N, P, K, Humidity, Moister, pH, and Temperature. We can further add more attributes to this list to make prediction more accurate and Precise.

C. Soil Health Card is being used for some input data, as it is cost effective. But further we can use N, P, K sensor and pH sensor for collecting same data from field.

D. This project only focuses on crop prediction, further we can add more functionality to this project like fertilizer recommendation, Water Management, Pest Management, Crop Protection from Climate Change. Etc.

E. This project can be more implemented and can be connect to the mobile application so that farmer can do the work when they are not present at home.

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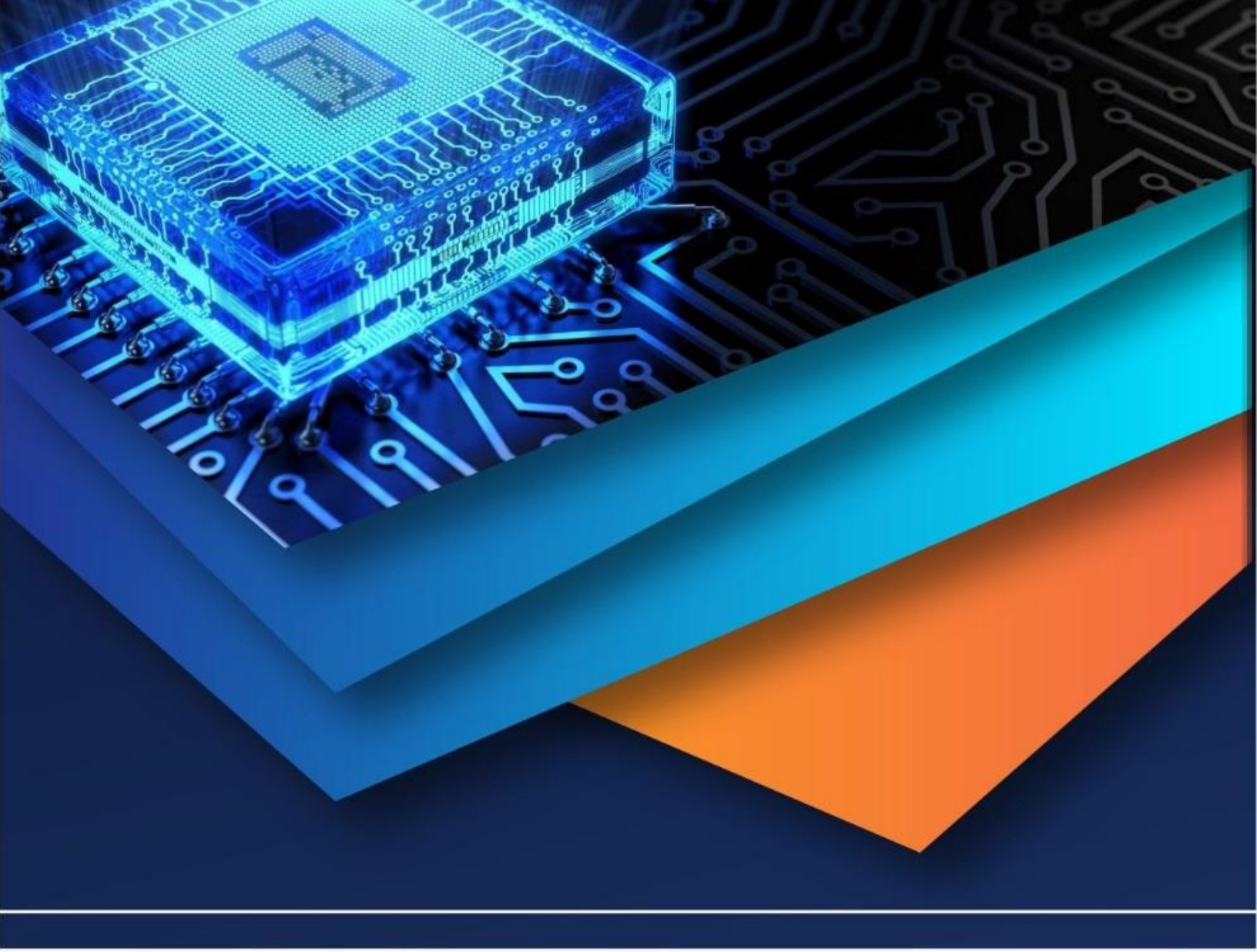
VI. CONCLUSION

As the food demand is increasing day by day due to increasing population, so the way of farming is very important to reach this demand of public. The traditional agriculture processes in India will not be able to feed such a large population. In order to do that our farmers have adopt new technologies. From this project we are taking one step towards making Indian agriculture more advance than it is today.

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