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IoT Based Smart Agriculture Using Machine Learning

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***Abstract*—Agriculture is one of the crucial sources of economic growth in the country. Agriculture plays a major role in increasing the overall economy of any country. Many countries are having tremendous growth in the production of crops as the demand for food grains and supply increases. India is one of the leading countries in producing a variety of different crops. However, most parts of India are still using the traditional methods for implementation and cultivation of crops, due to which farmers are facing a loss in their production due to inadequate supply of fertilizers and uncertain climatic conditions. To overcome this, there is a need to develop a system that will look for these soil, temperature, and climatic conditions. IoT-based Smart Agriculture using Machine Learning talks about the use of IoT and Machine Learning techniques that will not only look for sensor data but also recommend the farmers the suitable fertilizers and crops to be grown. Smart sensors will be used to get the values related to soil moisture, temperature, humidity, and pH values. These sensors will check for suitable soil conditions, and how wet or dry the soil is, and will also look for temperature values. The real-time data will be fetched and displayed on the live monitoring webpage and Android applications. We can get timely information about the soil moisture value and suitable temperature and humidity value. With the help of Data Analysis techniques, we can figure out which data to take for further exploration. Historical datasets that are publicly available can be used for training and building Machine Learning models. Farmers can access information about their field data, and machine learning algorithms will help the farmers in making informed decisions about what crops to grow in the specific environment.**

***Keywords*— Internet of Things, Sensors, Soil moisture, Temperature, Humidity, Microcontroller, Smart Agriculture, Recommendation Model, Crop Prediction, Fertilizers Prediction, Machine Learning Model.**

I. INTRODUCTION

"Farmers: The architects of a nation's sustenance, cultivating not just crops but the very foundation of life." Agriculture, sometimes known as farming, is growing food and rearing cattle. Agriculture plays a vital role in the Indian economy, by producing many raw resources and food products for livelihood. India represents the second-largest producer of wheat and rice. Almost 70 % of the Indian population is dependent on agriculture to fulfil their necessities. 16.5 % of India's GDP is contributed by the agricultural industry. Agriculture not only contributes to food production but also generates resources for commercial items. India has a high soil fertility rate and a high rate of water resources for irrigation. Despite the good availability of these resources, it is still not producing the results that are equivalent according to the availability. The main reason behind this is the incomplete use of smart technology, and less awareness, and knowledge among the farmers. The field of agriculture is undergoing significant growth periodically, and increased technological advancements can help to enhance productivity.

Maharashtra, one of the major agricultural states, suffers from severe problems like recurring droughts, fluctuating rainfall, low soil fertility, and lack of use of modern technology. Global agriculture is also dealing with food security problems due to population growth, the effects of climate change, and the decline in arable land. Technologies such as the Internet of Things (IoT), artificial intelligence (AI), and machine learning are being explored globally in order to develop intelligent agricultural systems IoT to facilitate sensor-based data collection so the edge in real-time as AI and ML models provide insights that can be used to solve agricultural challenges. However local stakeholders are important as agricultural practices vary according to geographical location, topography, socio-economic factors, etc.

The objective of the proposed project is to develop an IoT-based smart agricultural system that will track the field data and also provide predictions demonstrating sustainable crop environment management and providing personalized advice to strengthen local farmers' decision-making. Key innovations include the usage of automated sensor data collection and hyperlocal ML prediction models for important parameters affecting crop yield and quality. All the data including soil moisture, temperature, and humidity will be monitored and displayed on the screen for live demonstration. Machine learning models will be used to predict the recommendation for crop cultivation and suitable fertilizer selection. The project contributes to the increase of productivity and profitability through technology-enabled data-driven actions tailored to local enabling environments.

A. Background

Agriculture has been the primary source of food and livelihood for generations in all cultures. Agriculture continues to be the primary source of income for over 58% of India's population, accounting for over 16% of the national GDP. The agriculture industry remains critical to the country's socioeconomic development and progress. Despite the relatively faster growth of the non-agriculture sector, agriculture remains the primary source of employment, with 45 percent of the workforce involved in agricultural and allied activities. During 2021-22, the sector contributed 18.6 percent of national income in current prices.

Agricultural land in India was reported at 60.05% and agricultural irrigated land was reported at 42.27% in 2021, according to the World Bank collection of development indicators. The percentage of land area that is arable, under permanent crops, and permanent pastures is referred to as agricultural land. India is the leading producer of various crops in the world. There can be numerous ways to divide different types of crops (depending on region, season, economic value, etc.). Crops in India are classified into three types according to the seasons: Rabi, Kharif, and Zaid.

Rice grown in the fertile plains of the Ganges thrives on extensive irrigation systems, positioning India as the leading rice producer in the world. Wheat thrives on well-drained soil and grows in the cold during the slower months of the season, maize and cowpea are the second most cropped cereals after rice and other coarse grains in the dry plateau regions, Sugarcane dominates the more humid regions throughout peninsular India with moderate rainfall and temperature.

Despite India being one of the leading producers of several agricultural commodities, the yields per hectare are quite low compared to other developing and developed countries. Sensors and IoT devices can enable real-time data collection of environmental parameters along with machine vision for plant health monitoring. Computer vision trained through deep learning techniques can accurately detect pest attacks, and disease occurrence and even estimate expected yield well in advance for the farmer to plan mitigation and marketing logistics. The project aims to build such integrated smart agriculture using IoT and machine learning solutions demonstrating technology-led optimization of resource usage and farm productivity enhancement within practical constraints of small landholder context in India.

B. Purpose

The purpose of this project is to develop an integrated smart agriculture system using IoT devices and machine learning techniques to deliver data-driven advisory to farmers in order to enhance productivity, resource optimization, and risk mitigation. The main target users are farmers across India with a primary focus on small and marginal landholders with average operational area.

1. IoT-based sensors capture data related to multiple soil parameters like nitrogen, phosphorous, potassium (NPK) levels, pH value, temperature, and moisture at pre-set frequencies relayed over communication networks.
2. Weather station and satellite imagery feed additional datasets around rainfall, humidity, and local weather predictions into a cloud-hosted platform to process aggregated structured and unstructured data using ETL tools.
3. A crop recommendation model developed through supervised deep learning techniques leveraging the historical multi-parametric datasets suggests ideal crops for the season factoring agro-climatic conditions.
4. Machine Learning fertilizer prescription module correlates currently measured soil attributes with existing properties and projected season
5. forecasts to provide tailored amendments for site-specific soil types and cropping patterns.
6. A Convolutional Neural Network model identifies the onset of disease incidence signals on plant leaves through image capture and classification algorithms to limit spread through timely interventions.

This project aims to empower farmers with precise advisories based on geo-tagged fields' soil health cards for sustained land productivity and minimize input wastages through custom recommendations and automated early alarms on emerging risks. The smart agriculture IoT and ML models have been designed keeping in mind applicability for small and marginal farmers with landholdings. The sensors, connectivity modules, and computing backends have been architected for rural conditions with modest infrastructure availability.

Overall, the purpose of this project is to design and develop an integrated smart agriculture platform using sensors, instruments, IoT devices, and machine learning techniques to address some of the most pressing challenges facing Indian farmers like resource constraints, climatic vulnerabilities, and lack of customized advisory.

C. Objective

The project's main objective is to revolutionize farming by using innovative technology and smart features that will make farmer's life easy. Using the IoT-based smart sensors in the field to detect the values of soil moisture, temperature conditions, and other minerals present in the soil. It captures the data from the soil and gives you real-time analytics of critical elements like soil moisture and temperature. Computers will be trained to interpret the data using machine-learning technology. The predefined datasets will be trained and tested to give accurate recommendations based on the data you received from the sensors. It will alert farmers about potential outbreaks in the field and also help in predicting the spread of pests and diseases. Imagine getting recommendations about what crops to grow, when to water the crops, and which fertilizers to apply. This will not just make the farmer's life easier but also motivate them to increase their production for growing healthy crops while conserving and limiting the excess use of water and other resources.

D. Scope

The scope of the project involves leveraging IoT sensors installed across agricultural fields, satellite data-based imagery analytics, weather forecasts, and historical datasets to develop machine learning models. These models provide actionable farm-level advisories related to optimal crop selection, precise input recommendations, and disease identification through dashboards. The insights cover key phases from planning to harvesting spanning advisory, predictive analysis, automated response, and post-harvest enhancement recommendations. The sensors measure key parameters across soil temperature, moisture, pH, electrical conductivity, Nitrogen-phosphorous-potassium (NPK), and micronutrient levels. Additional instrumentation provides time series image datasets across crop growth stages. Custom-designed communication modules transmit field data to the cloud storage and analytics layer. The solution is targeted as customizable modules applicable to marginal farmers owning operational landholding engaged in essential and cash crop cultivation. It demonstrates a commitment to accessibility, explainability, and continual improvement required for pragmatic precision agriculture implementations attuned to on-ground needs. In simple terms, our project's scope isn't just about the fields; it's about creating something that farmers can count on, now and in the future. It's about making farming a bit simpler and a lot more fascinating.

II. MATERIALS AND METHODOLOGY

A. Problem Definition

Many structural problems challenge Indian agriculture, such as reliance on the seasonal monsoon, scarcity of resources, deterioration of soil health, and a lack of organized knowledge of ecosystems to predict and manage weather, pest, and production uncertainties and variations. Small and marginal farmers, who account for more than 86 percent of all operating landholdings and have landholdings smaller than two hectares, are the stakeholders most impacted. In addition, extreme weather events and more variable rainfall due to climate change are increasing the frequency of droughts and floods, which have a major negative influence on crops during crucial times. The combined impact of these difficulties results in annual losses of 19%, which is a 10-15% deficit in relation to the agricultural production that may be achieved given current scientific breakthroughs.

The majority of technological solutions ignore the full agricultural cycle in favor of addressing certain issues like post-harvest price discovery or simple automation. The goal of this research is to demonstrate an all-inclusive integrated agriculture system in order to address this problem. It integrates analytical algorithms, satellite data, instruments, and sensors. The system will cover the pre-sowing through post-harvest phases and handle issues with profitability, resource efficiency, and variability. The aim is to offer recommendations and insights that support inclusivity and small farms by utilizing holistic data patterns. With precision farming in particular, this proposed method has the potential to increase agricultural output and sustainability

.

B. Requirement Specifications

The project is aimed to monitor on-field data which is done with the help of IoT devices assembled using a microcontroller NodeMCU ESP8266, which has different sensors connected to it that are continuously working to show real-time data to the farmers. The Temperature and humidity sensors like DHT-11 which consist of a thermistor, humidity sensing component is used to calculate the temperature of its surrounding medium from its capability of varying its resistance due to temperature. A moisture-holding substrate is placed between two electrodes in the humidity-sensing component. The variation in humidity produces a variation in resistance between electrodes. The variation in resistance is measured and processed by the IC which gives the humidity value to the NodeMCU.

The two probes that make up the soil moisture sensor are used to gauge the amount of water present in the soil. These two probes allow the current to flow through the soil, allowing the resistance value to be used to calculate the moisture value. If there is a greater amount of electricity produced from the soil, then we have plenty of water available. Water supply to the crops is regulated by an automated pumping motor if the moisture level falls below a predetermined threshold.

The values obtained from the sensor data are saved and subsequently utilized by the crop prediction model. Additionally, the data is presented graphically for quick comprehension of the front-end application in the form of graphs and gauges. The prediction model classifies the data using various classifiers. Train and test data are separated inside the dataset. The outcomes are verified using the test data. The output will be forecasted and shown on the best crops to plant and the fertilizers to use based on the best model and classification. Giving farmers the best answer to their agricultural problems is the primary goal of the machine learning-based, Internet of Things-based Smart Agriculture System.

C. List Of Materials

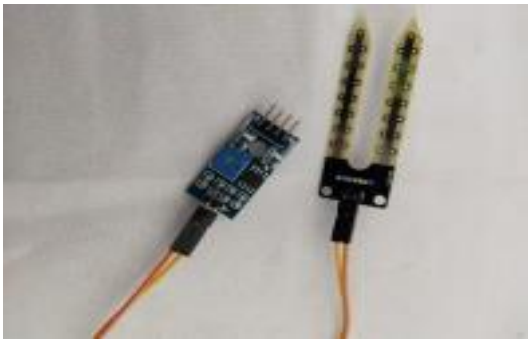

Fig 1: Soil Moisture Sensor

Fig 2: Temperature and Humidity Sensor

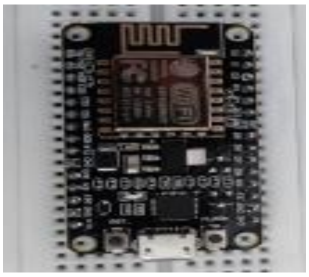

Fig 3: NodeMCU

Soil Moisture Sensor:

In agriculture, soil moisture sensors (Fig 1) are used to measure the amount of water in the soil. They assist farmers in knowing when to water their plants so that they receive the proper quantity of moisture without being over- or under-watered, which could damage the plants. It is small, cheap, and easily available. Its operating voltage is 3.3-5V DC. It consists of a moisture sensor, resistors, capacitors, comparator LM393, and Moisture LED. Easy to use with microcontrollers. The sensor has both analog and digital output. When there is more water present in the soil, it will conduct more electricity which means resistance will be low and moisture level will be high. When there is less water present in the soil, it will conduct less electricity which means resistance will be high and moisture level is low.

Temperature and Humidity Sensor:

In farming, temperature and humidity sensors (Fig 2) are used to track air temperature and moisture content. Avoiding issues like heat stress or high humidity that could harm the plants, aids farmers in making sure the environment is suitable for their harvests. The humidity and temperature sensor (DHT11) shown in Fig, consists of a thermistor, humidity sensing component, and an IC. A thermistor calculates the temperature of its surrounding medium from its capability of varying its resistance due to temperature. A moisture-holding substrate is placed between two electrodes in humidity humidity-sensing component. The variation in humidity produces a variation in resistance between electrodes. The variation in resistance is measured and processed by the IC which gives the humidity value to the NodeMCU. This sensor operates at a voltage range of 3.3V to 5V. The range of temperature is 0- 50°C, range of humidity is 20 - 90% RH.

NodeMCU (ESP8266):

NodeMCU (Fig 3) is an open-source IoT platform that includes firmware that runs on the ESP8266 Wi-Fi module. Programming is done in Arduino IDE using C/C++ language or Lua script. NodeMCU has 16 GPIO pins which can be used to control other peripheral devices like sensors, LEDs, switches, etc. These pins can also be used as PWM pins. It has two UART interfaces and uses the XTOS operating system. It can store 4M Bytes of data. The operating voltage of NodeMCU is 5V. It uses L106 32-bit processor, and the processor's speed is 160MHz.

Fig 4: Relay Module

Fig 5: Passive Infrared Sensor

Relay Module:

A relay module (Fig 4) also functioning as an electronic switch, is used in smart agriculture to operate the water pump. The relay consists of 3 pins a normally open, common, and a ground pin. Based on sensor inputs or pre-programmed conditions, it enables the water pump to operate automatically. The relay is capable of handling large power loads, making it appropriate for water pumps. For smart system control, microcontrollers are easily integrated into the system.

PIR Motion Sensor:

PIR motion sensor is used in smart agriculture because of its motion detection capabilities. Any type of activity is monitored with the help of this sensor. Farmers can track animals' activity inside the field which can be helpful for farm management. We can develop an alert system with the help of this sensor. It also reduces any type of manual labor which is required

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D. Methodology

The system is designed to deliver real-time analytical data of the agriculture field based on the soil nutrients and other parameters gather them and display them at the same time and also save them for future predictions. Machine learning models will help to get recommendations based on the values present in the soil and temperature and moisture values. Crop prediction will predict the type of crop to be grown based on the NPK values and climatic conditions. Fertilizer prediction will be responsible for getting the suitable fertilizers to add to the crop to make it fertile.

Traditionally, the farmers need to collect the amount of soil from different spots on their farm and need to combine them, and take them to the agricultural data centers where after 15 to 20 days they receive their soil data and information but by using the IoT based Smart Agriculture using machine learning the farmers can track their field data whenever required also they can use their field data to get the recommendation for suitable crops and fertilizers.

E. Architecture

To keep it simple, we are dividing the system into two modules the first part is the IOT Module and the second part is the Recommendation module. The main components in the proposed system architecture are temperature, humidity, soil moisture, and ESP8266 microcontroller.

- Because it hosts a web server and stores datasets, ESP8266 is essential to the system.
- As illustrated in Figure, the DHT11, PIR sensor, and soil moisture sensor are placed in the field and connected to the ESP8266 microcontroller
- The information obtained from these sensors is transmitted to the ESP8266, where it is stored and processed.
- The data is presented in the form of visuals on the output application through a Wi-Fi connection.
- There is a manual button to ON/OFF the water pump based on the moisture level of the soil.
- A warning message will be displayed on the screen as soon as the PIR sensor is turned on. It will check for any motion on the field.
- Every piece of information transmitted from the sensors to the ESP8266 and with the help of wifi is transmitted and displayed on the output screen.
- The recommendation model will recommend the suitable crops to grow and fertilizers to add based on the input values entered by the farmers.

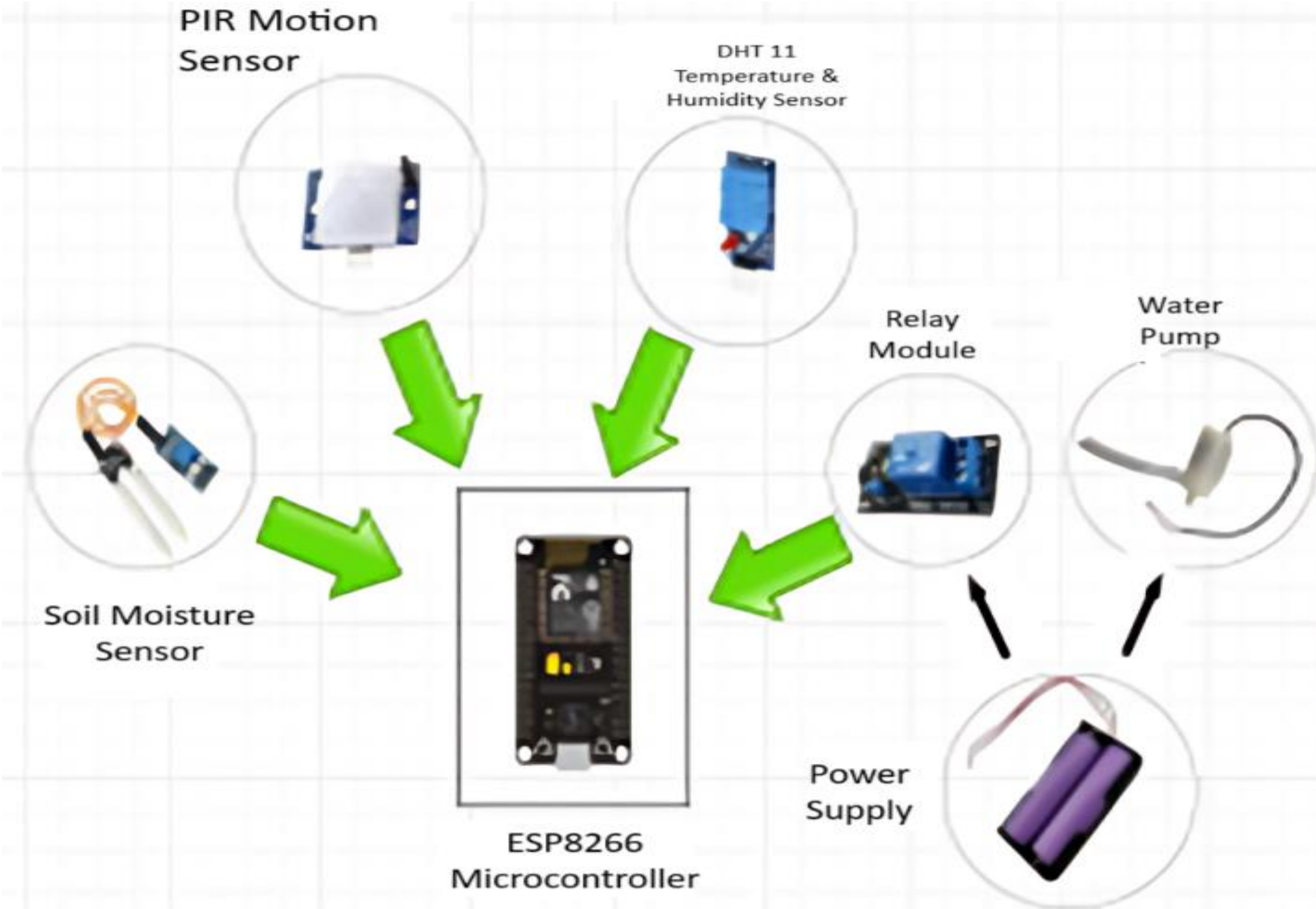

Fig 6: Block Diagram

III. RESULTS AND FINDINGS

Features including temperature, humidity, pH, rainfall, and the elements nitrogen, potassium, and phosphorus are all present in the training dataset that was used to train the crop prediction model. In contrast, the model for recommending fertilizers includes elements like pH, soil moisture, potassium, phosphorus, and nitrogen. The training dataset was subjected to several machine learning techniques, including Random Forest, Decision Tree, Naive Bayes, Support Vector Machine, Logistic Regression, and XGBoost, and was contrasted according to the accuracy of the model. Since Random Forest had the best accuracy, it was chosen to be the prediction model. Using our platform, the user (a farmer) will be able to obtain precise recommendations about which crop to cultivate depending on variables like rainfall, pH, and humidity. In addition, the user will be able to receive fertilizer recommendations based on various parameters such as moisture, nitrogen, potassium, and phosphorus.

```
Decision Tree --> 0.9
Naive Bayes --> 0.990909090909091
SVM --> 0.9795454545454545
Logistic Regression --> 0.9522727272727273
RF --> 0.990909090909091
XGBoost --> 0.990909090909091
```

Fig 7: Recommendation Model

Fig 7 is the crop recommendation model, where a sample value is taken to get the prediction based on the best accuracy model (i.e. Random Forest). Using the N, P, K, Temperature, Humidity, pH, and Rainfall values we are getting the recommendation for the best crop to grow.

```
[245]:
data = np.array([[104,18, 30, 23.603016, 60.3, 6.7, 140.91]])
prediction = RF.predict(data)
print(prediction)

['coffee']

[246]:
data = np.array([[83, 45, 60, 28, 70.3, 7.0, 150.9]])
prediction = RF.predict(data)
print(prediction)

['jute']

[247]:
data = np.array([[230,42, 43, 82.603016, 82.3, 6.7, 202000.91]])
prediction = RF.predict(data)
print(prediction)

['rice']
```

Fig 8: Model Prediction

Fig 9: Implementation Demonstration

IoT sensors are assembled on the breadboard along with the microcontroller acting as the center control for fetching all the sensor data and sending it to the output application with the help of the wifi module present in the microcontroller. Real-time analytics and values are shown on the application and webpage from where the users can get the soil moisture, temperature, and humidity value of their crops.

IV. CONCLUSION AND FUTURE SCOPE

Agriculture is a major source of the economic development of India. Traditional farming practices include farmers suffering from various conditions like inadequate crop growth, climatic conditions, and insufficient use of fertilizers.

This IoT and Machine Learning recommendation system will surely help the farmers to understand more about their crops and soil condition, which will reduce the overall cost, and farmers will be able to make strategic decisions. The use of remote sensors like soil sensors, moisture sensors, temperature sensors, humidity, and pH sensors, will provide an idea for a productive farming. The real-time data coming from the sensors and the applications of Machine Learning Algorithms will not only help farmers make informed decisions about which crops are suitable for their field but will also recommend fertilizers based on soil and climatic conditions. This technology can be used by farmers as an effective decision-making tool to help them reduce manual labor, conserve energy, and increase output. It represents a step toward an agricultural future that is more technologically advanced and sustainable. Through continuous monitoring, learning, and adaptation, this project will aim to address the evolving needs of the agricultural community.

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