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Smart Soil Fertilizer Monitoring and Crop Recommendation System by Using IOT and Machine Learning Technology

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***Abstract*—The paper suggests an efficient IoT-based soil nutrient monitoring and machine learning-based crop recommendation system to assist farmers in optimizing crop production. It proposes deploying various sensors to continuously collect soil data, including nitrogen (N), phosphorus (P), potassium (K), temperature, pH, humidity, and rainfall. These sensors transmit data wirelessly to a cloud database via a wireless sensor network (WSN). By monitoring these values and analyzing soil behaviour, machine learning algorithms recommend suitable crops based on the land's production potential.**

The adoption of machine learning technology in agriculture facilitates the selection of high-yielding crops while minimizing unnecessary fertilizer use and reducing manual labour. This approach enhances crop management and boosts productivity. By leveraging IoT-based soil nutrient monitoring and machine learning algorithms, farmers receive tailored recommendations for optimal crop selection, ultimately contributing to national agricultural growth

Keywords:*InternetofThings(IoT),MachineLearning(ML),Wireless Sensor Networks (WSN),Potential of Hydrogen(pH),Crop Recommendation*

I. Introduction

Agriculture stands as one of the most crucial sectors in human civilization. With the world population continuing to burgeon at an accelerating rate, the task of feeding this vast populace has emerged as a significant challenge. Consequently, the adoption of technologies that enhance agricultural productivity, simplicity, time-efficiency, and energy conservation has become imperative, ushering in the concept of smart agriculture. Smart agriculture encompasses the application of various technologies, both software and hardware, including Machine Learning (ML) [1], the Internet of Things (IoT)[6], Big Data Analytics (BDA) , Cloud computing , sensors, Integrated Circuit systems , and more.

Transitioning the agriculture sector towards smart solutions aims at achieving efficiency and sustainability by addressing critical issues such as energy consumption, enhancing food and product safety, reducing waste, and mitigating environmental impacts to maintain an ecological balance. This includes implementing systems for livestock, soil, and field equipment monitoring, pest control, greenhouse automation, autonomous irrigation, weather observation, water management, and other processes collectively known as precision farming [2]. These functions constitute the core of smart farming or agriculture, ensuring sustainable, efficient, and highly productive outcomes by replacing human-based agriculture with automation and technological integration. Consequently, while traditional farming relies on outdated systems, smart agriculture leveraging ICT improves all aspects, rendering the entire system more economically viable, minimizing labor requirements, and enhancing production and energy efficiency[6].

Moreover, the agriculture sector heavily relies on energy for various operations, from irrigation to lighting systems, with farms consuming substantial amounts of electricity. In recent times, the adoption of renewable energy sources has gained traction as a means to achieve energy sustainability in agricultural operations, with solar energy being a prominent example. However, the application of renewable energy faces constraints in fully supporting the energy demands of large-scale farming or agricultural environments, particularly in developing countries like Bangladesh, which host diverse types of agricultural farms. These farms primarily focus on the production of meat and eggs, highly demanded food items, and typically involve enclosed spaces equipped with various electrical appliances, such as electric bulb.

II.LITERATURE SURVEY

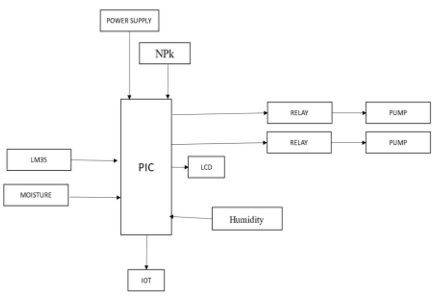
The utilization of machine learning in agriculture renders this sector highly efficient and manageable. The machine learning process comprises three main steps: data preprocessing, model building, and generalization. Instances where human skills prove insufficient are addressed through machine learning algorithms. Machine Learning (ML) involves leveraging past experience and data to facilitate decision-making by computers. Various applications of ML exist to extract crucial features from data and information [9]. Supervised learning and unsupervised learning are the two primary subcategories of machine learning methods, with semi-supervised and reinforced learning serving as additional categories into which some researchers further categorize machine learning algorithms. Pest control techniques can be enhanced through ML.

In supervised machine learning, the model generates an output based on predetermined evidence and training data, while in unsupervised machine learning, the technique predicts outcomes using a defined set of input variables and labels.In,the authors discussed the beneficial classification of machine learning in laboratory medicine and healthcare. In, a crop production model was established, leveraging 20 yearsworth of agricultural data for forecasting. Subsequently, stacking analysis was employed to enhance the regression model. Four machine learning algorithms—XGBoost, KNN classifier, Random Forest, and Logistic classifier—were tested to predict crop yield using parameters such as rainfall and temperature. Ultimately, it was concluded that, among all the algorithms tested, the random forest classifier exhibited the highest accuracy. The algorithm was then hybridized to enhance yield forecasting accuracy, considering factors such as area, rainfall, and soil type[3][7]. Subsequently, the system could determine the appropriate crop for cultivation based on the aforementioned attributes[8][9].

III.EXISTING METHOD

Agriculture holds immense significance for our country, and numerous individuals depend on it for their livelihoods. Production in agriculture faces hindrances from various factors. Monitoring soil parameters plays a crucial role in ensuring the presence of essential nutrients. The identification of issues concerning nutrient levels in the soil holds paramount importance. Food safety can be enhanced through computer vision, which aids in detecting bacteria and diseases in plants. A framework integrating sensors, Arduino and WiFi[16],[17] can be developed for crop monitoring and disease detection. Analysis and classification techniques like K means and SVM can be employed for data analysis[11].

IV.PROPOSED METHOD



A significant portion of the challenges related to monitoring soil[4] and its constituents in cropland can be tackled through the application of Internet of Things (IoT) technology. Moreover, the use of machine learning technology can facilitate crop recommendations to determine the most suitable type of crop for a specific piece of land[10]. This system model is divided into two modules to efficiently carry out the complete task.

The Soil Fertilizer Monitoring Module entails the real-time collection of data on soil properties parameterssuch as Phosphorus (P), Nitrogen (N), Potassium (K), Humidity, pH, and temperature, followed by transmission to the cloud. Determining the nutrient quality of cropland soil allows for the application of appropriate fertilizers to ensure profitable production. Infertile soils often lead to various plant disorders and low yields[13]. Various sensors are utilized for collecting soil data, and camera sensors capture images of crops for disease diagnosis and pesticide needs. The collector device (e.g., Arduino, Raspberry Pi) processes the collected data and transmits it to the receiver end (e.g., ESP32) through wireless communication modules such as Bluetooth, Wi-Fi, ZigBee, Radio, or GSM. The receiver end then relays the data to the cloud database system, empowering farmers to analyze received information and take necessary measures. The system is suggested to be powered by batteries in addition to a direct power source, with renewable solar energy being a viable option[14].

The Crop Recommendation Module employs a machine learning-based model to suggest suitable crops based on the dataset acquired from the Soil Fertilizer Monitoring Module. To enhance accuracy in crop recommendation, supervised machine learning algorithms like Linear Regression (LR), Random Forest Regression (RFR), Decision Tree, and XGBoost are employed. Parameters including N, P, K, Humidity, pH, Soil Temperature, and Average Rainfall in millimeters are considered in the implementation of the crop recommendation model[15].

The crop recommendation model incorporates the Decision Tree and XGBoost machine learning algorithms. Seven parameters, including N, P, K, Humidity, pH, Soil Temperature, and Average Rainfall in millimeters, are considered for machine learning to determine the most suitable type of crop. The system model analyzes these parameters to suggest the type of crop that would grow best based on their respective levels.

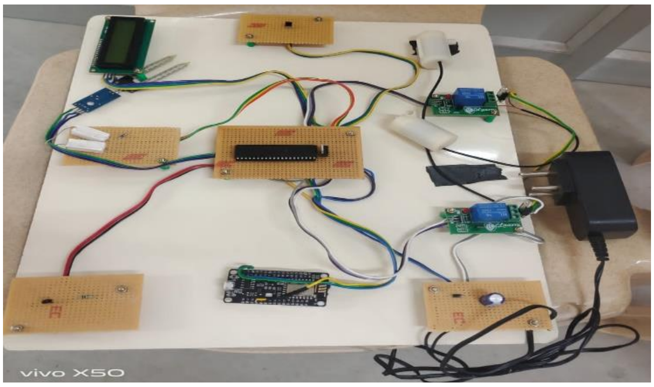
V.METHODOLOGY

1)The necessity for efficient and intelligent management of agricultural systems using IoT was identified.
2)The essential components required for IoT-based agricultural management were determined, including sensors (humidity, water level, wind flow, moisture), LM35, crop growth sensors, PIC controller, relays (1 & 2), fertilizer pump, water pump, LCD, and IoT.
3)Appropriate sensors were implemented to gather real-time data on humidity, water levels, wind flow, and moisture.
4)The LM35 sensor was utilized to measure temperature and make decisions based on the collected data.

202410th International Conference on Advanced Computing and Communication Systems (ICACCS)

5)Crop growth was monitored precisely using crop growth sensors.
6)All sensors were connected to the PIC controller for data processing and analysis.
7)Relays (1 & 2) were employed to regulate the functions of the fertilizer pump and water pump.
8)Relevant data and control options were displayed on the LCD for easy access and management.
9)Remote access and control were enabled through IoT technology for enhanced efficiency and convenience in management.
10)The system was continuously evaluated and adjusted based on real-time data to optimize crop growth and yield.

VI.HARDWARE SETUP



1)The relative humidity sensor can be either DHT11 or DHT22, which measures relative humidity (%).
2)Air velocity is measured using an anemometer as the wind flow sensor (m/s).
3)The water level sensor can be a float switch or ultrasonic level sensor, measuring water level (cm).
4)Temperature is measured with either an LM35 or DS18B20 sensor, which measures temperature (°C).
5)Soil moisture is detected using a soil moisture sensor, measuring soil moisture (%).
6)Distance is measured using an ultrasonic sensor like HC-SR04 (cm).
7)Display of data is facilitated by a 16*2 LCD using HD44780, providing a 16 character by 2 lines display.
8)Wireless communication is enabled through the ESP8266 module.
9)The 12V relay, typically SRD-12VDC-SL-C, is utilized for switching operations, rated for 12V DC and 10A.
10)The 12V DC pump motor is chosen based on specific requirements, rated for 12V DC and current draw.
11)An 8-bit microcontroller with various input/output capabilities, the PIC16F877-A Microcontroller, is employed for system control[8].

VII.DISCUSSION

The project practical and affordable design opens up numerous possibilities for various applications[18]. Furthermore, the data can be seamlessly displayed on android applications to enhance accessibility. Currently, the program prioritizes data monitoring, with subsequent phases aimed at expanding its capabilities . Future iterations envision broadening data acquisition capabilities to a central base station, accompanied by the integration of remote units for direct supervision of irrigation mechanisms. Additional enhancements include integrating web services for

notifications and analytical insights, as well as developing an intuitive user interface for monitoring purposes [11]. Additionally, the incorporation of Wi-Fi-enabled web cameras is seen as a feasible option for capturing real-time imagery of crops.

VIII.CONCLUSION AND FUTURE WORK

The primary objective of this study is to support growers in making well-informed decisions prior to planting by advising them on the optimal crop selection based on various factors. With accurate information about the soil composition of agricultural land, it becomes feasible to cultivate more profitable crops. The proposed modules serve as practical tools for farmers to assess different soil properties on their land and receive recommendations for the most profitable crops suitable for cultivation.

Particularly, farmers in rural areas will be incentivized to embrace new technologies such as IoT, Cloud Computing, AI, and ML to enhance agricultural yield, thereby fostering the realization of smart villages. The envisioned framework is poised to unlock new opportunities in soil and agricultural research, offering efficient solutions through the development of an integrated agricultural management system based on IoT and machine learning.

Future enhancements to the system may include additional features tailored to specific seasons, such as weather forecasting, detection of extreme droughts and floods, and prediction of agricultural prices. To enhance usability for farmers, a mobile application will be developed and integrated with the proposed system, providing ease of access and utilization.

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