Smart-Agri: A Smart Agricultural Management with IoT-ML-Blockchain Integrated Framework

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***Abstract*—This paper presents intuitive directions for field research by introducing a ground-breaking IoT-ML-driven intelligent farm management platform. This study's main goal is to address agricultural difficulties by providing a thorough, integrated solution. This work makes a variety of important contributions. By utilizing cutting-edge technology like IoT and Machine Learning (ML), it first improves conventional farm management procedures. Farmers now have the capacity to remotely monitor and regulate irrigation management thanks to sensor-based real-time data. Second, based on data gathered from agricultural fields, our machine learning model offers improved water control management and fertilizer use recommendations, maximizing production while minimizing resource usage. The suggested solution also uses blockchain technology to create a safe, decentralized network that guarantees data integrity and defends against threats. We also introduce energy harvesting technology to address the issue of continuous energy supply for IoT devices, which lessens the load on farmers by removing the requirement for additional batteries. We achieved 89.5% accuracy in our proposed machine learning model. The suggested model would provide a variety of services to farmers, including pesticide recommendations and water motor control via mobile applications and a cloud database.**

***Keywords*—Smart agriculture; machine learning; internet of things; energy harvesting; blockchain technology**

I. INTRODUCTION

Without a doubt, agriculture is the most important source of livelihood in Bangladesh. As the world's population expands, increased agricultural output is essential. The amount of fresh water and appropriate fertilizer used in irrigation must be raised in order to maintain enhanced farm productivity. Unintentional water waste happens when water consumption is not planned. Choosing the right fertilizer for a particular farmland is likewise a difficult challenge for our farmers. This demonstrates the urgent need for alternatives to reduce water waste and appropriate fertilizer choices without placing farmers under stress. In the Electronic age, agriculture is rapidly becoming a data-intensive sector, with farmers collecting and analyzing massive amounts of data from various sources (e.g., sensors, farming machinery, etc.) to obtain vital information and become more efficient in production. Technology nowadays has advanced a lot. With the help of Machine Learning and IoT devices, a drastic change can be made possible in the agricultural industry [1].

With the release of open-source Arduino devices and the availability of different sensors, it is now possible to build devices that can monitor soil moisture content and irrigate fields or landscapes as needed. Machine learning algorithms are used to assess various agricultural data and may readily forecast which decisions should be made to improve farmland productivity. In comparison to their previous farming ways, the farmer may easily combine ML and IoT into their farming and create an automated system that is more time effective and less risky. Here, Fig. 1 depicts the difference between the traditional system with the ML-based agricultural framework.

Wireless Sensor Networks(WSNs) technologies have a major challenge with limited energy. Many research in WSNs has also been focused on reliable energy supply to extend the survival time of limited power sources in a network [2]. Energy harvesting techniques are used to overcome the energy-scarcity problem of WSNs. Energy harvesting is a process in which energy is obtained from the environment as renewable energy sources like solar radiation, Radio Frequency (RF), wind, geothermal, electromagnetic (EM) waves, hydro, etc., and is stored effectively for driving various applications systems which may include wireless sensor networks (WSNs) [3] [4]. Therefore, it can be used to operate the devices of the embedded system for a reliable energy supply.

Security is one of the most critical aspects of IoT, as it deals with the protection of data and devices from unauthorized access, use, disclosure, disruption, modification, or destruction [5]. Encryption mechanisms are mostly used to ensure that data is securely transmitted. But, regularly used encryption algorithms such as DES, AES, and RSA will be heavy for small-scale embedded systems. Therefore, blockchain technology can be used as a lightweight calculation technique to reliably operate and secure an IoT system[6] [7].

This paper presents the latest IoT-ML-driven intelligent agricultural management and provides a substantial new research direction. The central insight of this work is to offer possible solutions to farming hazards while providing a combined framework. Some significant contributions of this paper are outlined as follows:

- **Smart Management:** Traditional agricultural management is strengthened with edge-cutting technologies (i.e., IoT and Machine Learning).
- **Distant Monitoring and Controlling:** Farmers can monitor and control irrigation management from a distance in terms of sensor-based real-time data.
- **Intelligent Decision Making:** Our machine learning model provides substantial water control management

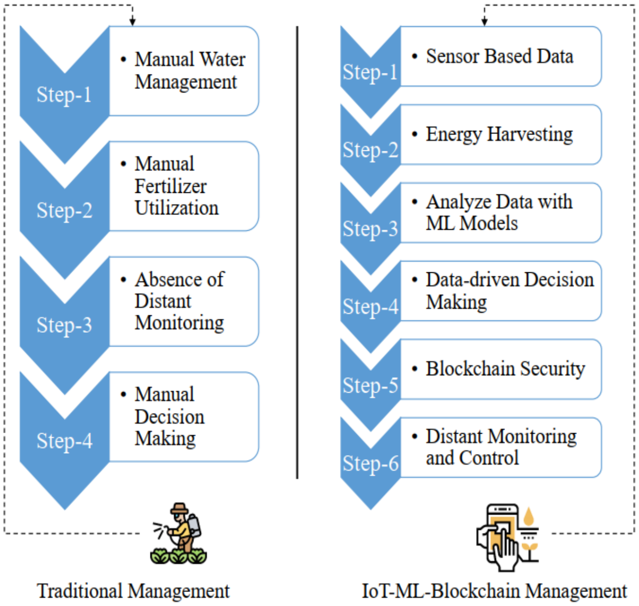

Fig. 1. Architectural differences between traditional agricultural management with IoT-ML-Blockchain based agricultural framework.

and fertilizer utilization direction for a minimum resource with a maximum throughput based on the data collected from the farming field.

- **Block chain Based Security System:** Our proposed solution uses blockchain technology to create a secure and decentralized network that can ensure data integrity and protect data from denial of service (DDoS) attacks, and man-in-the-middle (MITM) attacks.
- **Energy Harvesting:** To ensure a continuous energy supply for the IoT system, we have introduced energy harvesting technology which reduces the hassle for the farmers of using extra batteries.

The rest of the paper is organized as follows: Section II provides an overview of existing works related to our proposed framework. Section III provides a detailed description of the hardware that have used in this research. Section IV discusses the proposed IoT-ML-based smart agricultural framework. Section V discusses the blockchain-based security of our system. Section VI presents the real-life implementation of our project. Next, Section VII illustrates and analyzes the experimental result from our machine learning models. Section VIII future research directions in this field of research. Finally, Section IX gives a brief conclusion.

II. RELATED RESEARCH

Several ML-IoT-based researches and project works on agriculture systems have been carried out till today.

In [8], For remote sensing and smart agriculture, Ullo et al. presented a review of research on the developments in smart sensors and IoT. They put forth some suggestions for IoT advancements that will support researchers and agriculturalists in their work.

In [9], Samuel et al. analyzed numerous techniques for crop selection, crop sowing, weed detection, and system monitoring. They have recommended different image processing methods for weed and leaf detection and evaluated the benefits and drawbacks of each. Drone implementation has been considered for real-time monitoring and seed planting. However, no actual implementation is shown in this research; they have only reviewed several smart agricultural strategies.

In [10], they analyze soil moisture levels and apply auto irrigation to the crops. In order to eliminate the need for human involvement, this system also senses temperature, humidity, and the presence of impediments in the targeted region. These data are accessible to the user via mobile from the cloud. By giving the motor driver the command YES/NO based on this data, the user can control the operation of the motor.

In [11], they use a cloud-based architecture and the Internet of Things to examine a smart irrigation system. This system is designed to measure soil moisture and humidity and then process this data in the cloud using a variety of machine-learning techniques. Farmers receive accurate information regarding water content regulations. If farmers apply smart irrigation, they can reduce their water usage.

In [12], they use IoT and machine learning to predict late blight disease in potatoes and tomatoes prior to the first occurrence. This will send farmers a warning message on the precise time to apply the protective pesticides.

In [13], for yield prediction, they present a hybrid ML model using IoT. They use a two-tier ML approach named aKNCN and ELM-mBOA.In the first tire, they estimate soil quality and in the second tier, they predict the crop yield.

In agriculture, supply, and demand have always been crucial issues for sustainable production management. To address and provide a possible solution to this problem, M. Lee et al. proposed an IoT-based controlled agricultural production management [14]. The authors developed a decision support system to predict specific criteria based on IoT-enabled sensor data.

A cloud-based real-time data analysis model is proposed in [15] instead of dew-point humidity. In this regard, they designed a CMM index measurement model to evaluate the crops' comfort level of relative humidity levels.

To increase the crop production rate, real-time data analysis based on an artificial model is proposed by Y. Zhou et al. in [16]. The current innovation trend expects farmers to use IoT and technology to identify the organization of those difficulties they face, such as water management deficiencies in agriculture and productivity concerns. This research has attempted to build dazzling agricultural cultivation patterns utilizing IoT technologies. IoT has significantly improved agriculture by analyzing various agricultural difficulties and issues.

An IOT-based intelligent technology for agriculture that can sense soils and environmental factors was proposed by Abhijith H. V. et al. in [17]. In order to identify the urgent needs for optimal crop growth, they applied data mining techniques to the sensed data.

Abraham et al. [18] create a proof-of-concept farm surveillance system that employs IoT and deep learning to identify farm encroachment.

The purpose of the study Wongpatikaseree et al. [19], is to propose a traceability system, summarizing and presenting observed data from the smart farm.

For smart farming, Deden Ardiansyah et al. [20] suggested a WSN Server that can handle and optimize agricultural data. They instantly store the data in the database, which is afterward represented as a website and accessible through the Internet network.

Automation in agriculture is a basic need for remote control-based agricultural management to ensure sustainable development in this field of research. In this regard, L. Vijayaraja et al. proposed an IoT-based monitoring system using wireless communication networks in [21]. The power supply management used in this framework is entirely from the renewable energy source that provides a cost-effective model for sensor-based decision management in intelligent farming.

In [22], Yaw-Wen Kuo, et al. presented a Long-range IoT system where they developed four types of IoT units based on Long-range technology. They employed pH, ORP, and EC in Type A and water, air, and humidity sensors in Type B. In type C, the pump can be operated remotely, and in type D, a water flow or water meter-controlling system is provided.

They presented a cloud service-based architecture in [23] that includes a variety of services for farmers, including agri-food-related services, financing, fostering, warehouse management, etc. They have suggested interactive video conferencing, voice-based services, text messaging, web portal services, and more under the heading of cloud services.

A key component of practicing smart agriculture is precision agriculture. In this context, Patil et al. [24] suggested a system that measures soil moisture using sensors for temperature, humidity, and soil moisture. Additionally, they offered various methods for highlighting the issue of data loss.

In [25], Quasim et al. use blockchain techniques in smart healthcare systems to ensure the security of healthcare data. It provides the security, privacy, and efficiency of the data in transmission between wearable sensors and Internet of Things (IoT) devices.

In [26], Makhdoom et al. made a blockchain-based framework for privacy-preserving and secure data sharing in smart cities. The system secures data sharing by segmenting the blockchain network into different channels, where each channel consists of a limited number of authorized organizations and handles a particular type of data, such as financial information, health data, smart car data, or data related to smart energy. Additionally, smart contracts contain access control rules that regulate who has access to the data of users within a channel.

Many different types of intelligent agricultural systems were developed in the earlier work. Some of these current systems are tabulated in Table I.

III. SYSTEM HARDWARE

To set up the IoT environment for a smart agricultural system, we have selected a variety of hardware components, including the ESP8266 Node MCU (Fig. 2) processing unit and several sensors, including capacitive soil moisture (Fig. 3), PH sensor (Fig. 4), MH-RD Rain Sensor (Fig. 5), and LDR Sensor (Fig. 6). Our IoT system is powered by DC-DC power converter (Fig. 9), solar energy harvesting components (Fig. 10), single-channel relay modules (Fig. 7), DC motors (Fig. 8), etc.

A. Node MCU ESP8266

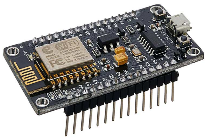

Fig. 2. Node MCU module.

Features[1]**:**

- Operating Voltage: 3.3V
- Input Voltage: 7-12V
- Digital I/O Pins (DIO): 16
- Clock Speed: 80 MHz
- Small size module

B. Capacitive Soil Moister Sensor v1.0

Fig. 3. Soil moisture sensor.

Features[2]**:**

- Operating Voltage: DC 3.3-5.5V
- Output Voltage: DC 0-3.0V
- Digital I/O Pins (DIO): 16
- Analog output
- Supports 3-Pin Sensor interface

C. PH Sensor(SEN-00239)

Features[3]**:**

- Supply voltage: 5V
- Current: 5-10 mA
- Consumption: $\leq$ 0.5 W
- Working temperature: 10-50°C

TABLE I. PREVIOUS RESEARCH WORKS IN TERMS OF OBJECTIVES, USED TOOLS, AND POSSIBLE RESEARCH GAPS

Reference	**Research Purpose**	**Used Technologies/Techniques**	**Focused Methods**	**Challenges/Research Gaps**
[11]	IoT-Cloud based automated Irrigation	Raspberry Pi, central cloud storage, soil data set, machine learning techniques, and mobile applications	Focused to measure soil moisture and humidity and then process this data in the cloud using a variety of machine learning techniques	Farmers get information about water only, no other necessary information.
[12]	IoT-based agriculture monitoring system for predictive analysis	Air temperature sensor, air humidity sensor, and soil moisture sensor, Microcontroller Unit (NodeMCU), MQTT protocol, R-Pi 3 microcontroller, MYSQL	Focused to predict the late blight disease in potatoes and tomatoes before the first occurrence	Not fully automated, need human interference to apply the action
[14]	IoT-based agricultural production System	Dual CDMA protocol, pH sensor, water sensor, and temperature sensor	Focus on reliable agricultural production management	Absence of dynamic data analysis model
[15]	IoT-Cloud based agricultural monitoring system	Arduino UNO, temperature and humidity sensors, Arduino Ethernet shield and ThingSpeak cloud platform	Finding the index of thermal control functions to find the comfort levels of agricultural parameters	Sensor data processing time is slower in terms of CMM-MIST measurement algorithm.
[16]	Machine Learning based agricultural management	Threat Model (TM), Deep Crop Mapping Model (DCMM), Random Forest Regression Algorithm (RFRA)	An intelligent management to predict soil moisture content based on the ML architecture	The key challenge of this research is real-time data processing
[17]	Intelligent technology for IOT-based agriculture	PH sensor, temperature, rainfall, humidity sensor, Predictive classification algorithm, MatLab	Focused on the identification of urgent needs for optimal crop growth	Prediction of specific need isn't gained properly
[18]	Comprehensive farm monitoring system	Arduino Board, Node MCU, Sensors, mobile App, machine learning, deep learning	Centered on a surveillance system prototype and an app-based remote administration solution	Remotely monitoring but not fully automated controlling
[19]	IoT-based Smart farming	Sensors, mobile technology, Wi-Fi, cloud computing	Can measure soil temperature, soil moister, humidity, pH and EC values	Human interaction, water wastage
[20]	Water management based on IoT	Soil moisture, Wi-Fi segments	Real-time data monitoring for soil moisture and remote data access	Low or excessive irrigation, and water waste
[21]	IoT-based cost-effective agricultural management	Moisture and Water sensors, Node MCU, Solar panel and LCD display unit	Focused on the low-cost parameter while ensuring a sustainable energy efficient management	The key research gap of this work is that this model is applicable for small farming areas.
[22]	IoT platform has a long range for controlling pumps and monitoring agriculture	LP WAN, Base station, Ph sensor, Electrical Conductivity sensor, Water Temperature Sensor, GY39	Presented a complete IoT system including the design of a remote unit and server construction	It is required to conduct additional research on the pH sensor because the data that has been gathered is inaccurate and collected from other vendors.
[23]	Cloud service architecture for agriculture using IoT and Big Data	Different Sensor, Central Cloud Database	Proposed a cloud-based architecture for the agricultural industry that comprised a range of services, including farm monitoring, market-oriented service, agri-business monitoring, etc.	Not implemented just proposed an architectural model.
[24]	AI in smart agriculture applications	Arduino UNO, Soil moisture sensor, Wi-Fi module	Aimed to use a single moisture sensor and make decisions, such as turning on or off the pump, based on the data collected.	Discussing the disease of crop using image analysis technique but no actual implementation is shown.
Proposed System	Smart agricultural system based on an IoT-ML-Blockchain Integrated Framework	IoT devices, Mobile Application, Machine Learning, and Blockchain-based security system	Focused on intelligent decision making, Distant Controlling, Energy Harvesting, and Security based smart agricultural management system	Future target to ensure Low latency network and high bandwidth transmission, easy deployment of Networks elements and Edge computing technology.

Fig. 4. PH Sensor with module.

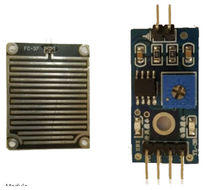

Fig. 5. MH RD rain sensor.

D. MH-RD Rain Sensor

Features[4]:

- Working voltage: 5V
- Output format: Digital switching output (0 and 1)
- With bolt holes for easy installation
- Uses a wide voltage LM393 comparator

E. LDR (Light Dependent Resistor)

Features[5]:

- Able to detect variable light resistance (50-100 K Ohms)

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[1] $https : //components101.com/development - boards/nodemcu - esp8266 - pinout - features - and - datasheet$

[2] $https : //how2electronics.com/interface - capacitive - soil - moisturesensor - arduino/\#Features_0 38_Specifications$

[3] $https : //www.techshopbd.com/detail/2576/PH_Sensor_with - Module_techshop_bangladesh$

[4] $https : //components101.com/sensors/rain - drop - sensor - module\#\%20value$

[5] $https : //www.indiamart.com/proddetail/ldr - light - dependent - resistor - 18812839691.html$

Fig. 6. Light dependent resistor.

- Photo-resistor (photo-conductive cell)
- Power Level: 200 W
- Diameter: 3-20 mm

F. Single-Channel Relay Module

Fig. 7. Single-Channel relay module.

Features[6]:

- Ground Voltage: 0 V
- VCC: Provide input to the relay coil
- Supply Voltage: 3.75 to 6 V
- Current: 2 mA
- Relay Maximum Current: 10 A

G. DC Motor 6V

Fig. 8. DC motor.

Features[7]:

- Diameter of the motor: 23.5mm
- Height: 30mm
- Start voltage: 0.8V
- Rated voltage: 6V
- Non-charging current: 25mA
- Speed: 2980 RPM

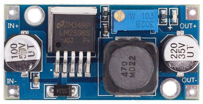

Fig. 9. Adjustable DC-DC power converter.

H. Adjustable DC-DC Power Converter (1.25V - 35V-3A)

Features[8]:

- Input Voltage: 3.2V - 40VDC
- Output Voltage: 1.25V - 35VDC
- Max. Output Current: 3A
- Max. Efficiency: 92
- Output Ripple: $\leq$ 100mV
- Switching Frequency: 65KHz
- Operating Temperature: -45°C to +85°C
- Dimensions: 43mm*21mm*14mm(l*w*h)

I. MSP430 Solar Energy Harvesting Tool

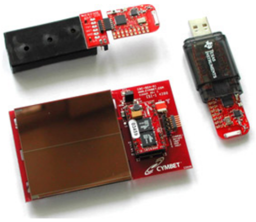

Fig. 10. MSP430 solar energy harvesting development tool texas instruments EZ430-RF2500-SEH.

Features[9]:

- Battery-less operation
- Functions in dim ambient light and 400+ transmissions
- Adaptable to any RF network or sensor input
- Inputs available for external harvesters (thermal, piezo, 2nd solar panel, etc.)
- USB debugging and programming interface with application backchannel to PC
- 18 available analog and communications input/output pins
- Highly integrated, ultra-low-power MSP430 MCU with 16-MHz performance

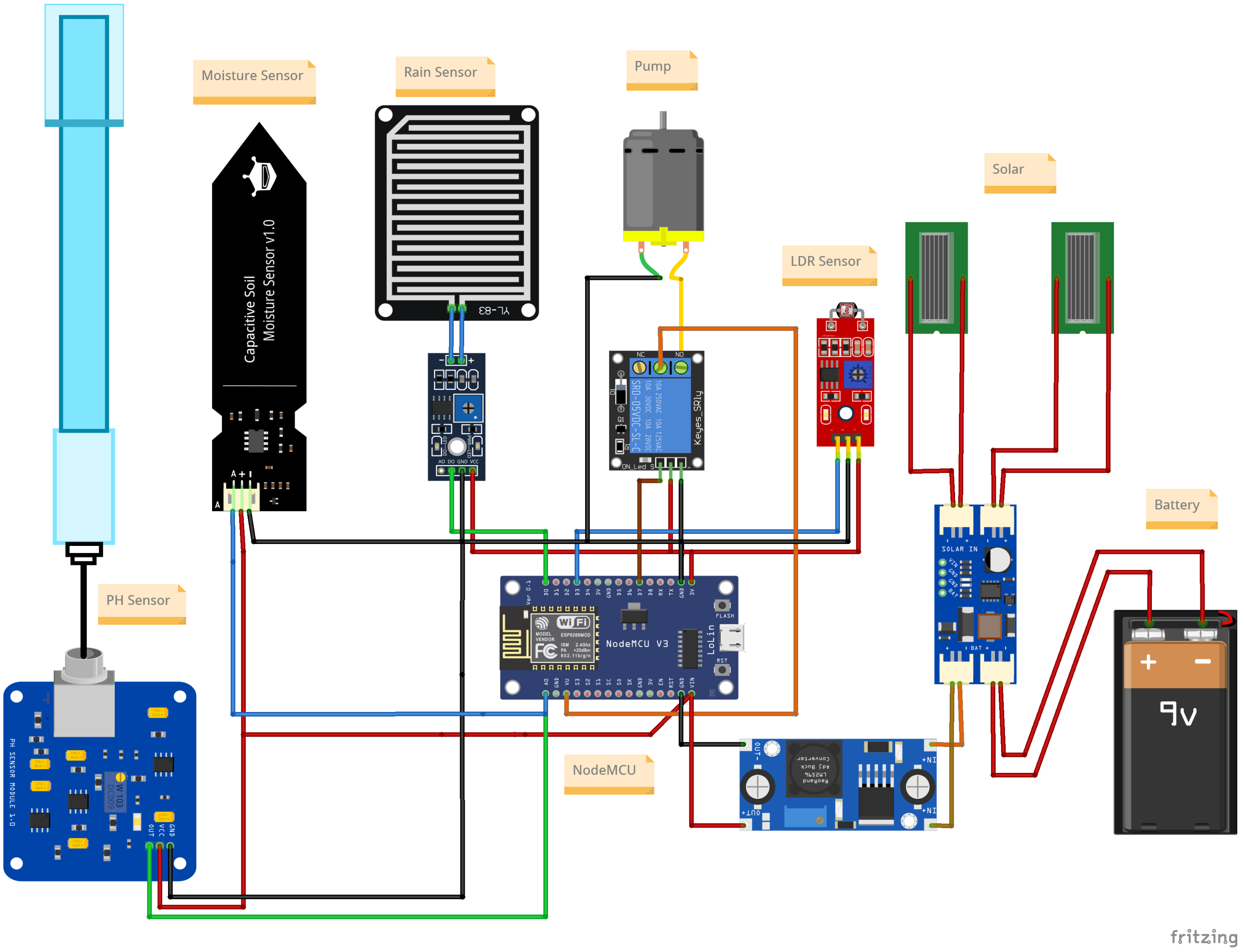

Fig. 11. Schematic pin configuration of our proposed framework.

IV. PROPOSED FRAMEWORK

A. Circuit Diagram and Connections

We used Fritzing[10], an open-source hardware online application to make a schematic pin (Fig. 11) diagram of our smart agriculture system.

We used ESP8266 NodeMCU V3, with an integrated WIFI module as our processing hardware component. The system connects an analog capacitive soil moisture sensor and an analog pH sensor using multiplexing to the A0 analog input of NodeMCU, a photo-resistor known as Light Dependent Resistors (LDR) sensor to a D3 digital input, and a raindrop sensor with rain board and control module to D0 input Pin. In addition, the device is connected with a D3 output pin to a DC 5V micro submersible mini water pump with the relay. We used the NodeMCU's 5V VU pin to power the Motor and Relay. However the LDR Sensor and Rain Drop Sensor, only need a 3.3V supply, the Capacitive Soil Moisture Sensor and pH Sensor need 5V. The GND pin serves as the common ground for every sensor. A solar panel system that is coupled to a 9-volt battery backup powers the system.

B. Working Principle

We have divided our proposed framework into different subparts and each part's working procedure is given below. The overall working procedure is depicted in Fig. 12.

1) Collecting Data From Sensor: We used four different types of sensors, including capacitive soil moisture sensors, pH sensors, MH-RD rain sensors, and LDR sensors, to execute smart IoT agriculture. We can estimate how much water is in the soil with the aid of a soil moisture sensor. A pH sensor, which ranges from 0 to 14, allows us to determine the water's acidity or alkalinity. Water turns acidic if the value falls below 7, else it is alkanoic. Consider levels 5.5 to 7 to be ideal for growing crops. We can choose the best fertilizer for the soil with the aid of a pH sensor.

Basically, a rain sensor is used to detect rain. A rain board that can detect rain and a control module that can compare

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[6] *https : //components101.com/switches/5v − single − channel − relay − module − pinout − features − applications − working*

[7] *https : //techshopbd.com/detail/248/DC*$_M$*otor*$_6$*V*$_t$*echshop − bangladesh*

[8] *https : //techshopbd.com/detail/2067/Adjustable − DC − DC − Power*$_C$*onverter*

[9] *https : //www.radiolocman.com/op/device.html?di = 66638&/eZ430 − RF2500 − SEH*

[10] *₁Fritzing − circuitdesign, ȷhttps : //fritzing.org/*

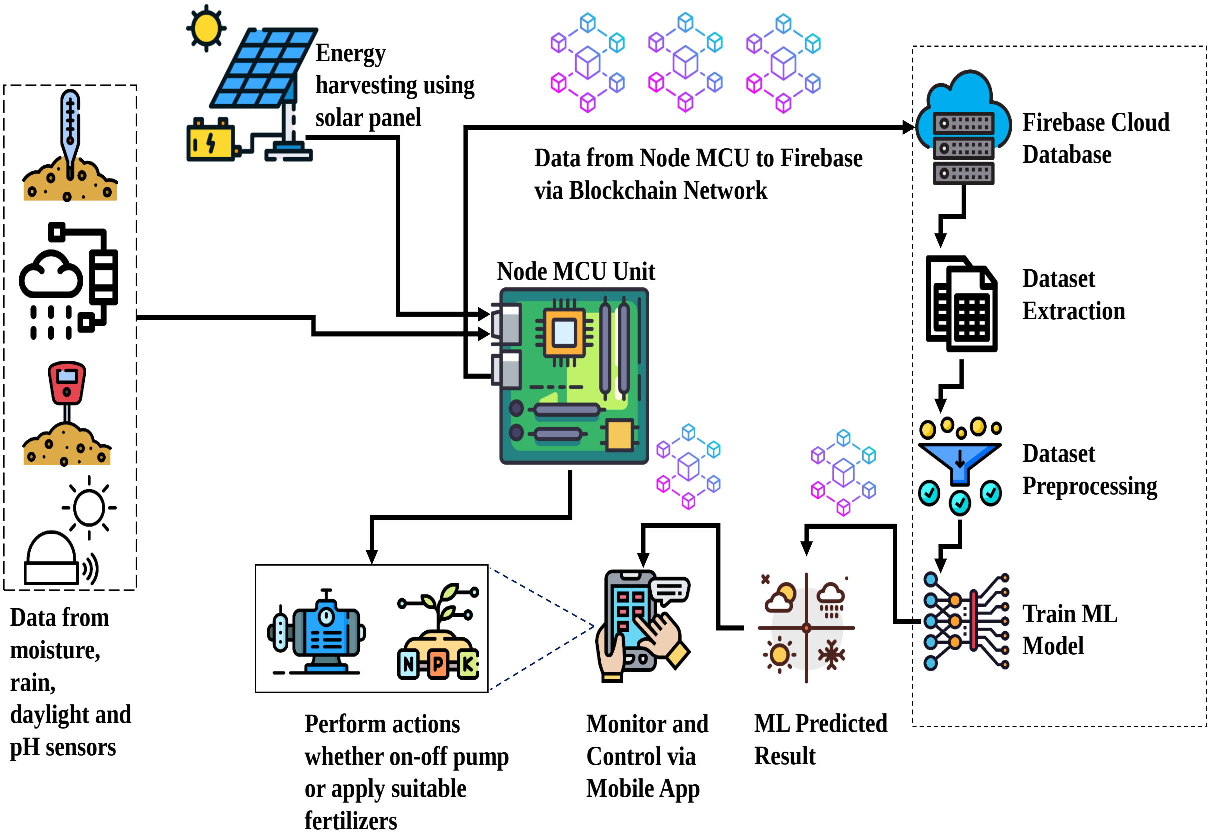


Fig. 12. Proposed IoT-ML-Blockchain framework for smart agricultural management.

analog and digital values are both included. The raindrop sensor aids in our selection of how to operate the motor. The LDR sensor, which is used to detect the presence of light, has also been employed.

Now, each of these sensors is linked to a node MCU board in our project, and data from the sensors is uploaded to the node MCU board and shown on the serial monitor of the Arduino UNO editor and

2) Sending Data to Cloud Server: The node MCU board receives all sensor data, which we would love to save in the cloud in order to control for remote distance. We have utilized Firebase as a cloud server. We linked the Firebase authentication and real-time database URL that we built for our project with the Arduino UNO script in order to integrate Firebase with Node MCU.

All data is sent as a parent-child combination to Firebase. All of the sensor data is sent from the node MCU as a child of Smart Irrigation, which we have constructed as Parent. The Firebase stores the child value as a key-value pair.

3) Data Collection: The Firebase's database contains all of the sensor data, which is compiled as a CSV file. Four columns make up our dataset: pH, LDR, Rain, and Moisture. Nearly 820 data are in our dataset. Only integer values are accepted in the Moisture column here, whereas string values are accepted in the Rain and LDR columns.

4) Data Pre-processing: Data can be often inconsistent. Missing values or values out of range is typical. So, the dataset needs some pre-processing before it can be used to train any model [27]. For this reason, we have considered three such cases.

- **Missing Value Handling:** While exploring our dataset, we observed humidity, raining status, daylight status, and pH level fields with missing values. Therefore, we have filled them with average values of the respective field.
- **One Hot Decoder:** Label encoding is simply the process of converting each value in a column to a number. By using label encoding, we have converted the categorical text data into model-understandable numerical data. We had to use the label encoding to get our dataset ready for our model.
- **Abnormal Data Handling:** Some data contain abnormal values. For example, the range of the temperature in our dataset falls between -20 to 30 degrees Celsius. However, we have even found some data above and below this range. Data tuples with these abnormalities have been dropped from the dataset.
- **Normalization:** Normalization is used to increase the accuracy of models [28]. It is simply the process of having all the data on the same scale. We have used

temperature, pressure, relative humidity, and pressure as features to train our model. The features used to teach a machine-learning algorithm have different ranges of values. This can badly affect the machine's learning ability. To solve this problem, we have standardized the feature values so that all the features stand equal in their representation. By normalization, all the feature values are mapped in the range between 0 and 1.

5) Machine Learning Model: The developed architecture is a Neural Network (NN) based because of its great accuracy. The fundamental advantage of NN over classical machine learning models is that it recognizes significant traits automatically and without human intervention. It's a feed-forward NN with parameters using the back-propagation algorithm and stochastic gradient descent. Distinct processing layers serve different purposes. The output of the feature map is produced by conventional layers, which conduct linear convolution between a series of input tensors and filters. The nonlinear transformation is performed using the $ReLU$, which is the most widely employed activation function. The activation function for the fully connected layer to the end must be careful on the tasks. Batch normalization and an activation layer are performed after each convolution.

$$ReLU = max(0, X) \tag{1}$$

$$d(x) = activation(w^x + b) \tag{2}$$

$$Dropout(x, p) = (x : prob., p)\ (x : prob., 1 - p) \tag{3}$$

$$S(x) = \frac{1}{1 + e^{-x}} \tag{4}$$

6) Mobile Application Development: A smart remote control application can ease our maximum task [29]. We have used the MIT app inventor to make the mobile application that will be connected to our system and by using this app we can do the following task

- **Fertilizer Suggestion:** By analyzing the pH value, the app may suggest which fertilizer is best for a given soil. The app will recommend some alkanoic fertilizer if the pH value rises to help reduce the rising pH value and vice versa. Algorithm 1 depicts how the fertilizer is suggested in our system.
- **Visualization of Predicted Results:** In order to predict whether the motor would turn off or not based on the moisture, LDR, and raindrop sensor values, we construct a neural network model and link it with our mobile app. Algorithm 2 depicts how the remote controlling is done to control the motor in our system.
- **Remote Motor Controlling:** The farmer can use the app to control the motor from any distant or remote location based on the prediction outcome. When the farmer presses the off button, it sends a value of 0 to the firebase, which then passes this signal on to the node MCU via the wifi module and sets the pin value to the LOW, so turning off the motor.

Algorithm 1: Decision Making for Fertilizer Suggestion

```
1. Initialize the pH sensor
2. Read data from pH sensor
3.if $pH >= 6.5\ \&\&\ pH <= 7.5$ then
    Soil is balanced.
    No fertilizer is recommended.
4.else if $pH < 6.5$ then
    Soil is acidic.
    Store the pH amount.
    Find the level_id corresponding pH amount.
    Search through the fertilizer data(in JSON format)
    if $level\_id == keyofJSONdata$ then
        Send the fertilizer name back to the user.
    else
        The result doesn't match our dataset.
else
    Soil is alkanoic
    Store the pH amount
    Find the level_id corresponding pH amount
    Search through the fertilizer data(in JSON format)
    if $level\_id == keyofJSONdata$ then
        Send the fertilizer name back to the user
    else
        The result doesn't match our dataset
```

Algorithm 2: Decision Making for Pump on/off

```
1. Initialize the Moisture, Rain, and LDR sensors.
2. Read data from each sensor.
3. Send the data to the server using an HTTP POST
   request.
4. Apply machine learning to the collected data.
5. Retrieve the predicted result(PUMP ON/OFF).
6. Send Predicted results to the mobile phone.
7. Wait for user input from the mobile phone.
8. if $user\_action = true$ then
    Send a signal to the node MCU board.
    Perform action according to signal.
else
    Wait for 300 seconds
    Take an automated action according to the
      predicted result (PUMP ON/OFF)
```

V. BLOCKCHAIN-BASED SMART-AGRI

Blockchain was described as a data structure using asymmetric encryption algorithms and hash functions to ensure that data tampering and forgery are impossible [30] [31] [32]. Every smart system needs to be taken under the shelter of a security system to avoid getting an external attack. Our smart agricultural system is public so any intruder can make attacks such as DoS attacks to crash the system, and spoofing to alter the control. In the IoT environment where high computational encryption, decryption, and high-level security are not possible.

Therefore, We are implanting blockchain technologies into our smart agricultural system through which we are capable to maintain high throughput, low latency, low communication cost, and tamper-proof and traceability. Blockchain refers to a distributed ledger system where data or transactions are stored in blocks that are connected to each other through making hash which can not only serve as unique IDs but also prove the integrity of the blocks. The hash of the previous block is used to make a hash for the next block along with its data. If any intruder wants to tamper or alter the block data, all the consecutive block hash will be changed. Therefore, any intruder attempts to alter the data or spoof the blockchain will not be possible.

In this system, we consider nodeMCU, Firebase cloud, and mobile app as nodes. In order to avoid altering data in the network, we are using blockchain technology. When any node wants to send data to other nodes, it encapsulates the data into a block along with its hash values (SHA256) and nodeID then adds it to the blockchain. All these nodes will contain the blockchain locally. After adding the block, the node sends it to the cloud through the network. We are not using any PoW, PoS, or accountant selection algorithms which is not possible because of a very small amount of nodes and our nodeMCU has very limited capabilities to run these algorithms (Algorithm 3). When the block is sent to the cloud, I validate the block by checking all the hashes of the previous block along with the nodeID. If it gets any error, the node will consider the block as from an attacker and reject the block from adding to the chain. Fig. 13 depicts the blockchain in our system.

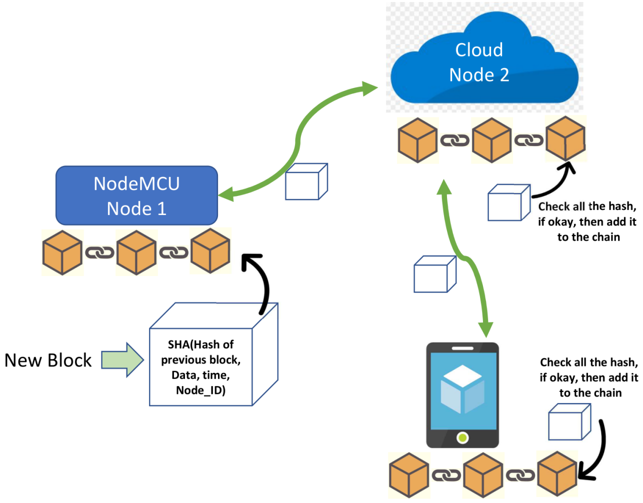


Fig. 13. Blockchain in the system.

Algorithm 3: Blockchain-based data security in smart-agri

```
1. Initialization
2. Read data
3. $Block\_Hash \leftarrow SHA256$ (Previous_hash, data, nodeId, timestamp, nonce)
4. Make a block (Block_hash, data, nonce, nodeID, timestamp)
5. Add the block to the chain locally.
6. Send the block to the cloud.
7.if $Block\_hash = Previous\_Hash$ then
    Accept the block, then add it to the chain.
    Send acknowledgment.
```

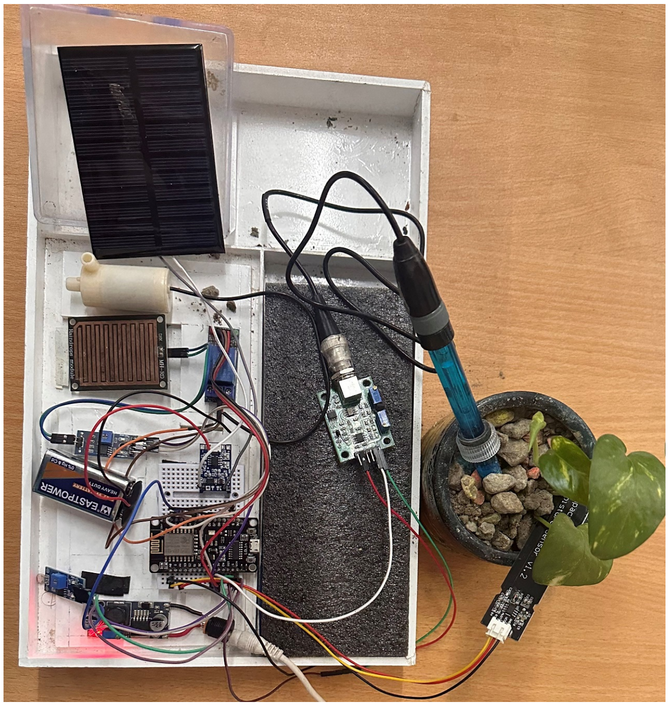


Fig. 14. Hardware set-up of our proposed framework.

VI. IMPLEMENTATION

A. Hardware Implementation

Our Smart-agri system hardware demo showed in Fig. 14.

B. Mobile App Implementation

The interface of the mobile app that we developed in the MIT App Inventor resembles (Fig. 15). The “Fertilizer Suggestion" button can be found in the app. Depending on the pH sensor measurement, this button tells us whether the soil is alkanoic or acidic when we click it. We used the decision tree algorithm to determine the ideal fertilizer for a given soil based on its quality.

The farmer can view the data from the moisture, raindrop, and daylight sensors in our app. Our program uses a neural network model that we built and implemented to forecast whether the motor would be on or off. We can operate our motor using the two buttons in our app labeled “ON" and “OFF". The motor status in the firebase changes to 1 when we press the “ON" button, and the firebase sends a signal to the nodeMCU board, which then turns the motor on automatically. And that is how we can use our mobile app to implement remote control.

TABLE II. SYSTEM EVALUATION WITH THE EXISTING SYSTEMS

Reference	**Remote Motor Controlling**	**Energy Harvesting**	**Customised Mobile Application**	**Machine Learning Integrated Framework**	**Creating Own Data set**	**Central Cloud Database**	**pH based fertilizer suggestions**	**Blockchain based Security**	**Full automation**
[11]	×	×	✓	✓	×	✓	×	×	×
[12]	×	×	×	✓	×	×	×	×	×
[14]	×	×	×	✓	×	×	×	×	
[16]	×	×	×	✓	✓	×	×	×	×
[17]	×	×	×	✓	×	×	✓	×	×
[18]	✓	×	✓	✓	×	×	✓	×	×
[19]	✓	×	✓	×	×	✓	×	×	×
[20]	✓	×	✓	×	×	×	×	×	✓
[21]	×	×	×	×	×	×	×	×	×
[22]	✓	×	✓	×	×	✓	×	×	×
[23]	✓	×	×	×	✓	✓	×	×	×
[24]	✓	×	✓	×	×	✓	×	×	×
Proposed Method	✓	✓	✓	✓	✓	✓	✓	✓	✓

TABLE III. SUMMARY OF PROPOSED NEURAL NETWORK PERFORMANCE PARAMETERS

Epochs	**Processing Time /msec**	**Binary Cross Entropy Validation Loss**	**Gradient Descent Neural Network Validation Accuracy**
10	7	0.5478	0.8947
25	8	0.4525	0.8948
50	7	0.3766	0.8948
75	7	0.3462	0.8949
100	8	0.3376	0.8948

VII. EXPERIMENTAL RESULT ANALYSIS

A. System Evaluation

In Table II, we have shown the difference between our system and the existing systems. The criterion based on which we have shown the differences are remote monitor control, data visualization, customized mobile application, machine learning integrated framework, creating own database, central cloud database, pH-based fertilizer suggestions, Machine learning model development, and full automation. The references from [11] to [24] there is no such system that has implemented all the criteria in their system. But we have successfully implemented all the criteria in our systems.

B. Machine Learning Model Evaluation

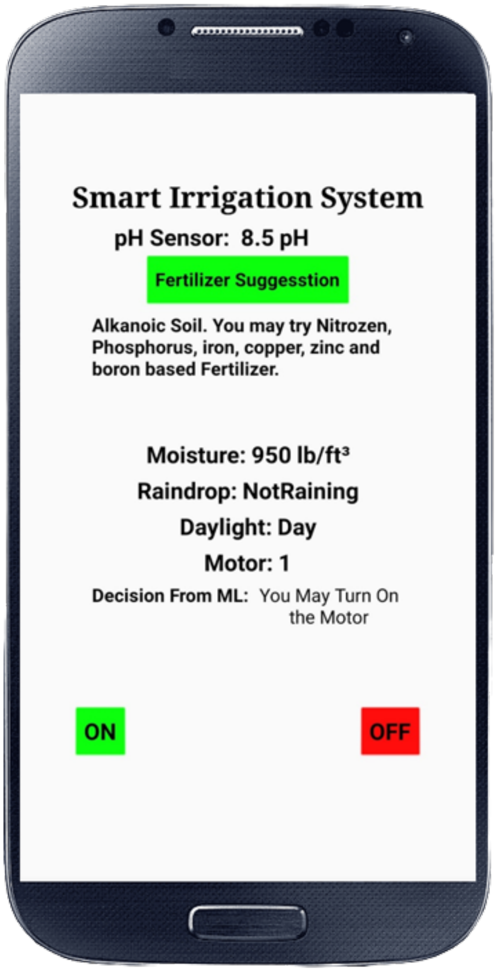
Our deep learning neural network is implemented with the help of our own dataset. We split the dataset into 80-20 ratios for training and validation purposes. The heat map of the features columns is illustrated in Fig. 16. We fit our gradient descent neural network within the data set. The input layer of the neural network receives 3 input lines from the features column, namely, rain status, moisture level, and daylight status respectively. Then we add one dense layer with 16 neurons and the activation function as $ReLu$. The next layer is a dropout layer with a 20% drop rate. Next, we add another dense layer with 8 neurons and apply the activation function as $ReLu$. Then we add another dropout layer with a 20% drop rate. Finally, for the output layer, we add another dense layer with a single neuron with is satiable for binary classification (i.e. motor on-off decision) with activation function as $Sigmoid$.

The experimental result of our model is represented in Table III while showing the validation loss rate as binary cross entropy and validation accuracy level in different epochs. Our model successfully outcomes a stable level of accuracy for the different epochs. We got almost 89.5% accuracy in our experimental set-up.

VIII. FUTURE RESEARCH DIRECTION

For future smart irrigation management, several issues must be addressed as follows:

- **Low-latency in Real-Time Application:** The monitoring and controlling mobile application must be able to transmit real-time data to the farmers or its entity while ensuring a low latency network.
- **High Bandwidth:** To facilitate a buffer-less transmission, we need to ensure maximum bandwidth level to the transmission process.
- **Connectivity:** To meet the high communication demands of future IoT-ML integrated irrigation systems, reliable synchronization between linked autos would be required.
- **Deployment of Network Elements:** When a network has a high enough number of nodes, its overall performance increases. Because network equipment deployment is costly, it is vital to have the required number of network components up and running as quickly as feasible.
- **Augmented Reality:** AR is a multimedia application that mixes real-world scenes into virtual scenes and superimposes virtual scenes over real-world scenes to supplement traditional real-image information. This technology has the potential to help farmers become more aware of the app's functionality.
- **Edge Computing:** This networking approach is built on a network control layer that is logically centralized.



Smart Irrigation System

pH Sensor: 8.5 pH

Alkanoic Soil. You may try Nitrozen, Phosphorus, iron, copper, zinc and boron based Fertilizer.

Moisture: 950 lb/ft³

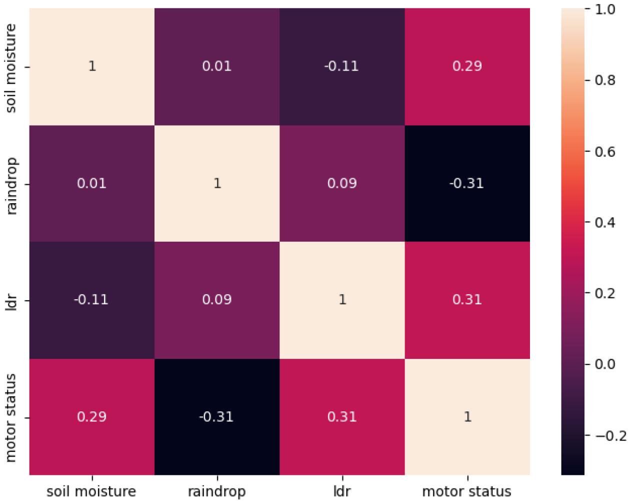
Raindrop: NotRaining

Daylight: Day

Motor: 1

Decision From ML: You May Turn On the Motor

Fig. 15. Mobile application interface.



	soil moisture	raindrop	ldr	motor status
soil moisture	1	0.01	-0.11	0.29
raindrop	0.01	1	0.09	-0.31
ldr	-0.11	0.09	1	0.31
motor status	0.29	-0.31	0.31	1

Fig. 16. Heat-Map of the features of our ML part.

It contributes to the creation of a dependable resource management and traffic control system.

IX. CONCLUSION

We have put forth an integrated solution that enables farmers to solve the challenges that limit their production and profitability by utilizing cutting-edge technologies like machine learning (ML), the Internet of Things (IoT), and blockchain. Through user-friendly mobile applications and a secure cloud database, this model, implemented with a generated database, offers helpful insights and recommendations to farmers, including pesticide usage and water motor control. Real-time monitoring and data collecting is made possible by the integration of IoT devices, enabling accurate decision-making and assuring optimal resource allocation. Incorporating blockchain technology also improves data traceability, transparency, and integrity, fostering trust and accountability throughout the agricultural ecosystem. Farmers may gain from higher productivity, decreased expenses, and enhanced general agricultural management by implementing our Smart-Agri framework. They can obtain up-to-date, accurate information, make decisions that will increase productivity and reduce waste, and improve their agricultural techniques. We have applied the gradient descent neural network model for water control management and achieved up to 89.5% accuracy. In addition, the suggested structure creates chances for cooperation, information exchange, and market access, all of which help the agricultural industry thrive and flourish sustainably.

In the future, the framework's scalability, and its interoperability can all be explored through more research and development in this area, along with potential problems like connectivity problems and data privacy issues. We can build an ecosystem that really revolutionizes the agriculture sector by continually improving and building upon these technological achievements, making it more intelligent, efficient, and robust in the face of changing global issues.

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