A Developed IoT Platform-Based Data Repository for Smart Farming Applications

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***Abstract*—Generally, it is possible to increase agricultural output while decreasing the time required for human oversight by automating routine tasks. In this work, the Internet of things (IoT) played a vital role in designing a platform to monitor a farm wirelessly, reducing human involvement, allowing remote observing, and remote control of the design using a public IP address based cross-platform, Apache, MySQL, PHP and Perl (XAMPP) Apache package. A cloud is appealing when a wireless sensor network generates a lot of data. Cloud-based wireless communication systems are being tested to monitor and manage a set of sensors and actuators to estimate paddy (rice) water requirements in a particular location. The proposed design shows robust interaction between two microcontrollers to deal with different sensors and simultaneously act as a WiFi unit. The row data obtained from the sensors is uploaded to the cloud through specific Hypertext Preprocessor (PHP) files to store and fetch the data from the database. Through the programming method, the system focuses on tracking the paddy growing value and the amount of water available in the soil, which should be around (10 Kpa) for an optimum paddy environment. The results emphasized that 80% of water is retained when a maximal 10 Kpa of soil moisture is achieved.**

***Keywords*—Smart irrigation system, automatic plant watering, intelligent farming system, IoT-based monitoring systems, data warehousing, paddy production**

I. Introduction

Smart farming uses data and information technology to optimize complicated agricultural operations [1]. The IoT is a system that connects and monitors items remotely through the Internet. Over the last 50 years, agriculture has seen profound changes. Agricultural machinery has allowed for more efficient cultivation of a larger area of land, resulting in increased speed, production, and scale. 5G is a massive boon to the digital transformation of farming practices. Connectivity between field data and farm management smart devices is crucial to the success of smart farming and precision agriculture. Here is where the Internet of Things comes in. To maximize their yields and efficiency, farmers may use smart gadgets and sensors; however, this would demand massive amounts of resources and internet speeds. Some 4G networks can struggle to handle the influx of devices and traffic. Overcoming this obstacle, 5G will allow for high-speed, real-time communications between sensors and other devices. Rural assets' performance, sustainability, and resilience benefit significantly from incorporating artificial intelligence, big data, analytics, and upcoming technologies like the IoT and 5G [2]. Asset tracking, such as farm machinery, livestock surveillance, storage monitoring, and more, are all aspects of IoT and 5G's usefulness in agriculture. In this way, farmers can save cost and time by remotely controlling their autonomous tractors, soil sensors can notify them of irregular situations like insufficient irrigation and lack of acidity, and livestock sensors can notify them when livestock leave the herd. Because of advancements in 5G network speed, cloud computing, and artificial intelligence, the time it takes to check farms has been cut from a week to an hour [3]. Lessening the number of fertilizers, insecticides, and herbicides needed directly results from careful plot analysis. Intelligent irrigation systems ensure that water is applied precisely where and when it is needed.

The development of an IoT platform to monitor and cultivate rice plants is the main focus of this research. Rice is a significant food crop all over the world. Rice seedlings raised in a central location give the required assurance for large-scale rice planting. The goal of centralized rice seedling growing is to transition from conventional field-scattered rice seedling raising to concentrated rice seedling. Seeds are saved, the land is saved, water is saved, labor is saved, and seedlings are grown quickly in this focused growing manner. As a result, this centralized rice seedling growth method has been widely pushed in various regions of the world [4]. Smart agricultural technology undoubtedly aids farmers in various duties to increase crop yields. As rice is becoming an important staple food in

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Asia and other areas of the world, the importance of paddy farming has widely emerged. Furthermore, among the few variables affecting rice yield production are unexpected weather conditions and ineffective weather forecasting procedures [5, 6]. In terms of data refinement, data quality (DQ) is crucial to efficient data quality measurement. It is imperative from a financial standpoint when dealing with the realized data from the planned database. In DQ, missing data, also known as incomplete data in relational databases, is the most common error in sensor data and can occur for several reasons. These include, but are not limited to, an unstable wireless connection due to network congestion, the power failure of sensor devices due to limited battery life, and environmental interference like artificial blockage, walls, weather, and vandalism. When referring to data, "completeness" means that all required characteristics are present and non-null and that all relevant data is included in the collection [7, 8].

To be more specific about the challenges of this field, the gaps were formalize as follows: the existing planting processes mainly rely on fertilizers and pesticides to boost productivity, which does not promote the creation of sustainable rice harvests because these activities are not ecologically friendly agricultural practices [9]. In addition, most of the farmers forget to water/irrigate their plants, which mainly affects crop production (especially rice planting) and disappoints the day of harvest [4, 10–12]. As a result of this, keeping rice plants always absorbed in plentiful water levels can be a distinctive challenge [1, 13], knowing that soil water concentration must be maintained under 10 Kpa (kilo Pascal) for proper water distribution [14]. When a farmer fails to turn off the engine manually, power and water are wasted [15]. Furthermore, most conventional microcontrollers cannot be connected to the Internet usually, and the Internet chipset makes the system expensive or increases the complexity of the electronic circuit design. Hence, the system must be developed and controlled based on optimum circuit integration to support the sensors and reduce costs [16–19]. In addition, the current IoT platforms are complex, unreliable, and expensive with the restricted workspace environment, responding delay time, and need extra energy to deal with more sensor options, making dealing with different sensors and actuators rigid [20–24]. Furthermore, researchers have discovered that DQ issues can arise in various IoT structure layers and impact the DQ of IoT platforms. Hence, the completeness dimension of the data quality needs to be addressed by the developer solution in the proposed platform design [25].

In this research, a smart farming system is designed depending on a developed IoT platform using PHP and structural query language (SQL) to deal with different outputs of the sensors employed in the farm environment.

The rest of the paper is summarized as follows: a comprehensive introduction to smart farming and IoT technology is given in Section I. Section II presented and discussed the research on smart systems in agricultural fields. Moreover, the methodology of the proposed work is presented in Section III. Section IV discussed and analyzed the results. Finally, the conclusion of the research was illuminated in Section V.

II. RELATED WORKS

Many efforts have been made in the agricultural industry utilizing IoT technologies to construct smart farming solutions [26]. The IoT has caused a massive transformation in the agriculture environment by researching various challenges and impediments presented by Ray [27]. Agriculturalists and technologists are expected to be able to handle problems that farmers experience, such as water crises, cost optimization, and productivity constraints, by leveraging IoT [28, 29]. These issues have been addressed by cutting-edge IoT technology, resulting in solutions that increase productivity while lowering costs. The improvements in the field of wireless sensor networks proposed by Ojha, *et al.* [30] helped awfully in collecting data from sensing devices and transferring it to the central servers [31]. Those Sensors data give comprehensive information on various environmental variables, allowing for proper monitoring of the entire system. Field administration, soil and crop monitoring, unwanted item transportation, wild animal attacks, and theft are only a few elements that affect agricultural yield [32, 33]. Furthermore, IoT provides for properly coordinating resource constraints, ensuring that IoT is used to its full potential. There are many applications, protocols, and prototypes in the agricultural field. IoT agricultural research themes include network platforms, infrastructure, applications, security, and challenges [34–36]. Moreover, Several IoT laws and standards in agriculture have been implemented by some managements and companies around the world. However, much work was performed in the IoT agricultural environment, and to fully appreciate the current research situation, a complete analysis of IoT in farming is necessary. The challenge of food production in the 20th century gets increasingly severe as the world's population expands. The world's biodiversity is predicted to maintain around 9.4 and 10.1 billion people by 2050, increasing the need for specialized food production regions, mainly for planting and livestock [37]. Human-caused environmental changes can stymie the establishment of new crops.

Moreover, increased urbanization reduces personnel in food-producing regions, raising prices and lowering the sector's productivity capability [38, 39]. Consequently, smart farming is a new farm administration concept that employs techniques and technologies at various levels and scales of food land to address concerns such as growing food production demands and labor shortages [40, 41]. For example, smart farming may use a variety of sensors to collect data (e.g., temperature, humidity, light, pressure) by connecting the devices to send or receive data and administrative information technology and data analysis solutions to organize and analyze the data [42–44]. In addition, recent technological breakthroughs in IoT-related domains have made intelligent farming with IoT simpler to adopt and apply, as stated by Ibarra-Esquer, *et al.* [45]. Technological breakthroughs include network access, device size minimization, optimization of power usage, and price. Furthermore, the world's leading farming practices are promoting IoT in smart farming through incentive schemes and government regulations that finance research and training [46, 47]. Numerous research on IoT technology for smart farming have been published in recent years, demonstrating that this research area is constantly growing and developing [27, 48−51]. In the previous works, the authors have suffered from the deficiencies of preexisting restricted IoT platforms such as (Blink, ThinkSpeak, NetPie, etc.). These platforms are rigid in interacting with various controllers and ban most crucial parts until an update (pre-subscription) is made available. Since the proposed IoT platform is adaptable, this study contributes substantially and plays a critical role in resolving the innovative agricultural challenge. Additionally, the sensors and Internet-based dataflow were separated into two independent sections. All the components were designed and processed individually to be as error-proof as possible. Each section conducted different tests and analyses, allowing for a thorough examination of every variable and circumstance. The proposed system is decentralized, so any future issues will surface immediately and be dealt efficiently. It is worth mentioning that each part is complementary to the other.

III. IoT Farming System

This section describes the proposed IoT-based intelligent farming tracking system for reducing the environment of bolting rice fields. With the advancement of connection technologies, the principles of the IoT, and the power of cloud computing, it is possible to develop low-cost alternatives and services in intelligent farming. The suggested intelligent agricultural monitoring system comprises five sensors that collect data, including temperature-humidity, soil moisture, wind speed, tank water level, and motion detection (Fig. 1).

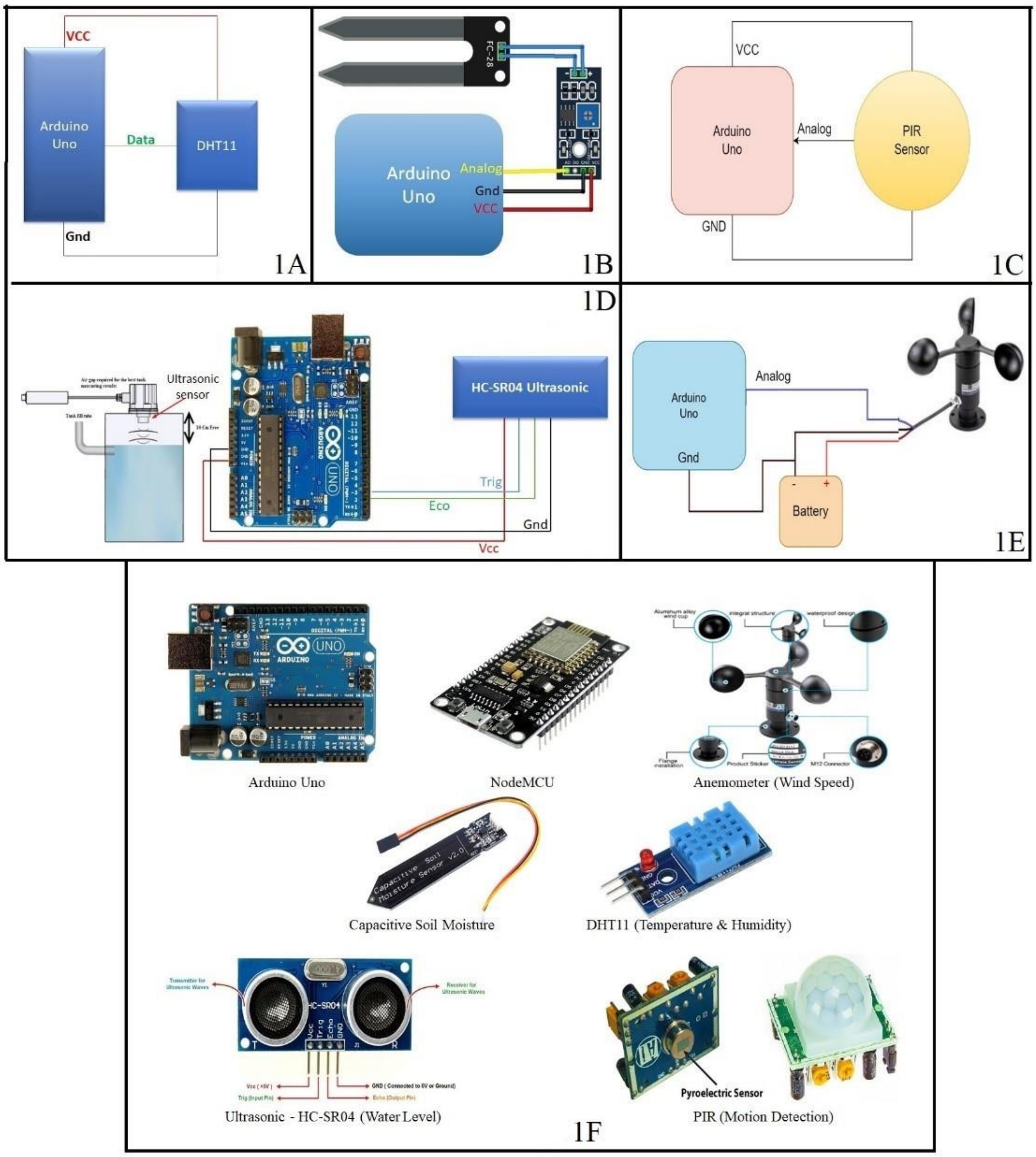

Figure 1. Connection method with arduino: (A) DHT11, (B) Soil Moisture, (C) PIR, (D) Ultrasonic, (E) Wind Speed, (F) Smart Farming Sensors and Microcontrollers.

The raw data is delivered through a gateway to a cloud for analysis. The farmer is notified through the website to take any necessary preventative actions. Arduino is a free and open-source platform for building and programming electronics. It can receive and deliver data to most devices and command special electronic equipment through the Internet. The DHT_{11} given in (Fig. 1A) is a temperature-humidity sensor that uses optical signal output modification to read and monitor temperature (T) and humidity (H) and display them separately [52]. In addition, the internet connection occurs using ESP8266 Wifi-chip, which is offered as a built-in module (Embedded) with the open-source Arduino-based NodeMCU board [53]. Since it is a complete System on Chip (SOC) with an integrated TCP/IP protocol stack, the NodeMCU-based ESP8266 WiFi Module is preferred due to its ability to connect any microcontroller to any WiFi network. The ESP8266 can act as a standalone application host or delegate all WiFi networking tasks to another application processor. Moreover, the capacitive soil moisture sensor presented in (Fig. 1B) uses capacitance fluctuations to measure the soil's moisture [54]. It may be programmed to automatically water plants or alarm farmers on plant situations. Passive infrared (PIR) sensors, shown in (Fig. 1C), measure ambient heat energy for motion detection using a pair of pyroelectric sensors [55]. The sensor turns off if there is a change in the signal strength between the two sensors, as may occur if an unknown person enters the area. Furthermore, the HC-SR04 Ultrasonic sensor in (Fig. 1D) can easily be used across a broad range of distances (up to 13 feet) and employs SONAR (sound navigation and ranging) waves to identify and locate items without physically touching them [56]. The water level inside the tank is controlled depending on the indication from the free space that shows the stages inside the tank using the HC-SR04 Ultrasonic sensor [57]. Once the ultrasonic sensor refers that the distance between the top and water level equals 10 Cm, the electrical water pump starts filling the tank until it gets to the top again. Another sensor presented in (Fig. 1E) is the Adafruit Anemometer sensor that needs a voltage range of 7 to 24 volts DC to measure wind speed [23]. Noteworthy that the sensor functioned properly using the 5V provided by the Arduino Uno Microcontroller. However, the solar system is utilized to boost the voltage of the Lithium-Ion Battery (3.7 – 7.5) V to centralize the voltage terminal. Finally, the real sensors and microcontrollers are depicted in Fig. 1F [23].

Traditional farming relies solely on the farmers' knowledge, and very little or no technology is used in conventional farming. There is no data analysis, prediction system, or knowledge regarding the impacts of environmental factors on rice crop growth, health, and productivity. To overcome these issues and lessen the drawbacks, we are working on an IoT-based intelligent farming monitoring system in this work. The objective is to bridge the gap between the employment of new technologically-based solutions for improved rice crop growth and production and the increase in crop production. Furthermore, there is no indigenous technology option for rice farm drawbacks reduction. Traditional farming's problems can be eliminated with IoT-based farming. IoT-based solutions can improve the quantity and quality of the rice crop, reduce rice bolting, and increase production. The architecture of the proposed intelligent farming monitoring system is based on the abovementioned generic of all sensors used in this work. The sensors have been deployed in the rice farm at the sensing layer of the architecture to capture various events occurring in the field. The network then sends the collected data to a remote cloud server, where it is analyzed for intelligent decision-making while data on the server are visualized.

As an essential point, the percentage moisture value given by the soil moisture sensor must be converted into kilopascal (KPa) to satisfy the rice planting specification. A kilopascal is a unit of pressure, and it is used to measure that pressure. 10g mass on a 1 cm^2 surface generates roughly the same pressure as 1 kPa. One atm (Atmosphere) is equal to 101.3 kPa. One kilopascal is equal to 1000 pascals of pressure. For simplicity, the conversion formula needs to be illustrated using the diagram in Fig. 2.

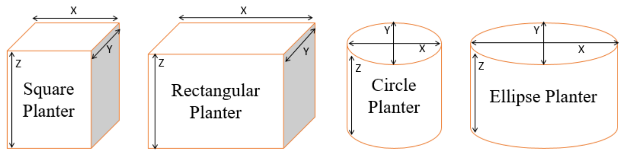

Figure 2. Planters in different sizes and shapes.

Noteworthy that the height of the moisture sensor plays a vital role when measuring the amount of moisture available in the soil since the sensor must be absorbed fully in the planter to sense the exact moisture tension. The formula is defined in the programming code and calculated as follows:

$$cm^3 = x \times y \times \left(\frac{level\ \%}{100\ \%}\right) \times z \tag{1}$$

$$m^3 = \frac{cm^3}{100^3} \tag{2}$$

$$liters = m^3 \times 1000 \tag{3}$$

$$Kg = liters \times 1 \tag{4}$$

$$K\ (Pressure) = \frac{kg}{m^2} \tag{5}$$

$$Bar = \frac{K\ (Pressure)}{c} \tag{6}$$

$$Kpa = Bar * 100 \tag{7}$$

where the diagram presents planters with different sizes and is symbolized by (x) for the top width of the planter, (y) for the entire length of the planter, and (z) for the height of the moisture sensor. In addition, the term (c) presented in Eq. (6) is the constant used to convert $K\ (Pressure)$ To (Bar), where $c = 10197$. Considering that 100% of moisture represents 0.2 L of water. A bar is a unit of pressure defined as precisely 100.000 $pascals$ (symbol: Pa). It is equivalent to 0.987 atmospheres (101.325 Pa), the standard pressure reference unit.

The intelligent farming system consists of five sensors, temperature and humidity, soil moisture, wind speed, water level, and motion detection. Motion detection sensor detects the invasion of birds, animals, or strangers to the farm region, as illustrated in Fig. 3, connected all through Arduino Uno microcontroller as an independent sub-system to facilitate reading the output typically (sub-system 1).

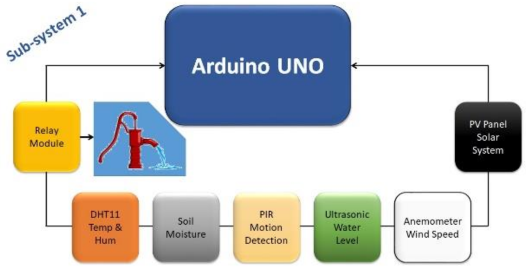

Figure 3. Coupling sensors to an Arduino uno.

The connection is made between the (Tx) pin of Arduino Uno to the (Rx) pin of the NodeMCU, as illustrated in Fig. 4, such that the Arduino sends the data generated from the sensors to the NodeMCU (sub-system 2) through the Rx port concerning the common Gnd (Ground-V) of both microcontrollers.

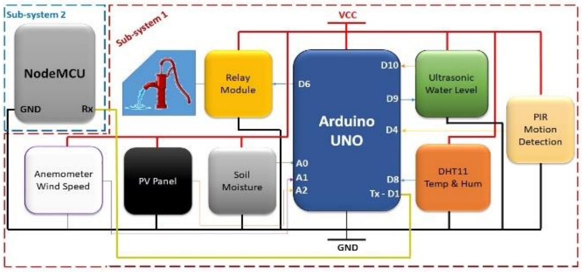

Figure 4. Connecting sub-system 1 with NodeMCU.

The stored data in the cloud server was accessed via a PC/laptop, which is used in this work. The behavior of the observed data is visualized using an intelligent software program like PHP, which then provides an alert message if any significant change occurs that impacts the environment and might cause the quality of the rice. The data is stored through the IoT platform developed in this work based on the SQL language provided by a particular public IP-based website and PHP programming language to satisfy the problems given in the introduction. It is worth mentioning that the system started by creating the required connections among the proposed sensors to get better coupling between the Arduino Uno and the NodeMCU microcontroller as a part of the data collection processes. Then the row data is transferred to the cloud and written there through the (dbwrite.php) file (sub-system 3). After that, the information is accumulated inside the database system established by the XAMPP Apache package. Finally, the collected data are fetched by (dbread.php) from the proposed database system to display on the website as regular information (sub-system 4). The database of the proposed IoT platform is created using the XAMPP package as an easy-to-install Apache installation that includes the MariaDB, PHP, and Perl languages. Afterward, the database and the aforementioned IoT platform design methodologies were organized using a specific public IP address identified as (160.20.147.239) for security reasons. For more clarity, the entire system that describes the procedures mentioned above is given in Fig. 5.

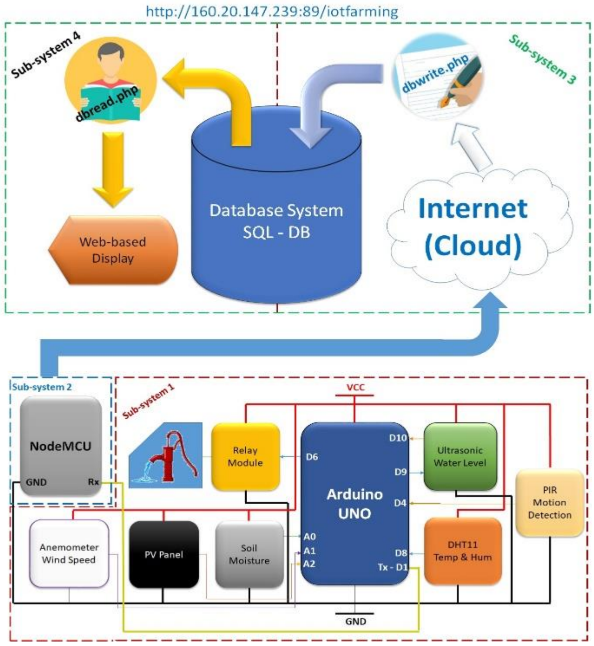

Figure 5. Overall Sub-systems – Connecting all sub-systems with Cloud Section.

As aforementioned, the data can be transferred from the Arduino to Node MCU through the link from Arduino's TX to the RX of Node MCU concerning the common GND between the two microcontrollers. However, the data can be transferred from the Node MCU to the (dbwrite.php) file based on POST instruction after realizing sensors data (d1 – d5) depending on Arduino IDE software code as given in Table I.

TABLE I. POST FROM NODE MCU

1	String srv = “http://160.20.147.239:89/iotfarming/dbwritephp.php”;
2	http.begin(srv);
3	data = “ps=“ + ps;
4	data = data + “&d1=“ + sd1 + “&d2=“ + sd2 + “&d3=“ + sd3 + “&d4=“ + sd4;
5	data = data + “&d5=“ + sd5;
6	int httpcode = http.POST(data);

TABLE II. POST TO DBWRITE.PHP

1	$host = “localhost”;
2	$dbname = “id18295348_iotfdb”;
3	$username = “id18295348_iotfdb”;
4	$password = “*************”;
5	$conn = new mysqli($host, $username, $password, $dbname);
6	d1='';
7	if(!empty($_POST['d1'])) d1 = $_POST['d1'];
8	.
9	d5='';
10	if(!empty($_POST['s1'])) d5 = $_POST['d5'];
11	$sql = 'INSERT INTO tabledb (d1, d2, d3, d4, d5, date1, time1)';

After collecting the variable (data) from in Node MCU side and injected to the (dbwrite.php), the realized data can be loaded and stored in the database based on the following PHP code presented in Table II.

Last but not least, the complete data are fetched from the proposed database and presented through the (dbread.php) file based on the following PHP code given in Table III.

TABLE III. READ DATA FROM DATABASE USING DBREAD.PHP

```
$host = “localhost”;
$dbname = “id18295348_iotfdb”;
$username = “id18295348_iotfdb”;
$password = “*************”;
$conn = new mysqli($host, $username, $password, $dbname);
$sql = “SELECT rowid, d1, d2, d2, d3, d4, d5, date1, time1
FROM tabledb”;
$result = $conn->query($sql);
```

It is worth mentioning that the (dbread.php) is the PHP file used to fetch the data from the database. That is why the end part of the IoT platform link is ended with (dbread.php). Furthermore, the (000webhost.com) was utilized first to stabilize the database management systems, test the connection between the microcontroller unit and the website, and transceiving processes. Afterward, the database created for the IoT platform was migrated to be organized using a specific public IP address identified as (160.20.147.239) for security reasons.

The development of the novel independent IoT platform is depicted in Fig. 6. The proposed IoT platform is reachable via the following link, which refers to (dbread.php) at the end section of the links (http://160.20.147.239:89/iotfarming/dbreadphp.php).

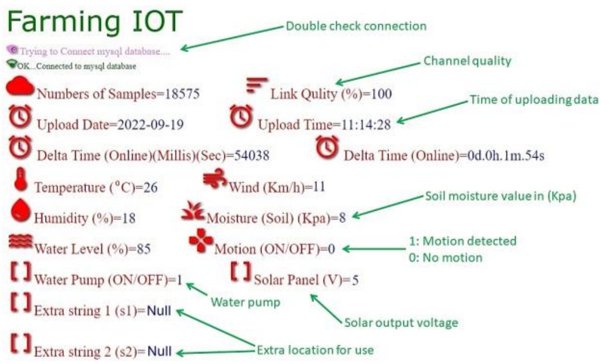

Figure 6. The proposed IoT platform (Farming IoT).

The file (dbread.php) is programmed to read the data written to the database from (dbwrite.php) and display them on the proposed webserver. The main attributes presented in the platform are identified by several samples that represent the data records uploaded to the system from the beginning. Upload time and date refer to the date and time the IoT platform was activated.

Moreover, delta time indicates the time that platform stayed online. The temperature, humidity, wind, soil moisture, motion detection, solar panel, and water level outputs were recorded and uploaded to the webserver periodically through the NodeMCU section (sub-system 2). Specifically, the percentage moisture value given by the soil moisture sensor must be converted into kilopascal (Kpa) using equations 1 to 7, respectively.

The primary purpose of the data integration algorithm is to combine the different data from various locations in one format and location. In this study, multiple types of sensors are used to gather the data for other purposes, such as measuring the temperature, humidity, signal quality, etc. The data with different formats are followed inside our system, and all the gathered data must be saved based on the predefined data format. To get a clear picture of the data obtained from various sensors used in this study, Table IV describes each system's metadata.

TABLE IV. ATTRIBUTES DESCRIPTION OF THE REALIZED DATA

Attribute Name	Data Type	Description
Time (Hour)	Time	Depicts the period of recording data.
Delta Time (Sec)	Number	It shows how long the system is connected to the Internet.
Signal Quality (%)	Number	It shows the strength of the signal, which depends on how the WiFi chip is close to the router.
Temperature (°C)	Number	Shows the temperature degree in the proposed area.
Humidity (%)	Number	Shows the amount of humidity in the proposed area.
Wind Speed (Km/h)	Number	Depicts the strength of the wind in the proposed area.
Soil Moisture (Kpa)	Number	Shows the moisture in the soil, which should be kept <10 Kpa for a better paddy planting environment.
Water Level (%)	Number	Depicts the level of the water in the tank.
Motion Detection	Text	Shows action when a motion is detected in the farming area.
Solar Output (V)	Number	Indicates the amount of power stored from the sun (Max=5 V).

TABLE V. ALGORITHM 1 – TRANSFORMING THE DATA TO THE CENTRAL REPOSITORY

Input: variables (x1, x2, x3, x4, x5), MySQL database
Output: Table (Table IV)

```
Begin
Username = “id18295348_iotfdb”
Password = “*************”
Database name = “id18295348_iotfdb”
// Create the connection with the target database//
Use (Database name, Username, Password)
// “id18295348_iotfdb” is the database name //
// Table I is the table name//
For per second, read the data
Insert data into Table IV {
x1 = Temperature-Humidity
x2 = Soil Moisture
x3 = Water Level
x4 = Wind Speed
x5 = Motion Detection
Update Table IV
View Table IV
}
Next
End
```

Algorithm 1 defined in Table V works in MySQL database using the assigned username, password, and database name. Furthermore, for each sensor data, *Algorithm 1* automatically sets the unique attribute (column) to receive the data from the defined source and save the data. All the data are stored in one location (table) from different sources (sensors). As a result of *Algorithm 1*, a table denoted by (Table IV) is generated. Table IV involves several columns specified by Time (hour), Delta Time (Sec), Signal Quality (%), Temperature (°C), Humidity (%), Wind Speed (Km/h), Soil Moisture (Kpa), Water Level (%), Motion Detection, and Solar Output (V).

TABLE VI. ALGORITHM 2 – DATA QUALITY VALIDATION ALGORITHM FOR EACH SENSOR

Input: Connection name (X, Y, R) **Output: Report to check the completeness of the data**
Begin
Use the connection name
/ * local connection */
X = the number of rows extracted from the sensor
Y = the number of attributes extracted from the sensor
R = table name that used to store the extracted data
Checking the difference (X and R)
Checking the difference (Y and R)
If (X does not equal R), then
Print (Error in the rows number)
If (Y does not equal R), then
Print (Error in the attribute number)
Data completeness Report
End

To validate the data quality for each obtained data from each sensor, *Algorithm 2*, "Data quality validation," was used for that purpose. Algorithm 2 in Table VI checks the data between the source and the repository (target). The first function of this algorithm is to check if the data is wholly extracted on the source side and stored in the defined repository. The algorithm reads the number of data for each sensor from the sensor table and then compares the data with the repository based on the mapped attribute (column) between the source and target systems. If any error happens, the algorithm generates the data completeness report.

TABLE VII. ALGORITHM 3 – ASSIGN THE CLASS VALUE AND WATER MANAGEMENT

Input: Different sensors (Table I) **Output: (Collected data for each sensor)**
Begin
/ * Form each sensor */
Read time of each extracted data
Read (Time of being online)
Read Signal Strength
Read DHT11 – Temperature
Read DHT11 – Humidity
Read Anemometer
Read Capacitive Soil Moisture
Read Ultrasonic - HC-SR04
Read Passive Infrared Receiver – PIR
Read PV Unit
If (Capacitive Soil Moisture) > 10, then
Class = 0, Set Irrigation OFF
If (Capacitive Soil Moisture) < 10, then
Class = 1, Set Irrigation ON
If (Ultrasonic - HC-SR04) < 100 then
Water pump = 'ON'
Else water pump = 'OFF'
End

After successfully checking the validity of the data quality, *Algorithm 3* presented in Table VII deals with assigning the class value (0,1) and water pump (ON, OFF) for the obtained data in (Table IV). This algorithm reads all the extracted data in (Table IV) and then makes the comparison. The first comparison is to assign the class value (0,1) based on the Soil Moisture (Kpa). Furthermore, the second comparison is to set the water pump (ON, OFF) based on the (Ultrasonic - HC-SR04) output. After assigning the class value based on the Soil Moisture sensor and the water pump, the realized data is generated using the attributes presented in Table IV.

After collecting the data successfully in the web server, the last part of the algorithm starts presenting the data based on the requirements. Different graphs are generated based on the stored data to provide visual information about the collected data based on the specifications. To achieve this point, *Algorithm 4* presented in Table VIII is used for that purpose.

TABLE VIII. ALGORITHM 4 – DATA REPRESENTATION BASED ON THE REQUIREMENTS

Input: Collected data for each sensor **Output: Data visualization (Results)**
Begin
Determine the requirement
Select the X data from the data repository
Select the Y data from the data repository
Select the representation algorithm
Represent the data
Print the report
End

IV. RESULTS AND DISCUSSION

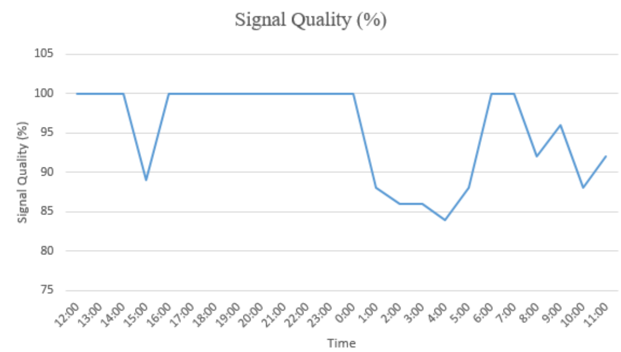

Figure 7. Signal strength of the NodeMCU.

Noteworthy that data collection processes are performed in a specific location and given in the form of latitude and longitude by decimal degrees: (35.760246, 44.155366). Based on algorithm 4, it is intended to display the relational data and show the relationships among the comparable data to understand the behavior of the environment clearly. Fig. 7 depicts the strength of the signal connection and shows that the quality of the received signal was perfect and stable. The signal quality was always more than 85%, considered in the optimum range for transferring the data to the cloud.

Moreover, the performance in Fig. 8 illuminates the relation among weather elements in the proposed farming area. The curve demonstrates that the temperature and humidity are relatively proportional since as temperature values increase, the humidity decreases in the proposed farming environment and vice versa. As a result, the high-temperature degree can also affect the soil's moisture, increasing water consumption. Furthermore, the result confirms that when the temperature reduces, the soil moisture rises and remains stable at less than (10 Kpa) for a definite period. This performance proves that the proposed location is optimal for paddy planting over this given period.

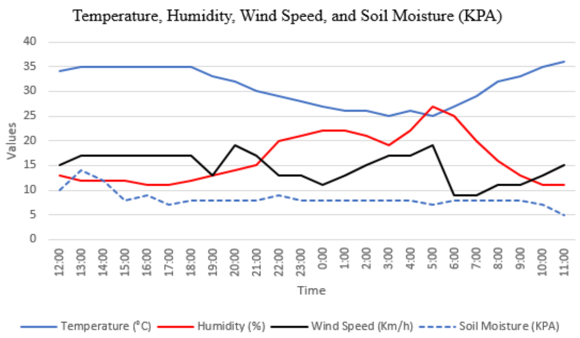

Figure 8. Climate impacts on soil moisture.

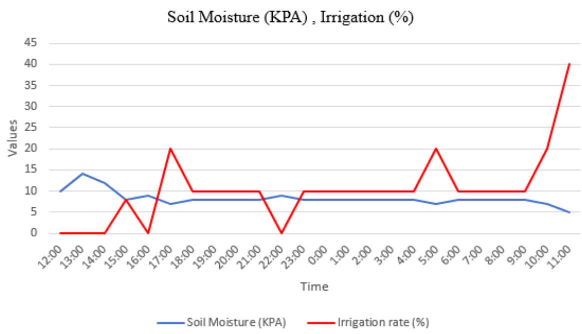

Figure 9. Soil irrigation based on water tension.

The data response in Fig. 9 shows that the pump operates automatically and irrigates the soil when the water tension is ($< 10\ Kpa$) and stops irrigation when it is ($\geq 10\ Kpa$), depending on the designed control system. This control system was designed to supervise the irrigation rate according to the exact water necessity in the paddy area. To control water flow into the paddy area, this smart irrigation process varies depending on the soil's necessity for water and the water level in the tank.

Lastly, the data visualization shown in Fig. 10 plays a vital role in evaluating the behavior in the farming environment since it represents the relationship between the water level in the tank and the moisture value in the soil. Fig. 10 shows that the irrigation was stopped when the moisture level in the paddy area reached ($\geq 10\ Kpa$). Hence, the tank maintained 80% water after reaching favorable soil conditions.

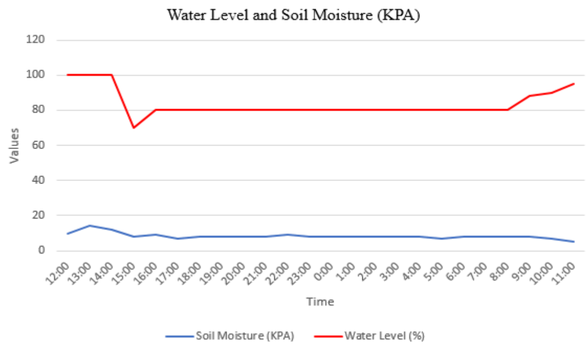

Figure 10. Water availability based on soil moisture.

V. Conclusion

A design and implementation of a low-cost intelligent farming module for monitoring the paddy environment are presented in this research. A new IoT platform was generated and designed using the XAMPP package and organized using a specific public IP address to dominate programming environments, optimize system response, and reduce costs significantly. This technique can distinguish each plant that needs to be watered. As a result, water consumption increased, and wasted water and energy decreased. The primary goal of this project is to keep an eye on the paddy environment and maintain the plant's water level (≤10Kpa). The proposed research is crucial for predicting the agricultural future, and the farmers benefit from it since it requires less labor. It was determined that five primary sensors were necessary for continuously monitoring the paddy field (temperature-humidity, soil moisture, water level, wind speed, and motion detection). The data quality of each sensor was validated, and each actuator's class was assigned using *Algorithms 1 – 4*. *Algorithm 4* found correlations between data sets, making it easier to visualize and analyze the information. More than 85% of communication signal quality was attained by the proposed approach, which is excellent for sending data to a cloud server. Due to its central role in the study, it is essential to mention that lower temperature values impact soil moisture to maintain 10Kpa of water tension for a long time. The presented statistics confirm that the selected location is excellent for paddy planting during this period. In addition, the findings indicated that irrigation processes stopped when the moisture content in the paddy area achieved (≥10 Kpa). It is worth noting that keeping the water tension in the paddy region at about 10 Kpa helps to maintain 80 % of the water. However, for any water lack in the tank, the pump pushes water from the primary water source to refill the tank. Finally, the achieved findings demonstrate that the suggested module can significantly contribute to agricultural areas and provide promising outcomes, mainly assisting farmers in enhancing crop productivity.

The drip and sprinkler irrigation systems are also on our radar for future innovative irrigation model development. Smart irrigation models and algorithms also need to be developed using additional sensors to deal with various soil types, such as gravel, silt, sand, and barren land. Furthermore, the proposed design and model can be applied to different crops, such as (wheat). This requires studying the environmental specifications like the amount of water in the soil, temperature degrees, pH values, etc. In addition, the proposed module can be applied to a colossal farming area to increase production and can be used in several locations to collect more data and compare the farming situation in each environment. Herds and cattle can be monitored and fed remotely using the suggested IoT-based agricultural system. The IoT technique allows farmers to watch livestock from a single place, giving them more insight into each animal's health and behavior. Finally, the proposed IoT platform can be upgraded to include more visualization gadgets such as gauges, indicators, Terminals, Super charts, etc.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Dlnya A. Aziz designed the Internet of Things platform, set up the sensors and microcontrollers, programmed all the necessary components, and wrote the article. Razieh Asgarnezhad supervised the research and revised the final draft. Mohammed S. Mustafa and Ali A. Saber edited the work and contributed to data collection and analysis. Sameer Alani has updated and reviewed the English grammar. The final paper has been reviewed and approved by all authors.

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