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Resources Management Consıderıng Envıronmental Condıtıons in Educatıonal Instıtutıons Based on IoT

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Abstract

One of the most significant issues affecting the majority of countries in the world today is resource conservation. Water is the most vital component for all life, hence protecting it is crucial. Optimal use of water maintains its sustainability and leads to energy savings. Educational institutions are considered among the largest institutions that use water because of the presence of large numbers of students and employees. This research concerned resource management in educational institutions taking into account environmental conditions based on Internet of Things (IoT). The results illustrated that the designed monitoring system for moisture content has the ability to enhance water sustainability by using the optimal water content. A significant efficiency of the proposed monitoring system in controlling the water level was achieved. The maximum error between the monitoring system reading and the actual reading was 2% and 2.44% for moisture content and water level, respectively. The results showed the sensor's high sensitivity to rainfall and the ability of the proposed monitoring system to save water that exceeds the need of soil

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1. Introduction

Many natural resources, like water, sea, air, and forests, have to be seen as part of humanity's collective legacy [1]. Because a large portion of the world's population lives in regions with issues related to water sustainability, water is a scarce resource that needs to be managed carefully [2]. Water is a renewable resource that will eventually run out if it is not controlled. As a result, careful handling of water management is required [3]. Approximately 20% to 25% of water is utilized for industry, 65% to 70% of water is used for agriculture, and just 6% is used for residential consumption [4]. Globally, treated water from urban supply systems is wasted annually in excess of 32 billion cubic meters, with developing nations accounting for half of this loss [5]. We can certainly live more conveniently and preserve our precious resources, like water, by integrating IoT technology into water management systems [3], [6], [7]. In universities and educational institutions, there are many green spaces that require good care to maintain them, and this is closely linked to maintaining soil moisture in an optimal way for plant growth without the exceed in water consumption. Accordingly, the soil moisture monitoring and rain sensor are a good tool to achieve that. In addition, a large amount of water is wasted from the tanks due to the inability to control the water level in the tank, so the efficiency of using the water level sensor was studied in this study.

Artificial intelligence (AI) is the term for a system or set of algorithms that employs information synthesized to enable machines to do specific jobs in place of human interaction and supervision throughout entire processes [8], [9], [10], [11]. A machine's ability to perceive, plan, reason, learn, make a decision, solve complex problems, communicate, act, and think like a human mind is a result of AI. This includes intelligent software agents that require human intelligence to perform certain tasks, such as monitoring visual/spatial and understanding auditory information, interacting with machines and humans, reasoning and making predictions, and learning and improving [12], [13].

According to the definition provided by the ITU, the Internet of Things is: "a global infrastructure for the Information Society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies [6]. Water management systems utilizing IoT technology surely will enhance our quality of life and preserve our scarce resources, such as water [3], [14]. Several sectors can benefit from the Internet of Things, such as logistics, retail, environmental monitoring, smart homes, smart grids, smart transportation, smart retail, etc [15].

Water is the primary resource and is necessary for all life on Earth because it is a limited resource that must be used wisely [16]. Monitoring different aspects of water usage provides a comprehensive awareness of the factors to consider in order to reduce water waste [8]. Barros [17] developed a system made up of various sensors such as a water flow sensor, water control valve, pH sensor, and a microprocessor. To guarantee uniform and sufficient water distribution to every connection, a web interface regulates a water control valve based on the value of a water flow sensor (end). The pH sensor is employed to gauge the water's quality. The pressure sensor measures both the water flow pressure and leak detection in pipes. It is possible to regulate how water is distributed and how it flows via pipes. Shah et al. [18] focused on using an ultrasonic level sensor which can be adjusted via a mobile application to evaluate the amount of water in tanks. Harika et al. [19]presented a method that uses real-time data from water flow meters at the household prototype level to make relevant inferences. An IoT gadget that aids in managing and scheduling water usage was introduced by Wadekar et al. [20]. In residential societies, this technology is simple to implement. Sensors installed within the tank regularly report the water level. The user can view the water level on a smartphone anywhere there is an Internet connection by using an Android application, and this data will be updated in the cloud. The motor will function automatically based on the water level in the tank. It will automatically start on at low water levels and shut off when the tank is ready to fill. Getu and Attia [21] suggested an IoT-based water monitoring system that monitors water levels in real time. The prototype is predicated on the notion that, particularly in regions vulnerable to natural disasters, water levels can be a highly significant factor in the likelihood of flooding. The required parameter is detected using a water level sensor, and if the water level meets the parameter, a real-time signal is sent to social media sites like Twitter. A cloud server was set up to serve as a repository for data. On the remote dashboard, the water level measurement is shown. Narendran et al. [22] created a system that reduces human intervention in water management and is suitable to both urban and rural contexts, including the sustainability component. The work presented by Kumar and Hong [23] used sensors to monitor both the flow of water between pipelines and the water source.

2. Methodology

Large amounts of water are consumed daily to irrigate plants and agricultural crops, and the inability to control the amount of water in tanks leads to the consumption of a large amount of water, especially in government institutions, including educational institutions. This research focused on increasing the sustainability of water by reducing water consumption. The water management can achieve this goal. Using water content according to soil needs leads to rationalization of water consumption. This is done by knowing the degree of soil moisture and the amount of rain falling or not. In addition, the possibility of determining the water level in the tanks and controlling it reduces water consumption. Figure 1 illustrates the general flow chart of the water monitoring system. The architecture of the proposed system is shown in Figure 2.

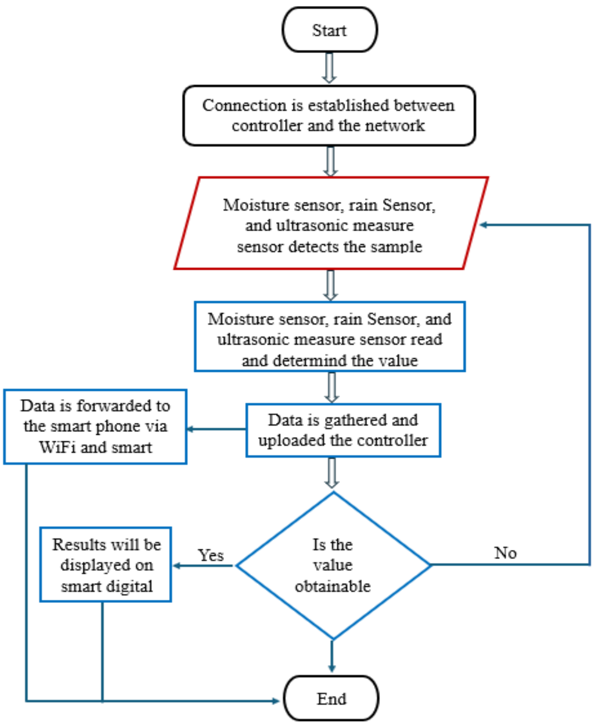

Figure 1. General flow chart of water monitoring system

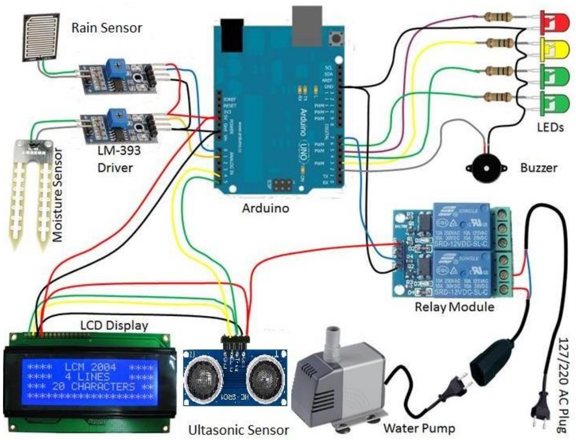

Figure 2. The architecture of the proposed system

2.1 Soil Moisture Monitoring

The soil moisture monitoring system is made up of sensor nodes and coordinators. The soil moisture sensor using capacitance measures the dielectric permittivity of the surrounding medium. Dielectric permittivity in soil depends on the amount of water present. The voltage produced by the sensor is proportionate to the soil's water content and dielectric permittivity. Over its whole length, the sensor averages the water content. The soil moisture-monitoring algorithm's flow chart, which is based on the needed water calculation approach, is displayed in Figure 3. This technique is intended to provide the estimated amount of water based on the measurement of the soil's current water content.

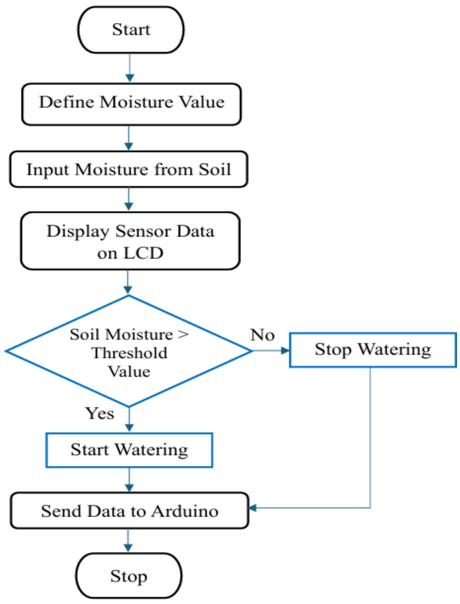

Figure 3. Flow chart of soil moisture monitoring system

The data collecting and output unit, which is a hardware system and data storage system, are the two components of the proposed system. The wireless hub serves as a communication gateway between them in the center of the system. The front end of the data storage system, which houses the user interface, and the back end, which houses the database, are the two sectors. Irrigation outputs, sensors, communication modules, and micro-controllers form the basis of the hardware system. In order to give significant input for the watering system, the Arduino UNO microcontroller was used for this project. Additionally, an ESP8266 WiFi module was selected as a communication tool. TDR technology of moisture sensors was also utilized throughout.

By utilizing the soil's bulk permittivity, or dielectric constant, the soil moisture sensors are intended to determine the volumetric water content of the soil. The soil's electrical transmission capacity can be conceptualized as the dielectric constant. With an increase in soil water content, the dielectric constant of the soil rises. This reaction results from water's far higher dielectric constant than that of the other soil constituents, including air. As a result, an accurate estimate of the water content can be obtained by measuring the dielectric constant. Figure 4 displays the soil moisture sensor module schematic diagram. The schematic itself is rather straightforward to construct and just requires a few standard parts.

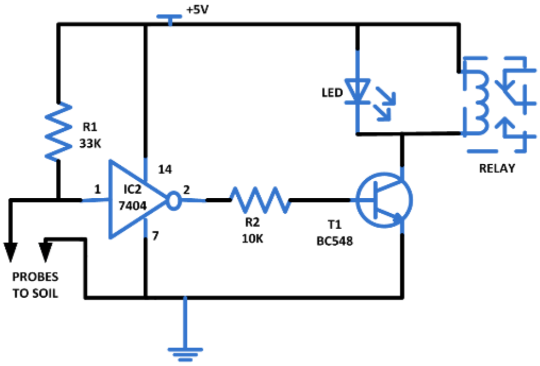

Figure 4. The soil moisture sensor module

The Arduino soil moisture sensor circuit diagram (see Figure 5) above illustrates how we have connected an LED to the digital PIN 6 of the Arduino, the analog out pin of the sensor to the A0 pin of the Arduino UNO board, and ground as a common connection between the LED and the sensor. The Arduino will be programmed to adjust the LED's brightness in response to the probe's sensed data on soil moisture.

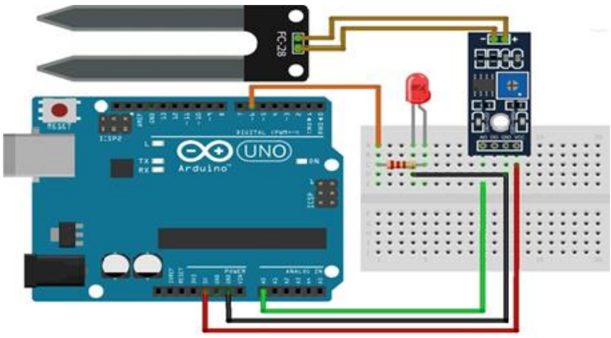

Figure 5. Arduino soil moisture sensor circuit diagram

Just by reading the analog data from the sensor, we may adjust the LED's brightness based on the information we have received. Please keep in mind that we are simply processing the analog data that the sensor provides; for the digital data, the module's inbuilt LED illuminates. Two macros are declared when we first initialize our code: one for the LED, to which we will attach an LED, and another for the sensor pin, which we use to retrieve data from the sensor.

Once the code has been verified, upload it to the board and turn on the serial monitor. When you submerge the sensor leads in dirt, you will notice a change in the sensor data displayed on the monitor. The calibration curve between soil moisture content and output voltage is determined using soil of different moisture contents. Equation 1 is utilized to ascertain the moisture content, and the dry weight of the soil and the volume of water added each time are computed. By figuring out the water content appropriate for the soil weight, a moisture content of 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50% was achieved.

$$\text{Moisture content (\%)} = (\text{weight of water} / \text{weight of dry soil}) \times 100 \qquad (1)$$

2.2 Water Level Monitoring

An apparatus that keeps track of the water level in reservoirs, tanks, and containers is called a water level sensor. These tools are helpful for a variety of applications since they measure level precisely using a variety of technologies. We are going to construct a water level indicator as part of this inquiry. We all know it is one of the most important products because every home or business has numerous water tanks, most of which are difficult to access in order to check the water level. In addition, I believe the majority of us have experienced some form of water shortage because we lack any means of precisely monitoring the situation. The flow chart for the water level monitoring system is displayed in Figure 6. Additionally, the ultrasonic sensor connection is shown in Figure 7.

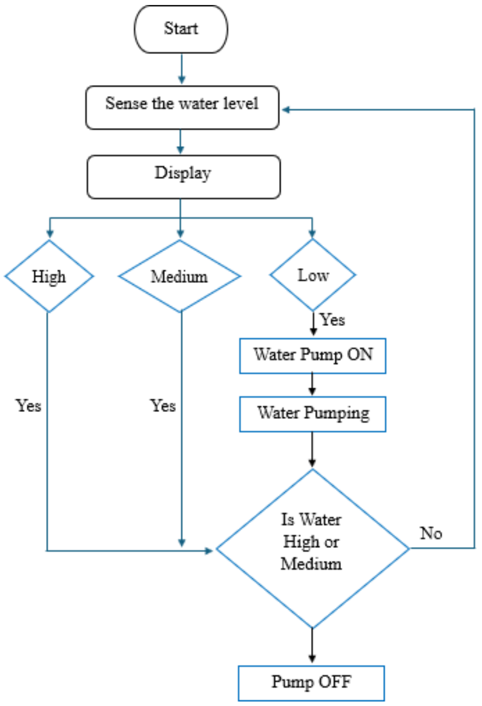

Figure 6. Flow chart of water level monitoring system

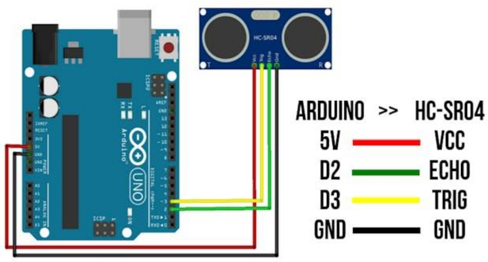

Figure 7. Ultrasonic sensor connections

2.3 Rain Sensing

Rain sensing is undoubtedly advantageous for irrigation systems. The benefits of rain sensing include easier installation, cost savings, healthier plants, and water conservation. The IC's Inverting Input (2) receives voltage from the sensor pad. Subsequently, the LM393 IC compares this voltage to the threshold voltage. When no water drops fall on the sensing pad surface, the sensor output turns LOW (0) because the input voltage is less than the threshold voltage. Figure 8 shows the rain sensor module's circuit diagram.

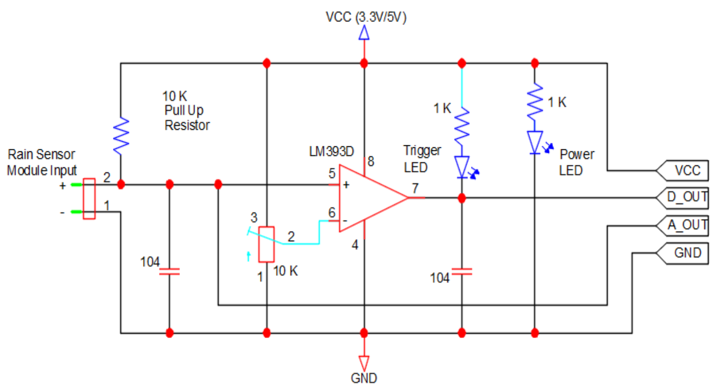

Figure 8. Circuit diagram for rain sensor module

As seen in Figure 9, this sensor is primarily composed of two components: the Sensing Pad and the Sensor Module. The switch will close when precipitation or water droplets land on the surface of the Sensing Pad. The sensor module processes the data after reading it from the sensor pad and converting it to an analog or digital output. Thus, the sensor is capable of producing both analog (AO) and digital (DO) outputs.

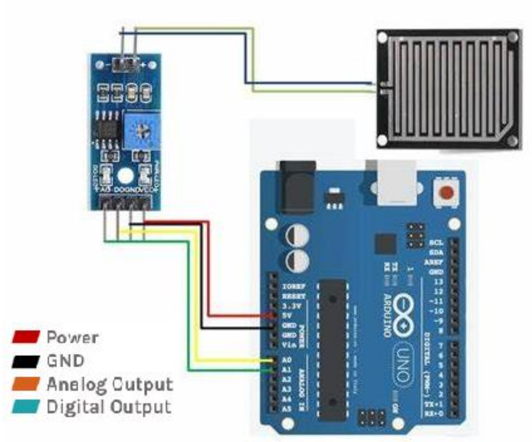

Figure 9. The rain sensor connections

2.4 WiFi Technology

Smart phones, computers, and other electronic devices use WiFi, which is a low power wireless communication technology. With the constraint of allowing clients to connect within close proximity to the router within the network, the router functions as a wireless hub point for correspondence in this configuration. In systems administration applications that control transportability wirelessly, WiFi is especially common. ESP8266 WiFi module is a popular IoT module. You may add Wi-Fi capabilities to your Arduino board by connecting an ESP8266 to it. The WiFi Shield, also known as the ESP-12E WiFi module, was created by the AI-thinker Team [23], [24].

3. Results and Discussions

3.1 Soil moisture-monitoring results

Volumetric water content was used in this experiment to feel the soil moisture levels. The ratio of the volume of water to the total sample volume of dry soil is known as the volumetric water content. The moisture content was measured using a conventional approach in order to assess the accuracy of the soil moisture sensor. The percentage of inaccuracy was then calculated. Figure 10 illustrates how the device can be used to detect and determine soil moisture, which in turn enables the control and sustainability of irrigation water use.

Figure 10. Determination of soil moisture using monitoring system

To obtain the calibration curve of the soil moisture sensor, the direct standard method was used to determine soil moisture by measuring the volumetric water content and the corresponding output voltage. Figure 11 illustrates the measuring of output voltage soil with varying moisture content is used to calculate the calibration curve between soil moisture and the output voltage.

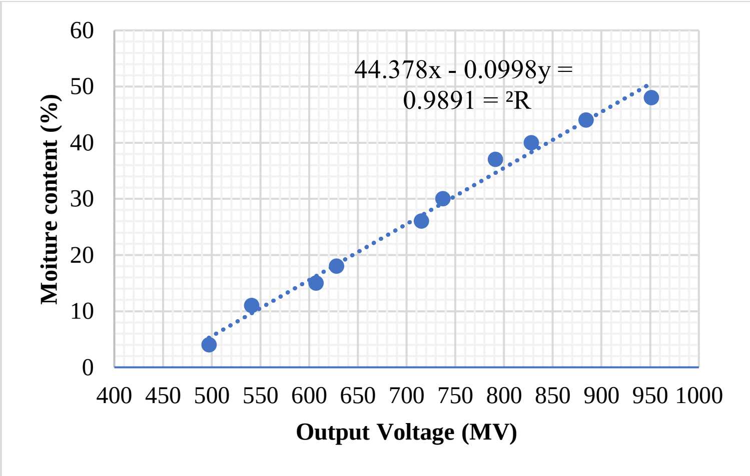

Figure 11. Relation between moisture content and output voltage

Through the results, it was shown that there is a strong relationship between the output voltage and the moisture content, as shown in Figure 11. Therefore, this relationship can be used to determine the value of soil moisture to control the amount of water used in irrigation. The results also showed the ability of the moisture content control device to sense the actual moisture value of the soil and supply it with water if this percentage is less than the specified percentage. The results indicate that the reading of the device is more accurate compared to Abdullah Na et al. [25] whose results reported that the mean error, averaging over 12 samples was 9.4%.

In order to determine the actual soil moisture content, the wet soil weight for each sample were determined as shown in Figure 12(a), then the samples were put in oven as shown in Figure 12(b) and the maximum temperature was set at 100 ^{o}C as shown in Figure 12(c), then samples are removed from the oven (see Figure 12(d)) and the dry weight of each sample was determined, finally the moisture content were evaluated according to Equation 2.

$$\text{Moisture content (\%)} = \frac{W1-W2}{W1} x100 \qquad (2)$$

Where W1: Weight of wet soil, W2: Weight of dry soil.

(a) Wet soil weight

(b) Drying the soil samples

(c) Set up the drying temperature

(d) Shape of samples after drying

Figure 12. Determination of actual soil moisture content

Table 1 illustrates the values of moisture content measured by soil moisture sensor and by traditional method (actual content). The results demonstrate the high accuracy of the monitoring system, as we find that the error rate did not exceed 2%. These results agreed with Vani and Rao [26], Kumar et al. [27], Chew et al. [24], and Chung et al. [28].

Table 1: Moisture content measurements

Sample No.	Moisture content (%) using		Error (%)
	Sensor	Traditional method	
1	4	3.95	-1.25
2	11	10.8	-1.82
3	15	15.05	0.33
4	18	17.7	-1.67
5	26	26.1	0.38
6	30	30.4	1.33
7	37	36.7	-0.81
8	40	39.2	-2
9	44	44.8	1.82
10	48	48.9	1.88

Here it can be said that the designed monitoring system for moisture content has the ability to enhance water sustainability by using the optimal water content. The LED will light up in response to both high and low moisture levels, updating the data on the web-based dashboard. A higher moisture content will signal a danger level, set off the suggested system's buzzer alarm, and turn off the pump. Furthermore, when the water level is low, the pump operates as seen in Figure 13 and a buzzer alarm sound.

Figure 13. Pumping water into the soil when the moisture content is low

3.2 Water level monitoring results

The data from IoT-based water monitoring systems are examined to see how well they function in terms of accuracy and reaction time. In this investigation, 300 readings in total were sampled. The distance in centimeters (cm) between the ultrasonic and water is measured during the experimental design. Three levels of indicators are categorized for benchmark and indicators: low level (distance less than 15 cm), medium level (distance between 15 cm and 30 cm), and high level (distance greater than 30 cm). The ESP8266 module will be notified by the water level sensor to switch the relay to the OFF condition so that the water pump motor is also turned off when the water level sensor registers a full high level (30 cm) during the filling operation.

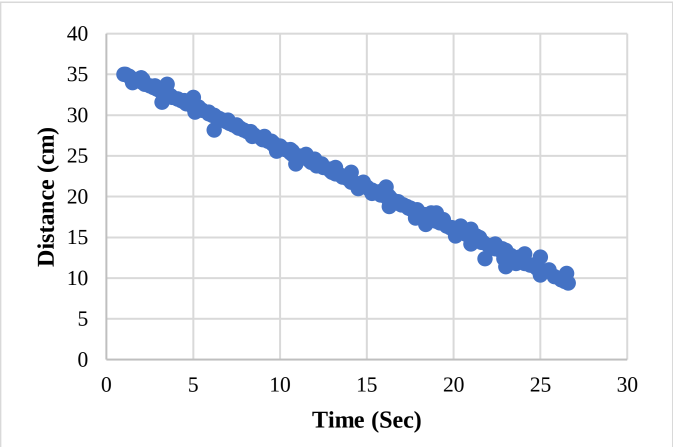

Figure 14. The result of the water level detection on distance versus time

The results in Figure 14 above show a linear correlation between distance measured (i.e. water level) and time taken for the water level indications. The result clearly indicates the reliability of the system in providing consistency reading throughout the sampling period.

The LED will light up at both high and low levels, and the web-based dashboard will then update with the new information. A higher water level will be interpreted as a dangerous level, set off the proposed system's buzzer alarm, and turn off the pump. In addition, the pump continues to run, and the buzzer alarm will sound to signal a low water level. Numerous manual water level readings were made and compared to sensor readings in order to assess the efficacy of the suggested water level monitoring system. Table 2 illustrates the values of water level measured by water level sensor and manually (actual content). The results demonstrate the high accuracy of the water level monitoring system, as we find that the error rate did not exceed 2.44%. These results in agreement with Muliadi and Isminarti [29].

3.3 Rain sensing results

The results showed the sensor's high sensitivity to rainfall as shown in Figure 15, which leads to water conservation and sustainability, as the rain sensor sends warning signals about the presence of rain, and then the irrigation process is stopped. Shiv Shankar Singh [30] reported that using rain sensor with water moisture sensor can reduce the electricity consumption of farm by 30% and the production of farm increased by 17.23% as a result of controlled water supply to crops. The results also reported that the ability of proposed monitoring system to save water exceeds the need of soil. When the rain falls and the soil is saturated with water, the pump works and draws the exceeded water and stores it in tanks.

Table 2: Water level measurements

Sample No.	Water level (cm)		Error (%)	Sample No.	Water level (cm)		Error (%)
	Manual	Using sensor			Manual	Using sensor	
1	5	5	0	17	21.3	21	1.41
2	6.1	6	1.64	18	22.1	22	0.45
3	7	7	0	19	22.9	23	-0.44
4	8.2	8	2.44	20	24.1	24	0.42
5	9	9	0	21	25.2	25	0.79
6	9.9	10	-1.0	22	25.8	26	-0.78
7	11.2	11	1.79	23	27.2	27	0.74
8	12.1	12	0.83	24	28.1	28	0.36
9	12.8	13	-1.56	25	29.3	29	1.0
10	14.1	14	0.71	26	30.2	30	0.66
11	15.1	15	0.66	27	31	31	0
12	16.2	16	1.23	28	32.1	32	0.31
13	17.2	17	1.16	29	33	33	0
14	18.1	18	0.55	30	34	34	0
15	19.2	19	1.0	31	35.2	35	0.57
16	20.2	20	1.0				

Figure 15. Sensitivity of sensor to rainfall

4. Conclusion

The designed monitoring system for moisture content has the ability to enhance water sustainability by using the optimal water content. Higher moisture content will indicate as danger level and trigger the buzzer alarm configured as part of the proposed system and the pump will off. In addition, if the water level is low, the buzzer alarm will indicate, and the pump works on. The results demonstrate the high accuracy of the monitoring system, as we find that the error rate did not exceed 2%. In addition, the results show the high accuracy of the water level monitoring system, as we find that the error rate did not exceed 2.44%. A significant efficiency of the proposed monitoring system in controlling the water level was achieved. Higher water level will indicate as danger level and trigger the buzzer alarm configured as part of the proposed system and the pump will off. In addition, if the water level is low, the buzzer alarm will indicate, and the pump works on. The results showed the sensor's high sensitivity to rainfall and the ability of the proposed monitoring system to save water that exceeds the need of soil.

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