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Smart Agriculture Using Internet of Things with Raspberry Pi

Zuraida Muhammad
Faculty of Electrical Engineering,
Universiti Teknologi MARA,
Cawangan Pulau Pinang,
Pulau Pinang, Malaysia
zuraida321@uitm.edu.my

Muhammad Azri Asyraf Mohd Hafez
Faculty of Electrical Engineering,
Universiti Teknologi MARA,
Cawangan Pulau Pinang,
Pulau Pinang, Malaysia
azrihafez@gmail.com

Nor Adni Mat Leh
Faculty of Electrical Engineering,
Universiti Teknologi MARA,
Cawangan Pulau Pinang,
Pulau Pinang, Malaysia
noradni@uitm.edu.my

Zakiah Mohd Yusoff
Faculty of Electrical Engineering,
Universiti Teknologi MARA,
Cawangan Pasir Gudang,
Johor, Malaysia
zakiah9018@uitm.edu.my

Shabinar Abd Hamid
Faculty of Electrical Engineering,
Universiti Teknologi MARA,
Cawangan Pulau Pinang,
Pulau Pinang, Malaysia
shabinar@uitm.edu.my

Abstract— **The term used for networking of objects, equipment, vehicles, and other electronics device into the network for information exchange purpose is called Internet of Things (IoT). Nowadays, IoT is widely used for connecting device and collecting data information. Therefore, the use of IoT is very relevant for agriculture. The project is about smart agriculture system that is implemented with IoT. The system is combined with irrigation system in order to cope with the unpredictable weather in Malaysia. Raspberry Pi 4 Model B is used as the microcontroller of this system. DHT22 and soil moisture sensor is used to detect the temperature and humidity in surrounding and moisture level of the soil respectively where the output will be displayed on smartphone and computer. So, Smart Agriculture Systems using Internet of Things with Raspberry Pi brings a tremendous impact on the farmer's working method. Plus, it will also bring a positive effect on the crop production in Malaysia. Where about 24.44% water savings rate in a year can be achieved when using IoT-based irrigation systems compared to traditional irrigation systems. This would save the expenditure for hiring workers and avoid water wastage in daily needs.**

Keywords—Raspberry Pi, Internet of Things (IoT), Soil moisture, automated irrigation.

I. Introduction

Initially Malaysia was a country based on agriculture and fisheries, it was a service that contributed about 55 per cent of Malaysia's gross domestic product (GDP). For decades, due to the growth of the local industry and the contribution services sector, the Malaysian agriculture sector has been declining. Almost 30 percent of GDP was contributed by agriculture in 1970 but this percentage has dropped sharply to 8.2 percent in 2017 [1]. The percentage drop in GPD value is due to farmers or gardeners are still using traditional methods which affect the production rate of crops and fruits due to low soil fertility, fertilizer abuse, water waste and climate change or diseases [2]. The most challenging threats of agriculture in Malaysia is climate change. Plus, the most challenging effects include unpredicted weather like variations and fluctuation of summer and monsoon seasons, high temperature (>26°C) and shortage of rainfall [3]. Therefore, the local agriculture sector should be given some improvements, especially the source of food crops. To reach that various technologies and innovations have been introduced to the Malaysian agricultural sector, such as agriculture which has the concept of industrial revolution 4.0 or smart agriculture to keep the agricultural sector in Malaysia in decline.

In order to realize the industry of revolution 4.0 there are several things to keep in mind as one of them is the internet of things (IoT). IoT can be described as a network of devices that enables communication between machine and device through internet connection. IoT can also be described as a connection that does not require physical contact either from device to machine or from person to machine and has many capabilities to transmit or receive data over the internet due to its interrelated with any peoples, animals, devices machines, or objects [4]. Refer to the [5], obtaining communication technology is the key in order to successfully develop IoT system. Short-range and long-range communication standard is the part of communication standard. Several examples of the short-range standards are near-field communications enabled device, Bluetooth, ZigBee, passive and active and active radio frequency identification (RFID) system and LoRa, Sigfox, NB-IoT and Wi-Fi are the example for the long-range standard.

Several semi-automated and automated irrigation control system have been proposed to overcome the water wastage and growth crops production. Timers, controllers and switches have been widely used as irrigation control systems to supply water to crops at specific intervals regardless of the soil moisture level. According to D. Amu and Dr. A. Amuthan [6], the use of Arduino microcontrollers, Global System for Mobile Communication (GSM) technology and soil moisture sensors can help improve irrigation systems and save water usage and increase productivity. In placing more emphasis, Rabiu Aminu [7] and Sudarshan K G [8] claimed that combination of soil moisture sensor and GSM module enables real time monitoring of crops remotely and all statuses can be received by the farmer via short message (SMS). Accordingly, the problem of distance and range can be solved besides ensuring that the irrigation system operates based on soil moisture content and it can reduce water consumption. But the mobile communication technology has transmission range that covers only the entire cellular area [9].

According to Hasnim Harun and Shazarin Ahmad Zainuddin [10], LoRa Technology is chosen for environment monitoring, especially temperature and humidity at Gunung Lang. This technology is chosen because it can provide long distance and remote monitoring using Long Range radio frequency before connecting to the internet through internet gateway. By using LoRa technology, farmers able to produce a stable crop, maintain a fertile farm and the amount of water used for irrigation can be saved [11]. The LoRaWAN is used as technology for the cloud and its do not required 3G internet or Wi-Fi to connect to internet. In addition, Wi-Fi is also one of the wireless communication technologies the communication protocol forms the backbone of the IoT system and enables network connectivity and coupling to applications that allow devices to exchange data over the internet.

By refering to the M.K.Gayatri, J.Jayasakthi and Dr.G.S.Anandha Mala [12], Internet of Things (IoT) is a network that contains physical objects that are embedded with the sensors, electronic devices, connectivity and software. It is needed to provide smooth and advance connections between the device and communication and handles a different of protocols, application and knowledge bases. Ubidots, ThingSpeak, Xively, Open.Sen.se, SensorCloud, Amazon IoT, IBM IoT, Blynk and Favoriot are several example of IoT middleware. These IoT middleware platforms aim to simplify the injected data from various kinds of source using common Application Programming Interface (API) [13].

The purpose of this Smart Agriculture with IoT using Raspberry Pi is to find the suitable system to be applied in future agriculture system. The aims of this project are to reduce time and water consumption as well as maximizing agriculture product and to improve the efficiency of management and control for agriculture farm. This paper also develop smart agriculture system using IoT with Raspberry Pi.

II. METHODOLOGY

A. Project architecture

This system uses 2 sensors connected to a Digital output relative humidity and temperature (DHT22) and soil moisture sensor. This system used a Raspberry Pi as its processor and connected to Analog and Digital Converter (ADS1115). This is because Raspberry Pi only has digital GPIO pins while Soil Moisture Sensor produce analog output. ADS1115 will convert the analog value to digital and readable for the Raspberry Pi. Ubidots Cloud connected to the Raspberry Pi through Wi-Fi connectivity. The data obtained from the DHT22 and soil moisture sensor is transmitted to the cloud and being stored in Ubidots server through the Raspberry Pi. Plus, the real time data also will be displayed on Ubidots Dashboard. For irrigation system, water pump will be turn on when specified condition is satisfied.

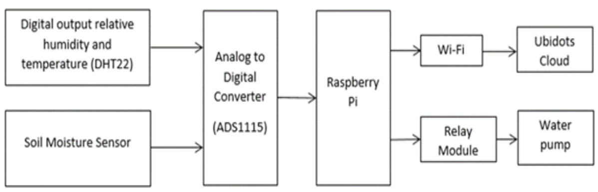

Fig 1: Block diagram Smart Agriculture with IoT using Raspberry Pi.

B. Hardware components

1) Development board

Raspberry Pi 4 Model B is the latest product in the popular Raspberry Pi range of computers. It offers ground-breaking increases in processor speed, multimedia performance, memory, and connectivity compared to the prior-generation Raspberry Pi 3 Model B+ while retaining backward compatibility and similar power consumption.

Fig 2: Raspberry Pi 4 Model B.

The raspberry pi 4 consists of forty GPIO Header pins located on the raspberry pi board. GPIO pins have different uses separately such as power supply, ground, clock, UART interface, SPI (serial peripheral interface bus), etc. A USB Type-C 5V USB port is available to supply power to the device. At the bottom of the SD Micro Card Slot is provided where the Micro SD card will be integrated with Raspbian boot software based on the Linux platform. It already have a built in Wi-Fi that is far more convenient to connect than certain processor that need a separate Wi-Fi connecting device [14].

2) ADC module, ADS1115

Raspberry Pi does not have analog input. Thus, Analog to Digital Converter must be included into the circuit. ADS1115 Analog to Digital Converter is chosen because ADS1115 provides 16-bits precision at 860 samples/second over I2C interface or protocol. The chip can be configured as 4 single-ended input channels, or two differential channels. As a nice bonus, it even includes a programmable gain amplifier, up to x16, to help boost up smaller single or differential signals to the full range [15].

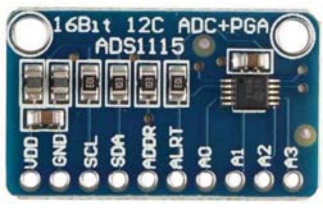

Fig 3: ADS1115 ADC Module.

Table 1: The pin connection of ADS1115 to Raspberry Pi.

Board Label	Raspberry Pi GPIO
VDD	3.3V
GND	GND
SCL	GPIO 3
SDA	GPIO 2

3) Sensors

For the Smart Agriculture, sensors are used to identify the different parameters in the atmosphere and in soil. The following are explanations of the chosen sensors.

- DHT22

The DHT22 measure the temperature from -40°C to +125°C with ±0.5 accuracy and the humidity is measured from 0% to 100% with 2-5% accuracy.

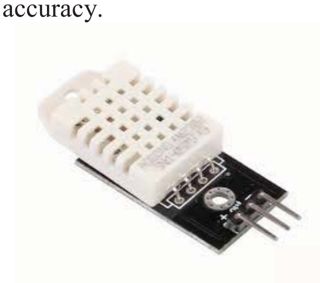

Fig 4: DHT22 Humidity and temperature module.

Table 2: The pin connection of DHT22 module to Raspberry Pi.

Board label	Raspberry Pi GPIO
VDD	3.3V
GND	GND
D0	GPIO 4

- Soil Moisture Sensor

There are two types of soil moisture sensor:

1. Resistive Soil Moisture Sensor

The sensor is made of two samples used to determine the volumetric quality of water.

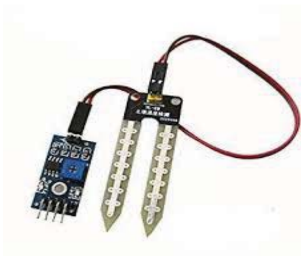

Fig 5: Resistive Soil Moisture Sensor.

2. Capacitive Soil Moisture Sensor

The sensor tests the levels of soil moisture by capacitive sensing, rather than resistive sensing as other moisture sensor types. An ADC Converter is necessary to make it compatible with a Raspberry Pi.

Fig 6: Capacitive Soil Moisture Sensor.

C. Software development

1) Coding in Raspberry Pi

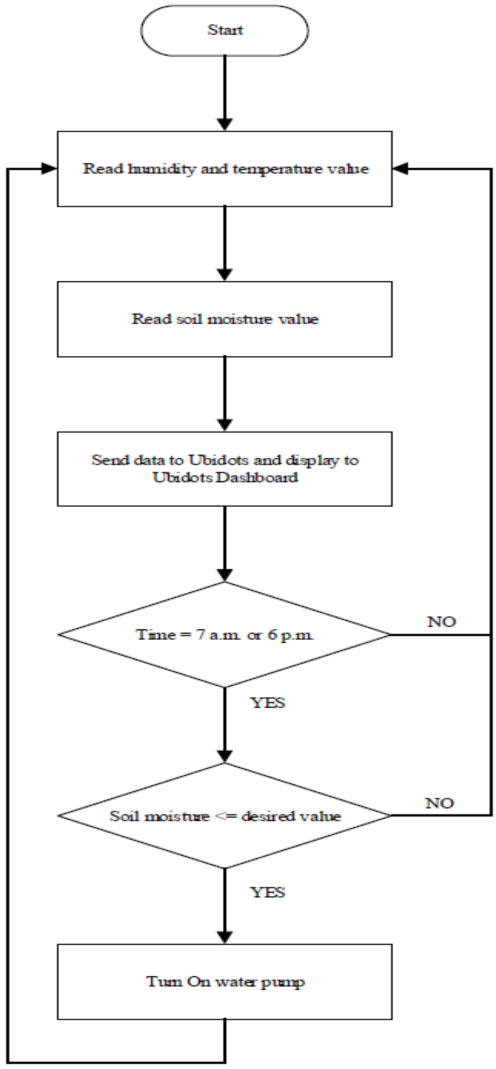

Fig 7: Flowchart of the Smart Agriculture System Using Internet of Things With Raspberry Pi..

Figure 7 shows the flowchart of Smart Agriculture with IoT using Raspberry Pi. Initially, all the sensors will obtain input. Then, it is collected by the Raspberry Pi. After the data is collected, it will be transferred to Ubidots cloud and will be displayed on Ubidots Dashboard that will be monitored by the farmer. Then, the water pump will be active if the current time is at 7am and 6pm at the same time the soil moisture level is below the desired value. The system will operate continuously until the microprocessor is disconnected from the power supply.

2) Interface with IoT Platform

Figure 8 shows, the webpage of Ubidots platforms. Ubidots is an IoT Platform empowering innovators and industries to prototype and scale IoT projects to production. The Ubidots platform are used to send data to the cloud from any internet enabled device. User can configure actions and alerts based on their real-time data. Ubidots offers a REST API that allows you to read and write data to the resources available such as data sources, variables, values, events and insights. Plus, the API supports both HTTP and HTTPS and an API Key is required.

Fig 8: Ubidots platform for monitoring purpose.

III. Experimental Setup

The figure below shows a prototype setup where the capacitive soil sensor, ADS1115 ADC module and all the components were connected to the Donut Board and interacted with Raspberry Pi 4 B+.

Fig 9: Prototype of Smart Agriculture with IoT using Raspberry Pi.

IV. Results And Discussion

A. Experimentral Result

The expected outcome of the prototype is all sensors properly functioning and detected the parameters accurately and transferring the data to raspberry pi which is exported to the server through the Wi-Fi. Figure 10 shows the value that the sensor has detected, and the data is displayed in the common line interface on the raspberry pi. Then, the data obtained by raspberry pi will be transferred to the Ubidots server via Wi-Fi for display on the Ubidots Dashboard in real time.

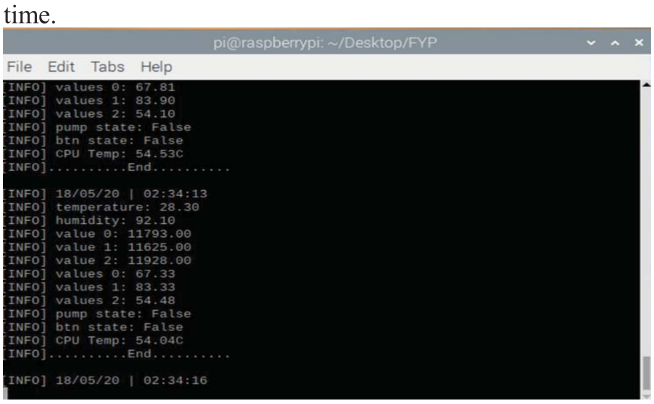

Fig 10: The value display on the Common Line Interface (CLI).

Fig 11: Data plotted on Ubidots Dashboard.

Figure 11 shows the overall data that display on Ubidots Dashboard and figure 12 shows the value of the temperature sensor over a period of one day. This value shows the environmental temperature rate while the Figure 13 shows the environmental moisture reading rate. The reading value of these sensors is taken continuously, and the data collected will be sent to the cloud server.

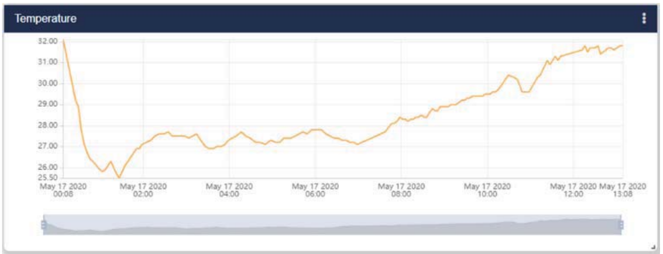

Fig 12: Temperature reading plotted in one day time laps.

Fig 13: Temperature reading plotted in one day time laps.

B. Specification of Soil Moisture Level vs Water Level

When the soil moisture value is below 14000, the soil should continue to dry. The dangerous state is when the surface becomes too dry where the soil moisture is below 18000. Soil moisture has a specified value which reacts with water. After adding every 25 ml of water the soil moisture value is increased. The soil is water scarcity if it is below 400 and very dry if it is below 18000. The ADC value of soil moisture will be obtained by using ADS1015/ADS1115 library.

Then the soil moisture value obtained will be calculated through the map function to obtain the appropriate percentage moisture content. The function is written as below:

```
def map (x, in_min, in_max, out_min, out_max) {
  return (x - in_min) * (out_max - out_min) / (in_max -
      in_min) + out_min;
}
```

By using the map function, the percentage of the amount of the soil sensor will be obtained where x is the ADC value, in_min is the ADC value when the sensor in wet condition, in_max is the ADC value when in dry condition. The out_min and out_max is the range of the output value where out_min is the minimum output value and out_max is the maximum output value. The amount of soil moisture is 34 percent when the soil becomes too warm, 60 percent in the absence of water and 85 percent in the excess of water.

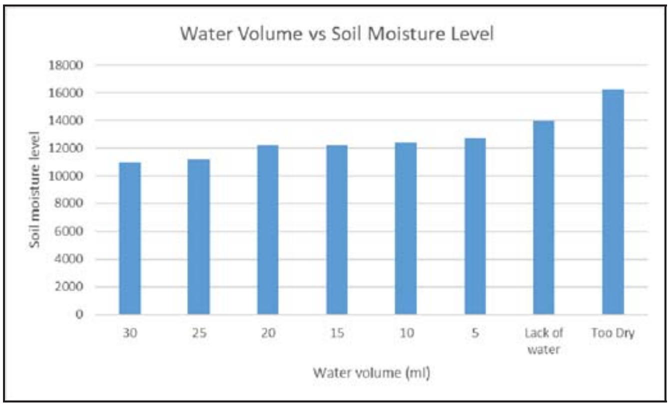

Fig 14: Water volume vs soil moisture level.

C. Experiment of soil moisture level

The experiment was performed in two different conditions, namely when the water pump was automatically controlled based on the control command from Ubidots. For the second case the water pump is manually controlled where the timer is used to turn the water pump on and off.

1) Automatic watering system

In this case the water pump will be controlled based on the variable set by Ubidots where when the current time is at 7am or 6pm, the controller will determine the setting to turn on or off the water pump and Ubidots will direct the controller to activate the relay when the value of soil moisture is under 60% moist. When the controller is instructed to turn on the water pump then the controller activates the relay for 9 seconds to provide 25ml of water to each pot. But when the Ubidots found that the soil moisture value was still above 60% the water level would be turned off even if it was at 7am or 6pm.

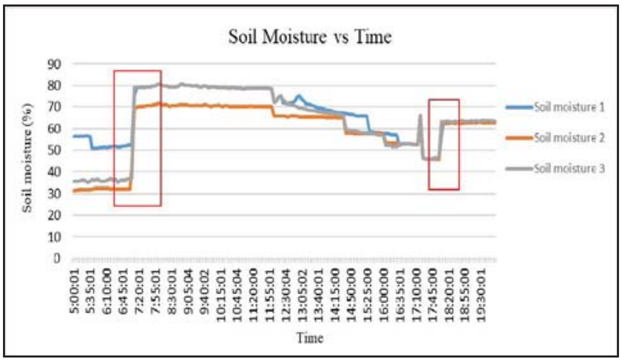

Fig 15: The soil moisture level during normal weather.

Based on the figure above, when the weather is in normal conditions where the days are not raining the soil moisture level decreases from 5am to 7am. After 7am the soil moisture level increased as soil moisture was below 60% humidity in the previous hour. At exactly 7am and 6pm the microcontroller sends the data to Ubidots for processing and Ubidots directs the microcontroller to activate the water pump to restore the soil moisture level to normal levels. This process can be seen in the diagram above and is highlighted with a red box. 25ml of water will be given to each pot.

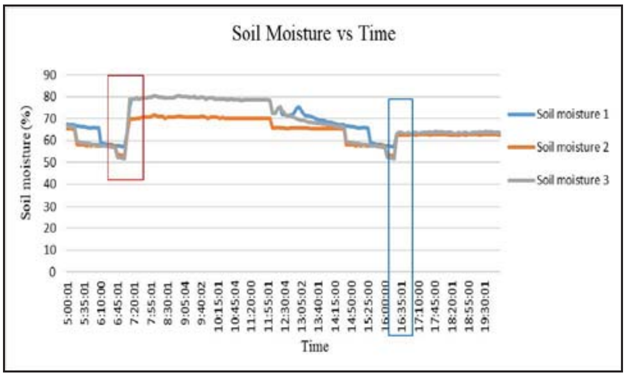

Fig 16: The soil moisture level during rainy day.

Based on the red box in figure 16, the water pump will turn on at 7am and the soil moisture value is below 60%. The volume of water supplied remains the same at 25ml per irrigation. When the weather is rainy, the soil moisture sensor will detect the rate of soil moisture rising. This happened just before 6pm as the blue box was highlighted and the soil moisture level was rising. As a result, the water pump will remain shut down due to the optimum soil moisture level. With this, water savings can occur because the spray rate is only done once a day.

2) Manual watering system

For this manual irrigation system, the timer is used extensively to control the water pump. The timer will turn on the pump for 9 seconds to supply 25ml of water per plant and the timer will turn on at 7am and 6pm. The system does not take any readings from the soil moisture sensor and relies solely on the timer.

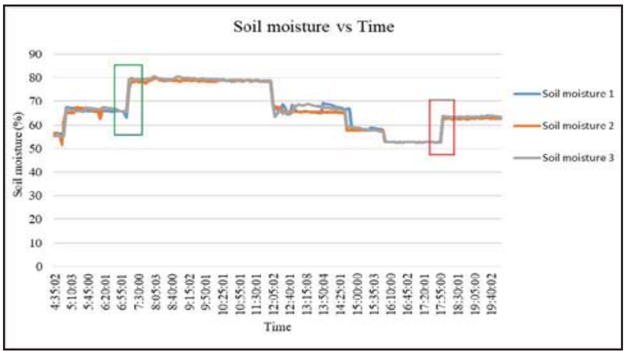

Fig 17: Soil moisture level in manual system during rainy day.

When in the manual watering system, the water pump is always turned on with the timer and the timer is set to turn on the water pump at exactly 7 am and 6 pm. The water pump will be turned on even though the soil moisture at that time was in sufficient condition. This situation can be seen in the diagram and is highlighted with a green box where the soil moisture level is over 60% but the water pump is still turned on by the timer at 7am. This has caused the soil to become too wet and water wastage has occurred. At 6pm the water pump will turn on normally based on the timer.

D. Comparison between Automatic and Manual Watering system

Based on some experiments, automatic irrigation systems have been found to be able to save water compared to manual irrigation systems or using a timer. This is because the irrigation system automatically delivers water to the plant based on the soil moisture and current rates of exactly 7 am and 6 pm. While the manually irrigation system is based on a timer where the timer will turn on the water pump at 7am and 6pm irrespective of the soil moisture level. The savings rate that can be obtained by the automatic irrigation system can be computed by performing a percentage calculation of the savings and compared to the irrigation system manually. Each time irrigation will take about 9 seconds in which 25ml of water is used.

For manual irrigation system that will take twice to irrigate the crop in one day. That means in one day its need 50ml of water to watering the plant. In a month, this system will need about 1500ml or 1.5 litres of water. While, for the automatic irrigation it will be in two condition where the first condition is the system in normal weather and the second condition is when the system in rainy day. For normal weather, water usage is like manual irrigation system and on rainy days water usage is based monthly rainfall distribution rate.

The water savings rate for the automatic irrigation system can be verified by performing the following calculations:

- Each irrigation = 25 ml
- 1 day = 2 time irrigation = 50 ml
- 30 days = 1500 ml = 1.5 litres
- If 10 days rainfall distribution in a month,
  10 days x 50 ml = 500 ml
  1500 ml – 500 ml = 1000 ml
  1000 / 1500 x 100 = 66.67 %

Based on the calculation above the saving rate of 66.67% will be obtained when using Smart Agriculture using Internet of Things with Raspberry Pi in a month.

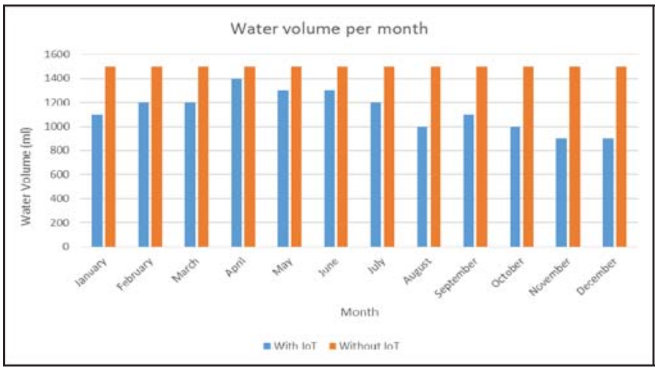

Fig 18: Average water consumption in 12 months.

Figure 18 shows the rate of water consumption within a month based on rainfall distribution. Rainfall distribution rates in Malaysia are estimated to occur between 2 and 12 days a month. By using IoT irrigation system, water consumption can be reduced while irrigation systems without IoT will use water with equal volume throughout the year. 24.44% water savings rate can be achieved when using IoT-based irrigation systems compared to traditional irrigation systems.

V. Conclusion

This research has successfully implemented water irrigation system which meets the target of water-saving purposes as it is equipped with self-intelligent capability. The findings revealed that the soil moisture state is under strong control because it is proven that the planned irrigation scheme did not conduct the watering process when the soil is above the level of excessive watering purposes or on rainy day. The network thus helps to conserve water use and to avoid overwater or contamination of the plants. For future improvement, pH sensor, light detection, soil condition checker, and crop observation could be added to make the system more efficient by using image processing. Consequently, authorities should start to think that more research on agriculture-related projects is worthwhile.

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