IoT Soil Moisture Monitoring and Irrigation System Development

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ABSTRACT
Agriculture is vital in human evolution and was the first activity to be emphasized ever since the beginning of time. With the population growing constantly, there are inventions of new means in the production of food to cater for those demands. Improvement in a variety of technologies is one of such effort conducted for the cause. Robotics or chemical technologies may not be the only improvements that could be exercised. Internet of Things (IoT) technology is one of an application widely used currently. The study aims to establish a less manpower plantation in smart city with the use of IoT technology to improve the crop cultivation. In preliminary, a wireless soil moisture monitoring and irrigation system was developed. The system aims to monitor the moisture and properties of soil for plants. At the same time, with a self-sufficient and self-organized irrigation system based on the water-control algorithm. The developed system covered the three layers in IoT architecture: perception layer, network layer and application layer. In perception layer, a microcontroller, soil moisture sensors and solenoid valves acted as the sensors, transducers and actuators. Wireless networking technology (WiFi) was used as the communication for data transmitting and receiving. Through the developed application, humidity and irrigation volume were collected, recorded and analyzed. These preliminary results help in visualizing the concept of a less manpower plantation in smart city.

CCS Concepts
• Networks → Network services → Cloud computing; Computer systems organization → Embedded and cyber-physical systems → Sensors and actuators; Hardware → Communication hardware, interfaces and storage → Sensor device and platforms.

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Keywords
Smart City, Agriculture, Internet of Things (IoT), Unmanned Plantation, Monitoring and Irrigation system.

1. INTRODUCTION
Despite the current technological achievements of basically any field in the modern era, ranging from medical to construction, there is just a minimal implementation to the agricultural region [1]. Farmers still inspect and maintain their crops in the conventional way. The development of a monitoring system is desirable for the ease of irrigation for crop maintenance to minimize the workload of the farmers. Research on the systems of the current timeframe is required to get a theory behind the basis of the method. Pros and cons of the existing system have been considered and evaluated during this investigation to assure that the system designed will have enhance performance in comparison to the current systems.

2. LITERATURE REVIEW
2.1 Internet of Things (IoT)
In the framework of IoT, there is an interconnection between all devices which results in the ability to transfer data to the "Cloud" or spread it amongst more than one interconnected tool [2]. The essentially expanding enthusiasm in IoT in agribusiness might be generally noticeable in Figure 1. As the day and age "Internet" infers, networking capability is one of the middle elements of the IoT devices. The Internet as we are aware of it these days is ordinarily an internet of human end-users, in the meantime as the IoT could be an Internet of non-human elements, thus an assortment of machine-to-device communication will be occurred.

Figure 1 shows the IoT system architecture that consists of three tiers that included the perception level (sense), the network level (data transfer), and the application level (data storage and manipulation) [3]. The first level of the IoT structure is the perception layer, which technologies are found such as Wireless Sensor Network (WSN) and Radio-Frequency Identification (RFID). A few overlaps may be found among WSN and RFID technologies, on account that semi-passive and active RFID tags can be appeared as wireless nodes bringing down computational and garage capability. A wireless sensor node included a processing unit,

regularly a low power microcontroller unit, at least one sensor modules and Radio Frequency (RF) communication module.
For the second layer, the network layer, where the wireless sensor nodes interface with the objects or environment. Wireless sensor nodes to communicate with their nearest nodes or a gateway. Networks work through which information are normally sent towards a remote infrastructure for storage. Communication protocols are built over wireless standards like 802.11 and empower the devices connection and link the air between the gateways and the end-nodes.

The third layer is the application layer. This layer's function is to convey in application specific services to the users [4]. Its miles of excessive is important that it stimulate the realization of the IoT. The challenge of the application layer is recognizing and tending to billions of devices around the world and controlling over devices through the Internet.

The possibility of IoT is to permit billions of devices which decent variety of specialized specifications which is form factor, power deliver, environmental, compatibility with different devices, computing power, peripheral device and networking subsystems to exist together in one between network. Progress in the domain of IoT is anticipated to have a high impact on the agribusiness [2]. Currently, the realistic IoT deployments in agribusiness are pretty harsh and they seem to be stayed in a difficult challenge task. Sensor modules should be exact adequate, with the exact estimating range for crop. Sensor modules additionally require protected contrary to the natural factors that may either make false readings or even destroy the sensor totally.

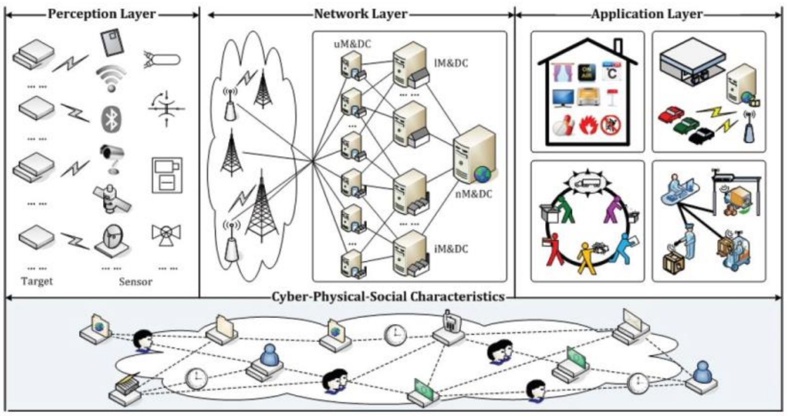

Figure 1. Internet of Things (IoT) system architecture [4].

2.2 Moisture Sensor

Agriculture burns through approximately 80-90% of freshwater [8] through poorly managed irrigation where areas with water are given some anyway as there is no efficient method to assume the moisture content and control over the discharge of water to only area with low water content. This becomes a problem to the ecosystem as water supply shortages are becoming the problem of the present. To fight the situation on hand, conservation of water in the agricultural sector can be done via the installation of soil moisture sensors. Soil moisture sensors gauge the water content in the soil to preserve ideal soil conditions for plants without providing excessive water content or water-deficiency in the soil. In some cases, there was a recoded reduction of residential irrigation as much as 50% with the installation of soil moisture sensors. As it has been deployed in residential areas, why not agricultural. The impact on residential water consumption could be a few tens of liters but in a plantation, it could be tones of water.

There are different types of soil moisture sensors including tensiometers, coaxial impedance dielectric reflectometry, gypsum blocks and volumetric [9].

Figure 2 presents a moisture sensor that uses Time Domain Reflectometry (TDR) technology. TDR technology as known as volumetric assesses genuine soil water content rather than soil water potential. The steel poles embedded in the soil accumulates electrical signs from the TDR device while the sensors gage the signal's rate of return which approximates the amount of water in the soil. In comparison, water-deprived soil returns signals faster than wet soil. Conversely, TDR sensors insist on data interpretation and may require different calibrations with dependency on the different variety of soil makeup.

The function of the soil moisture sensor is to measure the water content in the soil and with it, the user can distinguish with ease when soil requires more water or when water is over-compensated. Moisture levels of the soil are detected using this instrument and provides the outcome to Arduino (Analog Input). Subsequently, when the moisture of the soil has been reduced to a certain level of below, Arduino is programmed to trigger the water system to either dispel or withhold water.

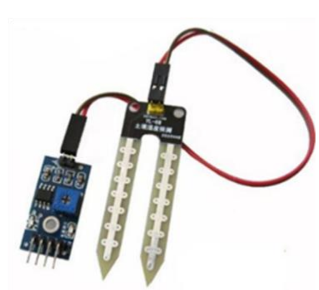

Figure 2. Moisture Sensor

2.3 WiFi Technology

Many electronic devices like smart phones, laptops, and more utilize a low power wireless communication also known as WiFi. In this setting, router capacities as a correspondence hub point wirelessly with the restriction of allowing clients to connect within close to the router within the network. WiFi is exceptionally normal in systems administration applications which manages transportability wirelessly. The maximum range of the WiFi is 100 meters and network type is a WLAN for lengthy distances [2]. The ESP8266 WiFi module is trendy for its IoT applications. The AI-thinker Team developed ESP-12E WiFi module as known as WiFi Shield [10]. The core processor ESP8266 in littler sizes of the module incorporates Tensilica L106 integrates industry-leading ultra-low power 32-bit MCU micro, Clock speed bolster 80 MHz, 160 MHz, integrated WiFi, on-board antenna. Created for space and power limited mobile platform designers, the ESP8266 is a high integration wireless SoCs that delivers unparalleled potential to implant WiFi capabilities within our system or to operate as a standalone application with minor expenses and negligible space requirement.

2.4 Water Control Algorithm

From the researcher's method [11], there are two type of watering method which are variable keep-pause time method and require water calculation method. Figure 3 shows that flow chart of the irrigation control algorithm based on the variable keep-pause time method. S1 is measure reading from sensor and S0 is threshold value that set by developer. The variable keep-pause method resembled an irrigation scheduling method in which a developer set the timer of the irrigation and respite the irrigation for a preset time thereafter. This method provides frequent small-volume irrigation events according the duration of the irrigation which is set by developer. After the irrigation perform, it will idle until the pause time which set by developer is finished. However, this method will perform loop until power down. The disadvantages of the variable keep-pause method of high water loss. Figure 4 shows that flow chart of the irrigation control algorithm based on required water calculation method. This method designed to supply the measure of water figured based on the measurement of the present water content in the soil.

Required water calculation method would give a straightforward irrigation operation without frequent irrigation, while providing the amount of water required at every irrigation. In stage of determining the volume of water needed, the equation of volume of water needed is calculated:

$$WN = 100\ \% - S1 \qquad (1)$$

where S1 is soil moisture reading in % and WN is water need in %. Irrigation time is based on the WN divide by water pump flow rate:

$$t = WN\ /\ flow\ rate\ (per\ second) \qquad (2)$$

where flow rate of water pump in ml, WN is water need in % and t is time in second.

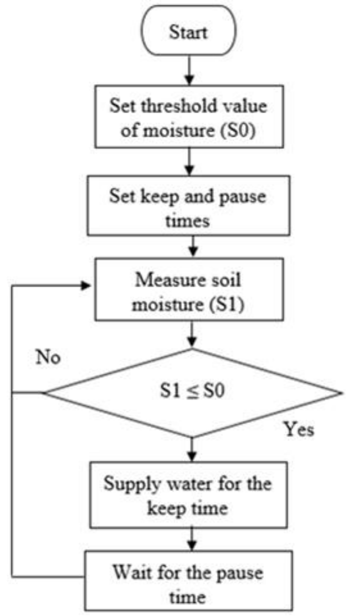

Figure 3. Flow chart of irrigation control algorithm based variable keep-pause time method

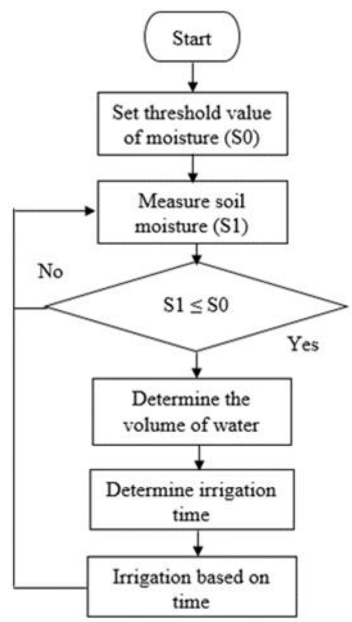

Figure 4. Flow chart of irrigation control algorithm based required water calculation method

3. METHODOLOGY

The systems consist of three sectors which are sensing layer, network layer and application layer. The methods of the system are used will be presented.

3.1 General Architecture of the System

The proposed system shown in Figure 5 that consists of two parts that are the data collection and output unit which is hardware system and data storage system. At the middle of system, the wireless hub as the gateway for communicate between them. The data storage system divided into two sector which is front end for user interface and back end for database. The hardware system is based on microcontroller, sensors, communication modules and irrigation outputs. The hardware that is chosen for this project is Arduino UNO which acts as the microcontroller, with the utilization of the TDR technology of moisture sensors to provide major input for the watering system as well as ESP8266 WiFi module as a communication tool.

The logic behind the hardware chosen is due to the fact that Arduino is comparatively economical in contrast to other microcontrollers and it is easier to program as it uses C programming language. Additionally, the moisture sensors that operate using the TDR method can gather to measure reading with high accuracy despite its low costs. Last but not least, the ESP8266 WiFi shield is chosen as its WiFi has a coverage of up to 100 meters for a wider internet connection range for site data transfer and communications.

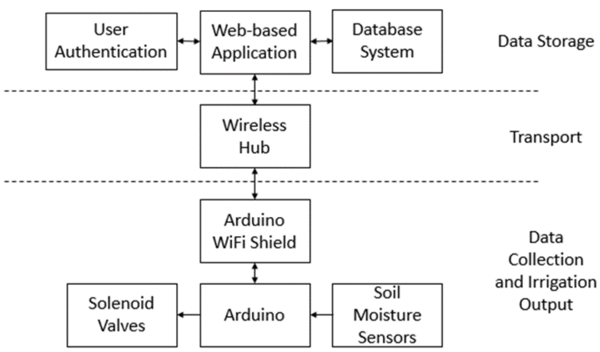

Figure 5. Block diagram of system

After appropriate hardware is chosen, the behind water control algorithm also need to execute the irrigation based on the measurement reading. The water control algorithm chosen is the required water calculation method. The reason of choose this method because it supplies water based on the measurement reading from the moisture sensor. In stage of determining the volume of water needed, the equation of irrigation time to supply volume of water needed is calculated:

$$t = 60\%\text{-}Input\ /\ flow\ rate\ (per\ second) \qquad (3)$$

where 60% is the threshold percent and input is the soil moisture reading in % from the sensors. After that, divide water pump flow rate in ml to calculate time for duration of supplying water needed.

The combination of hardware system and front end of the data storage system, which permits for to display real-time readings through the wireless hub in WLAN. The advantage of the system is its ability to obtain real-time readings from the pre-installed sensors and control irrigation outputs via remote manually

3.2 Hardware Circuit Design

Figure 6 shows the circuit design of the proposed hardware system. The system architecture contains six moisture sensors, six solenoid valve with relays, an Arduino microcontroller and ESP8266 WiFi Shield. As well as a computer as its web-based system with a wireless hub as the gateway for communication to and from the microcontroller.

Moisture sensors are used to measure the water content of the surrounding soil and transmit findings to the Arduino that will next trigger the initiation of the solenoid valve for irrigation when the moisture value of soil falls below the preset optimum level for the plant. After that, Arduino performs the calculation based on the last moisture reading gathered to determine volume of water needed. Then, Arduino will send a current signal to turn on the relay module. When the relay module receives current signals from the Arduino, the relay module becomes a switch that permits external power sources to activate the solenoid valve. The relay module stops the operation when adequate of water is supplied.

There is a limitation of Arduino that does not have adequate current and voltage to operate solenoid valve. A straight-forward connection may damage the Arduino due to over current. However, relay module is obligatory to activate the solenoid valve. Additionally, an external 12V power is needed to initiate the solenoid valve.

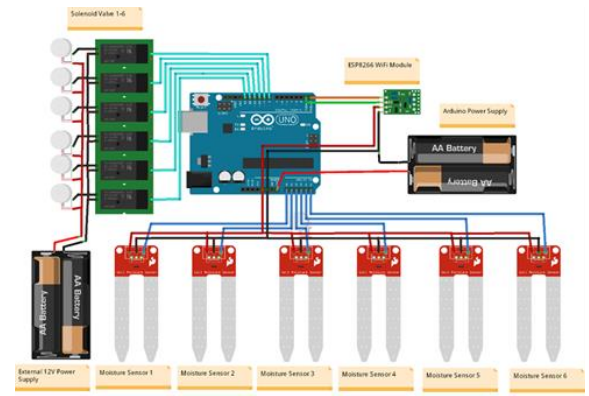

Figure 6. Circuit design of wireless soil watering system

3.3 Test-bed Design

Figure 7 shows the test-bed of green bean and the position of sensors and valves in the test-bed. The test-bed consists of six moisture sensors and solenoid value. The solenoid valve is put into the middle for each zones. The reason of put it in middle is water can be dispersing evenly. The test-bed consists of six zones and planted with different weight of green bean, (10g, 20g, 30g, 40g, 50, 60g) as shown in Figure 8. This test-bed is used to gather moisture reading of each different amount of the green bean in 15-days. It is for record the growth of the green beans as well. The investigation to decide the utilization of the water of every zone. All the data are recorded and upload to the database.

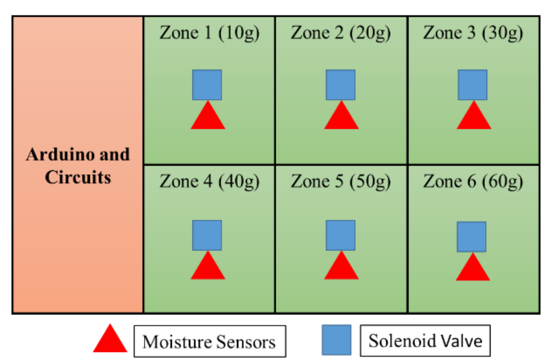

Figure 7. Test-bed position of sensors and valves (b) zones with different density of green bean

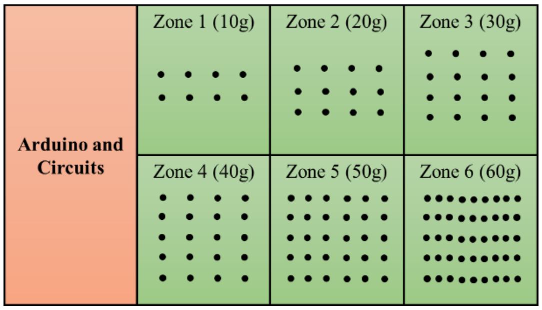

Figure 8. Test-bed zones with different density of green bean

4. RESULT AND DISCUSSION

Table 1 shows the height of green beans growth and total of irrigation volume in 15-days. The column filled in blue shows the day where the irrigation performed. The first irrigation start in day-6 for all zones while the green beans reached the average height of 17 centimeter (cm). Green beans growth consume the water content in the soil. The water content lower than 60 % trigger the sensor for irrigation operation. Total of irrigation volume increase from zone 1 to zone 6. Zone 6 with 60g of green bean planted record of highest irrigation volume, 106 ml. From the table, the total of irrigation volume in zone 3 and 5 are much less than zone 1. The phenomena cause by the water dispersion of the valve in zone 6. But for the total irrigation volume in zone 1, 2, 4 and 6, the irrigation performed accordingly to the need of the plants. Figure 9 shows in detail the each day moisture value and irrigation volume from zone 1 until zone 6. The zone with high density of green beans perform the irrigation more frequently.

Table 1. Height (cm) of green beans growth and irrigation volume (ml) for 15-days

Day	Height (cm)					
	Zone 1 (10g)	Zone 2 (20g)	Zone 3 (30g)	Zone 4 (40g)	Zone 5 (50g)	Zone 6 (60g)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	1.0	1.0	1.0	1.0	1.0	1.0
4	9.0	8.0	8.0	6.0	7.0	6.5
5	15.0	13.0	12.0	12.5	12.5	14.0
6	19.0	17.0	16.0	16.0	16.5	18.0
7	21.0	19.5	18.0	19.0	21.5	20.0
8	22.0	21.0	20.0	21.0	23.0	22.0
9	23.0	22.0	21.0	22.0	24.0	24.0
10	23.0	23.0	21.5	22.5	24.0	24.0
11	24.0	23.5	22.0	23.0	25.0	25.0
12	24.5	24.0	23.0	23.0	26.0	25.0
13	24.5	24.0	24.0	24.0	26.0	25.0
14	25.0	24.5	25.0	25.0	27.0	26.0
15	25.5	25.0	25.5	26.0	27.0	26.0
Total	Irrigation Volume (ml)					
	34.0	46.0	14.0	64.0	24.0	106.0

5. FUTURE WORK

This is a pilot project which aims to study the irrigation patterns for different plants. The study aims to produce the irrigation pattern of different plants which to be implemented in the precision framing in the agriculture IoT system. This precision farming will relieve a fully-autonomous monitoring and irrigation IoT system in saving the water and electricity consumption according to plants and its density.

6. ACKNOWLEDGMENTS

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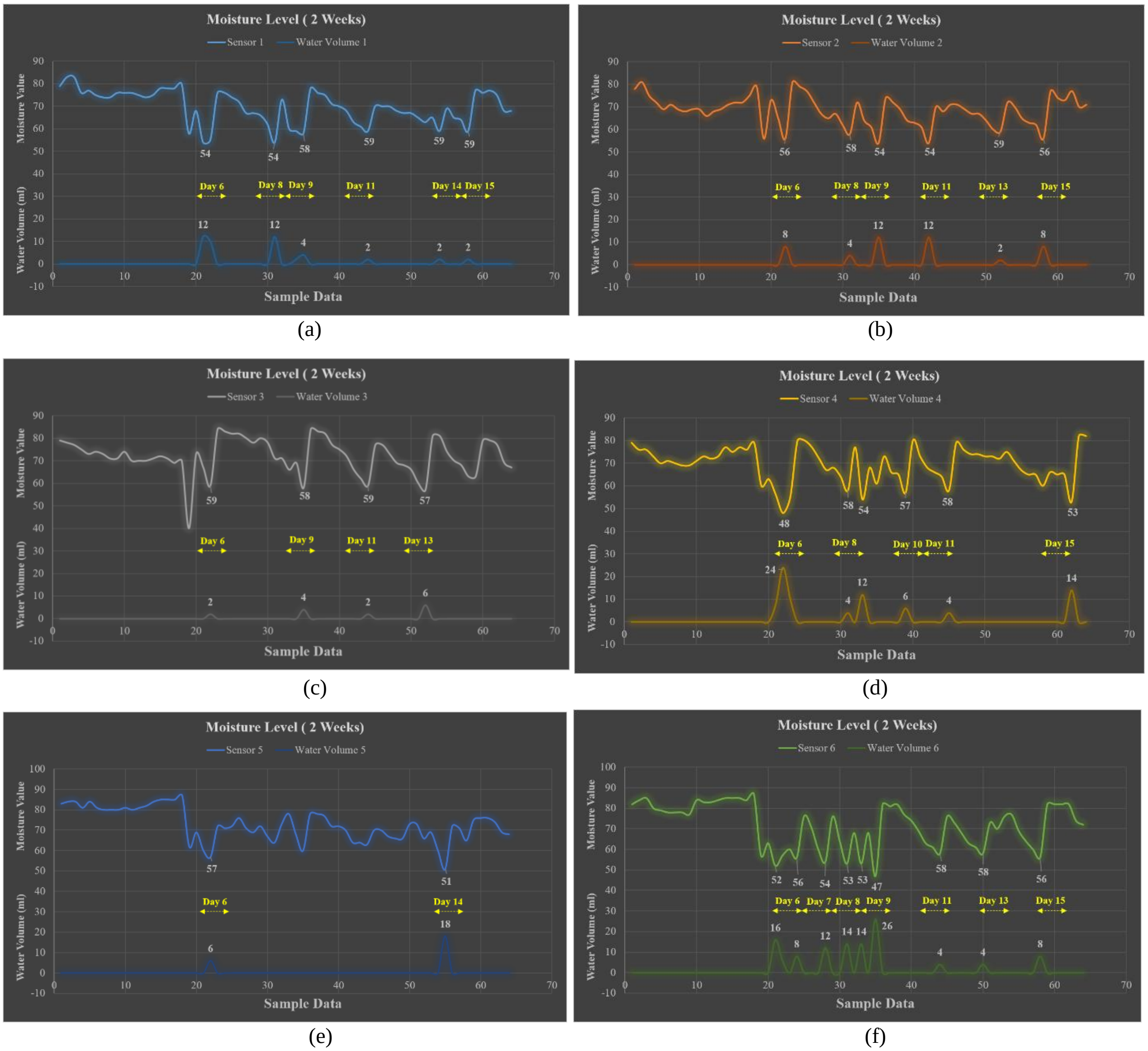

Figure 9. Moisture value and irrigation volume for 15-days at different zones