Wireless-Automated Water Irrigation System Monitoring Soil Moisture and Solar Radiance Powered by Solar Energy and Battery

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Bachelor of Science in Electrical Engineering

by

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APPROVAL SHEET

This is to certify that we have supervised the preparation of and read the research paper prepared by **Rhenz Fred A. Pacaigue and Mark Daniel A. Ragas** entitled **Wireless-Automated Water Irrigation System Monitoring Soil Moisture and Solar Radiance Powered by Solar Energy and Battery** and that the said paper has been submitted for final approval by the Oral Examination Committee.

Engr. Melissa B. Martin
Thesis Adviser

As members of the Oral Examination Committee, we certify that we have examined this paper and hereby recommend that it be accepted as fulfillment of the practicum requirement for the Degree in **Bachelor of Science in Electrical Engineering.**

Panel Member

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Committee Member/Panel Member

This practicum is hereby approved and accepted by the School of Graduate Studies as fulfillment of the practicum requirement for the Degree in **Bachelor of Science in Electrical Engineering.**

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ABSTRACT

Plants needs sunlight in order to conduct Photosynthesis, it provides plants their own food from water, carbon dioxide, and sunlight. It converts the light energy from the sunlight into chemical energy. But too much and high intensity sunlight can decrease the efficiency of plants in conducting Photosynthesis also refer as photoinhibition. Plants are prone to withering due to intense solar exposure, watering is one way is preventing plants to dry and wither. Innovating the water irrigation system with the solar radiation sensor, it can prevent plants from drying up and withering, by monitoring the solar radiance and sprinkling water to provide moisture to the leaves. This study can provide a solution in securing the health and growth of plants and prevent it from drying and withering.

Keywords: Water irrigation system, photoinhibition, plants, soil moisture, wireless-automated water irrigation.

Chapter 1

INTRODUCTION

Growing crops and plants have been one of the main food sources since ancient civilization. Crops and plants are most abundant in tropical areas, in which the area has a mean annual temperature and a high amount of rainfall. This means a balanced environment perfect for growing crops and plants [3]. The most important factors that a crop and plant need are sunlight and water. A plant needs a constant source of water, moisturizing the soil so that nutrients can flow easily. The second factor is the sunlight, which is very important for plants and crops to initiate Photosynthesis; it is the process in which the plants and crops convert light energy into chemical energy. Thus, creating their food and transforming carbon dioxide, water, and nutrients into oxygen [21]. There are a lot of crops and plants that are hard to grow, and some are sensitive to their environment. These kinds of plants need a monitored environment. The researchers choose the tomato plant because it needed consistent soil moisture and solar radiance for it to achieve a healthy growth. Tomato needed at least six to eight hours a day in constant sunlight [25]. However too much intense sunlight may cause sunscald to the fruit and leaves of the plant. This is where the wireless-automated water irrigation monitoring soil moisture and solar radiation sensor comes in. This study is applicable to all plants and crops, monitoring soil moisture and solar radiation to secure the plants or crops' healthy growth. The wireless-automated water irrigation system controls the soil moisture suitable for the plant or crop.

There are many versions of water irrigation systems. Some are just automatically water crops and do not consider the right amount of water in the soil, risking overwatering the plants and causing them to die. However, this study accurately measures the amount of soil moisture and the solar radiance that the plant or crop receives [4]. Thus, it minimizes the risk of overwatering and too much sunlight, ensuring the plant's healthy growth. This system can be operated wirelessly, using an application that displays the current situation of the plant. Based on statistics, the reason why there is a need for a good water irrigation system is due to inconsistent water supply to the crops and plants. Inconsistency of water supply causes the crops and plants to decrease in production and to wither [14]. A study that supports this is the "Mobile integrated smart irrigation management and monitoring system using IoT", their study is similar to this study, wherein it monitors the soil moisture wirelessly through a mobile application that is connected to the Internet [19]. Their objectives are to monitor the soil moisture, supply water, and wirelessly control the water system irrigation.

One of the related studies is the "Mobile integrated smart irrigation management and monitoring system using IoT". The related study used Arduino Uno, with a soil moisture sensor. The sensor is connected to the microcontroller, reads the data from the sensor, and is connected to a water valve. The microcontroller also sends an SMS to the mobile phones in order to alert the user whenever the water valve is opened or closed. The researcher's main innovation is to monitor solar radiance to prevent too much sunlight from causing the plant or crops to wither, and some plants are delicate when there is too much sunlight. The solar radiance sensor to be used is the solar radiance sensor. The soil hygrometer humidity detection module moisture water sensor is connected to the microcontroller for the soil moisture sensor of the study. These are the main innovations done by the researcher in order to provide wireless-automated water irrigation that monitors soil moisture and solar radiation.

The primary purpose of the study is to create a prototype wireless-automated water irrigation that monitors soil moisture and solar radiance powered by a solar panel and a battery and to maximize the plant growth. Specifically, this study wants to: (1) to detect water content of the plants using the solar radiance sensor and soil moisture sensor and automate the irrigation of water using the conditions that are set on the microcontroller which will either open or close the solenoid valves, (2) to develop a system using MySQL Database Software which can configure the microcontroller when needed and it will perform as the database and server of the water irrigation system and develop a mobile application which shows the output of the sensors, (3) to provide wireless automation of irrigation using a transceiver which will receive the data from the GPRS module and transmits the data to the database and software and provide feedback once readings go beyond normal range, (4) to measure the height, leaf number, leaf size of the plants.

The purpose of the study is to provide innovative knowledge and improvement towards the water irrigation system. The study proposes a wireless-automatic water irrigation system device that will have two sources of power: solar and battery. It is better than the existing automatic water irrigation system, which only has one power source, either solar panels or batteries. It will be able to measure the solar radiance in the plant to provide the accurate water needed to maximize its growth. The solar radiance measures if the plant receives an exceeding amount of radiation that will cause overexposure to sunlight and affect the growth and health of the plant. The solar radiance sensor will prevent that from happening for the reason that the prototype wireless-automated irrigation system will drizzle water to the leaf of the plant using a sprinkler to reduce the amount of evaporation that cause by overexposure to sunlight, reduce dust and insect manifestation on the plant specifically caterpillars. The wireless-automatic water irrigation will help promote water conservation because it will only water the plant when needed due to the installed sensors that measure the soil moisture and solar radiance of the plant. The proposed wireless-automatic water irrigation will maximize the product ion and growth of the plant even in the condition of limited water supply. The beneficiaries of the study are farmers, plant owners, agricultural sectors, and future researchers.

The research study focuses on improving and innovating the water irrigation system using modern technology. The study will be done in a controlled environment and compare two different irrigation systems: the conventional method of water irrigation and the wireless-automatic irrigation system. The conventional method of water irrigation is where the researchers will water the plant once or twice per week. The study will use specific components in building the prototype wireless-automatic water irrigation system: Arduino Uno as the microcontroller, capacitive soil moisture sensor, solar radiance sensor, and a GPRS module which will connect the system to the Internet and be able to send information to the mobile application for monitoring of the user. The study will use the same seedling of the plant and become the dependent variable of the study. It will use a similar soil composition, the same amount of fertilizer, and be placed on the same area to receive equitable sunlight. The prototype wireless-automatic water irrigation system can be used in any weather in a tropical country. It will be most effective when used during the summer seasons because the sensors will be able to measure the accurate amount of water needed for the plant. The effectiveness of the wireless-automatic water irrigation system in the simulated scenario may or may not be true after the simulation is finished. The solar panel and battery that will be use in the study will only serve as the power source of the whole system of the automatic water irrigation system and power the sensors installed on the conventional method of water irrigation.

CHAPTER 2

REVIEW OF RELATED LITERATURE AND STUDIES

This chapter uses relevant articles, books, journals, and related studies to discuss wireless-automated water irrigation monitoring soil moisture and solar radiation sensor. This chapter will also discuss using wireless-automated water irrigation with solar energy and battery.

2.1 Soil Moisture

Many factors affect the growth of the soil. One of the essential factors is soil moisture. Soil water is the component that serves as the carrier and solvent of nutrients for plant growth. In addition, water is the main component of Photosynthesis [21]. All plants need a soil moisture level between 20% and 60%. If the soil moisture is below 20%, the plant might not be able to produce its own food, and the nutrients are not distributed, causing it to die [20]. This is the reason why soil moisture must be monitored in order to prevent plants to wither. Another article entitled "Monitoring soil moisture for optimal crop growth" states that a good soil moisture must have a 40% to 49% of soil moisture as shown in Figure 2.1. [18].

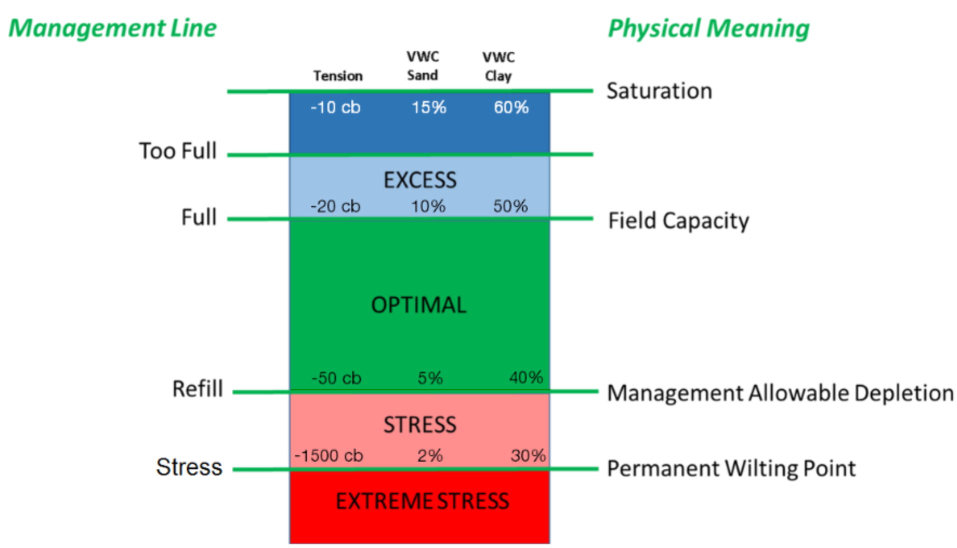


Figure 2.1. *Management Line of Soil Moisture [18].*

2.2. Solar Radiance

Plants needs to perform Photosynthesis in order to create food. It transforms solar radiance which is light energy into chemical energy. Solar radiance is one of the main components for a plant to conduct Photosynthesis. But too much exposure of solar radiance can cause bad effects for the plant such as decrease its photosynthesis efficiency, it is called photoinhibition. [6]. In addition to this article, the specific amount recommended for a plant to conduct Photosynthesis is 400 to 700 nm light radiation this range is the Photosynthetically Active Region (PAR). This is the range where the plants maximize their sugar production and also maximizes its growth. The earth receives approximately 90,000 lux and the recommended lux for a plant to receive is between 50,000 to 65,000 lux, which approximately more than this will result a decrease in the efficiency of the plants to conduct Photosynthesis, as shown in Figure 2.2. [7].

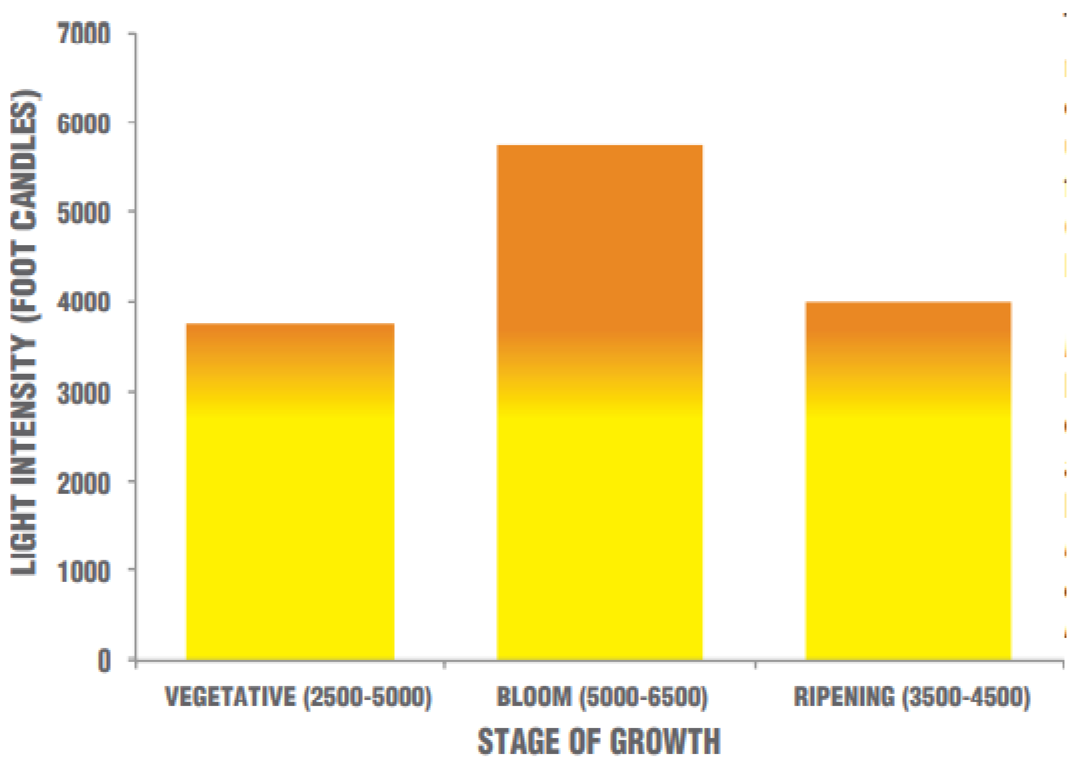


Figure 2.2. *Relationship of Light Intensity and Growth Rate [7].*

2.3. Soil Moisture Sensor

If the soil moisture of the plants is below standard, the soil is dry, causing it to be deprived of water and causing the plants to be withered. This idea is supported by the research study [17] entitled "Calibration and Validation of Low-Cost Capacitive Moisture Sensor to Integrate the Automated Soil Moisture Monitoring System" their sensors present real-time data of the soil moisture and avoid soil moisture stress and excess water application. Supported by the research [2] entitled "An Attempt to Find Suitable Place for Soil Moisture Sensor in a Drip Irrigation System," with the objectives of monitoring soil moisture for precision agriculture and proper positioning of soil moisture sensors, which is not too far from the roots in order to have the current state of moisture in the soil. This maximizes the full growth of the plants in order to be healthy.

2.4 Solar Radiation Sensor

Another essential factor that affects the growth of plants is sunlight. A plant must have enough energy sources to initiate Photosynthesis. However, too much sunlight can also damage the plants by evaporating or reducing the soil moisture [15]. These two factors greatly affect the growth of the plant. That is why the solar radiation sensor is used to monitor the solar radiation and soil moisture sensor.

2.5. Benefits of Watering the Leaf

In order to solve the problem of photoinhibition, one of the easiest ways to prevent it is to water the leaves of the plant. Watering the leaves of the plant can decrease the temperature and lessen the evaporation of water in plant leaves. [13]. In addition, watering the plant leaves helps cool the plant, minimize pests, and hydrate the leaves; this helps the plants reduce water loss. The sprayed water creates a barrier to the plants that gives them protection from evaporation, and it creates a layer of air that can give them an environment to maximize Photosynthesis. Since pests often eat plant leaves, water the plant leaves can displace them from eating the plant leaves. Water the plant leaves can significantly provide benefits to the plants [11].

2.6. Tomato Plant

Tomatoes are crops that love the exposure of sunlight to grow, but too much exposure may make the tomato wilt. It needed constant direct sunlight for at least six to eight hours a day [25]. It is needed since it can affect plant growth and the fruits it will bear. In the study [27], the plant was tested at high temperatures, and the result was it enhanced the early fruit growth, but the vegetative growth decreased. It explains that too much exposure can positively or negatively affect the plant. Tomatoes are also vulnerable to environmental factors or lack of water and sunlight that can physically affect plant growth. It is open to insect manifestation, cracking due to uneven moisture of the soil, and sunscald that causes by intense sunlight for an extended period. The plant will take sixty days to one hundred days to mature and bear fruits (Almanac).

2.7. Smart Water Irrigation

The water irrigation systems used by humankind always evolved to have more cost-efficient and more yield of crops. Smart water irrigation is the most recent innovation in improving water irrigation. The capacity to monitor either local weather conditions or real ground moisture level is one of the benefits of smart irrigation, and watering schedules are automatically changed to meet the actual need of the crop [16]. The installment of a smart water irrigation system will reduce water consumption, especially in an area that has a limited water supply.

2.8. Optimization of Water Irrigation

Water Irrigations are the most vital resource for crops to grow and are a constant problem for the agricultural sector. It is essential to optimize water irrigation to maximize water resources, especially in areas with a limited water supply, and promote water conservation. The low dynamic irrigation limit is determined by crop growth and development time, as well as water supply; when the water supply is limited, the irrigation limit should be modified to make the most use of the available water during the drier crop growth stage [22]. In order to have optimal water irrigation, extensive research on the area must be conducted. It is possible to do this by comparing agricultural water demand with crop water availability in the area. It will analyze the water demand and supply using satellite-based estimates of evapotranspiration and NDVI in irrigation performance metrics [1]. The satellite-based estimates can be used to forecast the irrigation in the area that will have a low water supply. Irrigation forecasting using dynamic irrigation low limits is an essential technical method for improving irrigation schedules in fields with limited water supply [22]. The optimization of water irrigation will be dependent on the soil moisture, nitrogen level, and atmosphere that can affect the growth and yields of crops. According to the study [24], the sensitivity index is crucial to the accuracy of the model's computation outputs in crop irrigation system optimization. It can reduce and avoid the unnecessary use of water resources and reduce the irrigation cost.

2.9. GSM Network

Technology advancements can help build the most effective and cost-efficient water irrigation system. In using the mobile network technology, the water irrigation system can be built using different sensors on the crop and pass through a microcontroller which sends the information wirelessly to mobile phones. In a study, the researcher used a GSM network to send feedback from the sensors through the mobile phone. The GSM-based irrigation is more adaptive since it reduces over-irrigation, under-irrigation, topsoil erosion, and water waste [5]. The construction of a GSM network on a water irrigation system is less expensive and more effective since it may be altered dependent on the type of crop utilized. Shown in Figure 2.3. is the Block Diagram of the Irrigation System using the GSM network [5].

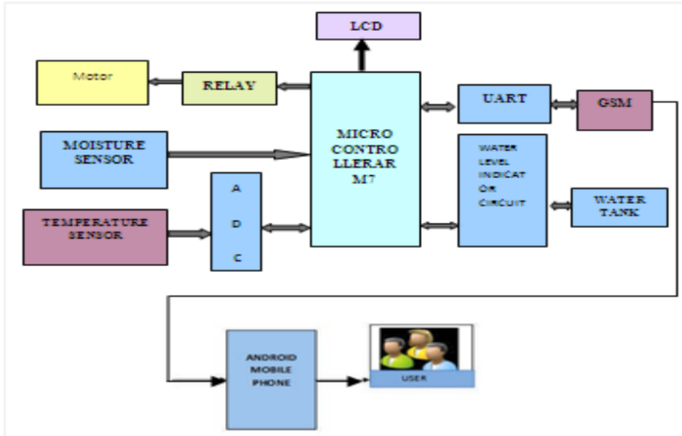


Figure 2.3. *GSM Network [5]*

2.10. GPRS Network

The GPRS network is one of the mobile network technologies that can transmit data from the sensors of the water irrigation system to mobile phones and computers. A revolutionary agricultural irrigation technique saves water using a data transmission unit (DTU), wireless radio frequency, and microcontroller [23]. It uses the wireless radio frequency to transmit data from the sensors and collect it in the DTU using the GPRS network. The data collected by the DTU will be transmitted to the monitoring center over the GPRS network and the Internet, where the monitoring center will control the water irrigation system that will ensure optimal efficiency—shown in Figure 2.4. the Structure Diagram of the System [23].

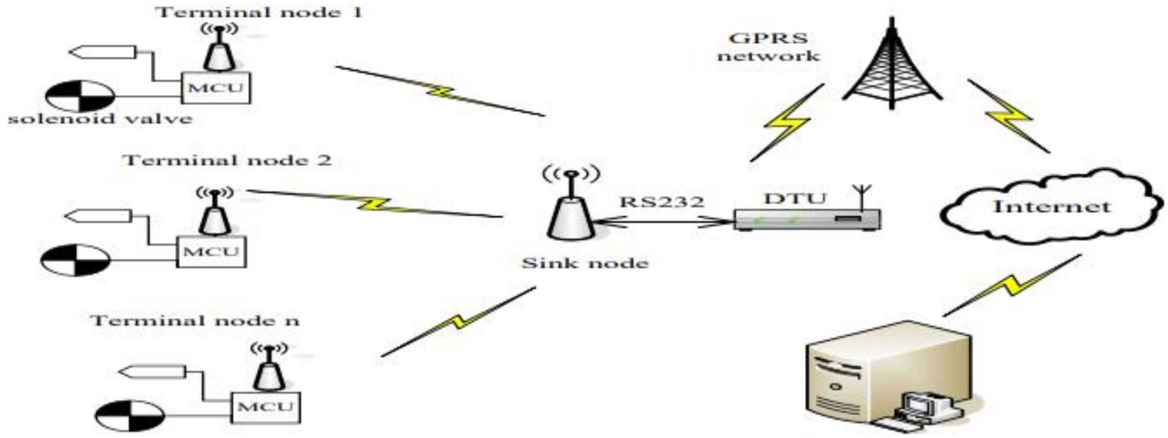


Figure 2.4. *Wireless Network using GPRS network [23]*

2.11. Database

Modern agriculture uses different technologies to improve the yield and health of the plant and to conserve water for irrigation. The usage of smart and digital technology on farms is proof that the agricultural industry is constantly changing to meet the growing demand due to the continuous growth of people in the world. It is a new revolution referring to the use of contemporary information and communication technology to manage farms and agricultural areas in order to increase product amount and quality while maximizing resource and human labor utilization [12]. Databases are critical components of modern farms that store different information from the sensors, programs, storage, production, and any data stored on the database software. The management of data on databases is the most difficult part, which processes, stores, and manages immense information. The introduction of the Internet and a slew of internet-connected apps significantly increased the volume of data generated, and newer types of databases, known as non-relational and, more recently, new relational databases, were developed to efficiently handle this vast amount of data: NoSQL and NewSQL databases, respectively [8].

Different variety of sensors is installed on smart farms that are managed and processed by databases and servers to irrigate and manage farms efficiently. The type of crop planted monitored, the numerous environmental elements to be investigated, or the agricultural activity done near the sensor all influence the data gathered and the deployment of sensor nodes on smart farms [12].

2.12. Sensors with Microcontroller

Smart farms use sensors and microcontrollers to operate and manage the farms efficiently, which helps to reduce water wastage and reduce human intervention. Microcontrollers are widely used for various applications that require processing data, monitoring, and controlling the system. It is attached to sensors in the plants to monitor the soil moisture, temperature, humidity, and other factors affecting the plant's health and growth. When the data from the sensors is compared to the threshold values, the microcontroller (AT89S52) triggers the relay, causing the motor to run and water the plants, which send the status to the farmer through the GSM Modem, as seen in Figure 2.5. [10].

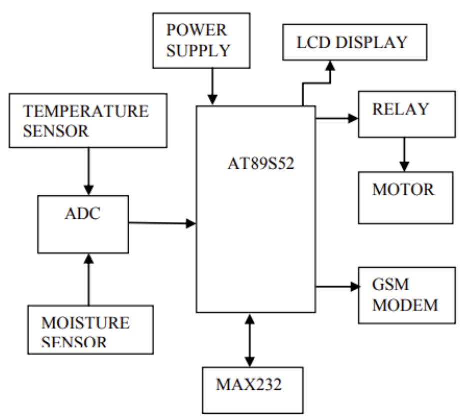


Figure 2.5. *Block diagram design using AT89S52 microcontroller [10]*

CHAPTER 3

METHODOLOGY

Keywords: Water irrigation system, photoinhibition, plants, soil moisture, wireless-automated water irrigation.

Introduction

This chapter discusses all the detailed information of the conceptual framework, hardware block diagram, system flowchart, data gathering, and statistical testing. This chapter confers the input, process, and output of the study.

3.1 Methodology

3.1.1 Conceptual Framework

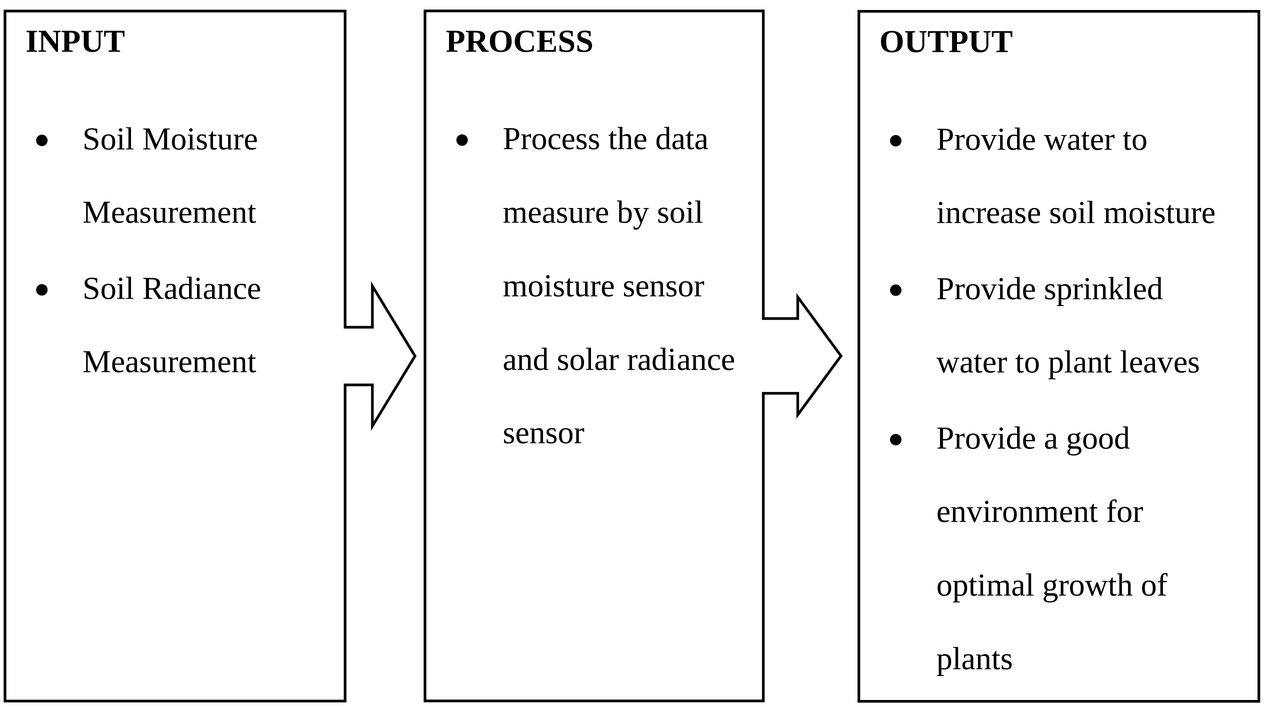


Figure 3.1. *Conceptual Framework*

Figure 3.1 describes the study's conceptual framework. On the leftmost panels are the framework inputs: soil moisture and solar radiance measurement using the sensors, then transmit the data to the microcontroller, the Arduino Uno.

The process stage of the study involves processing the data from the sensor, whether the measurement of soil moisture and solar radiance is within the condition. After the data is processed, the next step is for the microcontroller to make an action.

The output of the study is to provide water to increase soil moisture if the soil moisture measurement is below the condition and to provide sprinkled water to plant leaves to minimize overexposure to solar radiance to plant leaves.

3.1.2 Hardware Block Diagram

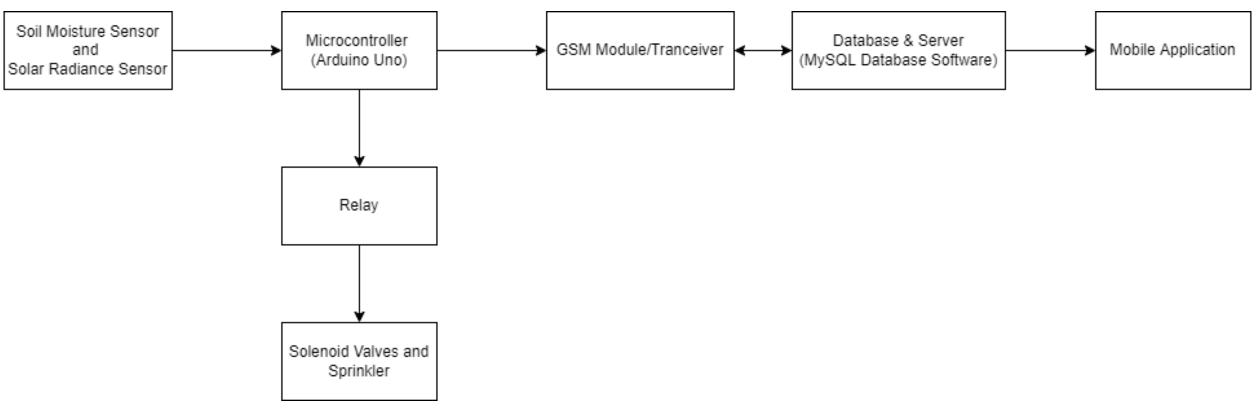
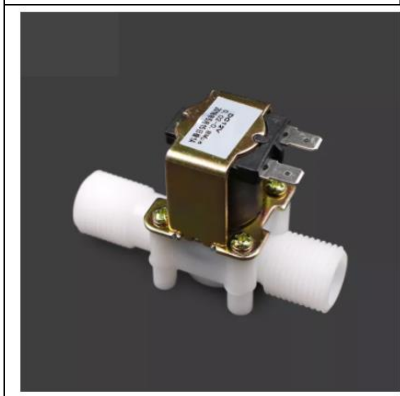
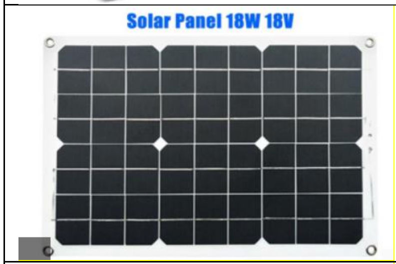


Figure 3.2. *Hardware Block Diagram*

Image of Hardware	Name of Hardware	Description/ Functions
	Capacitive Soil Moisture Sensor SEN0193	The soil moisture is placed in the soil to measure the soil moisture and then transmit the data to the microcontroller.

	Solar Radiance Sensor	The solar radiance sensor and placed close to the plant leaves in order to measure the solar radiance exposure, then transmits the data to the microcontroller.
	Arduino Uno	The Arduino Uno will serve as the microcontroller. It will process the data sent by the soil moisture and solar radiance sensors. It will also command when to open and close the solenoid valves. It is connected to the database/server to provide current data.
	Solenoid Valve	Solenoid valves are to the relay module. It is controlled by the relay module for when to open and close the valve.
	GPRS Module	This GPRS module is connected to the microcontroller. It connects the microcontroller to the Internet that can send data to the mobile application.
	MySQL Database Software	MySQL Database software is connected to the microcontroller and GPRS module. It will process the data from the microcontroller and transmit it to the GPRS module.

	Transceiver	The transceiver is connected to the GPRS Module and the database and server software. It can receive and transmit signals to the solenoid valves and sprinklers.
	Solar Panel (18W 18V ± 5%)	Solar panels will gather energy from sunlight and convert it to electrical energy and store it in the battery. It has a size of 420x280x2.5mm
	Power Inverter (4000W)	The power inverter provides an output voltage of AC 220V, 60 Hz. This will power the microcontroller, solenoid valve, and GPRS module.
	Solar Charge Controller	The solar charge controller will prevent the battery from overcharging. It controls when to discharge and reconnect from the battery.
	Lead-acid Rechargeable Battery (Panasonic)	This battery has a voltage of 12v and capacity of 7ah. This will serve as the electricity bank from the solar panel. It distributes the electricity to the microcontroller, solenoid valve, and GPRS module.

	2-Channel Relay Module	The 2-channel relay module is connected between the microcontroller and solenoid valves. It will send the electrical data from the microcontroller which will either open or close the solenoid valves.

Table 3.1. *Hardware Used and Its Description*

Figure 3.2 shows the hardware block diagram for this research. This shows the following tools or hardware that will be used in the study. First, the soil moisture and solar radiance sensors send the data directly to the microcontroller. Second, the microcontroller transmits the data to the database and server software. If the condition is met, it sends the command to the relay and to the solenoid valve will open to provide water. If the condition is not met, the relay will not open the solenoid valves. The database and server software transmits and receives data from the GPRS module that is connected to the mobile application. Afterward, the GPRS module will transmit the processed data from the database to the transceiver. The mobile application can control the solenoid valves and display the current status of the soil moisture and solar radiance.

3.1.3 System Flowchart

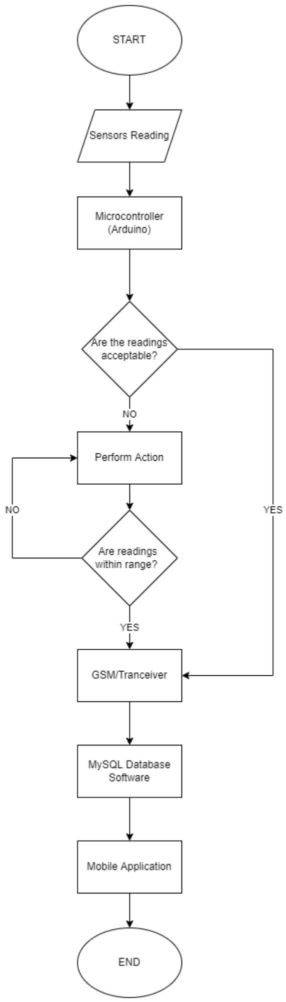


Figure 3.3. *System Flowchart*

Figure 3.3 shows the system flowchart of the wireless-automated water irrigation system. The first part shows the sensors readings from the solar radiance and soil moisture sensors. Both sensors will be connected to a microcontroller to be able to send their measured data. The microcontroller will compare the measured data from both sensors and separate whether the data comes from the solar radiance sensor or soil moisture sensor. If the measured reading is not acceptable, it will perform the action which opens the solenoid valve to water the plant or sprinkle the leaf of the plant. Otherwise, it will only record the readings and transmit them to MySQL Database Software. Afterward, the readings will be measured if it is within the specified acceptable range. When the readings are within the range, it will record the recent readings and transmit them to the MySQL Database Software; else, it will perform the action and open the solenoid valves. The GPRS module will allow the database and server software to connect to a mobile application. The mobile application will display the data from the sensors, the status of the valve, whether it is open or not and the status of the battery and solar panel

3.2. Calibration Process

In calibrating the SEN0193 capacitive soil moisture, the first thing to do is to set the sensor at 9600 baud rates. Subsequently, measure the sensor value when exposed from air and water. The sensor has three different categories of soil moisture: Dry, Wet, Water. The dry category has values equal to 430 up to 520 or above. The wet category has values from 350 to 430. While the water category will have values from 260 to 350. If the displayed values are not within the desired range, the calibration process for the capacitive soil moisture will be repeated.

Moisture Reading – Dry

Table 3.2.1. Calibration Table of Capacitive Soil Moisture Sensor

Trial	Actual Value	Expected Value
1		430-520
2		430-520
3		430-520

Moisture Reading – Wet

Table 3.2.2. Calibration Table of Capacitive Soil Moisture Sensor

Trial	Actual Value	Expected Value
1		350-430
2		350-430
3		350-430

Moisture Reading – Water

Table 3.2.3. Calibration Table of Capacitive Soil Moisture Sensor

Trial	Actual Value	Expected Value
1		260-350
2		260-350
3		260-350

In calibrating the solar radiance sensor, the solar radiance sensor will be place outdoors where there is available sunlight. Then, the researchers will record the maximum solar radiance, W/m^2, every three hours interval starting on 7 AM to 7 PM. The expected values will be measured from the solar power meter. The amount of tolerance to be used is +/- 5%. If the actual value is not within the desired range, the calibration process for the solar radiance sensor will be repeated.

Table 3.3 *Calibration Table of Solar Radiance Sensor*

Time	Actual Values	Expected Value
7 AM		xx
10 AM		xx
1 PM		xx
4 PM		xx
7 PM		xx

3.3 Data Gathering

The researchers will gather their data through quantitative observations. The researchers will set up two types of water irrigation: the conventional and the wireless-automatic water irrigation systems. The conventional method of water irrigation is where the researchers will water the plant once or twice per week and when needed. It will have its soil moisture and solar radiance sensor connected to data storage that will record and store the data over time until the plant grows. The period of the experiment will depend on the plant the researcher will choose. The data from the sensors of the conventional method of water irrigation and the wireless-automatic water irrigation will be collected, plotted to a graph, and compared after the experiment. Afterward, the researchers will conclude based on comparative data and quantitative observation.

Table 3.4 Solar Radiance Comparison Table

Day	Conventional Water Irrigation (%)	Automated Water Irrigation (%)
Day 1		
Day 2		
Day 3		
Day 4		
Day *n*		

Table 3.5. Soil Moisture Comparison Table

Day	Conventional Water Irrigation (%)	Automated Water Irrigation (%)
Day 1		
Day 2		
Day 3		
Day 4		
Day *n*		

In the table 3.4. and table 3.5 the researcher will measure the data of the soil moisture and solar radiance from the sensor. The unit that will be used in the table for soil moisture sensor will be the percentage of soil moisture and solar radiance measured. The measurement of the soil moisture will start from day one until the day when the plant matures.

The measurements are gathered every three (3) days to keep track of the growth of the plants and compare each result from the conventional water irrigation system and automated-wireless water irrigation system. Three categories are used to determine the plant growth from leaf size growth, leaf number growth, and the height of the plant.

Table 3.6 Leaf Size Growth Rate of Conventional Water Irrigation System

S1	Area of Leaf		S2	Area of Leaf	Leaf Size Growth Rate
Plant A			Plant A		
Plant B			Plant B		
Plant C			Plant C		
Plant D			Plant D		

Table 3.7 Leaf Size Growth Rate of Conventional Water Irrigation System

S1	Area of Leaf		S2	Area of Leaf	Leaf Size Growth Rate
Plant E			Plant E		
Plant F			Plant F		
Plant G			Plant G		
Plant H			Plant H		

$$Leaf\ Growth\ Rate = \frac{(S2 - S1)}{T} \qquad (1)$$

The table shows the leaf size growth rate of the plants from conventional water irrigation system and automated-wireless water irrigation system. For the conventional irrigation system, two measurements are gathered from different time, the S1 represents the first measure of the height of the plant, while the S2 represents the second measurement of the plant after 3 days after the first measurement. Then the height growth rate is calculated.

The equation (1) represents the formula for calculation of the leaf growth rate of the plant. In the equation 1, the S1 represents the area of the leaf size of the first measurement and the S2 represents the second measurement of the leaf size. The "T" represents the number of days between the S1 and S2. The leaf growth size from both irrigation systems is then recorded to keep track on the effectiveness of both water irrigation systems.

Table 3.8. Height Growth Rate of Conventional Water Irrigation System

H1	Height of Plant		H2	Height of Plant	Leaf Size Growth Rate
Plant A			Plant A		
Plant B			Plant B		
Plant C			Plant C		
Plant D			Plant D		

Table 3.9 Height Growth Rate of Conventional Water Irrigation System

H1	Height of Plant		H2	Height of Plant	Leaf Size Growth Rate
Plant E			Plant E		

Plant F			Plant F		
Plant G			Plant G		
Plant H			Plant H		

$$Height\ Growth\ Rate = \frac{(H2 - H1)}{T} \qquad (2)$$

The table shows the height growth rate of the plants from conventional water irrigation system and automated-wireless water irrigation system. For the conventional irrigation system, two measurements are gathered from different time, the H1 represents the first measure of the height of the plant, while the H2 represents the second measurement of the plant after 3 days after the first measurement. Then the height growth rate is calculated.

The equation (2) represents the formula for calculation of the height growth rate of the plant. In the equation 2, the H1 represents the area of the average height of the first measurement and the H2 represents the second measurement. The "T" represents the number of days between the H1 and H2 The height growth size from both irrigation system is then recorded to keep track on the effectiveness of both water irrigation system.

Table 3.10 Leaf Number Growth Rate of Conventional Water Irrigation System

L1	Number of Leaf		L2	Number of Leaf	Number of Leaf Growth Rate
Plant A			Plant A		
Plant B			Plant B		
Plant C			Plant C		
Plant D			Plant D		

Table 3.11 Leaf Number Growth Rate of Conventional Water Irrigation System

L1	Number of Leaf		L2	Number of Leaf	Number of Leaf Growth Rate
Plant E			Plant E		
Plant F			Plant F		
Plant G			Plant G		

Plant H			Plant H		

$$Leaf\ Number\ Growth\ Rate = \frac{(L2 - L1)}{T} \qquad (3)$$

The table shows the height growth rate of the plants from conventional water irrigation system and automated-wireless water irrigation system. For the conventional irrigation system, two measurements are gathered from different time, the L1 represents the first measure of the height of the plant, while the L2 represents the second measurement of the plant after 3 days after the first measurement. Then the height growth rate is calculated.

In the equation, the L1 represents the leaf number of the first measurement and the L2 represents the second measurement. The “T” represents the number of days between the L1 and L2 the leaf number growth size from both irrigation system is then recorded to keep track on the effectiveness of both water irrigation system.

3.4 System Setup

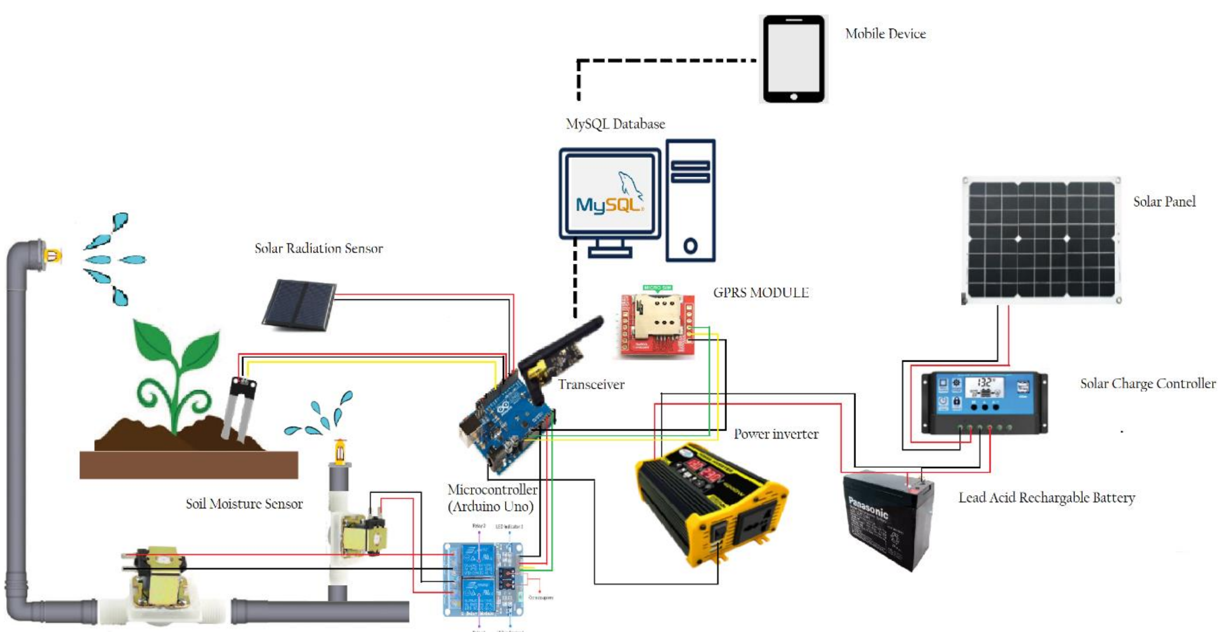


Figure 3.4. *Proposed System Setup*

The figure above is the proposed system setup of the study that shows the flow of the automated-wireless water irrigation system. Starting from the soil moisture sensor and solar radiation sensors, the data is sent to the microcontroller. The microcontroller then decides what action to execute according to the condition. Then the microcontroller will transmit the data to the database which is the MySQL database. The MySQL database then records and analyzes both the data from conventional and automated water irrigation systems. The live status of both the water irrigation systems can be monitored in the mobile device.

3.5. Data Processing

1. Preparation soil

   In preparing the soil, the research will filter out the solids from the soil. After the solids are removed, the researcher will add water until it starts to seep. After the water is distributed well, the research will now dry the soil in order to minimize the bias in each controlled environment

2. Calibrating the sensor

   In order to minimize the error in the data, the researcher will calibrate all the sensors in order to determine if the data received are accurate. The soil moisture is calibrated by preparing three categories (dry, wet, and water) with three trials each. And then, the data is compared with the expected value. The solar radiation sensor is calibrated by comparing its measurement to a solar power meter. And then, the data is compared with the expected value.

3. Analyzing the Measurement of Sensors

   The measurements of the sensors are sent to the microcontroller to be processed and decide the next action. If the measurements from the sensors doesn't meet the condition of the microcontroller, the microcontroller then signals the solenoid valves to open until it reaches the condition.

4. Forwarding the Measurements of the Sensors to MySQL database

   The measurements of the sensors are forwarded to the MySQL database for data processing and comparison. The MySQL database compares the data from the conventional water irrigation system and from the automated-wireless water irrigation system.

5. Measurement of the Plant's Physical Properties

   Every week, the plant's physical properties are measured in order to observe which type of water irrigation system (conventional water irrigation system or automated-wireless water irrigation system) is most effective in giving plants a good environment to optimize growth.

3.6. Statistical Testing

The researchers will conduct one-tailed t-tests to analyze the results of independent samples. It will compare the results of the manufactured device in which the wireless-automated water irrigation system is installed in the plant to the conventional water irrigation system in which the plant must be watered manually. The null hypothesis (H_o) of the study is that there will be less than to no differences in the growth between the conventional water irrigation method and the automated water irrigation system. Conversely, the alternative hypothesis (H_a) states that the wireless-automated water irrigation system would maximize growth more than the conventional water irrigation method. The hypotheses will be expressed as:

$$H_o\!: \bar{X}_1 \leq \bar{X}_2$$

and

$$H_a\!: \bar{X}_1 > \bar{X}_2$$

Hence, if the null hypothesis is rejected, the wireless-automated water irrigation maximized the growth of the plant more than the conventional water irrigation method.

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