

Automated Greenhouse Agricultural System (AGAS): Enhanced Efficiency and Sustainability in Agricultural Practices

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Abstract- This research aimed to develop a prototype of an automated Greenhouse Agricultural System (AGAS) for efficient and sustainable cultivation of plants in tropical regions. The AGAS prototype was built using an Arduino Uno microcontroller, which monitors and regulates temperature, humidity, and soil moisture, utilizing sensors and a servo motor for water distribution. Data is transmitted to a website for remote monitoring and control. Data were analyzed mainly using percentages, mean and t-test of independent means. Results showed that, the system achieved a 100% success rate in six trials, demonstrating accurate soil moisture detection, effective servo motor operation, and reliable pump functionality; the website is 100% success rate in four trials in recording analog values, it successfully maintained optimal growing conditions for lettuce, showcasing its potential to improve crop yields and resource efficiency; and the AGAS is efficient compared to the traditional greenhouse system in terms of temperature, humidity and soil moisture. This highlights the significance of AGAS in addressing the challenges of unpredictable weather patterns and resource scarcity in tropical regions. Further development, including a user-friendly application, HVAC system, and error detection mechanisms, is recommended. The AGAS holds the potential to revolutionize greenhouse agriculture, promoting sustainable practices and enhancing food security.

Index Terms- Automated smart greenhouse, Arduino Uno R3, IoT, DHT22 sensor, agriculture, agricultural monitoring system, soil moisture sensor

I. INTRODUCTION

Crop production refers to the growing of crops for food. It is a critical component of agriculture, contributing to global food security. However, farmers face a variety of obstacles. Climate change has been identified as the most serious problem, causing uncertainties in weather patterns, rising temperatures, and extremes of the same. These changes can lead to crop failure and lower harvests. Consequently, farmers might need to spend more money to protect their crops and make up for the losses, which makes the process more expensive. In addition, the rising temperatures cause agriculture to continue being a major consumer of freshwater resources globally, making effective management a must. To reduce water constraint while preserving food production, farmers must use long-term irrigation systems. This includes conserving and reusing water, as well as putting in place procedures to guarantee that crops get enough water without waste it. Additionally, the food security of metropolitan areas is jeopardized by the reduction in the quantity of land that is accessible as a result of urbanization. In order to promote more sustainable agriculture and increased food security,

farmers can enhance their resilience by implementing technology, practicing sustainability, and supporting legislation that will benefit them.

The agriculture sector in Vietnam is confronted with one of the most significant challenges in the country as a result of the country's unpredictable rainfall, increasing temperatures, and extreme weather conditions. It drew attention to the nation's efforts to rebuild its agricultural sector, with a particular emphasis on the growth of sustainable agriculture as well as the adoption of smart technology, free trade, and climate change as new trends that require adaptation (Giang, 2024). Furthermore, excessive temperatures were observed throughout California during the summer of 2020, which could have a significant impact on greenhouse crops (Morrow, 2021). Similarly, farmers in India confront significant challenges, including but not limited to inadequate training, extension, and irrigation infrastructure, as well as the effects of climate change (Deepika, 2023).

Farmers in the Philippines suffer from the effects of changing weather patterns on agricultural productivity. Rising temperatures reduce crop yields, and extreme weather events

like as floods and storms cause crop losses (PhilSEED, 2023). Smallholder farmers in North Luzon have obstacles due to outdated planting methods and a scarcity of modern farming equipment (Mayo & Villarta, 2023). In addition to the low prices for crops in market, farms are affected by landslides, floods, and droughts. Moreover, strong gusts and continuous rain causes fields to flood, destroying most of the crops. The lasting impact of these conditions continues to affect farmers nationwide (Grecon PH, 2021).

Despite making over Php 50,000 from their crop, local farmers in Magsaysay, Davao del Sur, expect a loss of income in the next El Niño (Dalumpines, 2023). Indeed, in April, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) announced that dangerously high heat indices will affect Cotabato City, which is among the top ten producers of corn and rice (Ombay, 2024). The city was expected to experience temperatures soaring up to 51 °C. Similarly, in-land rice production areas in Mindanao face issues in finding crops suitable to the changing weather patterns due to their susceptibility and the high risk of drought (Pugay & Sugay, 2021).

Several initiatives and studies on greenhouse projects have begun to solve the issue and improve agriculture (CEDTyClea, 2024; Mendoza and Villegas, n.d.). Despite improvements, there has been little research into how existing approaches might be successfully scaled for wider adoption by small-scale farmers, particularly those with limited access to resources and technology. Moreover, functioning projects do not fully integrate advanced technologies such as the Internet of Things (IoT) and automates systems for real-time monitoring and regulation of greenhouse conditions, which if applied, could further enhance its efficiency. With these gaps, the researchers developed the Automated Greenhouse Agricultural System (AGAS), equipped with components capable of monitoring and regulation. It combined the application of IoT, automated systems, and optimal plant growth conditions to automate monitoring and control of environmental conditions within the greenhouse. The system can significantly enhance operational efficiency by allowing farmers to manage their crops through a website, which is cost-effective and sustainable.

Statement of the Problem

This research aimed to develop an Automated Greenhouse Agricultural System (AGAS) that monitor and automatically control the environment inside a greenhouse for sustainable agriculture. Specifically, it sought to answer the following questions:

What is the percentage of successful trials when testing the Automated Greenhouse Agricultural System in terms of:

- soil moisture sensor's detection capability;
- servo motor's degree of spin;

- pump's compatibility with the servo motor and soil moisture sensor;
- ventilation capability to keep fresh air circulation;
- humidity detection capability;
- receiving data on the website "ENGTINGCO" based on the data value the system gives; and
- system programming?

What is the average analog value recorded on the ENGTINGCO website by the AGAS in terms of:

- Temperature;
- humidity; and
- soil moisture?

What is the average value of the parameters in the traditional greenhouse in terms of:

- temperature;
- humidity; and
- soil moisture?

Is there a significant difference in the parameter values between AGAS and traditional greenhouses?

Research Hypothesis

This study was tested at .05 level of significance.

Ho1: There is no significant difference in the parameter values between Automated Greenhouse Agricultural System (AGAS) and traditional greenhouse system.

Significance of the Study

The study will provide intervention and improvement in the traditional greenhouse problem. It can make monitoring efficient, reduce inspection costs, and provide an ideal environment for optimal crop growth in tropical areas, benefiting farmers, the City Government of Davao, the Department of Agriculture, and future researchers.

Farmers. The system automates environmental controls to create ideal conditions for plant growth, promoting sustainable agriculture through accurate management and reduced resource waste. The innovative approach enhances productivity and sustainability in farming practices, aiding the farmers.

City Government of Davao. The study aids the city government by promoting efficient greenhouse farming through innovation and integration of technology in agriculture to avoid food scarcity as urbanization increases drastically. Additionally, it provides numerous environmental, economic, and social benefits to the surrounding communities. Department of Agriculture. The study benefits them by potentially alleviating the Philippines' food security dilemma. Implementing an automated greenhouse agriculture system provides an effective, low-cost method for optimizing

greenhouse conditions, hence increasing crop growth and supporting sustainable agricultural practices.

Future Researchers. The finding opens up new avenues for agricultural robotics research. Future studies can examine how well these technologies work, how flexible they are, and how well they integrate into various urban environments. They might also modify and alter the study to make it more ecologically friendly.

Scope and Delimitation of the Study

This research focused on creating an automated greenhouse agricultural system that uses an Arduino Uno microcontroller to monitor and control the environment for healthy plant growth and sustainable farming practices.

In order to provide the ideal temperature ranges for lettuce growth and to regulate humidity levels to avoid leaf tip burn and encourage healthy growth, the device could automatically monitor temperature and humidity. Controlling air circulation for ideal CO₂ levels and temperature regulation, as well as monitoring and regulating soil moisture levels for effective water use and ventilation.

This study was limited to a system that maintains temperature, humidity, and soil moisture in the system. However, further is required to make a Proper HVAC and Error detection that would effectively improve and support this research.

Definition of Terms

The following terms were operationally defined:

- Arduino uno refers to the microcontroller that controls all the components of the system.
- DHT 22 refers to the sensor that measures the temperature around it using a thermistor and a capacitive humidity sensor before emitting a digital signal on the data pin.
- ESP8266e1 WiFi Module ESP.01 refers to a module that handles the website or the connection to the internet
- Relay module refers to the module that refers to one of the interface devices that enable the transfer of signals and information between different devices and send a signal whereupon to turn on or off the fan and pump.
- Servo motor SG90 refers to the component used to automate functions like moving a pipe that is connected to a water pump that waters the pots.
- Soil moisture sensor refers to the sensor that measures the soil moisture to identify the amount of moisture in the soil and also detect the soil if it's really dry.

II. METHODS

This section presents the method of the study, which contains four (4) phases: phase I – preparation and assembling of the

Automated Greenhouse Agricultural System (Mechanical and structural frame design); Phase II – testing of indicators; Phase III – data collection and analysis, phase IV – aesthetics. All the tests and experimental procedures were conducted at Carlos P. Garcia Senior High School.

Research Design

An experimental-quantitative research methodology was used in this study to collect related data and information. According to Knight (2010) as cited in Sirisilla (2023), researchers can more easily and effectively carry out their research aims when they use an experimental research design. An appropriate experimental design acts as a roadmap for the research techniques, giving readers a better understanding of the data collection process and, as a result, allowing an exact description of the findings. The very basic logic of this system was described in this work through the use of experimental design. In this system, soil's moisture content is detected by the moisture sensor, and when it detects a low moisture level, a microcontroller, and an automated switch enable the water pump to turn on and hydrate the crops.

In this study, automation of Automated Greenhouse Agricultural System (AGAS): Enhanced Efficiency and Sustainability in agricultural practices. This automatic greenhouse system senses the moisture content of the soil and automatically switches the pump on, The DHT 22 detects the temperature and if the temperature is high the DC fan automatically turns on and the LCDs the data of /temperature, humidity, and soil moisture. Using automation for the greenhouse, the farm can have energy-efficient control strategies, and integrating other renewable energy sources would enhance sustainability and make it more effective, sustainable, and accessible to farmers.

Phase I. Designing and Assembling the Automated Greenhouse Agricultural System Prototype

Materials. The prototype consisted of 26 materials containing the Arduino Uno, adaptor, water pump, fan, resistors, relays, jumper wires, breadboard, Nodemcu ESP8266(), LCD, DHT22, soil moisture sensor, servo motor, power supplies(Powerbank, cable, batteries & battery holder), water hose, pots, water, double sided tape, paint and recycled materials like wood, plastic, nails, and Polyethylene.

Building System Relay

Displayed in the figure below (Figure 1) are connections of the system (relay wirings). Researchers in this paper made connections to a small fountain pump system, relays, and Arduino which allows the pump to open or close automatically. Finally, the ground relay was connected to a line of the breadboard which is connected to the Arduino ground and relay input to the Arduino digital pins.

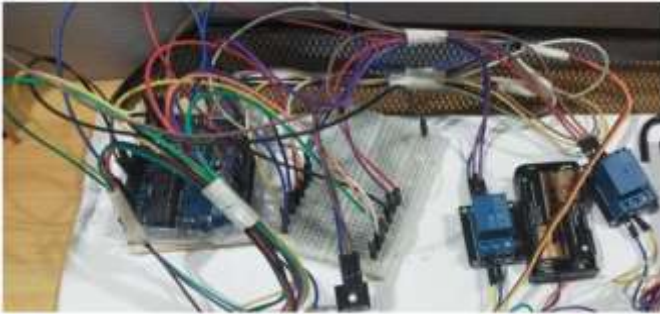


Figure 1. Relay wirings

Building up of System Reservoir

A submersible pump was used to supply a certain amount of water that is required for optimal plant growth. The submersible pump is placed in a tank.



Figure 2. Submersible pump in the tank

Building and Connecting System Tubing

The plastic lob feed pumps were connected and small holes through which water drops were drilled.

Building Irrigation System

Three pots were placed in three different spaces and a servo motor was put in the middle. Angles were set to successfully irrigate the plants.

As for detecting and determining the amount of moisture in the plant, a soil moisture sensor was attached to each pot to determine the amount of moisture in the plant.

Heating, Ventilation, and Air Conditioning (HVAC) System

A fan was integrated into the smart greenhouse system for air conditioning and to ventilate the greenhouse well. When the temperature is regulated, this prevents overheating and the fluctuations of temperature, as detected by the DHT22 sensor.

Coding

Figure 3 showed the circuit design of the automated greenhouse agricultural system prototype. The system was programmed using Arduino IDE software. The Arduino microcontroller checked the soil moisture level, if low, triggering the servo motor to spin the sprinkler on the specific plant, and also triggering the water pump on and off depending on the set delay. The system then re-checked the soil moisture regularly to see if it required more water. The relay delay and threshold can be changed by texting a specific number. Furthermore, the Arduino microcontroller checked the temperature and humidity inside the greenhouse, when these reached a certain point, the fan was triggered to turn on and off depending on the set delay. After this, the system re-checked the temperature, humidity, and soil moisture level regularly if these needed changing.

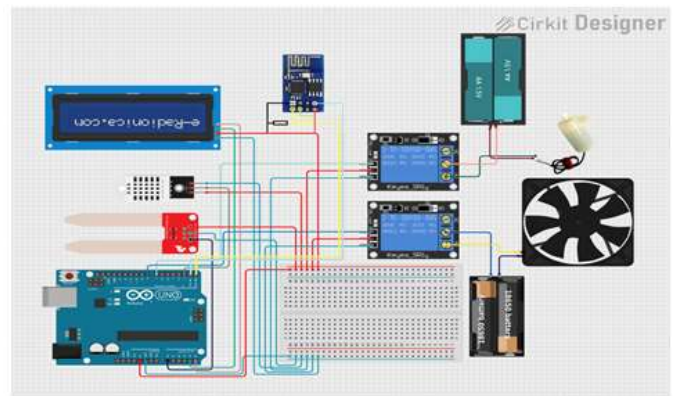


Figure 3. Circuit Design

Phase II. Testing of Indicators

Presented in Figure 4 is the schematic diagram of the automated greenhouse agricultural system prototype. The automated greenhouse agricultural system was tested using the miniature greenhouse with a plant; the sensors were tested to simplify the debugging process. Once it was determined that the sensors were fully functional and performed as foreseen, the next sensor was selected for testing.

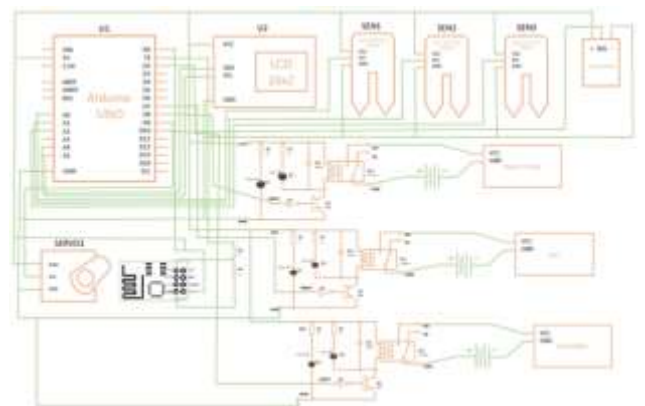


Figure 4. Schematic Diagram

Input and Output Connection

It showed below the input and output of pins used in the device to simplify the debugging process and easily differentiate the pins used.

Component - Function	In/Out – Pin
Water Pump	Output – N.O (Normally Open Relay)
Fan	Output – N.O (Normally Open Relay)
Relay for Fan	Input – Pin 8
Relay for Pump	Input – Pin 7
LCD	Output – A4, A5
DHT22	Input – Pin 2
Soil Moisture Sensor	Input – A0, A1, A2
Servo motor	Output - Pin 9
ESP8266 Wifi module	Input & Output - Pin RX & TX

Detecting Levels of Moisture, Humidity, and Temperature

The soil moisture sensor measured the amount of moisture in the soil, as the DHT22 sensor measured the moisture in the air and the temperature inside the greenhouse. A microcontroller was attached to an Arduino board. Arduino IDE software was used to program the board. Depending on the moisture of the soil, it gave an analog value. The higher the analog value the higher the moisture content and the lower the analog value the lower the moisture content. Furthermore, depending on the humidity and temperature inside the greenhouse, it gives a value. The higher the amount detected the higher the humidity and temperature.

Phase III. Data Collection and Analysis

Presented in Figure 5 is the flowchart of an automated greenhouse agricultural system. The system was tested after the coding and implementation were done to identify problems.

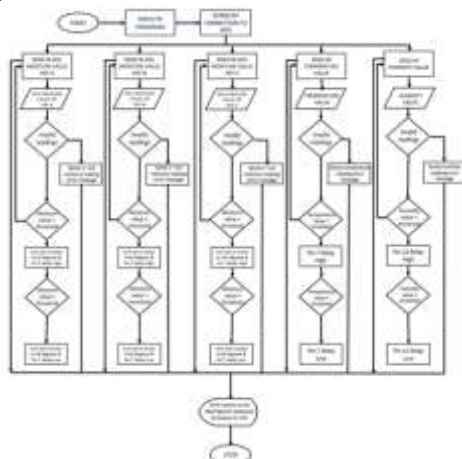


Figure 5. Flowchart of Automated Greenhouse Agriculture System

Phase IV. Aesthetics

Presented in Figure 6 is aerial view of the traditional greenhouse. The researchers included two objects in figure 6 to represent the temperature and humidity measuring instrument and soil moisture measuring instrument. Moreover, presented in Figure 7 is the aerial of the automated greenhouse agricultural system prototype. It shows the actuators and sensors used for automation. Both the traditional and automated greenhouse prototype was done after preparation, assembling, and then building a miniature. Materials were considered after searching and browsing the internet for the most appropriate and widely used materials in greenhouses.

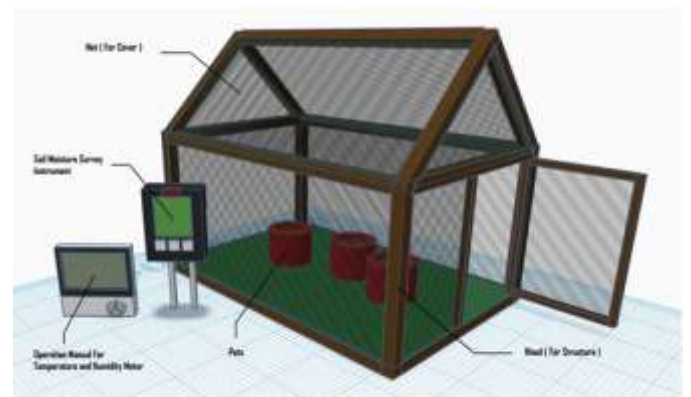


Figure 6. Aerial View of the Traditional Greenhouse

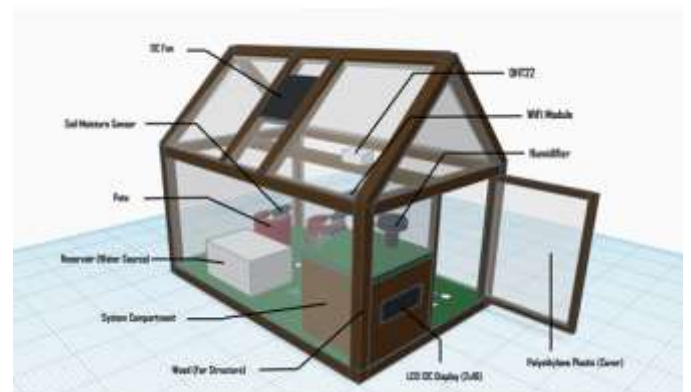


Figure 7. Aerial View of the AGAS

Waste Disposal

All damaged materials, debris and dust were placed in a sealed container with proper label. The researchers sent the waste materials to the Material Recovery Facility of Barangay 28-C, Davao City. While useful materials were recycled.

Data Analysis

The following statistical tests were used to analyze the data: Percentage. This was used to determine the successful trials that the automated greenhouse agricultural system prototype can perform according to the following indicators: soil

moisture sensor’s detection capability, servo motor’s degree of spin, pump’s compatibility with the servo motor and soil moisture sensor, ventilation capability to keep fresh air circulation, humidity detection capability, receiving data on the website “ENGTINGCO” based on the data value the system gives, and system programming.

Mean. This was used to determine the average analog value recorded on the ENGTINGCO website by the AGAS in terms of temperature, humidity and soil moisture. This was also used to determine the average value of the parameters in the traditional greenhouse in terms of temperature, humidity and soil moisture.

T-test of Independent Means. This was utilized to assess the significant difference in parameter values between AGAS and traditional greenhouses.

III. RESULTS

This section presents the findings and discussion based on the data gathered. The presentation is organized into two sections: 1) successful trials when testing the Automated Greenhouse Agricultural System; 2) analog value recorded on the ENGTINGCO website by the Automated Greenhouse Agricultural System; 3) value of the parameters in the traditional greenhouse; and 4) difference in the parameter values between AGAS and traditional greenhouses.

Table 1: Successful Trials When Testing the Automated Greenhouse Agricultural System in Pot Number 1

Parameters	Pot 1						Percent of Success
	T 1	T2	T 3	T 4	T 5	T 6	
Soil moisture sensor’s detection capability	√	√	√	√	√	√	100%
Servo motor’s degree of spin	√	√	√	√	√	√	100%
Pump’s compatibility with the servo motor and soil moisture sensor	√	√	√	√	√	√	100%
Ventilation capability to keep fresh air circulation	√	√	√	√	√	√	100%
Humidity detection capability	√	√	√	√	√	√	100%
Receiving data in the website “ENGTINGCO” based on the data value the system gives	√	√	√	√	√	√	100%
System programming	√	√	√	√	√	√	100%

Successful Trials When Testing the Automated Greenhouse Agricultural System (AGAS)

Presented in Table 1.1 is the successful trials when testing the Automated Greenhouse Agricultural Systems in pot number 1, in terms of soil moisture sensor’s detection capability, servo motor’s degree of spin, pump’s compatibility with the servo motor and soil moisture sensor, ventilation capability to keep fresh air circulation, humidity detection capability, receiving data on the website “ENGTINGCO” based on the data value the system gives, and system programming.

It shows that in pot 1, the automated greenhouse agricultural system prototype successfully performed by 100 percent across six trials in terms of soil moisture sensor’s detection capability, servo motor’s degree of spin which is 45-degree, pump’s compatibility with the servo motor and soil moisture sensor.

Moreover, the prototype also successfully performed by 100 percent ventilation capability to keep fresh air circulation, humidity detection capability, receiving data in website “ENGTINGCO” based on the data value the system gives, and system programming. This means that the automated greenhouse agricultural system prototype successfully passed the test in terms of its functionality for pot number 1.

Table 2: Successful Trials When Testing the Automated Greenhouse Agricultural System in Pot Number 2

Parameters	Pot 2						Percent of Success
	T 1	T 2	T 3	T 4	T 5	T 6	
Soil moisture sensor’s detection capability	√	√	√	√	√	√	100%
Servo motor’s degree of spin	√	√	√	√	√	√	100%
Pump’s compatibility with the servo motor and soil moisture sensor	√	√	√	√	√	√	100%
Ventilation capability to keep fresh air circulation	√	√	√	√	√	√	100%
Humidity detection capability	√	√	√	√	√	√	100%
Receiving data in the website “ENGTINGCO” based on the data value the system gives	√	√	√	√	√	√	100%
System programming	√	√	√	√	√	√	100%

Presented in Table 1.2 is the successful trials when testing the Automated Greenhouse Agricultural Systems in pot number 2, in terms of soil moisture sensor’s detection capability, servo motor’s degree of spin, pump’s compatibility with the servo motor and soil moisture sensor, ventilation capability to keep fresh air circulation, humidity detection capability, receiving

data on the website “ENGTINGCO” based on the data value the system gives, and system programming.

It shows that in pot 2, the automated greenhouse agricultural system prototype successfully performed by 100 percent across six trials in terms of the soil moisture sensor’s detection capability, servo motor’s degree of spin which is 90-degree, pump’s compatibility with the servo motor and soil moisture sensor, ventilation capability to keep fresh air circulation, humidity detection capability, receiving data in website “ENGTINGCO” based on the data value the system gives, and system programming. This means that the automated greenhouse agricultural system prototype successfully passed the test in terms of its functionality for pot number 2.

Presented in Table 1.3 is the successful trials when testing the Automated Greenhouse Agricultural Systems in pot number 3, in terms of soil moisture sensor’s detection capability, servo motor’s degree of spin, pump’s compatibility with the servo motor and soil moisture sensor, ventilation capability to keep fresh air circulation, humidity detection capability, receiving data on the website “ENGTINGCO” based on the data value the system gives, and system programming.

Table 3: Successful Trials When Testing the Automated Greenhouse Agricultural System in Pot Number 3

Parameters	Pot 3						Percent of Success
	T1	T2	T3	T4	T5	T6	
Soil moisture sensor’s detection capability	√	√	√	√	√	√	100%
Servo motor’s degree of spin	√	√	√	√	√	√	100%
Pump’s compatibility with the servo motor and soil moisture sensor	√	√	√	√	√	√	100%
Ventilation capability to keep fresh air circulation	√	√	√	√	√	√	100%
Humidity detection capability	√	√	√	√	√	√	100%
Receiving data in the website “ENGTINGCO” based on the data value the system gives	√	√	√	√	√	√	100%
System programming	√	√	√	√	√	√	100%

It shows that in pot number 3, the automated greenhouse agricultural system prototype successfully performed by 100 percent across six trials in terms of the soil moisture sensor’s detection capability, servo motor’s degree of spin which is 135-degree, pump’s compatibility with the servo motor and soil moisture sensor, ventilation capability to keep fresh air circulation, humidity detection capability, receiving data in

website “ENGTINGCO” based on the data value the system gives, and system programming.

This means that the automated greenhouse agricultural system prototype successfully passed the test in terms of its functionality for pot number 3.

Analog value Recorded on the ENGTENGCO Website by the Automated Greenhouse Agricultural System

Presented in Table 2.1 is the analog value recorded on the ENGTENGCO website by the Automated Greenhouse Agricultural System in terms of temperature during the seven (7) days monitoring.

Table 4: Analog Values Recorded on the ENGTENGCO Website by the Automated Greenhouse Agricultural System in terms of Temperature (oC)

Days	Time									Mean
	8:00 am	9:00 am	10:00 am	11:00 am	12:00 nn	1:00 pm	2:00 pm	3:00 pm	4:00 pm	
Day 1	29.14	30.56	30.87	30.81	31.25	31.44	31.52	31.49	30.60	30.85
Day 2	29.98	30.22	30.79	31.09	31.47	31.81	31.33	31.22	31.18	31.01
Day 3	29.30	29.13	30.40	30.43	30.48	31.61	31.22	30.98	30.64	30.47
Day 4	28.13	28.65	28.97	29.44	29.35	30.06	30.80	30.78	30.83	29.67
Day 5	29.65	29.88	30.18	30.74	31.40	31.48	32.06	31.98	31.03	30.93
Day 6	30.08	30.02	31.18	31.13	31.88	31.90	31.54	31.90	30.29	31.10
Day 7	29.18	29.34	29.94	30.08	30.25	30.86	30.74	30.65	30.42	30.16

It shows that, day 6 obtained the highest mean temperature value during the seven (7) days monitoring ($\bar{x} = 31.10$), followed by day 2 ($\bar{x} = 31.01$), while day 7 obtained the lowest mean temperature value during the seven days (7) days monitoring ($\bar{x} = 30.16$). it shows that the ENGTENGCO website in the Automated Greenhouse Agricultural System consistently recorded the temperature of the environment.

Presented in Table 2.2 is the analog value recorded on the ENGTENGCO website by the Automated Greenhouse Agricultural System in terms of humidity during the seven (7) days monitoring.

It shows that, day 1 obtained the highest mean humidity value during the seven (7) days monitoring ($\bar{x}=78.89$ percent), followed by day 7 ($\bar{x}=78.00$ percent), while day 5 obtained the lowest mean humidity value during the seven days (7) days monitoring ($\bar{x}=75.78$ percent).

Presented in Table 2.3.2 is the analog value recorded on the ENGTENGCO website by the Automated Greenhouse Agricultural System in terms of soil moisture in pot number 2 for seven (7) days.

Table 5: Analog Values Recorded on the ENGTENGCO Website by the Automated Greenhouse Agricultural System in terms of Soil Moisture (%) in Pot Number 2

Days	Time									Mean
	8:00 am	9:00 am	10:00 am	11:00 am	12:00 nn	1:00 pm	2:00 pm	3:00 pm	4:00 pm	
Day 1	78	77	79	76	77	75	76	79	79	77.33
Day 2	78	79	78	77	76	75	77	77	78	77.22
Day 3	79	79	78	76	75	76	77	78	78	77.33
Day 4	78	77	77	75	75	76	76	78	78	76.67
Day 5	78	78	78	75	75	77	78	77	79	77.22
Day 6	79	76	79	76	76	76	77	78	77	77.11
Day 7	80	77	78	77	75	77	77	77	78	77.33

In pot number 2, it shows that, days 1, 3 and 7 obtained the highest mean soil moisture value during the seven (7) days monitoring ($\bar{x}=77.33$ percent, respectively), followed by days 2 and 5 ($\bar{x}=77.22$ percent, respectively), while day 4 obtained the lowest mean soil moisture value during the seven (7) days monitoring ($\bar{x}=76.67$ percent).

It shows that the ENGTENGCO website in the Automated Greenhouse Agricultural System consistently recorded the soil moisture in pot number 2.

Presented in Table 2.3.3 is the analog value recorded on the ENGTENGCO website by the Automated Greenhouse Agricultural System in terms of soil moisture in pot number 3 for seven (7) days.

Table 6: Analog Values Recorded on the ENGTENGCO Website by the Automated Greenhouse Agricultural System in terms of Soil Moisture (%) in Pot Number 3

Days	Time									Mean
	8:00 am	9:00 am	10:00 am	11:00 am	12:00 nn	1:00 pm	2:00 pm	3:00 pm	4:00 pm	
Day 1	80	79	77	75	76	75	76	80	79	77.44
Day 2	79	77	78	76	75	76	77	79	78	77.22
Day 3	79	80	76	77	77	75	79	79	79	77.89
Day 4	78	80	76	77	75	75	76	78	80	77.22
Day 5	79	78	78	76	75	77	79	79	79	77.78
Day 6	80	79	77	76	76	76	79	80	78	77.89
Day 7	79	79	75	75	75	76	78	80	79	77.33

Table 7: Summary of Analog Values Recorded on the ENGTENGCO Website by the Automated Greenhouse Agricultural System (AGAS)

Parameters	Days							Mean
	1	2	3	4	5	6	7	
Temperature (°C)	30.85	31.01	30.47	29.67	30.93	31.10	30.16	30.60
Humidity (%)	78.89	77.89	77.89	77.44	75.78	76.11	78.00	77.43
Soil Moisture 1 (%) (Pot No. 1)	77.00	78.11	78.00	77.78	78.00	77.56	78.00	77.78
Soil Moisture 2 (%) (Pot No. 2)	77.33	77.22	77.33	76.67	77.22	77.11	77.33	77.17
Soil Moisture 3 (%) (Pot No. 3)	77.44	77.22	77.89	77.22	77.78	77.89	77.33	77.54

In pot number 3, it shows that days 3 and 6 obtained the highest mean soil moisture value during the seven (7) days monitoring ($\bar{x}=77.89$ percent, respectively), followed by day 5 ($\bar{x}=77.78$ percent), while days 2 and 4 obtained the lowest mean soil moisture value during the seven (7) days monitoring ($\bar{x}=77.22$ percent). it shows that the ENGTEGCO website in the Automated Greenhouse Agricultural System consistently recorded the soil moisture in pot number 3.

Presented in Table 2.4 is the summary of analog value recorded on the ENGTEGCO website by the Automated Greenhouse Agricultural System (AGAS) in terms of temperature, humidity and soil moisture during the seven (7) days monitoring.

Threshold values:

- Temperature: 23oC (Maria, 2022)
- Humidity: 55 % (Lugo, 2024c)
- Soil Moisture: 75 % (Argounik, 2021)

It shows that, in seven (7) days monitoring, the mean temperature record is 30.60oC, while 77.43 percent for the humidity. These are slightly far from the threshold values set by Maria (2022) for temperature (23oC) and Lugo (2024c) for humidity (55%).

Table 8: Temperature (oC) Value of Traditional Greenhouse System

Days	Time									Mean
	8:00 am	9:00 am	10:00 am	11:00 am	12:00 nn	1:00 pm	2:00 pm	3:00 pm	4:00 pm	
Day 1	30	33	36	38	40	39	38	39	37	36.67
Day 2	33	32	37	39	39	40	39	39	39	37.44
Day 3	32	31	36	38	40	40	40	38	36	36.78
Day 4	32	36	38	37	40	38	39	39	38	37.44
Day 5	33	35	37	38	38	39	38	39	37	37.11
Day 6	34	34	35	39	39	40	39	37	37	37.11
Day 7	34	33	37	39	39	38	40	39	37	37.33

Moreover, the mean moisture value for pots 1, 2 and 3 are 77.78 percent, 77.17 percent and 77.54 percent, respectively,

which are relatively similar to the threshold value set by Argounik (2021) for soil moisture (75%). It further shows that the ENGTEGCO website in the Automated Greenhouse Agricultural System consistently monitored and recorded the temperature, humidity and soil moisture in the environment.

Value of the Parameters in Traditional Greenhouse System Presented in Table 3.1 is the temperature values of traditional greenhouse system during the seven (7) days monitoring.

It shows that, days 2 and 4 obtained the highest mean temperature value during the seven (7) days monitoring ($\bar{x}=37.44$, respectively), followed by day 7 ($\bar{x}=37.33$), while day 1 obtained the lowest mean temperature value during the seven days (7) days monitoring ($\bar{x}=36.67$). it shows that the manual temperature monitoring device in the traditional greenhouse system consistently recorded the temperature of the environment.

Presented in Table 3.2 is the humidity values of the traditional greenhouse system during the seven (7) days monitoring.

Table 9: Humidity (%) Value of the Traditional Greenhouse System

Days	Time									Mean
	8:00 am	9:00 am	10:00 am	11:00 am	12:00 nn	1:00 pm	2:00 pm	3:00 pm	4:00 pm	
Day 1	79	78	83	85	87	89	90	91	88	85.56
Day 2	78	78	84	86	88	89	90	90	88	85.67
Day 3	79	80	84	87	89	90	90	91	89	86.56
Day 4	78	79	83	87	88	91	89	90	87	85.78
Day 5	79	80	82	86	89	89	90	89	87	85.67
Day 6	77	80	85	86	89	89	90	91	88	86.11
Day 7	78	79	83	87	88	90	91	89	86	85.67

It shows that, day 3 obtained the highest mean humidity value during the seven (7) days monitoring ($\bar{x}=86.56$ percent), followed by day 6 ($\bar{x}=86.11$ percent), while day 1 obtained the lowest mean humidity value during the seven days (7) days monitoring ($\bar{x}=85.56$ percent). it shows that the manual

humidity monitoring device in the traditional greenhouse system consistently recorded the humidity of the environment. Presented in Table 3.3.1 is the soil moisture values of the traditional greenhouse system in pot number 1 during the seven (7) days monitoring.

In pot number 1, it shows that day 1 obtained the highest mean soil moisture value during the seven (7) days monitoring ($\bar{x}=62.11$ percent), followed by day 3 ($\bar{x}=62.00$ percent), while day 7 obtained the lowest mean soil moisture value during the seven (7) days monitoring ($\bar{x}=60.22$ percent).

Table 10: Soil Moisture (%) Value of the Traditional Greenhouse System in Pot Number 1

Days	Time									Mean
	8:00 am	9:00 am	10:00 am	11:00 am	12:00 nn	1:00 pm	2:00 pm	3:00 pm	4:00 pm	
Day 1	70	71	70	67	61	58	55	53	54	62.11
Day 2	70	70	68	65	60	57	54	53	53	61.11
Day 3	71	71	69	65	62	58	56	52	54	62.00
Day 4	73	73	68	62	58	56	54	51	50	60.56
Day 5	72	71	67	64	60	55	55	52	50	60.67
Day 6	71	68	69	66	59	55	56	53	51	60.89
Day 7	73	70	65	64	59	54	56	51	50	60.22

It further shows that the manual soil moisture monitoring device in the traditional greenhouse system consistently recorded the soil moisture in pot number 1.

Presented in Table 3.3.2 is the soil moisture values of the traditional greenhouse system in pot number 2 during the seven (7) days monitoring.

Table 11: Soil Moisture (%) Value of the Traditional Greenhouse System in Pot Number 2

Days	Time									Mean
	8:00 am	9:00 am	10:00 am	11:00 am	12:00 nn	1:00 pm	2:00 pm	3:00 pm	4:00 pm	
Day 1	71	68	68	65	65	60	54	55	55	62.33

Day 2	70	68	66	63	64	61	56	55	54	61.89
Day 3	71	72	71	67	62	57	54	56	52	62.44
Day 4	68	70	67	64	61	57	54	52	50	60.33
Day 5	69	66	66	62	60	55	53	52	51	59.33
Day 6	71	68	67	63	63	55	52	51	50	60.00
Day 7	69	69	66	62	58	54	55	52	50	59.44

In pot number 2, it shows that day 3 obtained the highest mean soil moisture value during the seven (7) days monitoring ($\bar{x}=62.44$ percent), followed by day 1 ($\bar{x}=62.33$ percent), while day 5 obtained the lowest mean soil moisture value during the seven (7) days monitoring ($\bar{x}=59.33$ percent). It shows that the manual soil moisture monitoring device in the traditional greenhouse system consistently recorded the soil moisture in pot number 2.

Table 12: Soil Moisture (%) Value of the Traditional Greenhouse System in Pot Number 3

Days	Time									Mean
	8:00 am	9:00 am	10:00 am	11:00 am	12:00 nn	1:00 pm	2:00 pm	3:00 pm	4:00 pm	
Day 1	68	68	66	65	60	54	51	50	52	59.33
Day 2	66	67	65	63	60	56	52	53	54	59.56
Day 3	69	69	68	64	61	56	52	50	52	60.11
Day 4	68	69	68	63	57	52	50	50	50	58.56
Day 5	67	68	64	60	56	51	50	51	52	57.67
Day 6	68	66	66	61	57	52	50	50	53	58.11
Day 7	66	67	65	61	56	52	49	50	52	57.56

Presented in Table 3.3.3 is the soil moisture values of the traditional greenhouse system in pot number 3 during the seven (7) days monitoring.

In pot number 3, it shows that day 3 obtained the highest mean soil moisture value during the seven (7) days monitoring ($\bar{x}=60.11$ percent), followed by day 2 ($\bar{x}=59.56$ percent), while day 7 obtained the lowest mean soil moisture value during the seven (7) days monitoring ($\bar{x}=57.56$ percent). It shows that the manual soil moisture monitoring device in the traditional greenhouse system consistently recorded the soil moisture in pot number 3.

Presented in Table 3.4 is the summary of the parameter values of the traditional greenhouse system in terms of temperature, humidity and soil moisture during the seven (7) days monitoring.

Table 13: Summary of the Parameter Values of the Traditional Greenhouse System

Parameters	Days							Mean
	1	2	3	4	5	6	7	
Temperature (°C)	36.67	37.44	36.78	37.44	37.11	37.11	37.33	37.09
Humidity (%)	85.56	85.67	86.56	85.78	85.67	86.11	85.67	85.89
Soil Moisture 1 (%) (Pot No. 1)	62.11	61.11	62	60.56	60.67	60.89	60.22	61.22
Soil Moisture 2 (%) (Pot No. 2)	62.33	61.89	62.44	60.33	59.33	60	59.44	61.05
Soil Moisture 3 (%) (Pot No. 3)	59.33	59.56	60.11	58.56	57.67	58.11	57.56	58.89

Threshold values:

- Temperature: 23oC (Maria, 2022)
- Humidity: 55 % (Lugo, 2024c)
- Soil Moisture: 75 % (Argounik, 2021)

It shows that, in seven (7) days monitoring, the mean temperature record is 37.09oC, while 85.89 percent for the humidity. These are very far from the threshold values set by Maria (2022) for temperature (23oC) and Lugo (2024c) for humidity (55%). Moreover, the mean moisture value for pots 1, 2 and 3 are 61.722 percent, 61.05 percent and 58.89

percent, respectively, which are very far from the threshold value set by Argounik (2021) for soil moisture (75%). It further shows that the manual monitoring devices in traditional greenhouse system consistently monitored and recorded the temperature, humidity and soil moisture in the environment.

Difference in the Parameter Values between Automated Greenhouse Agricultural System (AGAS) and Traditional Greenhouse System

Presented in Table 4 is the test of difference in the parameter values between Automated Greenhouse Agricultural System (AGAS) and traditional greenhouse system in terms of temperature, humidity and soil moisture.

Parameters	Greenhouse	Mean	df	t	p-value	Decision on Ho
Temperature (°C)	Traditional	37.13	12	-28.31	<0.001	Failed to accept
	AGAS	30.60				
Humidity (%)	Traditional	85.86	12	-19.20	<0.001	Failed to accept
	AGAS	77.43				
Soil Moisture 1 (%) (Pot No. 1)	Traditional	61.08	12	53.89	<0.001	Failed to accept
	AGAS	77.78				
Soil Moisture 2 (%) (Pot No. 2)	Traditional	60.82	12	31.35	<0.001	Failed to accept
	AGAS	77.17				
Soil Moisture 3 (%) (Pot No. 3)	Traditional	58.70	12	48.21	<0.001	Failed to accept
	AGAS	77.54				

Temperature. It shows that the mean temperature value of the Automated Greenhouse Agricultural System ($\bar{x}=30.60$) is lower compared to the traditional greenhouse system ($\bar{x}=37.13$). It further shows that at 0.05 level of significance, there is a significant difference in the temperature value between Automated Greenhouse Agricultural System and traditional greenhouse system ($t=-28.31$, $p\text{-value}<0.001<0.05$ level of significance). Therefore, this research failed to accept the null hypothesis. This means that the Automated Greenhouse Agricultural System is efficient to lower down the temperature of the environment.

Humidity. It shows that the mean humidity value of the Automated Greenhouse Agricultural System ($\bar{x}=77.43$) is lower compared to the traditional greenhouse system ($\bar{x}=85.86$). It further shows that at 0.05 level of significance, there is a significant difference in the humidity value between Automated Greenhouse Agricultural System and traditional greenhouse system ($t=-19.20$, $p\text{-value}=<0.001<0.05$ level of significance). Therefore, this research failed to accept the null hypothesis. This means that the Automated Greenhouse Agricultural System is efficient to lower down the humidity of the environment.

Soil Moisture. In pot number 1, it shows that the mean soil moisture value of Automated Greenhouse Agricultural System ($\bar{x}=77.78$) is higher compared to the traditional greenhouse system ($\bar{x}=61.08$). It also shows that at 0.05 level of significance, there is a significant difference in the soil moisture value in pot number 1 between Automated Greenhouse Agricultural System and traditional greenhouse system ($t=53.89$, $p\text{-value}=<0.001<0.05$ level of significance). Therefore, this research failed to accept the null hypothesis. This means that the Automated Greenhouse Agricultural System is efficient to increase the soil moisture level in pot number 1.

Additionally, in pot number 2, it shows that the mean soil moisture value of Automated Greenhouse Agricultural System ($\bar{x}=77.17$) is higher compared to the traditional greenhouse system ($\bar{x}=60.82$). It also shows that at 0.05 level of significance, there is a significant difference in the soil moisture value in pot number 2 between Automated Greenhouse Agricultural System and traditional greenhouse system ($t=13.35$, $p\text{-value}=<0.001<0.05$ level of significance). Therefore, this research failed to accept the null hypothesis. This means that the Automated Greenhouse Agricultural System is efficient to increase the soil moisture level in pot number 2.

Moreover, in pot number 3, it shows that the mean soil moisture value of Automated Greenhouse Agricultural System ($\bar{x}=77.54$) is higher compared to the traditional greenhouse system ($\bar{x}=58.70$). It also shows that at 0.05 level of significance, there is a significant difference in the soil moisture value in pot number 3 between Automated Greenhouse Agricultural System and traditional greenhouse system ($t=48.21$, $p\text{-value}=<0.001<0.05$ level of significance). Therefore, this research failed to accept the null hypothesis. This means that the Automated Greenhouse Agricultural System is efficient to increase the soil moisture level in pot number 3.

IV. DISCUSSION

The results of the Automated Greenhouse Agricultural System (AGAS) studies show that it is highly reliable and effective in

all tested pots, with a 100% success rate in crucial parameters required for the best possible plant growth. The soil moisture sensor's reliable detection supplies accurate watering and the servo motors' effective function with spin angles ranging from 0 to 45 degrees lets the system adjust to different needs for watering. In addition, the pump's compatibility with the soil moisture sensor and servo motor increases its reliability, and the ventilation measures help to maintain the correct microclimate. No problems arose when the researchers gathered data. Still, the researchers already expected that the prototype system would not meet the standard temperature and humidity since the prototype did not have the right machine for proper HVAC. The machine used for effective and proper HVAC is too big and is not compatible with the prototype. Nevertheless, the data gathered still showed that it lowered the temperature and humidity inside the greenhouse which indicates that the system is efficient compared to the traditional greenhouse system. This finding is supported by the study of Nasution et al. (2020) that the automated greenhouse system is cost effective, efficient and effective in monitoring and analyzing major environmental parameters.

The Automated Greenhouse Agricultural System (AGAS) significantly improves traditional greenhouses through key advancements. It has automated temperature and humidity adjustment, which ensures optimal growing conditions without the need for manual involvement. The system also uses automatic irrigation, which changes water distribution depending on real-time soil moisture, decreasing waste compared to preset schedules in traditional setups. IoT integration enables continuous monitoring of environmental parameters, allowing for faster adjustments and better decision-making. This technology minimizes labor demands, allowing producers to concentrate on strategic objectives rather than regular checks (Dwinugroho & Hapsari, 2021). Furthermore, AGAS supports improved crop quality and consistency by allowing for exact control over growing conditions. It promotes sustainability by reducing dependency on chemicals and promoting healthier ecosystems. The scalable architecture of an automated greenhouse system makes it appropriate for a wide range of agricultural operations, from small farms to major enterprises (Weldeslasie et al., 2021).

While the initial expenses may be higher, the long-term benefits of reduced resource usage and better output make it economically viable. Furthermore, because the Philippines is located in the Pacific Ring of Fire, it is highly likely to experience frequent typhoons, increasing the risk of sensitive plants being harmed. During typhoons, farmers face difficulties while inspecting crop conditions. AGAS will be of help in terms of keeping plants that are highly sensitive and safe from these kinds of inconvenience. The AGAS allows informed decision-making and real-time monitoring by detecting humidity and transmitting data to the ENGTINGCO

website. These results are in line with earlier studies that emphasize the benefits of agricultural automation and demonstrate how it can boost productivity while consuming fewer resources (Hoque et al., 2020). Furthermore, the AGAS effectively maintains lettuce growth under ideal circumstances, demonstrating its worth as an eco-friendly alternative to contemporary farming practices. This is consistent with Bagagiolo et al.'s (2022) conclusion that the automated monitoring technique is a great illustration of how technology may improve crop productivity and solve the challenges of contemporary farming.

The finding also showed that the six trials of the proof-of-concept Automated Greenhouse Agricultural System were 100% successful for all three pots. The soil moisture sensor was operating correctly, the servo motor was acting properly, and the environment was maintained in a suitable condition for plant growth in pots 1, 2, and 3 even though pots 1, 2, and 3 were at 0, 90, and 180-degree spin, respectively (Rasanen, 2023). This steadiness in performance shows the ability and flexibility of this system; Agrounik (2021) agreed on the importance of having high-level sensors in agriculture since it is profitable in agricultural production. Besides, Lugo (2024) mentioned that automation of systems reduced the consumption of both water and energy with an increase in productivity. The AGAS prototype presents how automation can build efficiency and sustainability for modern agriculture practice.

V. CONCLUSIONS AND RECOMMENDATIONS

This section presents the conclusions that were drawn out of the findings of the study. This section further offers recommendations as to how the findings of this study can improve practice.

Conclusions

Based on the findings of the study, the following conclusions are drawn by the researchers:

The automated greenhouse agricultural system prototype successfully passed the functionality tests in terms of the soil moisture sensor's detection capability, the servo motor's degree of spin which is 45 degrees to the left, the pump's compatibility with the servo motor, and the soil moisture sensor, ventilation capability to keep fresh air circulation, humidity detection capability, receiving data in website "ENGTINGCO" based on the data value the system gives, and system programming. This implies that the system can continuously monitor and adjust variables to create an optimal environment for crop growth.

The website "ENGTINGCO" in the automated greenhouse agricultural system prototype was able to provide data on the temperature; humidity; and soil moisture. This indicates that farmers and greenhouse owners can access current environmental data from any location using the website. This allows them to constantly check the greenhouse's conditions without having to be physically present.

The efficiency of automated greenhouse agricultural system in terms of temperature, humidity and soil moisture is higher compared to the traditional greenhouse system. This indicates that the automated greenhouse agricultural system prototype can be adopted and implemented in a larger scale.

Recommendations

Based on the conclusions presented, the following recommendations are given:

- Create an application that farmers may use to control the amount of water sprayed in the soil automatically based on the type of plant they wish to plant. This would make the entire system user-friendly since our system only depends on the set threshold of the code.
- Create a proper HVAC. The researcher's AGAS only has a fan for regulating temperature, so, proper HVAC in the researchers' prototype is not achieved. This is greatly needed for greenhouses to keep their internal climate more or less stable.
- Create an application that records the irrigation time so that farmers can keep track of when their plants are being irrigated.
- Create a self-operating, automated irrigation system that runs on renewable energy. AGAS' power supply only includes batteries and a power bank and these are not rechargeable and will run out of power at some point. For this not to happen, making the system run on renewable energy will solve the power supply problem.
- Create an automated refilling feature for the water reservoir of the system. The researchers' prototype has a tank that needs to be refilled manually; making an automated refilling feature will make the system fully automatic and human intervention will not be needed.

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