



ISSN: 2617-5517 (issn.org)

Al-Farabi Journal of Engineering Sciences

<https://iasj.rdd.edu.iq/journals/journal/view/97>

مجلة الفارابي للعلوم الهندسية تصدرها جامعة الفارابي



## Artificial intelligence enhancements in the Smart greenhouse for agricultural crops

MOHAMMED ABED ABDULLAH

(AUL) Arts, Sciences, and Technology University In Lebanon

Computer Science/ communications

07800636142

m.abid.90m@gmail.com

### Abstract

The severe effects of climate change, the continuous loss of natural resources, and the fast urbanization and population growth have put traditional farming practices under an unprecedented strain. The urgent need to produce more food with fewer resources has spurred pioneering innovations in agriculture and technology, such as the "smart greenhouse," which represents a ray of hope. By integrating advanced technology with agriculture, smart greenhouses offer a paradigm shift, precisely optimizing resource use for crops, providing summer produce in the winter and winter produce in the summer. It conserves water, the most important resource in highly regulated environments, with unparalleled efficiency. Conventional irrigation is often ineffective due to significant water loss due to runoff and evaporation. On the other hand, smart greenhouses use sophisticated hydroponic, a aquaponics systems that use a closed-loop system to precisely feed water to the plant roots. Compared to conventional field farming, this recirculating design can save up to 90% on water usage. To avoid water waste and overwatering and ensure every drop of water is used efficiently, sensors track humidity levels and nutrient concentrations in real time, reducing waste and decreasing demand on fresh water supplies.

Light is another vital element that can be enhanced with smart lighting systems, as can climate control. While greenhouses traditionally rely on sunlight, smart greenhouses extend the duration of light, essential for plant life, to increase growth and flowering. Smart greenhouses use energy-efficient LED lights, which supply the plant with light and compensate for any shortages in sunlight, depending on the crop type and growth stage. This ensures the plant receives the optimal amount of light without wasting additional energy. Artificial intelligence algorithms can predict optimal periods for ventilation, heating, and irrigation, while using solar panels and other sustainable energy sources reduces energy consumption by operating systems only when absolutely necessary. Furthermore, smart greenhouses eliminate carbon emissions and their reliance on fossil fuels.

Smart greenhouses manage light energy, water, and agricultural land, as well as fertilizers and other plant-needed nutrients. By precisely distributing fertilizers evenly to plants, smart agriculture helps prevent the runoff of dissolved pesticides into waterways, which

can poison waterways and harm ecosystems. The requirement for pesticides and herbicides is much decreased in an enclosed environment since pests and illnesses are much simpler to control or prevent. This leads to cleaner, healthier food and a huge reduction in the usage of chemicals.. This improves food safety and quality while also helping the environment.

To sum up, smart greenhouses carefully manage and preserve vital resources, thereby embracing a comprehensive approach to agricultural production. They provide greater yields of superior quality crops all year round by transforming the problems of land scarcity, water stress, and energy demands into chances for innovation. The long-term advantages in terms of resource efficiency, environmental sustainability, and food security are indisputable, even though the initial capital expenditure may be high. The smart greenhouse emerges as a crucial model for a resilient, effective, and ecologically responsible agricultural future as the globe struggles to feed an ever-increasing population in the face of climate change.

**Keywords**—greenhouse; humidity; IoT; soil moisture; temperature

### ***I. Introduction***

The increasing population, growing industrialization, and continuous climate changes are reducing arable land across the globe every year [1]. Consequently, there is a significant and growing demand for food and crop production. According to the United Nations Food and Agricultural Organization (FAO), more cropland and water will be required to meet future food demands as the world's population rises to 9.73 billion people by 2050 [2]. The strain on farmers and agriculturists is further increased by a number of additional farming difficulties, such as a shortage of manpower, water, and sudden climate changes [3]. Therefore, traditional greenhouse farming methods are not enough and needed to change for sustainable food production. Greenhouse farming practice is considered to be the best alternate solution to overcome food crises and ensure sustainability [4].

In the 19th century, France and the Netherlands introduced the first greenhouse agricultural method [5]. Since then, the greenhouse farming method has gained popularity and grown at the quickest rate in the sector [6]. The primary purpose of the greenhouse is to grow crops throughout the year by modifying the growth environment for plants. Crop parameters and all other growth conditions in typical greenhouse farming systems are determined by the farmer, which requires sufficient time and labor costs [7]. However, technology-enabled greenhouse monitors and controls the farming variables effectively and efficiently by using smart devices and specific standards [8].

Farmers may better manage their farms and maximize their resources in this way. Future fruit and crop cultivation in an Internet of Things (IoT)-based greenhouse is expected to be completely automated and controlled remotely. Additionally, the Internet of Things is a mass system that includes devices such as sensors, controllers, actuators, and platforms for decision-making. This system allows for effective resource scheduling to optimize agricultural output.

### ***II. Review of literature***

The constraints presented by resource scarcity and climate change have led the agriculture sector to acknowledge the need for technology in recent years. In order to increase crop resilience and production efficiency, farmers have been forced to adopt cutting-edge communication and information technologies. Systems engineering and Internet of

Things (IoT)-based information infrastructure have drawn a lot of interest among the newer strategies. IoT solutions in agriculture matched the needs of Industry, have discovered usage in greenhouses [9]. The controlled conditions that greenhouses offer promote the best possible growth for plants. Real-time monitoring, data gathering, and processing are made possible by IoT technologies for smart greenhouses, which include sensor systems, gadgets, and connection infrastructure. Critical indoor characteristics like temperature, humidity, ventilation, light exposure, and carbon dioxide levels can all be effectively controlled thanks to this integration [10, 11]. The thorough study by Farooq et al. [12] includes in-depth talks on sensor devices, communication protocols, and IoT-based applications for greenhouse systems. Furthermore, Quan et al.'s work [13] has looked at the trends and potential of IoT applications in Vietnam's agriculture industry. Many noteworthy research have examined different facets of smart greenhouse technology. A methodology for artificial light control in smart greenhouses was put up by Pereira et al. [14], who methodically examined the effects of various light characteristics on plant growth. In order to maintain the ideal humidity and temperature conditions in greenhouse environments, a number of studies have investigated the combination of ventilation, exhaust fans, and vertical airflow fans [15, 16]. To optimize the yield of crops, Ullah et al. created an optimization technique for IoT-based smart greenhouse climate control that drastically reduced energy consumption while preserving the ideal indoor environment. While Siskandar et al. [18] looked into the supplies and equipment needed to put together prototype greenhouse models, Baeza et al. [17] concentrated on smart greenhouse covers. Le et al. [19] built a wireless sensor network based on accessible radio frequency technologies, using inexpensive solar-powered modules for autonomous sensor operation. Sensor communication is essential in smart greenhouses. In addition to offering important insights into maximizing plant growth, preserving ideal environmental conditions, and setting up effective sensor communication networks, these studies together advance smart greenhouse technology. Fatima et al. [20] investigated the practical use of deep learning methods for leaf image analysis. In designing a smart greenhouse based on the Internet of Things with disease prediction capabilities. The integration of IoT with mobile apps for remote control of smart greenhouses has been the subject of several additional research [21–22]. In the framework of intelligent greenhouse systems, these research projects apply cutting-edge technologies like deep learning and mobile applications, optimize greenhouse control tactics, and increase irrigation efficiency. Compared to earlier research, this publication makes a significant contribution to the field of smart greenhouses. Our study's accomplishment is noteworthy since it marks the start of an integrated smart greenhouse solution created especially for the agricultural industry. Our group's accomplishments extend beyond conventional greenhouse research. In the end, the greenhouse integration results in higher crop yields, resource efficiency, and improved environmental sustainability in greenhouse operations by enabling accurate plant life monitoring, data-driven decision-making, and automated management without human intervention. This accomplishment demonstrates our dedication to developing smart agriculture.

### **III. Research structure**

Building our intelligent greenhouse in order to produce an environment that is optimal for plant growth, building an intelligent greenhouse requires careful design and the integration

of multiple components. From the installation of the physical structure and steel bars to the installation and installation of the basic sensors, automation systems, and connectivity infrastructure, every detail is carefully planned to guarantee effective and sustainable cultivation. Let's examine the main factors and elements involved in building a smart greenhouse.

- **Structural Design** The greenhouse structure forms the foundation of the construction. It should be designed to provide adequate space for plant growth, allow optimal light penetration, and accommodate automation systems and equipment. Material selection, insulation, ventilation, and shading mechanisms are crucial to effectively regulating temperature, humidity, and light levels.
- **Sensor Networks** Setting up sensor networks is essential for tracking and gathering data on environmental conditions in real time. Sensors were used to measure temperature, soil moisture, light intensity, and water quantity sensors in the tanks and levels of essential nutrients. Data from these sensors is sent to a central control system for evaluation and judgment.
- **Automation Systems** In order to regulate and oversee several facets of the greenhouse environment, automation systems are essential. Temperature control, ventilation, shade, watering, and fertilization are all automated through the integration of actuators and control algorithms. By improving growth conditions and reducing the need for human interaction, these technologies guarantee exact modifications based on sensor data. The implementation of a smart greenhouse is covered in this research in its entirety, including monitoring, alerting, effective irrigation automation, and herbicide-based disease management. Temperature, humidity, and soil moisture sensors are used to generate inputs using sensor data.

#### IV. Methodology

The farmer is notified by the microcontroller when environmental factors deviate from or surpass normal. The microcontroller is programmed in Python to control the irrigation motor based on sensor data. Figure 1 shows a system diagram showing the components and their connections. Based on this definition, the developed system is divided into three subsystems, each with a different function:

- ❖ Ambient Condition Monitoring and Alerting System .
- ❖ Automated Irrigation System .
- ❖ An insect and disease control system.

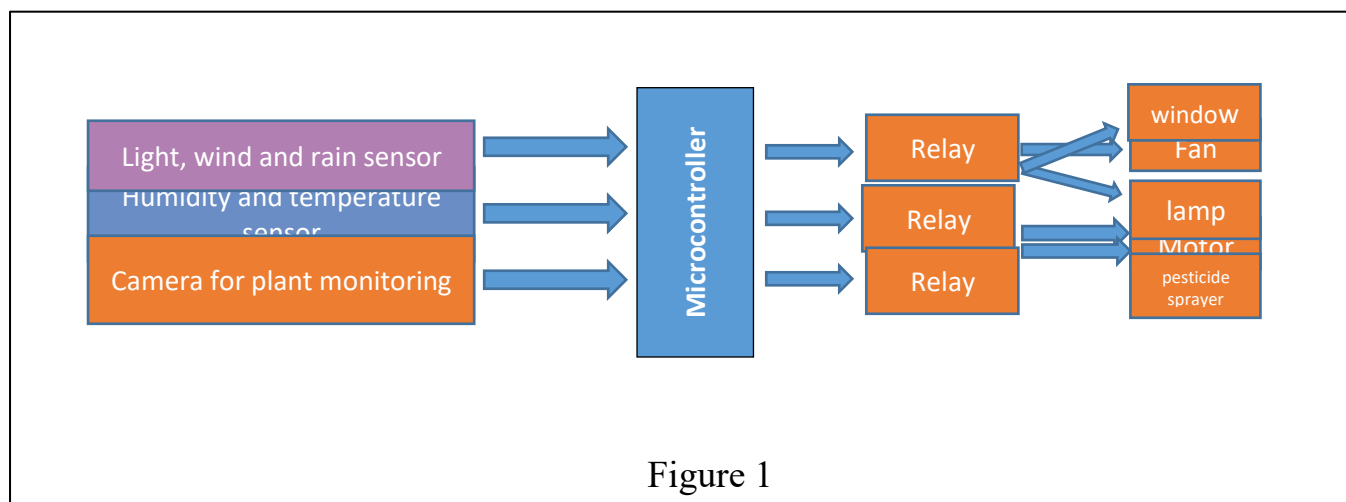


Figure 1

A. Ambient Condition Monitoring and Alerting System

❖ light sensor and temperature sensors have provided the sensor data. A maximum ambient temperature is established in this system. To cut down on heat, fans are told to turn and windows to open, and vice versa. There is a 50 degree Fahrenheit maximum temperature increase over the predetermined settings. As shown in the following code in Python:

```
from spidev import SpiDev
class MCP3008:
    def __init__(self, bus = 0, device = 0):
        self.bus, self.device = bus, device
        self.spi = SpiDev()
        self.open()

    def open(self):
        self.spi.open(self.bus, self.device)

    def read(self, channel = 0):
        adc = self.spi.xfer2([1, (8 + channel) << 4, 0])
        data = ((adc[1] & 3) << 8) + adc[2]
        #Read Temperature
        tempread=`cat /sys/bus/wi/devices/.../b/e/w/_slave`
        #Format
        temp=`echo "scale=2; "\echo ${tempread###*}\/ | bc` return data

    def close(self):
        self.spi.close()
        #Output
        echo "The measured temperature is " $temp "°C"
```

The light intensity that the plant needs can also be measured from one season to another and from one place to another. When the intensity is low, a lamp is turned on to provide adequate light for the plant, and when the intensity is high, the light can be turned off. It is also possible to shade the greenhouse to reduce heat and light, as shown in the following code in Python:

```
import RPi.GPIO as GPIO
import time

#Set the GPIO mode
GPIO.setmode(GPIO.BCM)

#Define the pin numbers
ldr_pin = 14 # Analog input pin for the light sensor
led_pin = 18 # Digital output pin for the LED
```

```
#Set up the GPIO pins
GPIO.setup(ldr_pin, GPIO.IN)
GPIO.setup(led_pin, GPIO.OUT)
try:
    while True:
        # Read the light sensor value
        ldr_value = GPIO.input(ldr_pin)
        if ldr_value == 0: # Check if light intensity is low
            # Turn on the LED
            GPIO.output(led_pin, GPIO.HIGH)
        else:
            # Turn off the LED
            GPIO.output(led_pin, GPIO.LOW)

        time.sleep(0.1) # Delay to avoid reading the sensor too often

except KeyboardInterrupt:
    GPIO.cleanup()
```

❖ The HT195 soil moisture sensor IC was used to measure the ambient moisture content of the soil. The sensor uses capacitance to determine the permeability of the surrounding medium. It measures loss in soil moisture in due course of time because of reasons like evaporation and plant uptake. It also helps to assess optimum soil moisture content for different plant species and to monitor soil moisture content to control irrigation. Fig 2. HT195 module

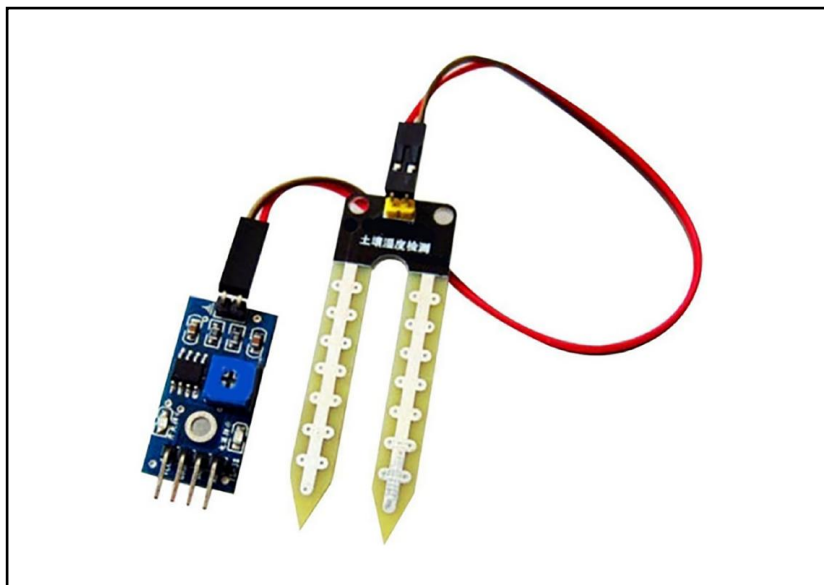


Figure 2

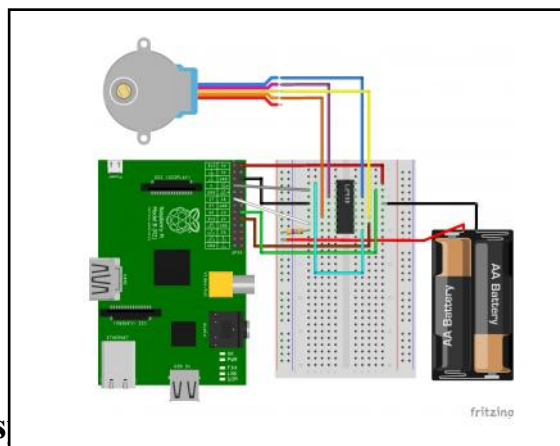
It can be programmed to measure the moisture level of the soil to determine the plant's need for water, as shown in the following Python code:

```
import spidev
```

```
import os
import time
delay = 0.2
spi = spidev.SpiDev()
spi.open(0,0)
spi.max_speed_hz=1000000
def readChannel(channel):
    val = spi.xfer2([1,(8+channel)<<4,0])
    data = ((val[1]&3) << 8) + val[2]
    return data
if __name__ == "__main__":
    try:
        while True:
            val = readChannel(0)
            if (val != 0):
                print(val)
                time.sleep(delay)
    except KeyboardInterrupt:
        print "Cancel."
```

**B. Automated Irrigation System**

- 1) The microcontroller continuously receives information from the temperature and humidity sensor and soil moisture sensor.
- 2) The microcontroller allows control of any device connected to it.
- 3) In this system, when the irrigation levels are too high, the water supply is turned off/on. and when the soil is dry i.e. the irrigation level is too low, the command is sent to turn on the motor to pump water to the plant. As shown in the figure3



**C. Foliar spraying s**

- 1) In this technique, the pesticide is pre-applied at a known rate to automatically spray the leaves without the farmer's assistance when the camera detects the presence of insects or wilting or yellowing of the leaves caused by insects.
- 2) When the weather is dry, this system can pump out water mist to cool the plants.

**D. System Schematic**

Figure 4 shows the schematic of the virtual electronic components and the pin connections for the system.

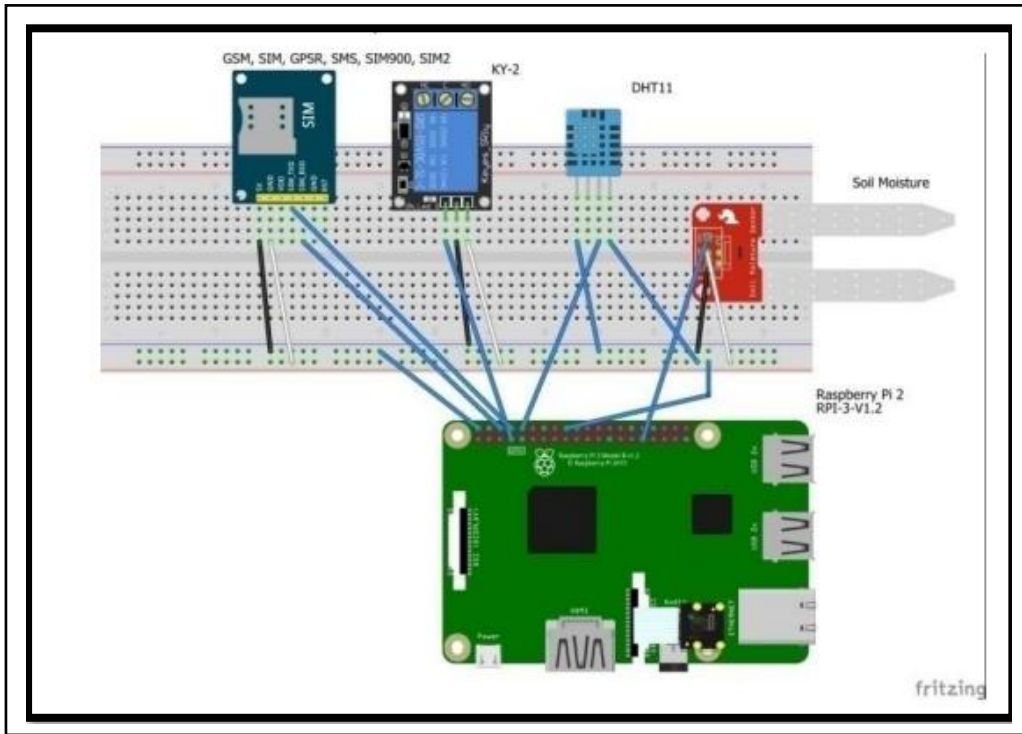


Fig. 4. System Schematic.

The SIM system is used to send data to farmers to inform them of soil moisture, temperature, and light intensity, and to inform them of any work performed by artificial intelligence.

### ***V. RESULTS***

- I. As illustrated in Figures 5 and 6, the temperature and humidity are continuously monitored in real time, even by electronic control systems.
- II. b) As seen in Fig. 7 and recorded in Table I, the measured soil moisture (as indicated by SMM) is likewise tracked in real time.
- III. The Root Mean Square Error calculated for Temperature, denoted by  $RMSET=1.292788$  and Root Mean Square error calculated for Humidity, denoted by  $RMSEH=1.040833$ .
- IV. When ambient circumstances diverge from the threshold levels, an alert is sent. Seasons can be taken into account when setting a threshold. For instance, during the summer, the maximum temperature is maintained at  $38^{\circ}\text{C}$  and the maximum humidity at  $55^{\circ}\text{R}$ . Planters will be notified if there is a larger departure from these limitations during the day.
- V. In the summer, 500 has been established as the threshold value. At 500 or more, the "dryness" triggers the activation of the irrigation motor; if it falls below that level, it stays

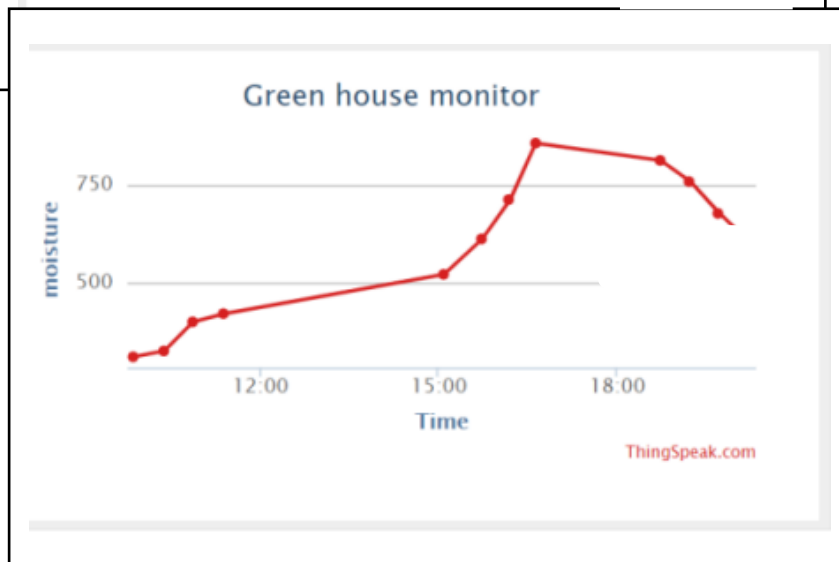
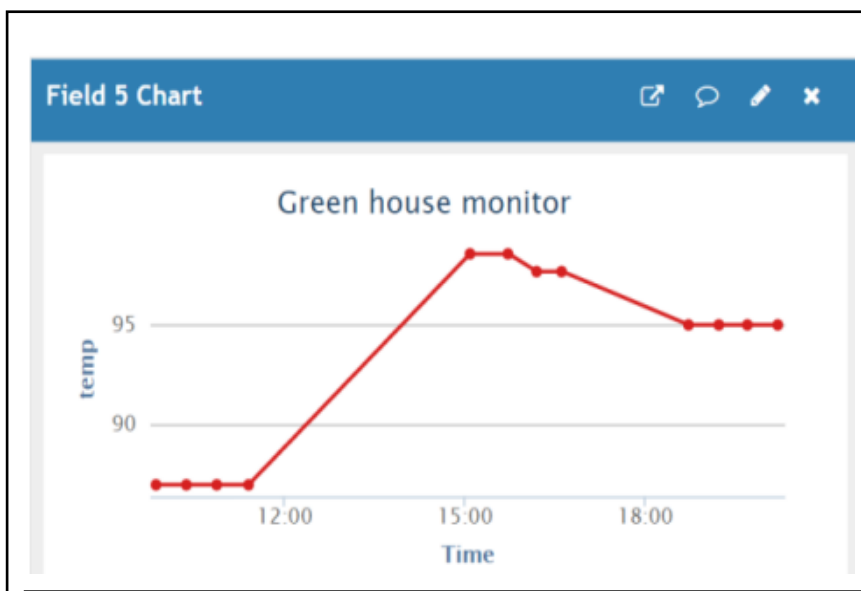


TABLE I. Temperature, humidity, and soil moisture readings, both measured and actual

Time Duration	T <sub>A</sub> (°F)	T <sub>M</sub> (°F)	H <sub>A</sub> (%)	H <sub>M</sub> (%)	Heat Index (°F)	SM <sub>M</sub>	Motor ON/OFF
Morning IST 0900-1100	86.9	87.08	45%	45.00	88.03	310	OFF
	86.9	85.10	46%	47.00	85.88	325	OFF
	89.6	87.80	41%	41.00	87.91	399	OFF
	89.6	87.62	40%	40.00	87.62	420	OFF
Afternoon IST 1500-1700	98.6	98.78	41%	43.00	108.86	520	ON
	98.6	99.14	41%	40.00	107.35	610	ON
	97.7	98.60	41%	41.00	106.92	710	ON
	97.7	98.78	41%	39.00	105.85	854	ON
Evening IST 1800-2000	95	96.44	44%	45.00	105.02	810	ON
	95	96.26	44%	43.00	103.27	756	ON
	95	96.26	44%	44.00	103.94	675	ON
	95	96.44	44%	45.00	105.02	602	ON

## VI. Discussion

Even in remote locations, the Smart Greenhouse System provides a complete, contemporary, and cost-effective substitute for a manually monitored system that is in place around-the-clock. In order to create a comprehensive IoT-based Smart Greenhouse system that can be widely implemented in both farms and greenhouses, it offers a unique combination of several components, including monitoring, alerting, cloud storage, effective predictive modeling, and precise disease prediction. The study develops and deploys a system that continuously checks the surrounding conditions, notifies users if levels exceed or fall below the threshold, and turns the irrigation motor on or off in response.

The system can be utilized both in small and large greenhouses. For smaller areas, a small compact kit is developed whereas for larger greenhouses, multiple Pi cameras in the same kit could suffice for accurate results. Modern sensors can be used to improve the performance of this system, allowing for faster signal transmission and faster detection of factors, making it an ideal system. This system can also be trained on more than one type of plant, recording the temperature and humidity levels required by each type, as each plant differs from the other in its requirements for irrigation, heat, and ventilation.

## VII. Conclusion

Smart greenhouse technology and IoT integration have advanced significantly as a result of this study. The research team has successfully achieved the basic objectives, which included developing a multifunctional system with automatic fertilization, precise watering, and comprehensive fertilizer record-keeping. The system provides valuable messages about weather conditions, fertilization, and irrigation techniques, enhancing the ability to make informed decisions. Our efforts have resulted in an easy-to-use interface accessible via a link that allows users to view temperature, soil moisture, plant fertilizer. Key features include continuous, 24/7 weather monitoring, automated irrigation decisions, and tracking of soil moisture sensor data with automated irrigation management. Additionally, this technology allows farmers to monitor and check on their farms anytime, anywhere. Additionally, the system has a fertilizer management feature that facilitates the

scheduling, categorization, and meticulous documentation of fertilizer applications. Our study has led to the successful development of an integrated smart greenhouse system, which includes detecting soil dryness and high temperatures and making the necessary decisions to solve the problem before farmers intervene. In this research, we propose and implement a comprehensive Internet of Things solution for smart greenhouses. It is important to emphasize that our work is a pioneering endeavor, demonstrating our distinguished contribution to this field. This achievement represents a comprehensive solution to address the challenges facing farmers in conventional agriculture, such as food supply, resource conservation, and environmental sustainability. Additionally, they have the power to totally change agricultural production. Thus, our research establishes the foundation for next developments in greenhouse and intelligent farming technology.

### **VIII. Acknowledgments**

The authors would like to sincerely thank all of the hardworking construction workers who helped make the experimental greenhouse a success.

### **IX. References**

1. T. Folnovic, *Loss of Arable Land Threaten World Food Supplies*. Agrivi, London, U.K., Accessed: May 1, 2021. [Online]. Available: <https://blog.agrivi.com>
2. O. Calicioglu, A. Flammini, S. Bracco, L. Bellù, and R. Sims, "The future challenges of food and agriculture: An integrated analysis of trends and solutions," *Sustainability*, vol. 11, no. 1, p. 222, 2019.
3. D. K. Ray, N. D. Mueller, P. C. West, and J. A. Foley, "Yield trends are insufficient to double global crop production by 2050," *PLoS ONE*, vol. 8, no. 6, 2013, Art. no. e66428.
4. G. N. Tiwari, *Greenhouse Technology for Controlled Environment*. Oxford, U.K. : Alpha Science Int.'l Ltd, 2003.
5. *Historical Background of Greenhouses*. Emerald Agr. Technol., Kolhapur, India. Accessed: May 1, 2021. [Online]. Available: <https://www.emerald-agri.com>
6. S. Vatari, A. Bakshi, and T. Thakur, "Green house by using IoT and cloud computing," in *Proc. IEEE Int. Conf. Recent Trends Electron., Inf. Commun. Technol. (RTEICT)*, May 2016, pp. 246–250.
7. S. El-Gayar, A. Negm, and M. Abdrabbo, "Greenhouse operation and management in Egypt," in *Conventional Water Resources and Agriculture in Egypt*. Cham, Switzerland : Springer, 2018, pp. 489–560.
8. I. L. López-Cruz, E. Fitz-Rodríguez, R. Salazar-Moreno, A. Rojano-Aguilar, and M. Kacira, "Development and analysis of dynamical mathematical models of greenhouse climate: A review," *Eur. J. Hortic. Sci.*, vol. 83, pp. 269–280, Oct. 2018.
9. Kumar N, Dey B, Chetri C, Agarwal A, Debnath A. Development of an IoT-Based Smart Greenhouse Using Arduino. In: *Advances in Communication, Devices and Networking: Proceedings of ICCDN 2020*. Springer; 2022. p. 455–465
10. Bersani C, Ruggiero C, Sacile R, Soussi A, Zero E. Internet of Things Approaches for Monitoring and Control of Smart Greenhouses in Industry 4.0. *Energies*. 2022;15(10):3834.
11. Rayhana R, Xiao G, Liu Z. Internet of things empowered smart greenhouse farming. *IEEE Journal of Radio Frequency Identification*. 2020;4(3):195–211.

12. Farooq MS, Javid R, Riaz S, Atal Z. IoT Based Smart Greenhouse Framework and Control Strategies for Sustainable Agriculture. *IEEE ACCESS*. 2022;10:99394–99420
13. Quan DM, Thi HVT. Potential and Trends of IoT Application in Agriculture in Vietnam. *Journal of Social Science*. 2023;4(3):666–676
14. Pereira J, Mouazen AM, Foo M, Ahmed H. A framework of artificial light management for optimal plant development for smart greenhouse application. *Plos one*. 2021;16(12):e0261281. pmid:34898651
15. Minanda MA, Idris I, Sumardi D. Design and Simulation of Smart Greenhouse for Agrivoltaics Microclimates Optimization. In: 2021 International Symposium on Electronics and Smart Devices (ISESD). IEEE; 2021. p. 1–6
16. Bafdal N, Ardiansah I. Application of Internet of Things in smart greenhouse microclimate management for tomato growth. *International Journal on Advanced Science, Engineering and Information Technology*. 2021;11(427):10–18517.
17. Baeza E, Van Breugel A, Hemming S, Stanghellini C. Smart greenhouse covers: A look into the future. In: XI International Symposium on Protected Cultivation in Mild Winter Climates and I International Symposium on Nettings and 1268; 2019. p. 213–224.
18. Siskandar R, Santosa SH, Wiyoto W, Kusumah BR, Hidayat AP. Control and Automation: Insmoaf (Integrated Smart Modern Agriculture and Fisheries) on The Greenhouse Model. *Jurnal Ilmu Pertanian Indonesia*. 2022;27(1):141–152.
19. Le Van T, Thi PN, Minh PV, Le Cong H, Phuong TNT, et al. Design and Implementation of a Wireless Sensor Network for Smart Greenhouse Controller. *CommIT (Communication and Information Technology) Journal*. 2022;16(1):1–8.
20. Fatima N, Siddiqui SA, Ahmad A. IoT-based smart greenhouse with disease prediction using deep learning. *International Journal of Advanced Computer Science and Applications*. 2021;12(7).
21. Šabić Z, Drakulić U, Mujčić E. The smart greenhouse system based on the the mobile network and iot. *Advanced Technologies, Systems, and Applications V: Papers Selected by the Technical Sciences Division of the Bosnian-Herzegovinian American Academy of Arts and Sciences 2020*. 2021; p. 285–298
22. Kumar T, Kumar D, et al. Greenhouse Monitoring and Controlling using Cloud-Based Android Application. In: 2023 IEEE 8th International Conference for Convergence in Technology (I2CT). IEEE; 2023. p. 1–8.