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# PRECISION GREENHOUSE ENVIRONMENTAL MONITORING SYSTEM USING IOT

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## ABSTRACT
Greenhouse automation offers a promising approach to enhance agricultural productivity and efficiency, particularly in regions facing challenges such as urbanization and land scarcity. By automating the monitoring and control of crucial environmental parameters, farmers can optimize crop growth and reduce manual labour. The various factors are depended each other in the environmental system . This approach can be applied to any applications like agricultural which can improve crop yields, reduce operational costs, and promote sustainable agricultural practices. The proposed system shows significant variations with respect to temperature. This could be applied to any system integrating IoT for automatic control for enhanced outputs. This approach can be applied to any applications like agricultural which can improve crop yields, reduce operational costs, and promote sustainable agricultural practices.
**Keywords**: Greenhouse , IoT , Arduino , Sensors , Automation

## I. Introduction
Greenhouse automation represents a transformative approach to modern agriculture, integrating advanced technologies to optimize plant growth, resource utilization, and productivity. The increasing global demand for food, coupled with the challenges posed by climate change, has necessitated innovative solutions to enhance agricultural efficiency. Greenhouses provide a controlled environment that shields crops from external weather variations, pests, and diseases, but traditional management practices often rely heavily on manual intervention, which can be inefficient and error-prone. Automated greenhouse systems leverage technologies such as the Internet of Things (IoT), artificial intelligence (AI), and robotics to monitor and control environmental parameters like temperature, humidity, light, and soil moisture. These systems are equipped with sensors, actuators, and controllers that enable real-time data collection and decision-making, ensuring optimal conditions for crop growth while minimizing water and energy consumption. Automation in greenhouses not only improves crop yield and quality but also addresses critical sustainability goals by reducing resource wastage and labor dependency. Furthermore, advancements in machine learning and predictive analytics have empowered farmers to anticipate potential challenges, such as disease outbreaks or nutrient deficiencies, and take preemptive measures. This paper explores the latest developments in greenhouse automation, including sensor technologies, control algorithms, and the integration of renewable energy sources. It also examines the challenges and future prospects of adopting these technologies, highlighting their potential to revolutionize agriculture and contribute to global food security. By automating tasks such as watering and lighting, the system can significantly improve crop yield and quality while reducing operational costs and environmental impact. Furthermore, the system can be integrated with advanced technologies like IoT and AI to enable remote monitoring and control, predictive maintenance, and data-driven decision-making.

## II. Literature Survey
Greenhouse automation is an emerging field that aims to optimize agricultural production through the use of advanced technologies, sensors, and automation systems. The goal is to enhance the efficiency, productivity, and sustainability of greenhouse operations by automating processes such as temperature control, irrigation, ventilation, lighting, and crop monitoring. This literature review synthesizes key studies and trends in greenhouse automation, identifying challenges, technological advancements, and areas for future research. Technological Advancements in Greenhouse

automation has evolved significantly over the years, driven by advances in sensor technology, Internet of Things (IoT), artificial intelligence (AI), robotics, and machine learning. The integration of these technologies has allowed for the development of sophisticated systems capable of controlling multiple variables in real-time. IoT technologies enable continuous monitoring and control of environmental factors within a greenhouse. Sensors such as temperature, humidity, light intensity, CO2 concentration, and soil moisture can collect data, which is then transmitted to centralized systems for analysis and decision-making. These systems enable more precise control of the greenhouse environment, leading to improved crop yield and quality (Liang et al., 2020). Energy and Resource Efficiency as a significant advantage of greenhouse automation is its potential to reduce energy and resource consumption. Climate control in greenhouses is a major source of energy expenditure, and automation can help optimize the use of heating, cooling, and lighting systems.

### 2.1 System Design and Workflow

#### 2.1.1. Input Sensors:

Temperature and Humidity Sensor (DHT11): This sensor measures the temperature and humidity levels in the greenhouse. It provides precise data to ensure the environment remains within the ideal range for plant growth.
Light Intensity Sensor (LDR): The Light Dependent Resistor (LDR) detects the intensity of ambient light. If the light falls below the required level, artificial lighting is activated.
Soil Moisture Sensor: This sensor monitors the moisture content in the soil, enabling efficient water management by activating the spray system when necessary.

#### 2.1.2 Processing Unit:

Arduino Nano: The Arduino microcontroller serves as the brain of the system. It processes input data from the sensors, compares it with predefined thresholds, and sends commands to the respective actuators for corrective actions.

#### 2.1.3 Actuators

- Perform control actions based on monitored data:
  - **Temperature Regulation:** Heaters, coolers, and fans.
  - **Humidity Adjustment:** Humidifiers or dehumidifiers.
  - **Lighting Control:** Artificial lights like LEDs.
  - **Airflow Management:** Ventilation fans, shutters, or louvers.

#### 2.1.4. Communication Modules

- For remote monitoring and control:
  - Wi-Fi, Zigbee, LoRa, or GSM modules.

#### 2.1.5 Power Supply

- Power the system using renewable energy (e.g., solar panels) or a conventional grid.

#### 2.1.6 Data Storage and Analytics

- Store sensor data locally or in the cloud for historical analysis and predictive modeling.

#### 2.1.7 User Interface

- Provide real-time monitoring via dashboards accessible on PCs or mobile devices.
- Alert mechanisms such as SMS, emails, or app notifications for parameter deviations.

### 2.2 Methodology

The workflow of the greenhouse monitoring system involves the following stages:

**Stage 1: Data Collection**

- **Objective:** Gather real-time data on environmental parameters.
- Sensors placed at strategic locations continuously monitor temperature, humidity, light intensity, and airflow.
- Sensors are calibrated to ensure accuracy and reliability of readings.

**Stage 2: Data Processing**

- **Objective:** Analyze collected data for decision-making.

- The microcontroller receives raw data from sensors.
- Data is processed and compared with predefined thresholds for each parameter:
  - Example:
    - Optimal temperature range: 20–30°C.
    - Humidity: 40–70%.
    - Light intensity: 300–800 lux (depending on the crop type).

**Stage 3: Decision-Making**

- **Objective:** Determine necessary adjustments.
- Control logic is applied using algorithms:
  - **Threshold-Based Control:** Trigger actions when parameters exceed or fall below thresholds.
  - **Advanced Algorithms:** Use PID controllers or fuzzy logic for precise adjustments.

**Stage 4: Actuation**

- **Objective:** Regulate the greenhouse environment.
- Actuators perform corrective actions based on processed data:
  - Turn on/off heaters or fans to control temperature.
  - Adjust humidifiers/dehumidifiers to maintain desired humidity levels.
  - Activate artificial lights when natural light is insufficient.
  - Open/close vents or run fans to regulate airflow.

**Stage 5: Communication and Feedback**

- **Objective:** Notify users and provide data visualization.
- Processed data is transmitted to IoT platforms or cloud storage.
- Users receive real-time updates via dashboards or mobile apps.
- Alerts are sent for critical deviations.

**Stage 6: Data Logging and Analysis**

- **Objective:** Support long-term monitoring and optimization.
- Sensor data is logged for historical analysis.
- Data trends are used to refine thresholds and predict potential issues (e.g., pest infestations or disease outbreaks).

**2.3 System Workflow Diagram**

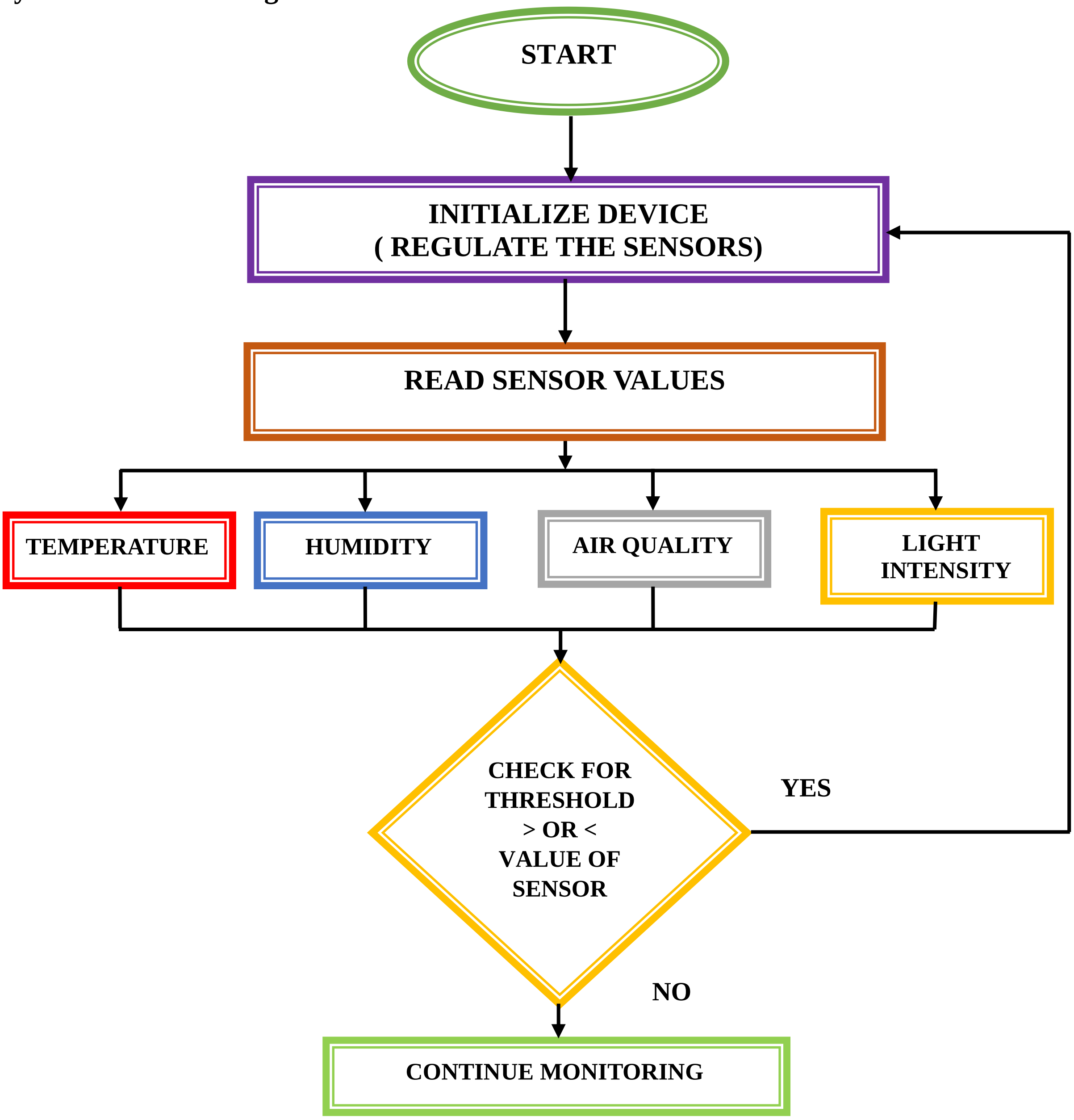


Figure 1: Workflow of Proposed Model

**2.4 Action triggered**

These thresholds are crucial for ensuring optimal plant growth and maintaining a stable environment. The system continuously collects data from sensors and compares it against the set thresholds to determine necessary responses. Table 1 shows the threshold value set for various parameters considers in proposed green house monitoring system. For better understanding, LEDs are connected to indicate the emergency. The upcoming sections shows the experimental setup of the proposed model and followed by the observed data of various metrics like temperature, humidity , light intensity and airflow followed with action taken.

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| **S.No.** | ***Temperature (°C)*** | ***Humidity (%)*** | ***Air Quality (PPM)*** | ***Light Intensity (lux)*** | ***Action Triggered*** |
|---|---|---|---|---|---|
| *1* | *25* | *90* | *171* | *142* | *LEDs OFF, normal conditions* |
| *2* | *30* | *80* | *250* | *200* | *LED2 ON (Poor air quality)* |
| *3* | *35* | *70* | *300* | *400* | *LED1 ON (High light intensity)* |
| *4* | *40(Fire Scenario)* | *60* | *>400* | *>500* | *Motor ON, LED1 and LED2 ON* |

**Table 1 : Threshold of each action**

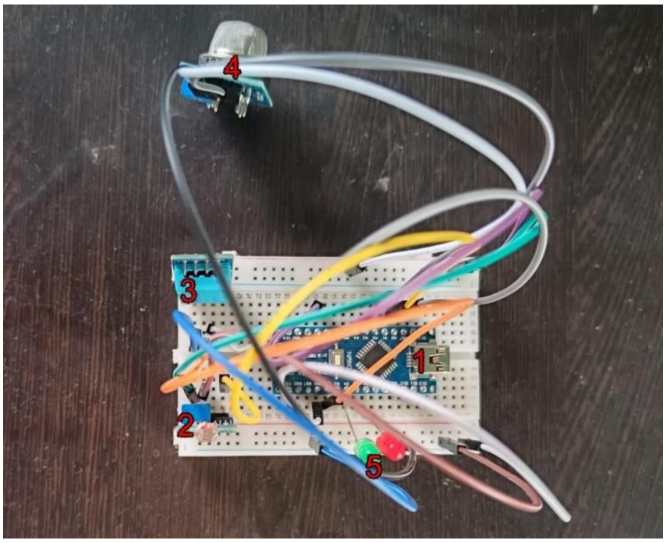


Figure 2: Experimental setup of the Proposed Model

### 2.4.1 Observed Output

All sensors and actuators functioned cohesively. Data collected by the sensors successfully triggered the LEDs and motor based on preset conditions. The Serial Monitor logged consistent and accurate readings, confirming system integrity and is shown in Figure 3.

```
---- Sensor Readings ----

Light Intensity: 338

Air Quality: 325

Humidity: 72.00%  Temperature: 27.60°C 81.68°F  Heat index: 30.14°C 86.25°F

Windows are Shutting Down

Air Purifier is Turned On
```

Figure 3: Serial Monitor Data observed

### 2.4.2. Performance Evaluation

The system performed efficiently under test conditions, with LEDs and the motor responding promptly to sensor inputs. No delays or errors were observed in sensor-actuator communication, ensuring smooth operation. Figure 4 illustrates a positive correlation between temperature and light intensity. It is evident that as the temperature increases, so does the light intensity. This suggests that higher temperatures are associated with brighter light conditions.

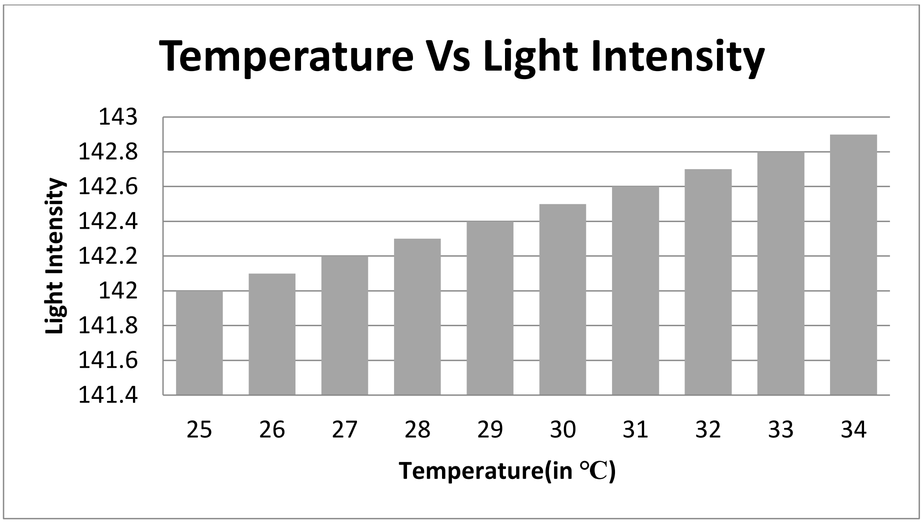


Figure 4 : Visual Representation of Light Intensity Vs Temperature

Figure 5 illustrates negative correlation between temperature and humidity. It is observed that as the temperature rises, the humidity tends to decrease. This could be due to various factors such as increased evaporation rates at higher temperatures.

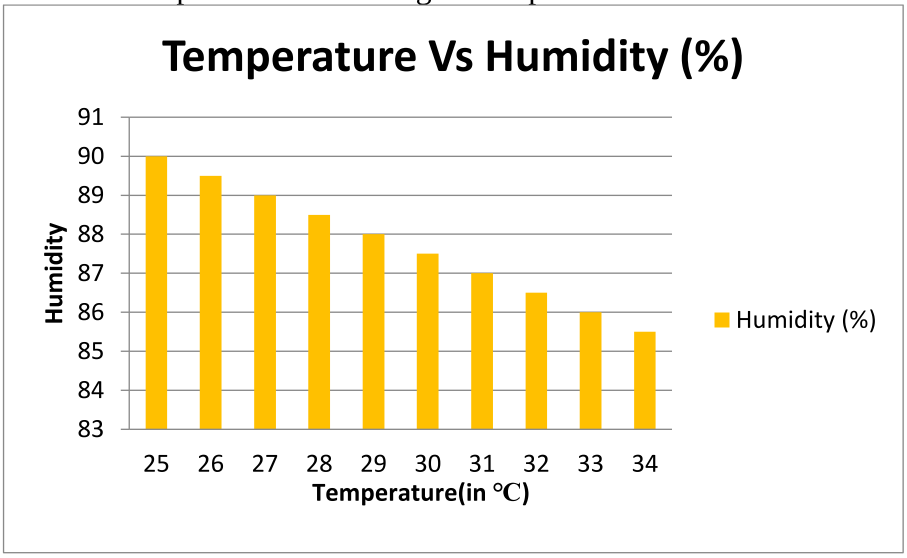


Figure 5 : Visual Representation of Humidity Vs Temperature

Figure 6 illustrates that air quality initially improves with increasing temperature, but then deteriorates at higher temperatures. This could be due to a combination of factors, such as increased pollutant formation at higher temperatures and improved dispersion of pollutants at moderate temperatures.

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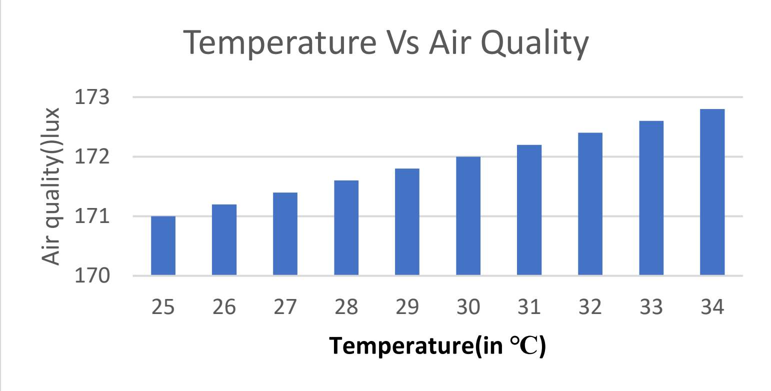


Figure 6 : Visual Representation of Temperature vs Air Quality

Figure 7 illustrates the relationship between temperature and several environmental parameters considered for the proposed system. It is observed that as temperature increases, humidity generally decreases, which is expected as warmer air can hold more moisture. Air quality exhibits a more complex pattern, initially improving with temperature but then deteriorating at higher temperatures. Light intensity demonstrates a strong positive correlation with temperature, indicating that higher temperatures are associated with brighter conditions.

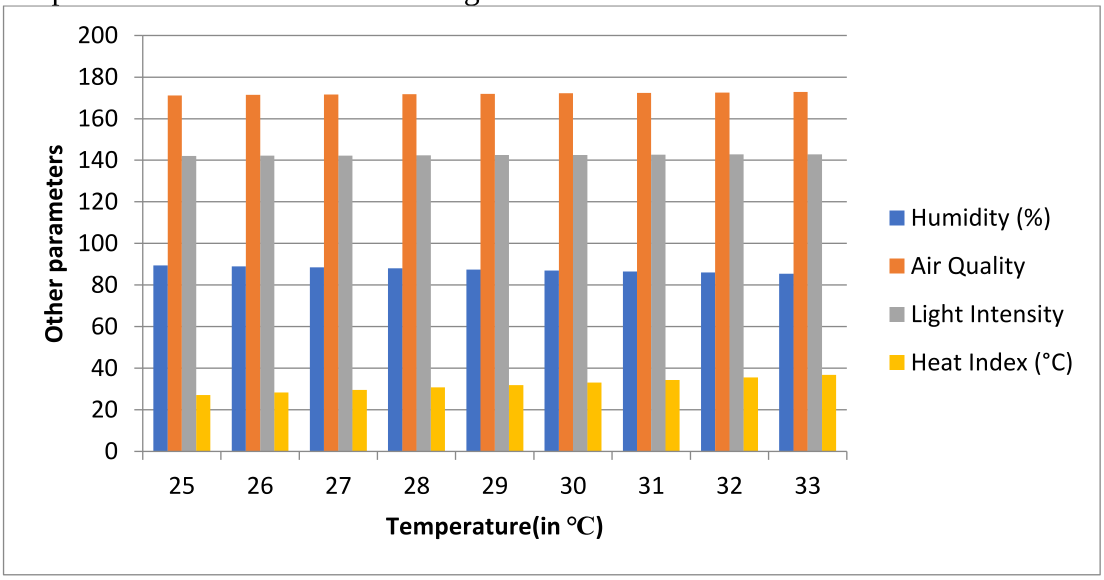


Figure 7 : Visual Representation of Temperature vs Other Parameters

## 3 Conclusion

In summary, greenhouse automation has the transformative potential to revolutionize agriculture by enhancing efficiency, sustainability, and productivity. These systems leverage advanced technologies to create optimized environments for crop growth, significantly reducing manual labour while increasing yield quality and quantity. However, despite these advantages, there remain challenges that must be addressed to unlock their full potential. Integration with cutting-edge technologies like artificial intelligence (AI), machine learning, and IoT (Internet of Things) can drive the next phase of innovation. AI-powered predictive analytics could enable more precise environmental adjustments, while IoT connectivity would allow for seamless, remote monitoring and control. Moreover, emphasis on sustainability, such as integrating renewable energy sources and reducing water consumption, will make greenhouse automation an environmentally conscious solution. By addressing these challenges and focusing on continuous innovation, the future of greenhouse automation promises to contribute significantly to building a resilient, sustainable, and efficient agricultural ecosystem globally, ensuring food security and environmental conservation for generations to come.

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