

To Study the Best Performing IoT Sensors for Environmental and Climate Data Collection

Prof. Divya Mahadik¹, Beldar Vijay², Pandechari Samyak³, Salve Bhushan⁴, Pawar Soham⁵.

¹(Professor Divya Mahadik, SRCOE, Department of Computer Engineering Pune)

²(Beldar Vijay, SRCOE, Department of Computer Engineering Pune)

³(Salve Bhushan, SRCOE, Department of Computer Engineering Pune)

⁴(Pandechari Samyak, SRCOE, Department of Computer Engineering Pune)

⁵(Pawar Soham, SRCOE, Department of Computer Engineering Pune)

Abstract This study focuses on the detailed investigation and performance evaluation of IoT-based sensors used for environmental and climate data collection. The research involves analyzing sensors such as temperature, humidity, rainfall, light intensity, and air quality sensors that play an essential role in IoT-based monitoring systems. Each sensor is examined for its precision, response time, energy consumption, and reliability under changing environmental conditions. The aim of this study is to identify the most accurate and efficient sensors suitable for continuous and real-time environmental data acquisition. Experiments are conducted to compare sensor performance, data stability, and adaptability across various climatic conditions. The collected data is analyzed to determine how effectively each sensor can monitor environmental parameters critical for smart irrigation and weather prediction. The outcomes of this investigation provide insights into selecting cost-effective and durable sensors for IoT-based climate and agricultural applications. The results also contribute to improving sensor integration and network design for future intelligent monitoring systems.

Key Word IoT Sensors, Environmental Monitoring, Climate Data Collection, Smart Irrigation, Sensor Performance

I. Introduction

The Internet of Things (IoT) has transformed environmental and agricultural monitoring by enabling smart, real-time data collection through intelligent sensors. IoT systems help track parameters such as temperature, humidity, rainfall, and soil moisture, which are essential for improving crop growth and sustainable resource management. Selecting suitable sensors with high accuracy, cost efficiency, and reliability is a key factor in building an effective environmental monitoring network. This study focuses on evaluating and comparing five widely used IoT sensors: the Robodo SEN6 Soil Moisture Sensor, YL-83 Rain Sensor, DHT11 Temperature and Humidity Sensor, SHT31 Temperature and Humidity Sensor, and Vegetronix VH400 Soil Moisture Sensor. Each sensor plays a vital role in gathering environmental and climatic data. The Robodo SEN6 measures soil moisture through resistive sensing, offering a simple and affordable option for irrigation systems. The YL-83 Rain Sensor detects rainfall using conductive traces, making it suitable for automatic rain detection applications. The DHT11 Sensor monitors temperature and humidity with decent accuracy for small-scale IoT projects. In contrast, the SHT31 and Vegetronix VH400 sensors provide higher precision and faster response but come at a higher cost. This study aims to analyze the working principles, advantages, limitations, and overall performance of these sensors. Through comparative evaluation, it identifies which sensors offer the best balance between accuracy, efficiency, and affordability for environmental and climate data collection. The findings of this study contribute to the development of smarter, more sustainable IoT-based climate monitoring and irrigation systems.

II. Literature Review

Yu et al. (2021) The Robodo SEN6 Soil Moisture Sensor, developed by **Robodo Technologies**, is a widely adopted sensor used in academic and prototype IoT projects. It works on the principle of electrical resistance variation between probes to determine soil moisture. Studies reviewed by show that resistive-type sensors like SEN6 provide a practical and low-cost solution for soil health monitoring, though their readings can be influenced by soil salinity and corrosion over time. Despite these limitations, Robodo SEN6 remains highly suitable for small-scale IoT irrigation systems due to its affordability and easy interface with microcontrollers such as ESP32.

B. Tech Students et al. (2025), The YL-83 Rain Sensor, produced by Keyes Technology, has been commonly used in automated irrigation and smart weather monitoring systems. It operates using a conductive plate that detects the presence of water drop lets. According to a study published in the *International Journal of Advanced Research in Science, Communication and Technology*

(2025), this sensor offers rapid response and reliable detection of rainfall onset, making it effective for automatic irrigation cu toff and real-time weather alerting. However, as noted by B. Tech Students et al. (2025), it cannot measure the intensity of rainfall quantitatively, limiting its application to basic detection rather than detailed climatology.

Zvinodashe Feresu et al. (2022) The DHT11 Temperature and Humidity Sensor, manufactured by Aosong Electronics, has become a benchmark for low-cost IoT environmental measurement. The study by Zvinodashe Feresu et al. (2022) evaluated DHT11's performance and found it to be sufficiently accurate for small-scale monitoring ($\pm 2^{\circ}\text{C}$ temperature and $\pm 5\%$ RH humidity accuracy). It utilizes capacitive humidity sensing and a thermistor for temperature measurement, providing digital output easily read by microcontrollers. Due to its simple structure, energy efficiency, and low price, DHT11 remains a reliable component for entry-level IoT weather and climate systems.

Sensirion AG (Switzerland) et al. (2022) The SHT31 Temperature and Humidity Sensor, designed by Sensirion AG (Switzerland), represents a new generation of high-precision digital sensors. It uses advanced capacitive sensing elements with an integrated 16-bit ADC, ensuring fast response and accuracy up to $\pm 0.3^{\circ}\text{C}$ and $\pm 2\%$ RH. The Sensirion SHT3x Datasheet (2022) highlights its I²C interface, low power consumption, and self-heating function for condensation prevention. Although Sensirion (2022) emphasizes its industrial reliability and long-term stability, several studies conclude that the SHT31's higher cost and configuration requirements make it less suitable for low-budget IoT applications compared to DHT11.

L. Yu et al. (2021) The Vegetronix VH400 Soil Moisture Sensor, developed by Vegetronix Inc. (USA), is a high-performance capacitive probe designed to measure volumetric water content with scientific-grade accuracy. The Vegetronix Datasheet (2020) and related studies describe the VH400 as a non-corrosive, fast-response sensor ideal for professional agricultural research and precision farming. Its linear analog output simplifies calibration and data interpretation. However, the high cost and need for soil-type calibration limit its use in educational and low-cost IoT systems. Researchers such as L. Yu et al. (2021) have noted that while VH400 performs exceptionally well in controlled experiments, it may not offer a cost-effective solution for mass deployment.

III. Sensors

The Robodo SEN6 soil moisture sensor measures soil water content using capacitive sensing, offering high accuracy and corrosion resistance, making it ideal for long-term use. The YL-83 rain sensor detects rainfall through a conductive plate, helping automate irrigation by preventing watering during rain. The DHT11 temperature-humidity sensor measures ambient climate conditions with low power consumption and good stability. Together, these sensors provide complete environmental data for smart irrigation an d climate monitoring. Their low cost, easy interfacing, and reliable performance make them suitable for IoT-based applications. Overall, they form an efficient and practical sensor combination for real-time environmental observation.

1. Robodo SEN6 Soil Moisture Sensor :-

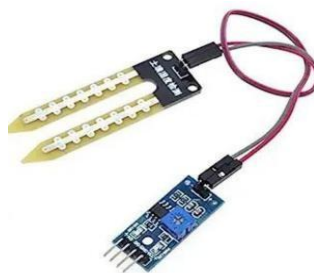


Fig.1 Robodo SEN6 Soil Moisture Sensor

Use:

The Robodo SEN6 soil moisture sensor is used to measure the amount of water present in the soil. It helps determine whether the soil has adequate moisture content for plant growth or requires irrigation. This sensor is primarily used in smart irrigation systems, agricultural monitoring, and greenhouse automation.

Purpose:

The main purpose of this sensor is to monitor the water content in soil to optimize irrigation schedules. By providing real-time moisture data, it prevents both overwatering and underwatering, which can harm crops and waste water resources. It enables automated irrigation based on actual soil needs.

Working Principle:

The Robodo SEN6 sensor operates on the principle of capacitance measurement. It detects changes in the dielectric constant of the soil, which varies according to the soil's water content. When the soil moisture increases, the capacitance value changes, and this variation is converted into an analog voltage signal that the microcontroller (ESP32) can read and process.

Advantages:

- Provides accurate readings compared to traditional resistive-type sensors.
- Corrosion-resistant due to capacitive sensing technology.
- Low power consumption and easy to interface with microcontrollers.
- Offers stable readings over long-term use.
- Ideal for outdoor environmental and agricultural monitoring.

Limitations:

- Requires proper calibration for different soil types.
- Accuracy may vary if installed too close to rocks or roots.
- Sensitive to large temperature variations.
- Limited sensing depth compared to advanced probes.

Why It Is Best:

The Robodo SEN6 is considered superior because it uses **capacitive sensing**, making it more durable and accurate than older resistive moisture sensors that degrade over time. It provides stable and long-term performance, making it highly suitable for IoT-based precision agriculture applications.

2. YL-83 Rain Sensor



Fig.2 YL-83 Rain Sensor

Use:

The YL-83 rain sensor is designed to detect rainfall and its intensity. It is used in automated irrigation systems, weather stations, and environmental monitoring setups to measure whether it is raining and how heavily.

Purpose:

Its main purpose is to sense rainfall in real time and help systems decide when irrigation should stop or be postponed to conserve water. It plays an important role in climate monitoring, automated wipers, and smart irrigation systems where rainfall data affects decision-making.

Working Principle:

The YL-83 sensor consists of a rain detection board and a control module. When raindrops fall on the conductive surface, they create a change in resistance. The control board converts this change into a corresponding analog or digital signal. The intensity of rainfall determines the output voltage — lower resistance indicates heavier rainfall.

Advantages:

- Simple and inexpensive design.
- Easy interfacing with microcontrollers such as ESP32.
- Capable of providing both digital and analog outputs.
- Helps save water by pausing irrigation during rain.
- Can detect even light rainfall.

Limitations:

- The sensing plate can corrode over time if not properly coated.
- Requires regular cleaning and maintenance for accurate readings.
- Sensitivity decreases in dusty or polluted environments.
- Provides limited quantitative rainfall measurement compared to professional rain gauges.

Why It Is Best:

Despite being a low-cost sensor, the YL-83 offers reliable performance for detecting rainfall. Its simplicity, quick response, and compatibility with IoT platforms make it ideal for automatic irrigation and weather-sensing systems. When integrated with the ESP32, it ensures timely rain detection for efficient irrigation control.

3. DHT11 Temperature and Humidity Sensor

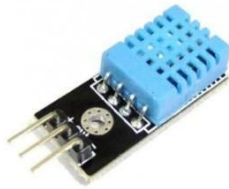


Fig.3 DHT11 Temperature and Humidity Sensor

Use:

The DHT11 sensor is used to measure ambient temperature and relative humidity in the surrounding environment. It is widely used in weather monitoring, greenhouses, smart homes, and IoT-based climate control systems.

Purpose:

The sensor's purpose is to provide real-time climate data that can help understand environmental changes affecting plant growth, soil evaporation rate, and air quality. In irrigation systems, it supports climate-based watering decisions by monitoring humidity and temperature variations.

Working Principle:

The DHT11 sensor uses a thermistor to measure temperature and a capacitive humidity sensor to measure moisture in the air. These two sensing elements generate analog signals that are converted into digital output by an internal microcontroller, allowing easy interfacing with systems like the ESP32.

Advantages:

- Low cost and easy to integrate with microcontrollers.
- Provides both temperature and humidity data in a single module.
- Calibrated digital output ensures stable performance.
- Suitable for indoor and outdoor environmental monitoring.
- Consumes very little power, making it ideal for IoT nodes.

Limitations:

- Limited measurement range (0–50°C temperature, 20–90% humidity).
- Lower accuracy compared to advanced sensors like DHT22 or BME280.
- Slower response time in high-humidity environments.
- Not suitable for very harsh or wet conditions without protection.

Why It Is Best:

The DHT11 is preferred for low-cost IoT systems due to its simplicity and sufficient accuracy for general monitoring tasks. It provides a good balance between cost, performance, and power consumption, making it ideal for academic, prototype, and small-scale IoT projects.

4. SHT31 Temperature and Humidity Sensor



Fig.4 SHT31 Temperature and Humidity Sensor

Use:

The SHT31 sensor is used to measure ambient temperature and relative humidity with high precision. It is commonly applied in IoT-based weather stations, environmental monitoring systems, greenhouses, smart homes, and industrial climate control applications. The sensor helps in collecting accurate atmospheric data that can be transmitted through IoT platforms for real-time analysis and automated decision-making.

Purpose:

The main purpose of the SHT31 is to provide reliable and precise temperature-humidity data for systems that require environmental awareness. It is designed to support data-driven climate regulation, ensuring stable environmental conditions in sensitive applications such as agriculture, laboratories, and storage facilities. Its integration enables smart systems to optimize operations based on climate variations.

Working:

The SHT31 uses capacitive humidity sensing and band-gap temperature sensing technologies. The humidity sensor works by detecting the change in capacitance of a polymer layer as it absorbs or releases water vapor. The temperature sensor detects voltage changes in a thermistor element. The built-in ADC (Analog-to-Digital Converter) converts analog signals to digital form, transmitted via I²C or SPI communication to microcontrollers like ESP32 for precise, fast, and low-noise data.

Advantages:

- High measurement accuracy ($\pm 2\%$ RH and $\pm 0.3^\circ\text{C}$).
- Wide operating range (-40°C to $+125^\circ\text{C}$; 0–100% RH).
- Fast response and long-term stability.
- Compact, low power, and easily integrated with IoT devices.
- Built-in self-heating feature to prevent condensation.

Limitations:

- More expensive than basic sensors like DHT11.
- Sensitive to contaminants such as chemicals or dust.
- Requires proper calibration for prolonged outdoor use.

Why It Is Best:

The SHT31 stands out due to its industrial-grade accuracy, stability, and reliability, even under harsh environmental conditions. It surpasses older models like the DHT11 in accuracy, response time, and measurement range, making it ideal for advanced IoT environmental and climate monitoring applications.

5. Vegetronix VH400 Soil Moisture Sensor



Fig.5 Vegetronix VH400 Soil Moisture Sensor

Use:

The Vegetronix VH400 is used to measure the volumetric water content (VWC) of soil. It is widely used in smart irrigation systems, agricultural automation, environmental research, and soil health analysis. It provides instant feedback about soil moisture levels, enabling efficient water usage and better crop management.

Purpose:

The main purpose of the VH400 is to ensure accurate soil moisture monitoring for optimizing irrigation and preventing water wastage. It helps in maintaining the right moisture balance in soil, which is crucial for crop yield improvement, soil conservation, and sustainable agriculture. It is designed to support IoT systems that automatically adjust irrigation schedules based on soil conditions.

Working:

The VH400 operates on a capacitive sensing principle, where it measures the dielectric permittivity of the soil, which changes with moisture content. The sensor outputs a linear analog voltage (0–3V) proportional to the moisture level. This output can be read by controllers like ESP32 or Arduino to convert voltage into moisture percentage, making real-time soil analysis possible.

Advantages:

- Non-corrosive and durable (no exposed metal parts).
- High accuracy and fast response time.
- Unaffected by soil salinity or temperature changes.
- Linear output simplifies calibration and data processing.
- Long lifespan and suitable for continuous monitoring.

Limitations:

- Costlier than low-end sensors like SEN6 or FC-28.
- Requires firm soil contact for precise readings.
- Needs calibration for different soil textures.

Why It Is Best:

The VH400 is considered one of the most reliable and accurate soil moisture sensors available. Its capacitive, non-corrosive design ensures long-term stability, making it superior to resistive sensors like SEN6. It delivers scientific-grade accuracy, making it the best choice for research, precision farming, and IoT-based irrigation systems that demand consistent and real-time soil data.

-Comparative Analysis of IoT Sensors for Environmental and Climate Monitoring

Sensor Name	Accuracy	Cost Efficiency	Performance	Remarks
Robodo SEN6 Soil Moisture Sensor	Moderate (±5%)	Very High	Good	Simple, reliable and ideal for low-cost IoT irrigation systems
YL-83 Rain Sensor	Moderate	High	Good	Fast rain detection; excellent for basic rainfall monitoring

DHT11 Temperature & Humidity Sensor	Moderate (±2 °C, ±5% RH)	Very High	Good	Affordable and accurate enough for small IoT weather systems
SHT31 Temperature & Humidity Sensor	High (±0.3 °C, ±2% RH)	Low	Average	Highly precise but costly; needs calibration and setup
Vegetronix VH400 Soil Moisture Sensor	Very High (±1%)	Low	Average	Professional- grade accuracy expensive and complex for IoT

IV. Applications

- Smart Irrigation Management: Automatically regulates water supply to crops based on soil moisture levels, ensuring precise and timely irrigation.
- Water Conservation Systems: Minimizes water wastage by delivering only the required amount of water according to real-time field data.
- Precision Agriculture: Enables data-driven decision-making for optimal crop growth, improving productivity and yield quality.
- Remote Farm Monitoring: Allows farmers to observe soil, temperature, and humidity data remotely through the Blynk IoT platform.
- Climate-Adaptive Farming: Helps adjust irrigation schedules based on changing weather conditions, such as rainfall or high humidity.
- Greenhouse Automation: Can be implemented in controlled environments to monitor and manage irrigation and humidity levels automatically.
- Energy-Efficient Irrigation: Reduces power usage by operating pumps only when required, leading to significant energy savings.
- Multi-Crop Cultivation Management: Supports different irrigation requirements for various crops by modifying sensor thresholds.
- Urban Gardening and Smart Landscaping: Can be deployed in urban farms, gardens, and parks for automatic watering and plant health management.
- Research and Development: Useful for agricultural research institutions studying soil behavior and environmental impacts on crops.
- Rural Development Projects: Provides a cost-effective technological solution to improve small-scale farming efficiency in rural areas.
- Disaster and Drought Management: Helps monitor soil dryness and predict potential drought conditions to assist in preventive actions.
- Integration with Cloud Analytics: Enables long-term data storage and trend analysis for improved future irrigation planning.
- Educational Demonstrations: Serves as a valuable academic project for students learning about IoT, automation, and agriculture technology.
- Sustainable Farming Practices: Promotes eco-friendly farming by conserving natural resources, reducing manual labor, and improving food security.

V. Conclusion

In conclusion, the integration of the Robodo SEN6 soil moisture sensor, YL-83 rain sensor, and DHT11 temperature-humidity sensor offers a highly reliable, efficient, and cost-effective approach for environmental and climate monitoring using IoT technology. These sensors collectively provide comprehensive data that helps in understanding soil, rainfall, and climatic variations for smart agricultural and environmental applications. The Robodo SEN6 soil moisture sensor is particularly effective

due to its capacitive sensing principle, which ensures long-term durability, corrosion resistance, and accurate moisture readings. This makes it suitable for continuous field use where soil health monitoring and irrigation control are critical. The YL-83 rain sensor efficiently detects rainfall by sensing the presence and intensity of water droplets on its conductive surface, providing quick and accurate responses. This feature is especially beneficial for automated irrigation systems that need to stop watering during rainfall, thus conserving water and preventing over-irrigation. The DHT11 temperature-humidity sensor complements the system by measuring environmental temperature and humidity, giving valuable insights into the climatic conditions affecting soil moisture and crop growth. Its low power consumption, compact size, and digital output make it an excellent choice for IoT-based monitoring systems. These sensors are considered the best for such applications because they combine accuracy, simplicity, affordability, and compatibility with microcontrollers like the ESP32. Their seamless integration with IoT platforms such as Blynk allows real-time data visualization and control through mobile or web dashboards, enhancing decision-making and system automation. The entire setup enables farmers and researchers to monitor environmental conditions remotely and make timely interventions based on actual data. Furthermore, the combination of these sensors supports sustainable agricultural practices by reducing water wastage, optimizing resource usage, and improving crop productivity. Their cost-effectiveness makes them accessible for educational research, small farms, and experimental projects, promoting the use of smart technology in rural and developing regions. Overall, the Robodo SEN6, YL-83, and DHT11 sensors together form a well-balanced and efficient IoT sensor network that ensures accurate data collection, dependable performance, and long-term environmental benefits. Hence, they stand out as some of the most practical and high-performing sensors for real-time environmental and climate monitoring applications.

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