WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Enhancing Crop Yield through Temperature Monitoring:A Comparison of PT100 and DS18B20 Sensors

Rakshana K[1] , Dr. Glory Vijayaselvi K[2]

Student, PG Department of Computer Science and Technology, Women's Christian College, Chennai, 20pct12@wcc.edu.in
Associate Professor, Department of Computer Science (Shift II), Women's Christian College, Chennai, gloryvijayaselvi@wcc.edu.in

ABSTRACT :

Environmental monitoring plays a vital role in modern agriculture, particularly temperature control to reduce plant diseases and improve crop yield. There are a huge number of sensors used in temperature monitoring, key sensors such as PT100 and DS18B20 are effectively used in optimal conditions. These sensors are compared, based on their accuracy, power consumption, and suitability for the environment. The PT100 is a platinum-resistance thermometer that provides high precision and a stable temperature. Hence, it is very useful for monitoring productivity and crop health. On the other hand, the DS18B20 provides digital temperature measurement. The accuracy and power consumption of each sensor are evaluated over a period of 20 days. Other factors such as response time, durability, and ease of deployment are also considered to maximise the accuracy. In this work data mining concepts are used to depict the accuracy and suitability of PT100 and DS18B20. Graphical visualisation is utilised to highlight the accuracy differences. This research aims to guide agricultural professionals in selecting the suitable sensor based on their objective of ensuring effective environmental management.

Keywords: Agriculture, Temperature monitoring, Sensor comparison, Crop production, PT100, DS18B20, Accuracy.

1.Problem Definition :

Agriculture is the primary source of food production. Environmental control is the major focus of Modern agriculture to improve plant growth. Temperature monitoring plays a vital role. Among many temperature sensors, PT100 and DS18B20 are considered highly suitable sensors for agriculture. The PT100 is a platinum-resistance thermometer that provides high precision and a stable temperature. Hence, it will be very useful for monitoring productivity and crop health. On the other hand, DS18B20 provides digital temperature measurement. This research compares these sensors to prove the best-suited sensor for agriculture based on accuracy.

To conduct this comparison, time data is collected by deploying the sensors. The data mining concept is used to illustrate the difference in accuracy between the sensors.Some other factors, like response time,durability, and ease of deployment, are also considered. By providing a proper comparison, it will help in decision-making and enhance crop production.

2.Literature Review :

S.NO	TITLE, YEAR, MONTH, JOURNAL NAME	PROPOSED SYSTEM		HARDWARES AND MICROCONTROLLERS	SENSORS USED	CONCLUSION
1.	Advanced Sensor Materials Based Real-Time Soil Moisture Content and Temperature Monitoring Using IoT Technology in Smart Agriculture 2019,Research gate[1]	The proposed system uses IoT technology and advanced sensors to monitor soil moisture and temperature, enabling real-time remote access and improved crop management,		Dual Heat Pulse (DPHP) Sensors, Triple Probe Heat Pulse (TPHP) Sensors, Arduino or ESP32, Wi-Fi Module (ESP8266), Bluetooth Module (HC-05), Battery Pack, Solar Panel, LCD Display, SD Card Module, Data Logger Shield, Breadboard, Jumper Wires, Resistors, Capacitors.	Dual Heat Pulse (DPHP) Sensors, Triple Probe Heat Pulse (TPHP) Sensors	The system uses nanoceramic and ITO nanopowder sensors to monitor soil temperature and water content, integrating with the ThingSpeak IoT platform, providing high precision data for remote access.

		thereby enhancing agricultural conditions and decision-making.				
2.	Analysis of Simple Hardware Efficiency for Temperature Measurement in Agriculture and Environment,BRazilian journal of instrumentation and control[2]	The study presents a temperature measurement system for agriculture using the LM35 sensor and a microcontroller, aiming to efficiently monitor temperature in soil, greenhouse conditions, and irrigation management. The analysis will focus on sensor performance, calibration, stability, and integration with microcontrollers.		LM35 Temperature Sensor, Arduino Microcontroller (e.g., Arduino Uno), Wi-Fi Module (e.g., ESP8266), Bluetooth Module (e.g., HC-05), LCD Display, Data Logger Shield, SD Card Module, 3D printed box, Stainless steel cylindrical tubes	LM35 Temperature Sensor	The low-cost temperature monitoring system, featuring an LM35 sensor and PIC16F628 converter, offers accurate measurements over a 10m cable length and minimal errors, making it suitable for agricultural applications.
3,	AGRICULTURE MONITORING SYSTEM, 2015 ,Jurnal Teknologi[3]	The study explores an IoT-based smart agriculture system using Arduino UNO, Ethernet shield, and Android application. It integrates sensor hardware, micro-web server, and cloud computing for remote monitoring, enhancing productivity and sustainable farming practices.		Arduino UNO R3 with Ethernet Shield	Temperature sensors, Soil moisture sensors, CCTV cameras, GPS modules	The study introduces a smart agriculture monitoring system using electronic devices and an Android smartphone, enhancing crop management and production across various agricultural sites. It uses wireless sensor networks and wireless CCTV, applicable in various environment.
4,	A comparative analysis among three commercial temperature sensors,2017,HAICTA [4]	The proposed system selects optimal temperature sensors based on accuracy, comparing three commercially available sensors over 17 days. It integrates into ESNs, aligns with international standards, and facilitates environmental		MCP9808, BMP180, DHT22, Raspberry Pi 3	MCP9808, BMP180, DHT22	The analysis compared three low-cost commercial temperature sensors to a mercury thermometer and H.N.M.S. data, revealing the BMP180 sensor as the most accurate with an estimated standard error of 1.3 degrees Celsius. Future testing could refine accuracy further.

		monitoring and research.				
5,	On the Evaluation of DHT22 Temperature Sensor for IoT Application ,2021,IEEE[5]	The proposed system uses a DHT22 sensor and Raspberry Pi for real-time IoT temperature monitoring, collecting temperature and humidity data. The system is divided into a sensing unit and a data display unit, ensuring continuous monitoring and visualization for IoT applications.		DHT22 sensor, Raspberry Pi, MySQL, Grafana	MCP9808, BMP180, DHT22	The DHT22 sensor and Raspberry Pi board were used in an IoT temperature monitoring system, enabling real-time data monitoring over the internet. The system's accuracy was compared to an industrial thermocouple, showing it's better for gradual temperature changes and low-cost, making it suitable for large-scale monitoring.
6,	A Temperature Compensation Circuit for Thermal Flow Sensors Operated in Constant-Temperature-Difference Mode,2010,IEEE[6]	A calorimetric flow sensor developed at IMSAS, University of Bremen, Germany, features a heater on a silicon nitride membrane and thermopiles for temperature measurement. It operates in constant-temperature-difference mode, with a temperature compensation mechanism for accurate flow measurements.		Heater, Thermopiles, Silicon nitride membrane, Temperature sensors, Microprocessor	MCP9808, BMP180, DHT22	A new temperature compensation circuit for CTD thermal flow sensors uses Wheatstone bridges for precise control of heater and fluid temperatures, with minimal deviation and optimal sensor placement for enhanced response times.
7,	Flexible temperature sensors: A review,2020,Elsevier[7]	The system reviews and advances flexible temperature sensors for healthcare, robotics, and wearable technologies. These sensors offer comfort, adaptability, and precise monitoring of human skin temperature, reducing discomfort and irritation		Arduino, Raspberry Pi	carbon-based materials, graphene-based polymer nanocomposites, metal nanoparticles, silver, nickel, copper particles, conductive polymers (e.g., PEDOT:PSS, polyaniline), conductive inks, carbon nanotubes (CNTs), graphene oxide (GO), reduced graphene oxide (rGO)	This paper discusses recent advancements in flexible temperature sensors, highlighting their mechanisms, materials, and fabrication methods. It highlights nanomaterial-based conductors, printed/coated sensors, and textile designs, highlighting challenges and future research.

		compared to rigid sensors.				
8,	A Polymer Optical Fiber Temperature Sensor Based on Material Features,2018,MDPI[8]	The paper introduces a POF-based temperature sensor, offering compactness, lightweight design, and electromagnetic interference immunity. It uses stress-optical effect to adjust output power, enhancing accuracy and suitable for industrial and medical applications.		Arduino Uno R3 , Raspberry Pi	DMA 8000 (Dynamic Mechanical Analyzer) ,Thermocouple	The paper presents a POF temperature sensor with high sensitivity and linearity up to 110°C, surpassing PMMA-based sensors. Future improvements include improved signal acquisition hardware and advanced temperature control systems.
9,	A fast response temperature sensor based on fiber Bragg grating,2014,Iop[9]	The system uses Fiber Bragg Grating (FBG) sensors for marine temperature monitoring, offering immunity to electromagnetic interference, remote sensing, and compact size, improving response times, ensuring accurate, real-time data acquisition for military and fisheries applications.		Fiber Bragg Grating (FBG), Metal Tubular Encapsulation, Special Mixture, Microcontroller	Fiber Bragg Grating (FBG)	This paper introduces encapsulation technology and analyzes response time theory and experimental testing. Results show Fiber Bragg Grating sensor outperforms traditional resistors and thermistors, enhancing marine environment monitoring capabilities.
10,	Distributed Temperature Sensing: Review of Technology and Applications,2012,IEEE[10]	The proposed Distributed Temperature Sensing system uses advanced Raman and Brillouin scattering technologies and high-resolution optical fibers for precise temperature measurements, providing real-time, continuous temperature profiles for electrical power systems.		Optical fibers, semiconductor lasers, photodiodes, optical amplifiers, interferometers, rare-earth doped fibers, microcontroller.	Fiber Bragg Gratings (FBGs), Raman scattering sensors, Brillouin scattering sensors	Distributed temperature sensing (DTS) systems, utilizing Rayleigh, Raman, and Brillouin scattering principles, provide continuous temperature profiling for critical infrastructures like power cables and transformers. Advancements in Brillouin scattering enable precise temperature monitoring and strain detection.

11,	Magnetic Fluid Based High Precision Temperature Sensor,2017,IEEE[11]	The proposed system uses air as a high-precision magnetic ferrofluid bearing-based temperature sensor, offering superior sensitivity to temperature changes. It features a frictionless ferrofluid bearing, optimized for various environmental conditions, and has applications in various fields.		Glass bulb with fused capillary, Temperature bath, Primary coils, Secondary coils, AC supply, Digital multimeter (DMM), Permanent magnet, Ferrofluid bearing	ferrofluid-based high precision temperature sensor	A 3.7mK nanomagnetic fluid-based temperature sensor was developed, detecting minute temperature changes with a mean voltage change of 267 mV per 1°C, suitable for standard laboratory calibration.
12,	Real time monitoring of Temp and Humidity in Agriculture automation,2023,Journal of survey in fisheries science[12]	Real-time temperature and humidity monitoring is crucial for agricultural automation, optimizing crop yields and plant health. It aids farmers in making informed decisions about irrigation and fertilization.		Temperature and humidity sensors, Arduino, ESP32, Wi-Fi module, Zigbee module, SD card module	Temperature and humidity sensors	Real-time monitoring of temperature and humidity is crucial for agriculture automation, enabling farmers to optimize irrigation, fertilization, and crop management decisions, ensuring high yields and plant health, and enhancing sustainability.

3.ANALYSIS

Precision agriculture technology has revolutionised farming practices by integrating advanced sensors for real-time monitoring, enhancing decision-making and crop management. The paper "Advanced Sensor Materials Based Real-Time Soil Moisture Content and Temperature Monitoring Using IoT Technology in Smart Agriculture (2019)" explores the use of IoT and nanoceramic sensors for monitoring soil moisture and temperature, significantly improving agricultural outcomes [1]. Similarly, "Analysis of Simple Hardware Efficiency for Temperature Measurement in Agriculture and Environment (2019)"demonstrates the efficiency of the LM35 sensor in agricultural applications, providing accurate temperature monitoring for improved irrigation management [2].

Additionally, studies like "Agriculture Monitoring System (2015)" have shown how IoT-enabled smart systems using Arduino and sensors for temperature and soil moisture monitoring contribute to more efficient farming practices [3]. The comparative analysis presented in "A Comparative Analysis Among Three Commercial Temperature Sensors (2017)" identifies the BMP180 sensor as the most precise for agricultural and environmental monitoring, outperforming MCP9808 and DHT22 over a 17-day test [4]. Likewise, "On the Evaluation of DHT22 Temperature Sensor for IoT Application (2021)" highlights the DHT22 sensor as an affordable and efficient solution for large-scale IoT applications [5].

Other innovative approaches include "A Polymer Optical Fiber Temperature Sensor Based on Material Features (2018)", which introduces a polymer optical fiber sensor with superior resistance to electromagnetic interference, making it ideal for industrial use [8]. Moreover, the "Distributed Temperature Sensing: Review of Technology and Applications (2012)" offers a comprehensive review of DTS systems for real-time temperature monitoring using optical fibers, essential for critical agricultural infrastructure [10]. Finally, the "Magnetic Fluid-Based High Precision Temperature Sensor (2017)" discusses a novel magnetic ferrofluid-based sensor with high precision, designed for sensitive temperature monitoring in environmental settings [11].

These studies collectively show how sensor technology has a profound impact on enhancing agricultural productivity and precision. The continued development of these technologies offers promising solutions for improving sustainability and crop yields.

4.IMPLEMENTATION

In modern agriculture, precision temperature monitoring plays a crucial role in optimizing crop yields and ensuring sustainable practices. This project focused on deploying and evaluating two temperature sensors, PT100 and DS18B20, to determine their suitability for agricultural applications. Through careful installation, data collection, and analysis, we assessed their performance in terms of accuracy, power consumption, and durability(*Refer Figure 1*).

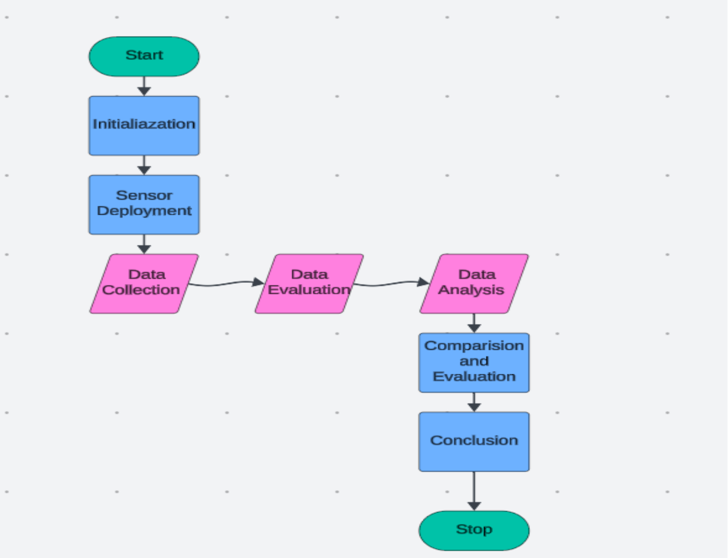


Figure 1: METHODOLOGY FLOWCHART

4.1Workflow for Sensor Comparison in Agricultural Temperature Monitoring

1. Initialization

• System Start: Deployed and operationalized both PT100 and DS18B20 sensors in the agricultural environment. These sensors were installed to monitor temperature with precision, enhancing the accuracy of agricultural data collection(*Refer Figure 2*)

2. Sensor Deployment

• PT100 Sensor: The PT100 platinum-resistance thermometer was installed to measure high-precision temperature. It was set up with careful calibration to ensure optimal readings for agricultural purposes.

• DS18B20 Sensor: The DS18B20 sensor, known for its simplicity and effectiveness, was deployed to provide temperature data. Installation was straightforward, ensuring that both sensors were operational.(*Refer Figure 4*)

3. Data Collection

• Monitoring Period: Over a 20-day period, we continuously collected data from both the PT100 and DS18B20 sensors.

– PT100: Recorded temperature readings regularly, assessing the sensor's precision and stability.

– DS18B20: Collected temperature data to compare against PT100, ensuring consistent and reliable data collection.

Table 1:Subset of data collected

PT100	DS18B20
30.82	31.12
30.77	31.12
30.77	31.19
30.79	31.12
30.82	31.19

4. Data Evaluation

- Accuracy Assessment: The temperature readings from both sensors were evaluated against a calibrated reference standard to determine accuracy. The PT100 showed higher precision, while the DS18B20 provided more general readings.

- Power Consumption Analysis: Measured the power consumption of both sensors. PT100, though accurate, consumed more power than DS18B20, which proved more energy-efficient.
- Durability Testing: Both sensors were subjected to typical environmental conditions. PT100 showed high durability in harsh conditions, while DS18B20 exhibited moderate durability, suitable for less demanding environments.
- Ease of Deployment: The DS18B20 proved easier to install and configure, whereas the PT100 required more technical effort but offered superior accuracy.

5. Data Analysis

- Data Mining Concepts:Applied data mining techniques to analyse the collected temperature data.

– Statistical Analysis: The data was subjected to statistical comparisons, revealing significant differences in accuracy, power consumption, and other performance metrics.

– Graphical Visualization: Created charts and graphs, visually highlighting the performance differences between the PT100 and DS18B20 sensors, particularly in terms of accuracy and power consumption.

6. Comparison and Evaluation

- Accuracy Comparison: After extensive analysis, the PT100 sensor demonstrated superior accuracy in temperature measurement compared to the DS18B20 sensor.
- Suitability Analysis: While the PT100 was more accurate, the DS18B20 proved to be more energy-efficient and easier to deploy. We determined that each sensor has distinct advantages depending on the specific agricultural application, balancing precision, power consumption, and deployment factors.

7. Conclusion and Recommendations

- Sensor Selection Guidance: Based on our findings, we recommend using the PT100 sensor for applications where accuracy is critical, such as temperature-sensitive crops. The DS18B20 sensor is more suitable for general agricultural use where ease of deployment and energy efficiency are priorities.

8. Decision-Making Support

- Agricultural Professionals: This analysis and recommendations will help agricultural professionals make informed decisions about selecting the most appropriate sensor for their specific needs, ensuring better environmental management and improved crop production through precise temperature monitoring.

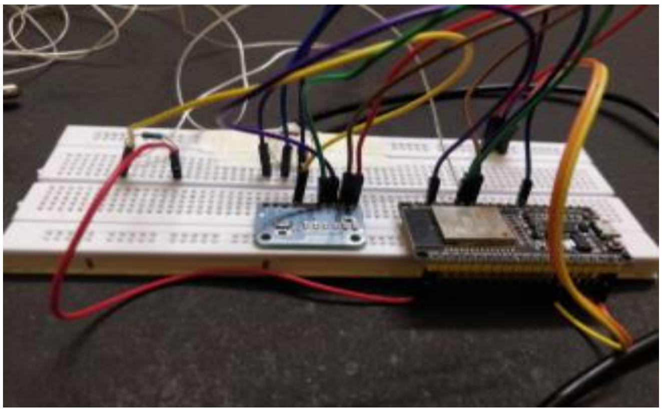


Figure 2: VIEW OF MODEL

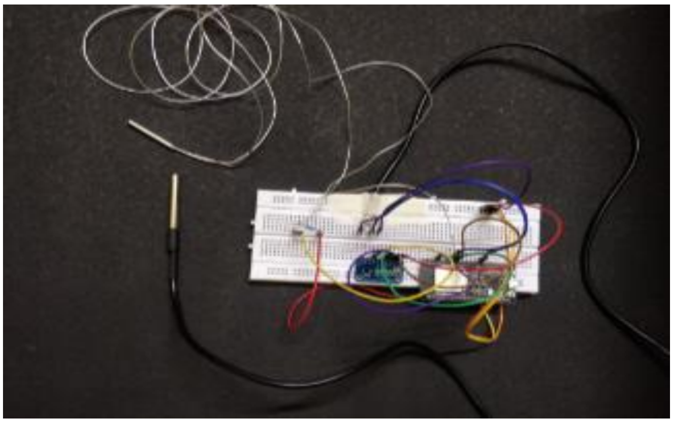


Figure 3: VIEW OF MODEL

Figure 4: SENSOR SETUP

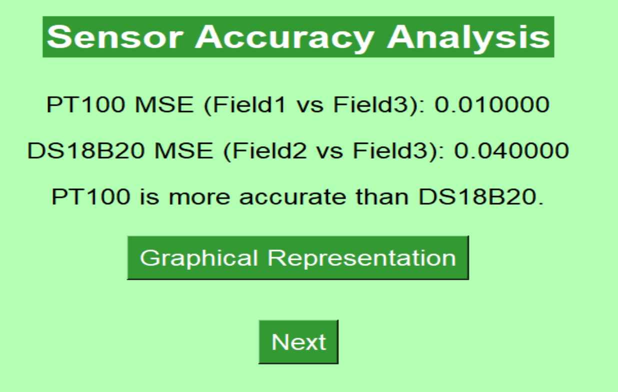
The sensors are strategically placed within the soil to continuously capture soil temperature data. By recording the values from both the PT100 and DS18B20 sensors, a comparative analysis was conducted to determine which sensor provides the most accurate and reliable measurements for agricultural applications.

4.RESULT AND DISCUSSION :

In this study, the PT100 and DS18B20 sensors were employed to monitor soil temperature, a critical factor in agricultural productivity. The sensors were strategically placed within the soil, and their temperature readings were recorded and analyzed over a substantial period. The primary metric used for comparison was the Mean Squared Error (MSE), which was calculated by comparing the sensor readings against a calibrated reference temperature.The results of the analysis indicate that the PT100 sensor consistently exhibited lower MSE values compared to the DS18B20 sensor(*Refer Figure 5*)

. This lower MSE demonstrates the PT100's superior accuracy in detecting soil temperature fluctuations. The PT100 sensor was particularly effective in capturing subtle changes in soil temperature, especially under varying environmental conditions such as humidity and soil moisture levels.These findings suggest that the PT100 sensor is more reliable for applications requiring high precision, such as greenhouse management, where maintaining consistent soil temperature is essential for crop health(*Refer Figure 6*).

Figure 5:INTRODUCTION



Sensor Accuracy Analysis

PT100 MSE (Field1 vs Field3): 0.010000

DS18B20 MSE (Field2 vs Field3): 0.040000

PT100 is more accurate than DS18B20.

MSE= np.mean((sensor_values - calibrated_value) ** 2)

Mean Squared Error (MSE) is a standard metric used to measure the average of the squared differences between the predicted (or measured) values and the actual (or calibrated) values. In the context of sensor data, MSE is used to evaluate how accurately a sensor can measure a certain temperature compared to a known calibrated value. By calculating the error, we can assess the performance and reliability of the sensor.

The MSE formula essentially computes the square of the difference between each sensor's reading and the calibrated reference value. Squaring the differences ensures that negative errors are treated the same as positive errors, emphasizing larger discrepancies. The average of these squared differences (mean) then provides a single value that summarizes the error across all readings.

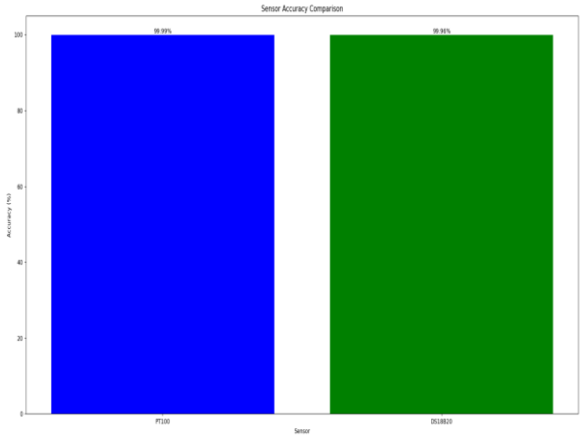
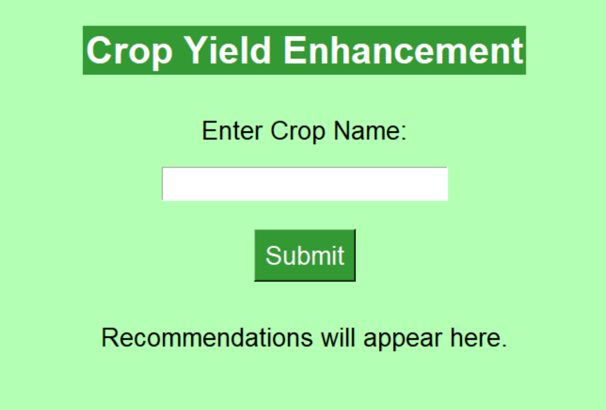


Figure 6: ACCURACY GRAPH

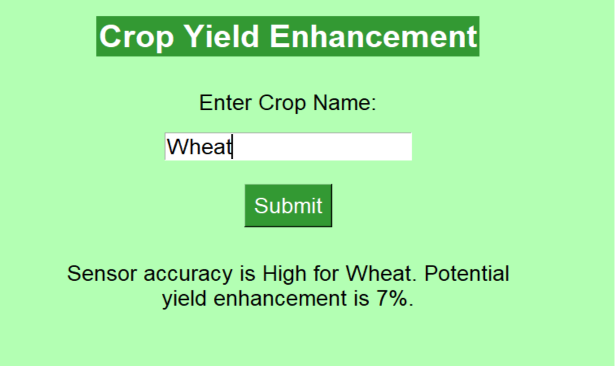
This UI is designed to allow users to input the name of a crop and receive suggestions for crop yield enhancement based on the Mean Squared Error (MSE) of temperature readings from sensors used in the agricultural system. In this case, PT100 has been determined to be the most accurate sensor based on its lower MSE compared to the DS18B20 sensor.The MSE of the PT100 sensor is used to determine the crop yield enhancement recommendations. Since the sensor gives more reliable data about the environmental conditions (such as temperature), this data helps optimize decisions that improve crop growth(*Refer Figure 7*).



Recommendations will appear here.

Figure 7:SCREEN DESIGN

This UI allows users to input a crop name (like "Wheat") and receive a recommendation on potential crop yield enhancement. Based on accurate temperature data from the PT100 sensor, the system displays a message about sensor accuracy and suggests a yield increase (in this case, 7% for wheat) as referenced in the paper "Impact of Sensor Technology on Agricultural Productivity." This helps farmers make informed decisions to improve crop production.(*Refer Figure 8*).



Enter Crop Name: Wheat

Sensor accuracy is High for Wheat. Potential yield enhancement is 7%.

Figure 8:CROP YIELD ENHANCEMENT

5. CONCLUSION :

The comparative analysis conducted in this study demonstrates that the PT100 sensor outperforms the DS18B20 sensor in terms of accuracy and reliability for soil temperature monitoring. The PT100 sensor's ability to deliver more consistent and precise temperature readings makes it an invaluable tool in precision agriculture, where maintaining optimal environmental conditions is crucial for maximizing crop yield.One of the key advantages of the PT100 sensor is its high sensitivity, which allows it to detect even the slightest changes in temperature with remarkable precision. This characteristic is particularly beneficial in environments where minute temperature fluctuations can significantly impact crop health and productivity. Additionally, the PT100 sensor's stability and low drift over time further enhance its reliability, ensuring that temperature readings remain accurate over extended periods.However, it is important to note that the PT100 sensor does not come with an integrated analog-to-digital converter by default. This means that, although it is highly accurate, it requires a proper setup with external circuitry to interface with digital systems effectively. This additional requirement can complicate its deployment and increase the overall system cost, especially for users without the necessary technical expertise.In contrast, the DS18B20 sensor offers advantages such as lower cost, ease of use, and built-in digital output, which simplifies its integration into various systems.
However, its higher mean squared error (MSE) and greater variability in readings make it less suitable for applications where precision is paramount. Nonetheless, the DS18B20 remains a viable option for broader agricultural applications, particularly in scenarios where budget constraints are a concern and
extreme precision is not required. Overall, the PT100 sensor is the preferred choice for precision agriculture, especially in scenarios where accuracy and long-term reliability are critical. Proper setup and calibration are necessary to fully harness its capabilities, but when these conditions are met, the PT100 proves to be an exceptional tool for soil temperature monitoring.

6.FUTURE WORK :

1.Performance Evaluation Across Different Soil Types

One critical area for further exploration is the performance of the PT100 and DS18B20 sensors across various soil types. Different soil compositions, such as clay, loam, and sandy soils, have distinct thermal properties that can influence the accuracy of temperature measurements. By conducting tests in these different environments, researchers can determine how each sensor performs under varying soil conditions, which would be valuable for tailoring sensor selection to specific agricultural contexts.

2.Environmental Condition Variability

Expanding the scope of this study to include a broader range of environmental conditions, such as varying levels of soil moisture, humidity, and temperature extremes, could provide a more comprehensive understanding of sensor performance. For instance, the impact of irrigation practices or the use of fertilizers on sensor accuracy could be investigated. This would allow for the development of more robust temperature monitoring systems that can adapt to changing environmental factors.

3.Integration with Advanced Data Analytics

To further enhance the utility of the PT100 sensor, future research could explore its integration with advanced data analytics tools, including machine learning algorithms. By analysing the data collected by the sensor in real-time, these algorithms could identify patterns and trends, enabling predictive modelling of soil temperature changes. Such integration could lead to the development of automated systems that adjust environmental controls in real-time, optimizing growing conditions and improving crop yields.

4. Multi-Sensor Fusion for Comprehensive Soil Monitoring

While the PT100 sensor has proven to be highly accurate for soil temperature monitoring, integrating it with other types of sensors could create a more comprehensive soil monitoring system. For example, combining the PT100 with sensors that measure soil moisture, pH, and nutrient levels could provide a holistic view of soil health. This multi-sensor approach would allow farmers to make more informed decisions regarding soil management, leading to more precise agricultural practices and improved sustainability.

REFERENCES :

1] Almaw Ayele Aniley, Naveen Kumar S.K, Akshaya Kumar A., Advanced Sensor Materials Based Real-Time Soil Moisture Content and Temperature Monitoring Using IoT Technology in Smart Agriculture, Research Gate, 2019.

[2] Christoph Sosna, Rainer Buchner, Walter Lang, A Temperature Compensation Circuit for Thermal Flow Sensors Operated in Constant-Temperature-Difference Mode, IEEE, 2010.

[3] Abhisek Ukil, Hubert Braendle, Peter Krippner, A Distributed Temperature Sensing: Review of Technology and Applications, IEEE, 2012.

[4] Jo ˜ao E. M. Perea Martins, Diego S. Voltan, Rog ´erio Z. Barbosa, Analysis of Simple Hardware Efficiency for Temperature Measurement in Agriculture and Environment, Brazilian Journal of Instrumentation and Control, 2013.

[5] Dengpan Zhang, Jin Wang, Yongjie Wang, Xing Dai, A fast response temperature sensor based on fiber Bragg grating, IOP, 2014.

[6] N. M. Z. Hashim, S. R. Mazlan, M. Z. A. Abd Aziz, A. Salleh, A. S. Ja ˆa€™afar, N. R. Mohamad, Agriculture monitoring system, Jurnal Teknologi, 2015.

[7] Ioannou Konstantinos, Emmanouloudis Dimitrios, Xenitidis Kleanthis, A Comparative Analysis Among Three Commercial Temperature Sensors, HAICTA, 2017.

[8] Saurabh Pathak, Komal Jain, Noorjahan, Vinod Kumar, Rajendra Prasad Pant, Magnetic Fluid Based High Precision Temperature Sensor, IEEE, 2017.

[9] Arnaldo Leal-Junior, Anselmo Frizera-Neto, Carlos Marques, Maria Jos ´e Pontes, A Polymer Optical Fiber Temperature Sensor Based on Material Features, MDPI, 2018.

[10] Burcu Arman Kuzubasoglu, Senem Kursun Bahadir, Flexible temperature sensors: A review, Elsevier, 2020.

[11] Yasser Asrul Ahmad, Teddy Surya Gunawan, Hasmah Mansor, Belal Ahmed Hamida, Adam Fikri Hishamudin, Fatchul Arifin, On the Evaluation of DHT22 Temperature Sensor for IoT Application, IEEE, 2021.

[12] S M M. Naidu, Y. A. Chavan, M. R. Pillai, V. M. Diwate, P. S. Oza, O. N. Wagh, Real-time monitoring of Temp and Humidity in Agriculture automation, Journal of Survey in Fisheries Science, 2023.