

# SMART AGRICULTURE FOR SUSTAINABILITY

*(The implementation of smart irrigation using real-time embedded system technology)*

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**Abstract:** This paper addresses the growing challenges of water management in agriculture by highlighting the limitations of traditional irrigation methods. It proposes an innovative solution that combines embedded systems and environmental sensors to develop a real-time intelligent irrigation system. The system uses a microcontroller and sensors to measure temperature, humidity (DHT22), soil moisture, and water level. This approach aims to reduce water wastage while improving agricultural productivity. By encouraging more sustainable farming practices, this solution contributes to the preservation of natural resources and the long-term sustainability of agriculture.

**Index Terms :** Embedded System, Microcontroller, Sensors, Irrigation

## I. INTRODUCTION

Smart agriculture represents the concept of carrying out agricultural activities in an innovative way, using the latest technologies to increase the quantity and quality of agricultural products. It represents the future of the food production sector, as well as new approaches to ensuring global food security. This approach enables farmers to rationalize their resources while increasing yields.

The integration of smart irrigation represents a crucial advance in modern agriculture, promoting sustainability and strengthening water security on a global scale. These system uses Embedded System technology and sensors to optimize water management. Additionally, in agriculture, sensors, linked with advanced technologies, are used in various facets of farming, providing real-time data and information crucial to informed decision making. By monitoring soil conditions, and crop needs in real-time, they enable precise irrigation, reducing water wastage and preserving the environment. This sustainable approach contributes to soil health by avoiding over-irrigation and mitigating negative environmental consequences.

In addition, this system has the concept of an irrigation system integrating humidity and temperature measurements using soil moisture sensors and an embedded controller. Humidity and temperature are meticulously measured and analysed using an embedded controller connected to an agricultural sensor.

## II. MAIN CONTRIBUTIONS

- This research proposes an intelligent real-time irrigation system using an advanced embedded system. This innovative approach aims to improve agricultural irrigation management to increase sustainability.
- The system integrates advanced sensors to monitor important environmental parameters such as temperature, humidity, soil moisture, and water level in real-time, improving the accuracy of the data collected.
- The system's ability to automatically adjust pump operation according to humidity and water levels emphasizes precise, adaptive management of water resources.
- Practical tests confirm the system's effectiveness in significantly reducing water wastage while maintaining agricultural productivity.
- This systematic approach offers a sustainable solution, promoting responsible use of water resources and an overall improvement in agricultural efficiency

## III. LITERATURE SURVEY

The complete literature survey for the project was published as a survey paper. A part of the literature is included here :

One notable study by Bechtold et al. (2020) explored the design and implementation of a smart irrigation system using an Arduino Mega microcontroller. The system integrated various sensors, including soil moisture, temperature, and rainfall sensors, to monitor environmental conditions. The microcontroller analysed the sensor data and used a custom algorithm to determine the optimal irrigation schedule, adjusting water application based on the specific needs of the crops. The researchers reported significant water savings, up to 30%, compared to traditional irrigation methods.

Similarly, Kamarudin et al. (2021) developed a smart irrigation system utilizing a Raspberry Pi microcontroller. Their system incorporated IoT connectivity, allowing for remote monitoring and control of the irrigation process through a mobile app. The researchers highlighted the importance of integrating weather data and predictive models to enhance the system's responsiveness to changing environmental conditions.

In a different approach, Mishra et al. (2019) investigated the use of a low-cost ESP8266 microcontroller for a smart irrigation system. Their system incorporated a web-based interface and cloud-based data storage, enabling users to access real-time information and adjust the irrigation schedule remotely.

Ramasamy et al (2017) developed an Arduino UNO-based smart irrigation system designed for real-time applications. The system operated as a local standalone unit, utilizing soil moisture sensors to monitor field conditions and control a relay-based motor to activate irrigation when needed. The design focused on simplicity and affordability, making it suitable for small-scale farms or individual garden plots. While the system effectively automated irrigation based on moisture thresholds, it lacked remote monitoring or alert mechanisms, and required manual calibration of soil moisture thresholds, which could limit its adaptability and responsiveness to dynamic environmental conditions.

#### IV. WORKING PRINCIPLE

The core of a smart irrigation system powered by a microcontroller is its ability to automate the water management process, based on real-time environmental data. The working principle of such a system revolves around the microcontroller's ability to continuously monitor and analyze various sensor inputs, then make intelligent decisions to control the irrigation schedule and water application.

The heart of the system is the microcontroller, which serves as the central processing unit. It is equipped with analog and digital inputs to interface with a variety of sensors, such as soil moisture sensors, temperature and humidity sensors, rain sensors, and flow meters. These sensors are strategically placed throughout the irrigation area to provide a comprehensive understanding of the local environmental conditions.

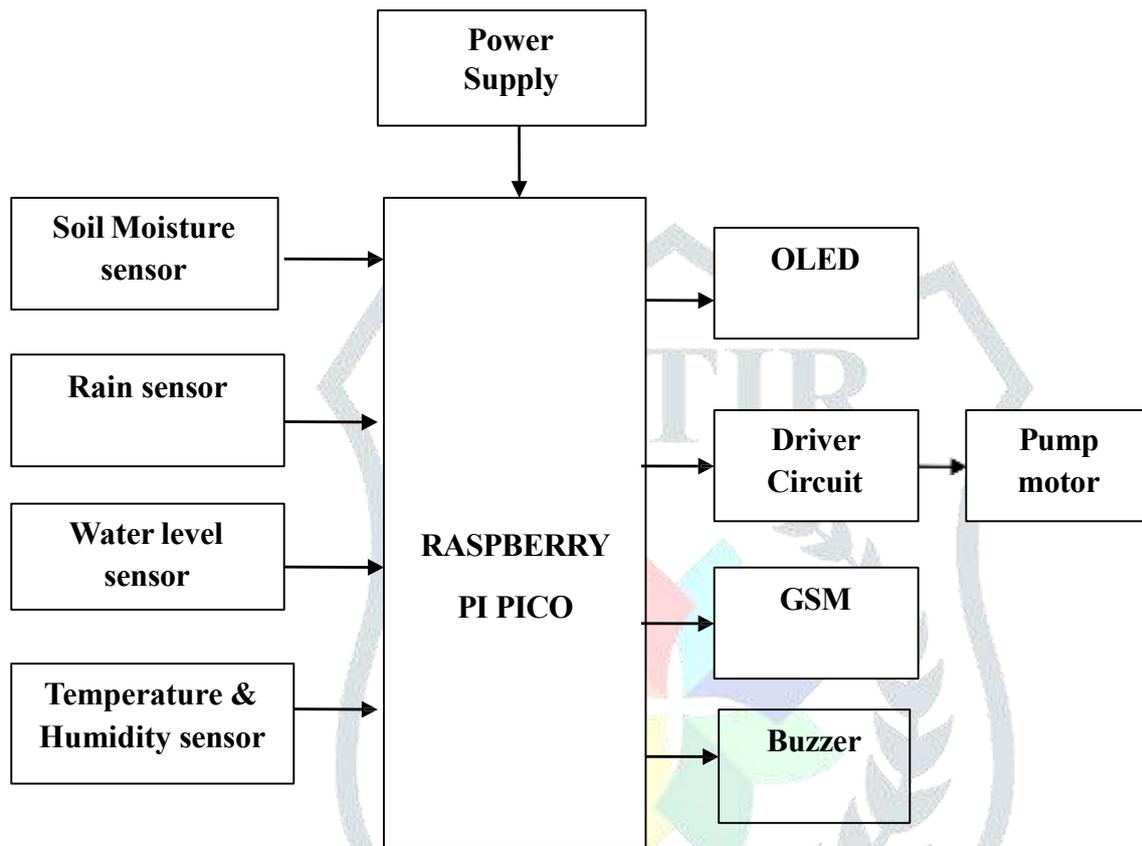
The microcontroller constantly reads and processes the data from these sensors, applying algorithms and decision-making logic to determine the optimal irrigation schedule. For example, if the soil moisture sensors indicate that the soil is sufficiently moist, the microcontroller may decide to postpone or reduce the scheduled irrigation cycle. Conversely, if the sensors detect dry soil conditions or impending drought, the microcontroller can trigger the irrigation system to provide the necessary water.

Beyond just monitoring and reacting to current conditions, the microcontroller-based system can also incorporate predictive capabilities. By integrating weather forecast data or historical weather patterns, the system can anticipate future water needs and proactively adjust the irrigation schedule accordingly. This enables the system to be more responsive and efficient, minimizing water waste while ensuring optimal plant health and crop yields.

The microcontroller's programmability also allows for the integration of advanced features, such as remote monitoring, mobile app integration, and automated alerts. This enables farmers and agricultural managers to have greater visibility and control over the irrigation system, allowing them to make informed decisions and quickly respond to any issues that may arise.

Overall, the working principle of a smart irrigation system revolves around the microcontroller's ability to gather, analyze, and act upon real-time environmental data, leading to a more efficient and sustainable approach to water management in agricultural applications. Key motivations include water conservation, precision farming, technology integration, sustainability, climate resilience, and farmer empowerment. This work aims to create a sustainable solution for agriculture, meeting current needs while laying the foundations for smart, adaptive agricultural practices in the future

## V. BLOCK DIAGRAM



## VI. FEATURES OF RASPBERRY PI PICO

- 1. ARM Cortex-M0+ Processor:** The Raspberry Pi Pico is powered by a 133MHz Arm Cortex-M0+ processor, providing a balance of performance and power efficiency.
- 2. RP2040 Microcontroller:** The Pico is built around the RP2040 microcontroller chip, a versatile and programmable system-on-chip (SoC) developed by Raspberry Pi.
- 3. Programmable I/O:** The Pico offers a flexible set of programmable general-purpose input/output (GPIO) pins, allowing for a wide range of interfacing and connectivity options.
- 4. Extensive Peripherals:** The board includes a variety of on-chip peripherals, such as ADCs, PWM, UART, I2C, and SPI, enabling diverse sensor and actuator integration.
- 5. Scalable RAM:** The Pico provides 264KB of on-chip SRAM, offering ample memory for embedded applications and projects.
- 6. Micro-USB Connectivity:** The board features a micro-USB port for power, programming, and serial communication, making it easily accessible and compatible.
- 7. Tiny Form Factor:** With its compact size of just 21mm x 51mm, the Raspberry Pi Pico is well-suited for space-constrained applications.
- 8. Low Power Consumption:** The Pico's efficient Arm Cortex-M0+ processor and power management features enable low-power operation, suitable for battery-powered or energy-conscious projects.

**9. Programmable with MicroPython and C/C++:** The Pico supports both the high-level MicroPython programming language and the traditional C/C++ development environment.

**10. Open-Source and Customizable:** The Pico's design is open-source, allowing for easy customization and integration into various projects and applications.

**11. Cost-Effective:** Priced at around \$4, the Raspberry Pi Pico offers a highly affordable microcontroller solution for hobbyists, makers, and educators.

**12. Extensive Documentation and Community Support:** The Raspberry Pi Foundation provides comprehensive documentation, tutorials, and a thriving community to support the Pico's development and usage.

## VII. DESCRIPTION OF HARDWARE COMPONENTS

**Microcontroller:** A microcontroller serves as the central processing unit and control hub within the smart irrigation system, orchestrating the interaction between sensors, actuators, and other components. As the brain of the system, the microcontroller processes data collected from sensors such as soil moisture sensors, temperature sensors, and humidity sensors to make informed decisions regarding irrigation schedules and water distribution.

**Soil Moisture Sensor:** The Soil Moisture Sensor is a vital component of the smart irrigation system, responsible for monitoring the moisture content in the soil. This sensor employs probes or electrodes that are inserted into the soil, allowing it to measure the water level present. By continuously assessing soil moisture levels, the sensor provides critical data to the microcontroller, enabling it to make informed decisions regarding irrigation scheduling and water distribution.

**Driver Circuit:** The Driver Circuit is an essential component of the smart irrigation system, tasked with controlling the operation of various actuators such as pumps, valves, or motors. This circuitry interprets signals from the microcontroller and converts them into power outputs suitable for driving these actuators.

**Water Level Sensor:** The Water Level Sensor is a crucial component of the smart irrigation system, designed to accurately measure the level of water in the irrigation source, such as a well, tank, or reservoir. Utilizing various technologies such as ultrasonic, pressure, or float sensors, the water level sensor provides real-time data on the availability of water resources.

**DHT11 Sensor:** The DHT11 Sensor is a fundamental component within the smart irrigation system, serving as a reliable tool for measuring temperature and humidity levels in the environment. Featuring a calibrated digital output, this sensor accurately detects changes in temperature and humidity, providing valuable data for optimizing irrigation schedules and ensuring ideal growing conditions for crops.

**GSM Module:** The GSM module is an essential component of a smart irrigation system, serving as the communication link between the system and the farmer. When triggered by predefined conditions such as low soil moisture levels or adverse weather, the GSM module

initiates communication by sending alerts and notifications to the farmer's mobile phone via SMS or calls.

**Pumping Motor:** The pumping motor is a vital component within a smart irrigation system, responsible for delivering water from the irrigation source to the crops. Typically controlled by the Raspberry Pi Pico or another central control unit, the pumping motor is activated based on data received from sensors such as the soil moisture sensor and water level sensor.

## VIII. DESCRIPTION OF SOFTWARE

**Embedded C:** Embedded C is a specialized version of the C programming language designed for developing software for embedded systems. It is the most widely used language in the embedded systems industry, powering a wide range of devices, from simple microcontrollers to complex system-on-chip (SoC) solutions. Embedded C provides a balance of low-level hardware control and high-level programming constructs, allowing developers to efficiently manage system resources, optimize performance, and interface with various peripheral devices. Its close integration with the underlying hardware, combined with its portability and extensive ecosystem of tools and libraries, make Embedded C a preferred choice for building reliable, real-time, and resource-constrained embedded applications. From automotive electronics to industrial automation, Embedded C remains a fundamental language in the world of embedded systems development.

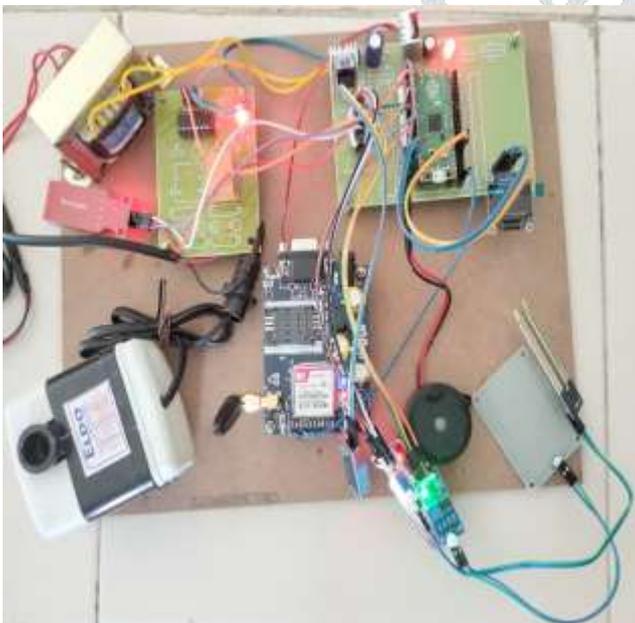
**Arduino IDE:** The Arduino IDE (Integrated Development Environment) is a popular open-source software platform that simplifies the process of writing, compiling, and uploading code to Arduino boards and other compatible microcontroller-based devices. Developed by the Arduino community, the IDE provides a user-friendly interface, making it accessible for both beginners and experienced developers. The Arduino IDE features a code editor, a compiler, and a built-in serial monitor, allowing users to write, test, and debug their programs with ease. It supports a wide range of Arduino boards, including the Uno, Mega, and Nano, as well as various third-party boards. The IDE's extensive library ecosystem and community support make it a versatile and powerful tool for creating a variety of embedded projects, from simple hobby projects to complex industrial applications.

## IX. CONCLUSION

In conclusion, this paper presented a real-time irrigation system that takes advantage of advanced technologies such as the microcontroller. The overall objective was to design an innovative solution for efficient irrigation management, with a focus on agricultural sustainability. Essentially, this involved creating an intelligent system capable of dynamically adjusting irrigation based on environmental parameters, including soil moisture and water level thresholds. This approach aims to reduce water wastage while improving agricultural productivity. The methodology involved the use of a microcontroller, and advanced sensors such as temperature, humidity (DHT22), moisture, water level, and pumps as actuators. The algorithm developed enabled continuous monitoring and adaptive control of the pump, as well

as data logging on the controller for real-time feedback. Practical test results proved the system's operational efficiency, confirming the ability of this innovative system to significantly reduce water wastage while maintaining agricultural productivity. This study is of crucial importance in the context of sustainable agriculture, as it provides a concrete technological solution for improving irrigation. The future work of this article is the development of an advanced intelligent irrigation system to further improve sustainable agriculture, basing it on new technologies such as IoT, cloud computing, and advanced communication technologies. These developments will position the system as a key reference in the field of smart, sustainable agriculture, giving it innovative scope and growing importance in farming practices in the world.

## XI.PROTOTYPE OF PROPOSED SYSTEM



*Figure 1: PROTOTYPE*



*Figure 2 : SOIL SENSOR*

## XII.ACKNOWLEDGEMENT

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## XIII.REFERENCES

- [1] R. K. Goel, C. S. Yadav, S. Vishnoi, and R. Rastogi, 'Smart agriculture – Urgent need of the day in developing countries', Sustainable Computing: Informatics and Systems, vol. 30, p. 100512, Jun. 2021, doi: 10.1016/j.suscom.2021.100512.
- [2] S. R. Barkunan, V. Bhanumathi, and J. Sethuram, 'Smart sensor for automatic drip irrigation system for paddy cultivation', Computers & Electrical Engineering, vol. 73, pp.

180–193, Jan. 2019, doi: 10.1016/j.compeleceng.2018.11.013.

[3] K. Obaideen et al., ‘An overview of smart irrigation systems using IoT’, *Energy Nexus*, vol. 7, p. 100124, Sep. 2022, doi: 10.1016/j.nexus.2022.100124.

[4] Z. Ahmed, D. Gui, G. Murtaza, L. Yunfei, and S. Ali, ‘An Overview of Smart Irrigation Management for Improving Water Productivity under Climate Change in Drylands’, *Agronomy*, vol. 13, no. 8, Art. no. 8, Aug. 2023, doi: 10.3390/agronomy13082113.

[5] A. Jabbari, T. A. Teli, F. Masoodi, F. A. Reegu, M. Uddin, and A. Albakri, ‘Prioritizing factors for the adoption of IoT-based smart irrigation in Saudi Arabia: a GRA/AHP approach’, *Frontiers in Agronomy*, vol. 6, 2024, Accessed: Feb. 27, 2024. [Online]. Available: <https://www.frontiersin.org/articles/10.3389/fagro.2024.1335443>

[6] D. Maria Manuel Vianny, A. John, S. Kumar Mohan, A. Sarlan, Adimoolam, and A. Ahmadian, ‘Water optimization technique for precision irrigation system using IoT and machine learning’, *Sustainable Energy Technologies and Assessments*, vol. 52, p. 102307, Aug. 2022, doi: 10.1016/j.seta.2022.102307.

[7] A. Morchid, R. El Alami, A. A. Raezah, and Y. Sabbar, ‘Applications of internet of things (IoT) and sensors technology to increase food security and agricultural Sustainability: Benefits and challenges’, *Ain Shams Engineering Journal*, vol. 15, no. 3, p. 102509, Mar. 2024, doi: 10.1016/j.asej.2023.102509.