Intelligent Irrigation System for Optimal Water Usage

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***Abstract* – In this current era, optimizing water usage and enhancing agricultural productivity are vital. This project introduces an IoT-based smart drip irrigation system that uses an ESP32 microcontroller to collect and analyze data from sensors, including a soil moisture sensor, DHT11 for temperature and humidity, and DS18B20 for soil temperature. The system controls a pump through a relay, automating irrigation timing and duration based on environmental conditions. Integrated with the Blynk IoT platform, users can remotely monitor sensor data and adjust irrigation settings via a smartphone. This system aims to conserve water, reduce labour, and boost crop yields, supporting sustainable agriculture.**

Index Terms: IoT, Smart Irrigation, Drip Irrigation, ESP32, Soil Moisture Sensor, Temperature Sensor, Humidity Sensor, Blynk IoT Platform, Remote Monitoring, Automation, Sustainable Agriculture, Water Conservation, Agricultural Productivity, Environmental Monitoring, Smart Agriculture.

I. INTRODUCTION

Our primary objective is to develop an intelligent irrigation system aimed at optimizing water usage and boosting agricultural productivity. This system leverages IoT technology to monitor environmental conditions and automate water delivery based on real-time data. Using an ESP32 microcontroller, the system gathers inputs from sensors measuring soil moisture, temperature, and humidity, allowing it to determine the ideal timing and duration of irrigation. The smart irrigation setup includes a relay-controlled pump that precisely regulates water flow to a drip irrigation network, ensuring crops receive the exact amount of water they need without wastage. Connected to the Blynk IoT platform, the system enables users to remotely monitor sensor readings, track pump activity, and adjust irrigation settings via a smartphone app. By automating irrigation decisions based on soil and environmental data, this project aims to conserve water, reduce labor costs, and improve crop yields. In promoting sustainable agriculture, this intelligent irrigation system exemplifies the potential of IoT solutions to enhance resource efficiency in farming, supporting both economic and environmental goals.

II. BACKGROUND

Water shortages and wasteful irrigation methods pose major risks to contemporary agriculture by causing excessive water usage and diminished crop yields. Conventional irrigation systems tend to distribute water evenly without regard to soil water levels, weather patterns, or the needs of the crops. An Intelligent Irrigation System solves these problems through the use of IoT, sensors, machine learning, and automation in the distribution of water. Soil water sensors track live water levels, and weather forecasting data allows the irrigation schedules to be corrected in accordance with rain and temperature. Machine learning-based algorithms read the history of irrigation to improve efficiency, and smart valves and pumps provide accurate delivery of water. Remote monitoring through mobile apps or cloud computing also allows farmers to manage irrigation systems effectively. Through combining these technologies, smart irrigation systems enhance yield, save water resources, decrease the cost of operations, and support sustainable farming.

III. PROBLEM STATEMENT

Water scarcity and inefficient irrigation methods are facing huge hurdles in sustainable agricultural production. Farmers use traditional irrigation with irrigation practices, which often lead to overwatering or underwatering hot-spots and both lost water due to evaporation, soil erosion, as well as reduced crop yields. Access to feedback information on soil moisture, weather, and environmental conditions is limited at real-time, making it difficult to establish effective irrigation schedules in growing plants. This problem is resolved by an Intelligent Irrigation System that stands on IoT, sensor technologies, and automation. It interfaces with sensors of soil moisture, temperature, humidity, rainfall, and light on a microcontroller (Raspberry Pi Pico) over the monitoring of several environmental conditions in real time. The supply of water to the crops is adjusted based on this real-time data; the control relay which controls the water pump optimally uses water by the intelligent irrigation system. An ESP32 module was used to send the data from the controller to a cloud platform (Blynk Server) for monitoring/remote control via a mobile app. The purpose of the smart irrigation system remains that of saving largely on water, increasing crop yields, cutting down the amount of human resources, and encouraging sustainable agriculture.

IV LITERATURE SURVEY

Y. Oladosu, M. Y. Rafii, "Superabsorbent polymer hydrogels for sustainable agriculture. This review likely discusses the application and benefits of superabsorbent polymer hydrogels in agriculture, focusing on their role in enhancing soil moisture retention and water efficiency. It may cover the technical properties of these hydrogels, their impact on sustainable farming, and their potential to improve crop resilience in water-scarce regions. The abstract could also outline future research directions in developing more efficient and environmentally friendly hydrogel materials for agricultural use [1].

H. Afzaal, B. Acharya, "Precision Irrigation Strategies for Sustainable Water Budgeting of Potato Crop in Prince Edward Island," This paper likely discusses precision irrigation strategies aimed at optimizing water use for potato crops in Prince Edward Island. It may highlight the technologies used, such as soil moisture sensors and weather data, to monitor water needs accurately.[2]

R. Pereira, S. Lopes, A. Caldeira, "Optimized Planning of Different Crops in a Field Using Optimal Control in Portugal," This study likely examines how optimal control theory can be applied to agricultural planning in Portugal, focusing on optimizing crop yields while minimizing resource use. It may discuss mathematical models used to determine the best planting schedules and resource allocation strategies. The abstract could also propose future research on enhancing these models to account for real-time data and changing environmental conditions. [3]

Z. Gu, Z. Qi, R. Burghate, "Irrigation Scheduling Approaches and Applications: A Review," This review likely provides an overview of different irrigation scheduling approaches, from traditional methods to modern, automated systems. It may discuss the advantages of using real-time data and sensor-based systems for optimizing irrigation efficiency. The abstract could outline future research on integrating advanced technologies, such as machine learning, to further enhance irrigation decision-making processes. [4]

K. H. Anabi, R. Nordin, "Database-Assisted Television White Space Technology: Challenges, Trends, and Future Research Directions," This paper likely explores the use of television white space (TVWS) technology for improving wireless communication in rural and remote areas. It may discuss the challenges of implementing database assisted TVWS systems, as well as current trends in the field. The abstract could suggest future research directions focused on enhancing connectivity for agricultural applications, such as remote sensing and precision farming. [5]

G. Cáceres, P. Millán, M. Pereira, "Smart Farm Irrigation: Model Predictive Control for Economic Optimal Irrigation in Agriculture," This paper likely discusses the use of model predictive control (MPC) for optimizing irrigation in smart farms. It may focus on how MPC can predict future water needs based on real-time data and reduce water usage while maintaining crop health. The abstract could propose future research directions aimed at improving the predictive accuracy of MPC models and integrating more complex environmental factors.[6]

V. GAP ANALYSIS

There are significant gaps in traditional irrigation methods, it often relay on fixed schedules rather than responding to the real-time needs of plants and soil. This approach can lead to both overwatering and underwatering, resulting in wasted water, soil degradation, and inconsistent crop health. Intelligent irrigation systems address these challenges by using environmental data to ensure water is delivered precisely when and where it is needed. Another limitation of conventional systems is the lack of real-time monitoring and control, as most setups require manual adjustments and don’t provide continuous visibility into soil conditions. With IoT-enabled sensors measuring soil moisture, temperature, and humidity, intelligent systems bridge this gap by enabling automated, remote management that adjusts water usage to actual environmental demands. Additionally, most irrigation systems do not integrate with mobile or IoT platforms, limiting remote access to data and adjustments. Intelligent irrigation systems overcome this limitation by connecting to cloud and mobile applications, providing users with realtime alerts, data logging, and monitoring capabilities. This makes irrigation history accessible, improving decision making and helping to optimize future water use. Traditional methods also contribute to water wastage, particularly problematic in drought-prone regions where fixed schedules and non-responsive systems often lead to over-irrigation. Smart irrigation solutions address this by adapting water delivery to soil and weather conditions, thus conserving water and promoting sustainability. Another gap lies in the lack of data-driven decision-making in agriculture. Many farmers lack access to historical climate patterns, soil health records, or crop-specific water needs, making it challenging to optimize their irrigation strategies. IoT-enabled intelligent irrigation systems collect and analyze this data, enabling more informed decisions that improve crop yield and water efficiency over time. Standard irrigation setups also do not account for the varying water requirements of different crops or their seasonal needs, leading to inefficiency. Intelligent irrigation systems, by contrast, can be customized based on crop type, growth stage, and season, providing a tailored approach to diverse agricultural requirements. By addressing these gaps, intelligent irrigation systems enable optimized water use, enhanced crop yield, and a more sustainable approach to agriculture.

VI. PROPOSED SYSTEM ARCHITECTURE

The design in the diagram in the system, irrigation and fertilization system using the Raspberry Pi Pico automates water and nutrient supply by monitoring soil moisture, temperature, and nutrient levels through sensors. The Pico acts as the controller, processing sensor data and activating pumps and valves to irrigate or fertilize based on real-time conditions. This system improves resource efficiency and enhances crop yield, with options for remote monitoring via wireless communication

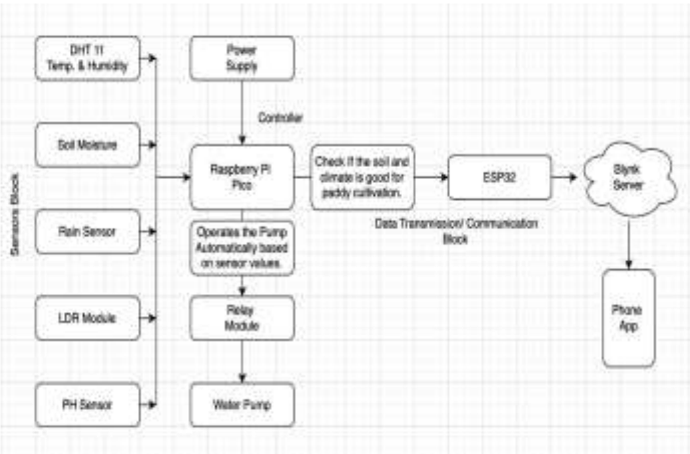


Fig 1. Block Diagram

VII. HARDWARE AND SOFTWARE

7.1 Hardware Components:

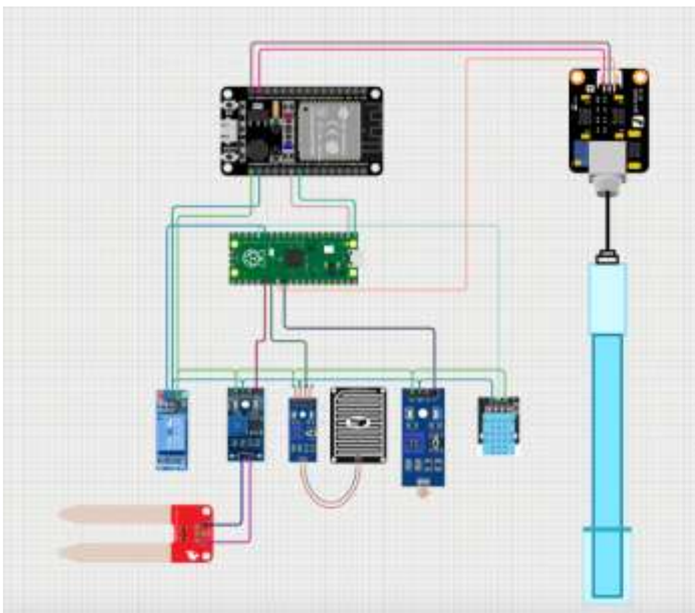
1. Sensors Block:
   - DHT11 Temperature & Humidity Sensor – Measures temperature and humidity.
   - Soil Moisture Sensor – Detects soil moisture levels.
   - Rain Sensor – Identifies rainfall presence.
   - LDR Module – Measures light intensity.
   - pH Sensor – Monitors soil pH levels.
2. Controller:
   - Raspberry Pi Pico – Processes sensor data and controls system operations.
3. Relay Module:
   - Controls the Water Pump based on sensor values.
4. Communication Module:
   - ESP32 – Transmits data wirelessly to the cloud (Blynk Server).
5. Power Supply:
   - Provides required voltage and current to the system.

7.2 Software Components:

1. Embedded Programming:
   - MicroPython/C++ (for Raspberry Pi Pico and ESP32).
2. IoT Platform:
   - Blynk Server – Cloud-based data visualization and control.
3. Mobile Application:
   - Blynk App – Displays real-time data and provides remote control.

4. Firmware for ESP32 and Raspberry Pi Pico:
   - Code to read sensor data, control the relay module, and communicate with the IoT platform.

VIII.CIRCUIT DIAGRAM



IX. RESULTS

- Efficient Irrigation: The system intelligently adjusts irrigation schedules based on real-time environmental conditions, such as soil moisture, temperature, and humidity. This minimizes water wastage and ensures optimal plant hydration, promoting healthy growth and reducing the risk of overwatering or underwatering.
- Remote Monitoring: Users can conveniently monitor sensor data and control the pump from anywhere using the Blynk app. This provides flexibility and peace of mind, allowing for proactive management of the irrigation system even when not physically present.
- Optimized Plant Health: By providing precise water delivery based on plant needs, the system promotes optimal plant health. This can lead to increased yields, improved plant vitality, and reduced susceptibility to diseases and pests.
- Cost Savings: The system's ability to efficiently manage water consumption results in significant cost savings on water bills. Additionally, by preventing overwatering, the system helps to reduce energy consumption associated with pumping excess water.
- Environmental Benefits: Conserving water through efficient irrigation practices contributes to environmental sustainability. This can help to protect

local water resources, reduce the strain on ecosystems, and support a healthier planet.

X. FUTURE SCOPE

The future of Intelligent Irrigation Systems is in more developments in artificial intelligence (AI), IoT, remote sensing, and data analytics to provide even higher precision and efficiency in water management. Predictive models based on AI will enhance irrigation scheduling by considering weather patterns, soil condition, and crop growth stages. The use of satellite imagery and drones will enable real-time monitoring of large fields and site-specific irrigation adjustments. Blockchain technology can increase data security and transparency in water use records, allowing for improved resource management. Moreover, the evolution of 5G and edge computing will provide faster data processing and real-time decision-making. With the aggravation of climate change, water scarcity, the innovation of self-sustaining smart irrigation systems with solar power and automated nutrient supply will be key to sustainable agriculture. The future applications also encompass urban smart irrigation for green spaces, parks, and landscapes, encouraging water saving in cities.

XI. CONCLUSION

This automated irrigation system represents a significant advancement in the field of agriculture technology. By leveraging the capabilities of the Raspberry Pi Pico, ESP32, and Blynk, the system offers a comprehensive and efficient solution for managing irrigation systems. One of the most notable features of this system is its ability to monitor environmental parameters in real-time. This enables the system to make informed decisions about when and how much to irrigate, thereby optimizing water usage and promoting plant health. Additionally, the integration of the Blynk app provides users with a convenient way to monitor the system's performance and make adjustments as needed. In conclusion, this automated irrigation system demonstrates the potential of technology to revolutionize agricultural practices. By automating irrigation tasks and providing valuable insights into plant health, this system can help farmers improve yields, reduce costs, and minimize their environmental impact.

XII. REFERENCES

[1] Y. Oladosu, M. Y. Rafii, F. Arolu, "Superabsorbent polymer hydrogels for sustainable agriculture: A review," Horticulturae, vol. 8, p. 605, 2022.

[2] H. Afzaal, B. Acharya, and T. Esau, "Precision Irrigation Strategies for Sustainable Water Budgeting of Potato Crop in Prince Edward Island," Sustainability, vol. 12, 2020.

[3] R. Pereira, S. Lopes, A. Caldeira, and V. Fonte, "Optimized Planning of Different Crops in a Field Using Optimal Control in Portugal," Sustainability, vol. 10, 2018.

[4] Z. Gu, Z. Qi, R. Burghate, S. Yuan, X. Jiao, and J. Xu, "Irrigation Scheduling Approaches and Applications: A Review," Journal of Irrigation and Drainage Engineering, vol. 146, 2020.

[5] K. H. Anabi, R. Nordin, and N. F. Abdullah, "DatabaseAssisted Television White Space Technology: Challenges, Trends, and Future Research Directions," IEEE Access, vol. 4, pp. 8162-8183, 2016.

[6] G. Cáceres, P. Millán, M. Pereira, and D. Lozano, "Smart Farm Irrigation: Model Predictive Control for Economic Optimal Irrigation in Agriculture," Agronomy, vol. 11, 2021.

[7] N. Islam, M. M. Rashid, and R. Kadel, "A review of applications and communication technologies for internet of things (Iot) and unmanned aerial vehicle (uav) based sustainable smart farming," Sustainability, vol. 13, p. 1821, 2021.

[8] I. Fernández García, J. Vera, W. Conejero, M. R. Conesa, A. Domínguez, J. J. Pardo, B. C. Léllis, and P. Montesinos, "Trends and Challenges in Irrigation Scheduling in the Semi-Arid Area of Spain," Water, vol. 12, 2020.

[9] J. Zinkernagel, J. F. Maestre-Valero, "New technologies and practical approaches to improve irrigation management of open field vegetable crops," Agricultural Water Management, vol. 242, 2020.

[10] K. G. Liakos, P. Busato, D. Moshou, S. Pearson, and D. Bochtis, "Machine Learning in Agriculture: A Review," Sensors (Basel), vol. 18, Aug 14 2018.

[11] A. Goap, D. Sharma, A. K. Shukla, and C. Rama Krishna, "An IoT based smart irrigation management system using Machine learning and opensource technologies," Computers and Electronics in Agriculture, vol. 155, pp. 41-49, 2018.

[12] R. Koech and P. Langat, "Improving Irrigation Water Use Efficiency: A Review of Advances, Challenges and Opportunities in the Australian Context," Water, vol. 10, 2018.

[13] H. Jaafar and S. A. Kharroubi, "Views, practices and knowledge of farmers regarding smart irrigation apps: A national cross-sectional study in Lebanon," Agricultural Water Management, vol. 248, 2021.