Journal of Intelligent Decision Support System (IDSS) 6 (3) (2023), pp. 107-111

Published by: Institute of Computer Science (IOCS)

Journal of Intelligent Decision Support System (IDSS)

Journal homepage: www.idss.iocspublisher.org

Solar-Powered smart irrigation and fertilization with loRa remote monitoring

Santi Febri Arianti[1], Antonius [2], Daniel Simbolon[3], Edwinner Lamboris Sitorus [4], Erdianto Parluhutan Sitorus [5]

[1,2,3,4,5] *Program Studi S1 Teknik Elektro, Institut Teknologi Del, Laguboti, Indonesia*

Article Info

Article history:

Received Aug 19, 2023
Revised Aug 22, 2023
Accepted Aug 24, 2023

Keywords:

Automatic Drip Irrigation
Fertilization
Rural Agriculture
Water Conservation

ABSTRACT

Efficient water management is a critical challenge in agriculture, particularly in rural areas where water resources may be scarce. To address this issue, this research introduces and assesses a solar-powered automatic drip irrigation system with a fertilization feature, specifically tailored for chili farming in the rural community of Banua Huta village. The system incorporates LoRa technology for remote monitoring, allowing farmers to efficiently manage water use and nutrient application. The study focused on evaluating the system's performance concerning water conservation, fertilizer application, and crop productivity. The results demonstrated a substantial improvement in irrigation efficiency, with water usage reduced by 33.5% compared to conventional methods. The fertilization feature of the system not only facilitated targeted nutrient delivery but also resulted in increased crop growth rates of up to 30% and improved leaf health by up to 35%. This innovative solar-powered automatic drip irrigation system showcases a practical and sustainable approach to water and nutrient management in rural agriculture, demonstrating its potential for widespread adoption in similar settings.

Corresponding Author:

Santi Febri Arianti,
Program Studi S1 Teknik Elektro,
Institut Teknologi Del,
Jl. Sisingamangaraja, Sitoluama, Laguboti, Kab. Toba, Sumatera Utara, 22381, Indonesia.
Email: santi.febri62@gmail.com

Introduction

Agriculture plays a vital role in the global economy, providing food, income, and employment for billions of people (Brown, 2021). The increasing demand for food due to population growth, along with climate change and resource scarcity, necessitates the development of more efficient agricultural systems (Layani, 2022). Drip irrigation is an effective method for precise water and nutrient delivery to plant roots, reducing water waste and improving crop yield (Bwambale, 2022) (Wang, 2023). However, manual control of drip irrigation can be labor-intensive, potentially leading to inconsistent watering and fertilization (Shi, 2023).

Technological advancements in automation and communication have led to the emergence of smart irrigation systems (Koech, 2018) (Badrun, 2021). Solar-powered smart irrigation systems provide an environmentally friendly solution, harnessing renewable energy and eliminating the need for grid power (Majeed, 2023) (Vinoth, 2022). By incorporating IoT devices and low-power wide-area network (LPWAN) technologies, such as LoRa, real-time remote monitoring and control of these systems can be achieved, increasing efficiency and convenience (Zhang, 2018) (Seyed Mehdi Mousavi, 2022) (McPherson, 2019).

This research aims to develop and implement a solar-powered smart irrigation and fertilization system with LoRa remote monitoring to address the challenge of efficient water and nutrient management in agriculture. The study focuses on designing the irrigation system, integrating solar power and LoRa communication modules, and evaluating the system's performance in a controlled environment. The primary goal is to assess the system's ability to function effectively and deliver water and nutrients accurately, supporting sustainable agricultural practices. As a case study, the system was implemented in the Banua Huta village, highlighting its applicability in rural areas where access to reliable energy sources and communication infrastructure is limited, further emphasizing the potential benefits of such a system in remote agricultural settings.

Method

This section describes the research methods used to investigate the effects of an automatic drip irrigation and fertilization system on chili pepper cultivation in Banua Huta Village.

Soil Analysis

Prior to the installation of the irrigation system, a comprehensive soil analysis was conducted to determine the soil's moisture retention capacity and set points for automatic drip irrigation (Soulis, 2018) (V. Terleev, 2021). Soil samples were collected from different locations within the study area and analyzed for texture, pH, and moisture content. Soil tester was used to measure soil moisture and pH. A moisture content threshold of 500 was established, with values below this threshold indicating moist soil and values equal to or above indicating dry soil.

System Design

The research team designed a solar-powered automatic drip irrigation and fertilization system for chili pepper cultivation. The system comprises two main components: the battery charging system and the automatic drip irrigation system (Idim, 2020). Solar panels were used to absorb sunlight and charge batteries that, in turn, power a microcontroller and water pump. The water pump, controlled by the microcontroller, activates or deactivates the irrigation based on soil moisture data collected by sensors (N. Chauhan, 2020) (Getu, 2020). The system model is depicted in Figure 1.

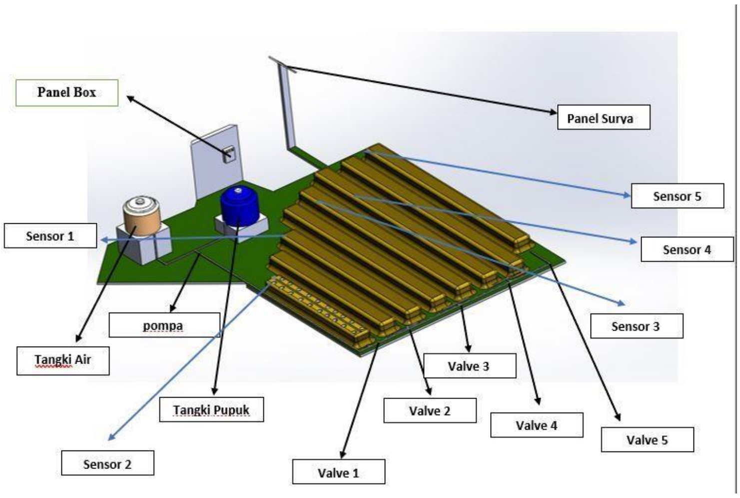

Figure. 1. System Design of solar-powered automatic drip irrigation and fertilization

Data Collection System

A data delivery system was established to collect soil moisture data from five sensors placed at various locations within the chili pepper fields (Wu, 2023). An Arduino microcontroller was used as the control center, receiving data from the sensors and transmitting it via a LoRa module (Shet*, 2020). The LoRa receiver, connected to a NodeMCU ESP8266, processes the data and sends it to a MySQL server running on a Raspberry Pi (Ambarwari, 2021). This data is then accessed and displayed on a website for analysis and monitoring.

Hardware Design and Implementation

The hardware system design focused on implementing the solar power system (Abd-Elhakim, 2020). The research team conducted a detailed analysis of the electrical design and component specifications, considering factors contributing to energy losses (e.g., cable resistance, inverter efficiency, shading effects, and solar panel efficiency degradation). A safety factor of 1.2 was applied to account for unexpected power fluctuations or emergencies. The solar module capacity was calculated based on this safety factor, resulting in the requirement of one 100 Wp unit.

Results and Discussions

This chapter presents the findings and analysis of the solar-powered automatic drip irrigation system for chili pepper farming in the Banua Huta village. The focus is on the technology's effects on irrigation efficiency, water conservation, energy usage, and crop productivity, supported by collected data and relevant literature.

Control System Testing

The control system of the automatic drip irrigation system was tested to evaluate its performance. During the tests, the system collected data on initial and final soil moisture levels, solenoid valve status, pump status, and watering duration for each sensor.

The test results reveal that the sensors, detecting dry soil with moisture levels between 558-605, activated the solenoid valve and pump, initiating irrigation for a duration of 7 minutes. Sensors indicating moist soil (moisture levels between 453-487) kept the solenoid valve off. The pump activation resulted from simultaneous sensor readings, with any dry soil sensor activating the pump.

Drip Irrigation System Performance

The analysis showed the average irrigation duration during the experiment was approximately 53 minutes, using a total of 26.6 m^3 of water weekly. Automatic drip irrigation can reduce operation times as water is directly delivered to the plants. Compared to conventional irrigation methods, the automatic drip irrigation system significantly improves water usage efficiency. In conventional systems, water is distributed through channels before reaching the plants, leading to water wastage and losses. The automated system delivers water directly to the plant roots, minimizing waste.

The data collected during the testing phase confirms the system's effectiveness in maintaining optimal soil moisture levels even during days with no rainfall. By adjusting irrigation based on soil moisture levels, the system prevents overwatering or underwatering.

Water Savings

A typical conventional irrigation system used for chili farming, which employs flood irrigation practices, typically requires around 40 m^3 of water per hectare per week (N. Rahayu, 2022). Comparing the two methods: (a). Conventional irrigation: 40 m^3 per week per hectare; (b). Automatic drip irrigation: 26.6 m^3 per week per hectare; (c). The difference in water usage is approximately 13.4 m^3 per week per hectare, or about a 33.5% reduction in water usage with the automatic drip irrigation system.

This significant reduction in water usage highlights the efficiency of the automatic drip irrigation system. By delivering water directly to the plant roots, the system minimizes losses due to evaporation and runoff, allowing for precise and efficient water management. Adjusting irrigation based on real-time soil moisture levels further optimizes water usage and ensures plants receive the right amount of water at the right time. The substantial water savings not only benefit the environment but also translate into cost savings for farmers, addressing one of the main challenges faced by farmers in the Banua Huta village.

Fertilization using Drip Irrigation System

An important feature of the solar-powered automatic drip irrigation system implemented in the Banua Huta village is the incorporation of a fertilization function. This study included an assessment of the effectiveness of the system in delivering fertilizer to the chili plants through the drip irrigation system. Fertilization was carried out once a week, as per the recommended agricultural practices for chili cultivation.

During the fertilization process, the system was programmed to mix the appropriate amount of fertilizer with water and deliver it directly to the chili plants' root zone through the drip irrigation system. The system allowed for precise control of the fertilizer concentration and application rate, ensuring that the plants received the required nutrients at the right time.

The data collected during the study showed that the drip irrigation system's fertilization function was successful in delivering the nutrients to the plants. The chili plants that received fertilization through the drip irrigation system exhibited an increased growth rate of up to 30% and an improvement in leaf health of up to 35%, compared to those that were not fertilized using this method.

Furthermore, the use of drip irrigation for fertilization proved to be more efficient than traditional methods of fertilization. It reduced the risk of nutrient loss due to runoff or leaching, and minimized the labor and time required for manual application of fertilizer. Moreover, the system's ability to deliver fertilizer directly to the root zone ensured that the plants could absorb the nutrients more effectively.

LoRa Signal Loss Study

The quantitative study of LoRa signal loss due to physical obstructions observed a consistent degradation in signal quality with increasing tree density. Multiple LoRa transceivers at different distances and tree densities measured signal strength (RSSI) and signal-to-noise ratio (SNR). Results showed a linear decrease in both RSSI and SNR with increasing tree density, confirming trees negatively impact LoRa signal propagation. In high tree density scenarios, signal loss reached up to 60%, making communication unreliable. Careful LoRa device placement, considering natural obstacles' impact on signal quality, is necessary for reliable and robust long-range communication.

The results demonstrate the potential of solar-powered automatic drip irrigation systems to address challenges faced by farmers in Banua Huta village. The technology provides an efficient solution for irrigating chili plants and serves as a model for sustainable and innovative agricultural practices, particularly in water conservation.

Conclusions

In this research, a solar-powered drip irrigation system tailored for chili farming in Banua Huta village was developed. The system successfully reduced water consumption by 33.5% and resulted in a significant 30% improvement in crop growth through precise nutrient delivery. Notably, the embedded LoRa technology for remote monitoring encountered some signal transmission issues due to local obstructions. For enhanced results in the future, it is imperative to refine the LoRa communication pathways for increased reliability, further adjust the system for diverse soil conditions, and expand trials to ascertain its effectiveness across various crops. This exploration can pave the way for a more resilient and sustainable agricultural practice.

References

Abd-Elhakim, A. E.-S. (2020). Effect use of pulsed deficit drip irrigation for tomato crop in greenhouse powered by solar energy. *Misr Journal of Agricultural Engineering, 38*(1), 1-14.

Ambarwari, A. W. (2021). Ambarwari, A., WidySistem Pemantau Kondisi Lingkungan Pertanian Tanaman Pangan dengan NodeMCU ESP8266 dan Raspberry Pi Berbasis IoT. *Jurnal RESTI (Rekayasa Sistem Dan Teknologi Informasi), 5*(496–503).

Badrun, B. &. (2021). The Development of Smart Irrigation System with IoT, Cloud, and Big Data. *IOP Conference Series: Earth and Environmental Science.* Lampung.

Brown, V. R. (2021). Risks of introduction and economic consequences associated with African swine fever, classical swine fever and foot-and-mouth disease: A review of the literature. *In Transboundary and Emerging Diseases, 68*(4), 1910–1965.

Bwambale, E. A. (2022). Bwambale, E.Smart irrigation monitoring and control strategies for improving water use efficiency in precision agriculture: A review. *Bwambale, E., Abagale, F. K., & Anornu, G. K. (2022). Smart irrigation monitoring and control strategies forAgricultural Water Management, 260*.

Getu, B. N. (2020). Remote control of garden plantation water pumps using arduino and gsm mobile. *Advances in Science, Technology and Engineering Systems Journal, 5*(4), 499-504.

Idim, I. F. (2020). Design and implementation of solar powered automatic irrigation system. *American Journal of Electrical and Computer Engineering, 4*(1), 1.

Koech, R. &. (2018). Improving Irrigation Water Use Efficiency: A Review of Advances, Challenges and Opportunities in the Australian Context. *Water, 10*(12), 1771.

Layani, G. B. (2022). Layani, G., Bakhshoodeh, M., ZibaSustainable Water Resources Management Under Population Growth and Agricultural Development in the Kheirabad River Basin, Iran. *Layani, G., Bakhshoodeh, M., Zibaei, M., & Viaggi, D. (2022). Sustainable Water Resources Management Under PopulatioBio-Based and Applied Economics., 10*(4), 305-323.

Majeed, Y. K. (2023). Renewable energy as an alternative source for energy management in agriculture. *Energy Reports, 10*, 344–359.

McPherson, R. H. (2019). Using LoRaWAN Technology to Enhance Remote Power Network Monitoring. *2019 IEEE 89th Vehicular Technology Conference (VTC2019-Spring).* Kuala Lumpur.

N. Chauhan, U. P. (2020). Wireless automatic irrigation system for sandy loam soil. *The Pharma Innovation, 9*(5), 181-185.

N. Rahayu, H. A. (2022). The effect of pottery material composition as subsurface irrigation on the growth of chilli (capsicum annum l.) in alfisols and entisol. *IOP Conference Series: Earth and Environmental Science, 1016*(1), 012012.

Seyed Mehdi Mousavi, A. K. (2022). The role of low-power wide-area network technologies in Internet of Things: A systematic and comprehensive review. *Communication Systems, 35*(2).

Shet*, K. a. (2020). Implementation of water grade inspection system using multiple sensors. *International Journal of Innovative Technology and Exploring Engineering, 9*(4), 1607-1611.

Shi, K. K. (2023). Magnetized Water Irrigation Alleviates Emitter Clogging of a Drip Fertigation System. *Agronomy, 13*, 108.

Soulis, K. X. (2018). Optimum soil water content sensors placement for surface drip irrigation scheduling in layered soils. *Soulis, K. X., & Elmaloglou, S. (2018). Optimum soil water content sensors placement for surface drip irrigatioComputers and Electronics in Agriculture, 152*, 1-8.

V. Terleev, I. D. (2021). Soil-hydrophysical information support of precise irrigation farming. *Taurida Herald of the Agrarian Sciences, 2*(26), 244-260.

Vinoth, R. N. (2022). Power Electronics for Renewable Energy System With Smart Grid. *Vinoth, R., Nedumaran, R., Alexraj, P., Srinivasan, S., & Abinaya, S. (2022). Power Electronics for RenewaInternational Journal for Research in Applied Science and Engineering Technology., 10*(11), 175-181.

Wang, J. H. (2023). Alternate Drip Irrigation Regulates the Soil Fungal Community Structure and Metabolic Function Based on Root–fungus Interactions. *Land Degradation and Development, 34*(4), 1133-1144.

Wu, Y. Y. (2023). Internet-of-Things-Based Multiple-Sensor Monitoring System for Soil Information Diagnosis Using a Smartphone. *Micromachines, 14*(7), 1395.

Zhang, X. Z. (2018). Zhang, X., Zhang, M., Meng, F., QA Low-Power Wide-Area Network Information Monitoring System by Combining NB-IoT and LoRa. *IEEE Internet of Things Journal, 6*(1), 590 - 598.