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MORALITY BEFORE KNOWLEDGE

Development of an automated irrigation system based on artificial intelligence technology to support efficient and sustainable integrated agriculture

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ABSTRACT

Background: The need to enhance agricultural productivity while ensuring sustainability in the modern era has become increasingly urgent. One of the challenges faced is inefficiency in irrigation, which can lead to water wastage, land degradation, and reduced agricultural productivity, thereby threatening the sustainability of this sector. This scientific paper aims to find a solution by developing an automated irrigation system based on artificial intelligence technology that can support and enhance efficiency and sustainability in integrated agriculture. **Methods**: Data collection for this paper employed documentary study techniques. The data used as supporting references were obtained from journals and other credible sources relevant to the discussed topic. **Findings:** Based on the results of the documentary study, AI technology can assist farmers in efficiently managing their land. With an automated irrigation system, farmers' tasks can be carried out more easily, and water resources are utilized only as needed. Furthermore, energy consumption is significantly reduced, leading to overall cost savings and high cost efficiency. Efficiency in irrigation and water management ensures that crops and harvests receive only the necessary amount of water, thereby minimizing waste caused by both water shortages and excesses. **Conclusion**: he implementation of an automated irrigation system based on artificial intelligence (AI) technology can enhance the efficiency and sustainability of integrated agriculture by adjusting water usage based on real-time weather data and soil conditions. However, several unresolved challenges remain in applying this technology. **Novelty/Originality of this article:** This article introduces an AI-based automated irrigation system designed for sustainable agriculture. It optimizes water use by leveraging real-time weather and soil data, thereby enhancing both productivity and sustainability. By addressing barriers to technology adoption, this study provides valuable insights for future research, demonstrating the economic viability and efficiency of AI-driven irrigation systems for farmers.

KEYWORDS: Artificial intelligence; irrigationl; agriculture

1. Introduction

Agriculture in Indonesia plays a vital role in the national economy and food security. The need to enhance agricultural productivity while ensuring sustainability in this modern era has become increasingly urgent. An essential element of integrated agriculture is the irrigation system, which significantly impacts the management of water resources that are becoming more limited. Inefficiencies in irrigation can lead to water wastage, land degradation, and reduced agricultural productivity, ultimately threatening the

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sustainability of the sector. Water is the primary resource supporting agricultural activities, and without it, farming cannot proceed (Cahyani et al., 2023).

Automated irrigation is a system that employs more advanced and modern technologies compared to traditional irrigation, aiming to optimize water use, reduce waste, and improve agricultural yields (Anggraeni et al., 2024). Moreover, the development of automated irrigation systems is crucial for delivering water to agricultural areas that are difficult to reach by conventional irrigation systems. By integrating artificial intelligence (AI), automated irrigation systems enable more efficient monitoring and management of water resources.

The development of AI-based irrigation technology represents an innovative solution that can enhance efficiency and sustainability in integrated agriculture. AI refers to artificial intelligence that can be controlled and applied across various scientific contexts (Cahyani et al., 2023). One example of AI-based automated irrigation systems is the use of Internet of Things (IoT) technology. This concept involves the interconnection of smart devices through the internet, allowing for real-time data collection via sensors and connected devices. In agriculture, sensors placed on crops or in fields can gather data on soil moisture, temperature, and other parameters (Hasibuan, 2023). This information is utilized to optimize water usage and monitor crop development. The integration of this technology allows devices to work together harmoniously, providing more efficient and innovative solutions across various applications and industrial sectors.

The application of AI in automated irrigation systems not only enhances water efficiency but also contributes to more environmentally friendly and sustainable agricultural practices. That the implementation of AI in irrigation can reduce water wastage and distribute nutrients more effectively. Additionally, Cahyani (2023) emphasizes that AI-supported automated irrigation systems can lower operational costs while increasing crop yields, making them an ideal solution for sustainable agriculture.

2. Methods

The method employed in this study is a documentary study technique. This approach involves the systematic collection and analysis of existing literature related to AI-based automated irrigation systems. The data used as supporting references were obtained from various scholarly journals that focus on relevant issues concerning the implementation and efficiency of automated irrigation technologies. By utilizing this method, the study aims to gather comprehensive insights into the current state of research in this field, ensuring that the findings are grounded in established knowledge and practice.

In conducting the documentary study, a thorough review of literature was undertaken to identify key themes, trends, and gaps in the research surrounding AI technology in irrigation. This involved analyzing articles, papers, and case studies that discuss the technological advancements, operational frameworks, and sustainability implications of automated irrigation systems. The information collected not only provides a solid theoretical foundation for the study but also highlights the practical applications of AI in enhancing irrigation efficiency. By synthesizing these findings, the research seeks to contribute to a deeper understanding of how AI can be effectively integrated into agricultural practices, thereby addressing contemporary challenges in water management and agricultural productivity.

3. Results and Discussion

3.1 Application of AI-based automated irrigation systems

In recent years, the application of Artificial Intelligence (AI) in the agricultural sector has gained significant attention in efforts to achieve sustainable agriculture, particularly regarding irrigation. Developing countries often use more water than developed nations to

achieve similar yields due to the lack of intelligent and cost-effective automated irrigation systems (Goap et al., 2018). Significantly, AI technology can enhance agricultural productivity. Additionally, AI can create environmentally friendly products, reduce resource overuse, and support global food security. The modernization of agriculture through AI is crucial for future agricultural development (Maulana & Sari, 2024).

The primary aim of AI technology is to develop systems that can replicate or surpass human capabilities in performing specific tasks with greater accuracy and efficiency (Maulana & Sari, 2024). The implementation of AI in automated irrigation systems has led to significant changes in the agricultural sector. This AI technology enables intelligent irrigation by measuring water needs based on weather data and plant conditions, thus allowing for more effective water use and optimal plant growth. Automated irrigation systems aim to maximize crop yields while minimizing water waste, energy consumption, and other resource use. Some benefits of automated irrigation systems include improved plant health, reduced water usage, and savings on energy and water bills (Raouhi et al., 2023).

The implementation of AI-based automated irrigation systems can be achieved through Machine Learning (ML) methods, which have the capability to process large and complex datasets and provide accurate analytical results across various tasks. ML methods in automated irrigation systems are utilized to analyze data related to weather conditions and soil moisture levels. Furthermore, the application of ML in conjunction with other technologies, such as the Internet of Things (IoT), facilitates real-time data collection through various field sensors, including moisture, temperature, and light sensors. This data is then analyzed using ML algorithms (regression, classification, and clustering) (see Figure 1) to generate actionable insights, such as automatically adjusting water usage based on current soil conditions (Maulana & Sari, 2024).

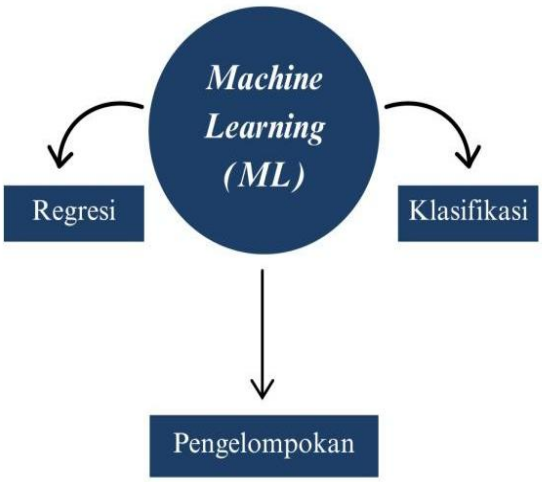

Fig 1. Machine learning (ML) algorithm

The application of AI-based automated irrigation systems, utilizing IoT technology and CNN-LSTM models, can be presented in the form of applications like AIDSII. The main principle of this application is to optimize water distribution by focusing on specific areas while employing advanced techniques to achieve efficient irrigation. Through sophisticated algorithms, this application enables precise water management by accounting for factors such as soil moisture, weather conditions, and plant needs, resulting in optimal irrigation schedules and minimized water waste. Additionally, AIDSII provides intelligent water allocation, proactive monitoring with alerts, and historical data analysis to support informed decision-making (Raouhi et al., 2023).

Table 1. AIDSII

Purpose	Algoritma
a. Disease and weed identification	Convolutional Neural Networks (CNN)
b. Yield prediction and estimation	
Air energy yield estimation	Long Short-Term Memory (LSTM)
For estimating water usage volume	Regresi

According to Shandilya & Khanduja (2020), the implementation of IoT sensors combined with the Seasonal Autoregressive Integrated Moving Average with Exogenous (SARIMAX) algorithm for automated irrigation systems that can detect soil moisture in real time is an essential step in modernizing agriculture. This technology has the potential to enhance efficiency in water resource management and plant care. Additionally, Linaza et al. (2021) indicate that the QUHOMA irrigation platform, utilizing AI-based predictive analysis, can significantly optimize water management and reduce consumption.

3.2 Challenges in implementing AI-based automated irrigation systems

The application of Artificial Intelligence (AI) technology in agriculture, particularly in automated irrigation systems, represents a transformative approach to food crop production, leveraging advanced technology to optimize agricultural practices and enhance sustainability across various cultivation systems. The advent of AI has revolutionized the agricultural industry, offering opportunities to improve efficiency, productivity, and resource management. However, several challenges still impede widespread adoption. Key factors such as data quality, privacy issues, and the necessity for farmers to acquire deeper data analysis skills must be addressed. Initial investment costs, along with the need for ongoing training and education, may also pose barriers to the adoption of this technology. Furthermore, the development and application of this technology are often specific to each field (Peñailillo et al., 2024).

Another challenge in implementing AI-based automated irrigation systems includes building intelligent systems, transforming data communication, integrating hardware, decision-making, data analysis, and more. AI-based automated irrigation systems utilizing IoT may face issues related to cost and implementation. Additionally, these systems require intelligent automatic microcontrollers, which necessitate effective smart irrigation infrastructure, automatic switches, and pumps for enhanced automation. Moreover, climate parameters must also be considered when implementing automated irrigation systems (Angelin & Kumar, 2021).

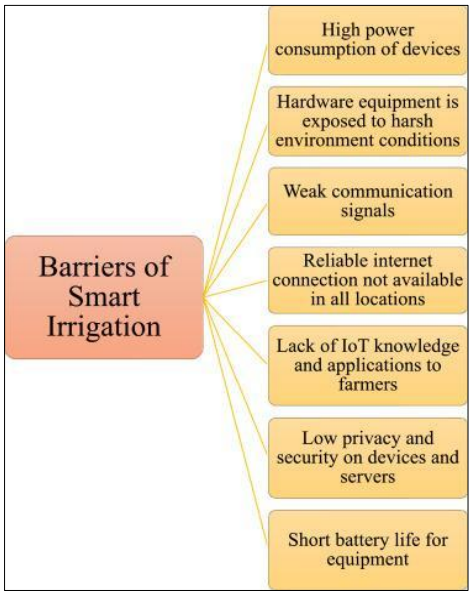

Fig 2. Challenges and barriers in implementing AI-based automation irrigation systems

3.3 Efficiency and sustainability of integrated agriculture through AI-based automated irrigation systems

The implementation of automated irrigation systems has the potential to transform traditional agriculture into a more sustainable and productive sector. Automated irrigation systems emerge as a new field of study that utilizes data-driven methods to enhance agricultural productivity while minimizing environmental impacts. These systems can improve efficiency and represent an innovative approach that automates irrigation processes while conserving water. The system adjusts irrigation according to real-time soil and weather conditions, enabling farmers to meet their needs through more water-efficient techniques (Obaideen et al., 2022).

Water management can be viewed as an effort to regulate soil moisture to ensure the provision of optimal water amounts at the right times. Efficient water management is crucial for the agricultural sector as it can reduce costs and increase yields. Furthermore, effective water management enables farmers to allocate resources and carry out activities according to their needs, influencing the effectiveness of irrigation networks. Water use efficiency is determined by the volume of water supplied from a given irrigation area relative to the volume of water utilized (Harahap et al., 2023).

With automated irrigation systems, much of the handling and operations that were previously done manually will be automated, requiring minimal human involvement and ensuring that water resources are used only as needed. Additionally, energy consumption will significantly decrease, leading to overall cost savings and high cost efficiency. Moreover, enhanced efficiency in irrigation and water management ensures that crops and yields receive only the necessary amounts of water, thereby reducing waste caused by under- or over-watering (Obaideen et al., 2022).

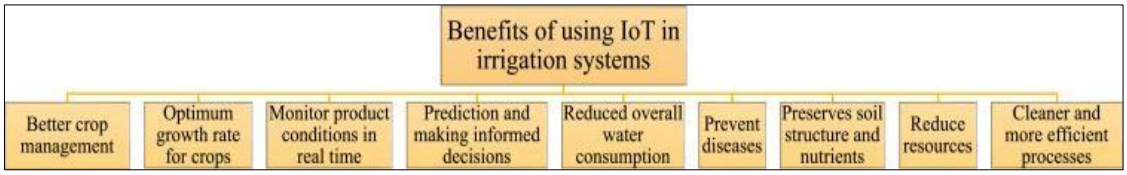

Fig 3. Benefits of implementing Ai technology in automated irrigation systems with IoT

4. Conclusions

The application of Artificial Intelligence (AI)-based automated irrigation systems has the potential to significantly enhance the efficiency and sustainability of integrated agriculture. By adjusting water usage according to real-time weather data and soil conditions, these systems optimize crop yields while minimizing water waste. This technological advancement not only supports agricultural productivity but also plays a vital role in ensuring food security, particularly in regions facing water scarcity. The ability to monitor and manage irrigation dynamically allows farmers to respond swiftly to changing environmental conditions, ultimately leading to healthier crops and better harvests.

Despite these advantages, the widespread adoption of AI technology in automated irrigation systems is impeded by several challenges. High implementation costs, the need for ongoing training for farmers, and the necessity for robust infrastructure remain significant barriers. Addressing these challenges is essential for facilitating the transition to AI-driven irrigation practices. If these obstacles can be overcome, the implementation of AI in automated irrigation systems could revolutionize agricultural practices, leading to a more efficient and sustainable farming landscape. By harnessing the power of AI, we can promote a future where agriculture not only meets the demands of a growing population but also does so in an environmentally responsible manner.

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