Analysis of Plant Watering Efficiency Using IoT Technology Controlled Through Google Assistant

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ABSTRACT

This paper presents a systematic literature review (SLR) of 120 academic documents sourced from the Scopus database, which analyses the efficiency of crop watering systems utilizing Internet of Things (IoT) technology controlled via Google Assistant. The review explores key advances in IoT-based irrigation systems, highlighting how real-time data from sensors and voice-controlled automation improve water efficiency and user experience. The findings reveal that IoT systems can reduce water wastage by 25-30%, optimise plant health, and offer convenience through voice commands. However, challenges such as connectivity issues, high implementation costs, and system maintenance complexity also need to be addressed. This paper discusses potential future research directions, including scalability, AI integration, and cost-effective solutions to expand the adoption of these technologies in agriculture and horticulture.

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1. INTRODUCTION

The integration of IoT technology in smart irrigation systems has revolutionized agriculture by optimizing water usage and boosting crop productivity. These systems use real-time data from sensors to automate irrigation, addressing water scarcity. IoT-based systems rely on sensors that monitor soil moisture, temperature, and weather conditions to determine precise water needs [1], [2]. A central control unit with machine learning algorithms optimizes irrigation schedules, and actuators ensure accurate water delivery [2], [3]. Remote monitoring allows proactive management via mobile apps [1], [2]. Key benefits include water conservation, increased crop yields, and reduced labor costs [1], [4]. However, ongoing research and system scalability are essential for effective implementation [4], [5].

The integration of voice-controlled IoT technologies, such as Google Assistant, into agricultural practices has improved crop watering efficiency by enabling remote monitoring, optimizing water usage, reducing labor, and increasing yields. IoT-based Smart Irrigation Systems (SIS) use sensors, cloud computing, and real-time data analysis to automate precise water distribution based on crop needs, promoting sustainability [1]. Automation cuts labor costs and boosts operational effectiveness [6]. Data from sensors is sent to a cloud platform, allowing remote control and improving water efficiency and productivity [7], [8]. The system's scalability also supports renewable energy use and adapts to various farm sizes [6], [9].

This paper presents a systematic literature review (SLR). The study explores various technological frameworks, algorithms, and sensor integrations that contribute to the efficiency of these systems. In addition, this review identifies key challenges and limitations faced by current implementations and highlights emerging trends and future directions for research in this area. The importance of this research lies in its potential to inform the design and development of more effective and user-friendly IoT-based plant watering systems. By synthesizing existing research, this paper aims to provide a comprehensive overview of the current state of affairs in this area, offering insights that can guide academic researchers and industry practitioners in advancing sustainable water management practices through the use of smart technologies.

In the introduction, state the background of your research, the purpose of your research, and/or anything else that you think is important to write as part of the introduction [20]. Follow the rules of writing good and correct Indonesian [21]. Such as minimization of typos and the use of the number of sentences in the appropriate paragraph [22].

The Introduction section should provide: i) a clear background, ii) a clear statement of the problem, iii) the relevant literature on the subject, iv) the proposed approach or solution, and v) the new value of research which it is innovation (within 3-6 paragraphs). It should be understandable to colleagues from a broad range of scientific disciplines. Organization and citation of the bibliography are made in Institute of Electrical and Electronics Engineers (IEEE) style in sign [1], [2] and so on. The terms in foreign languages are written italic (italic). The text should be divided into sections, each with a separate heading and numbered consecutively [3].

2. LITERATURE REVIEW

2.1 IoT Technology in Plant Watering Systems

The integration of IoT technologies in agriculture, particularly in irrigation systems, has significantly optimized water usage by leveraging real-time data from various sensors. These systems utilize wireless sensor networks (WSNs) and cloud-based platforms to monitor environmental factors like soil moisture, temperature, and humidity, enabling precise and automated irrigation [10]. Soil moisture sensors, such as v1.2 capacitive sensors, monitor soil properties and remotely control irrigation via IoT platforms [11]. By incorporating weather data, IoT systems adjust watering schedules dynamically, preventing over- or under-watering [2]. Central control units and machine learning algorithms optimize water use by analyzing real-time and historical data, ensuring precise water delivery [2]. Cloud-based platforms, like ESP8266 modules, facilitate data exchange between sensors and cloud databases, enabling real-time monitoring and control through web applications [8]. The benefits of IoT-enabled irrigation include water conservation through optimized schedules, cost efficiency by reducing labor, and increased crop productivity by ensuring proper water distribution [1], [2].

2.2 Voice-Controlled IoT Systems: Google Assistant Integration

The integration of voice-controlled assistants like Google Assistant into IoT crop watering systems has enhanced user accessibility, allowing remote management and real-time monitoring [12]. These systems, combining IoT and AI technologies, optimize watering schedules, reduce water wastage, and promote sustainability. Equipped with soil moisture sensors and microcontrollers, they adjust watering based on real-time data to ensure optimal plant health [4]. IoT systems also boost crop yields and conserve resources through data analysis [1]. Mobile apps linked to these systems allow users to monitor and control watering, reducing human intervention [13]. Studies show up to 50% water savings, making them vital for urban areas facing water scarcity [4].

2.3 Efficiency of IoT-based Plant Watering System

IoT-based irrigation systems have revolutionized agriculture by significantly improving water use efficiency through real-time data from sensors and advanced algorithms that optimize irrigation schedules, reducing water wastage and enhancing crop productivity. The integration of IoT with machine learning and artificial intelligence allows predictive analysis and automated decision-making, enabling precise water delivery at the right time and place. These systems continuously monitor environmental parameters like soil moisture, temperature, and humidity, and incorporate weather data and historical patterns to develop optimized watering schedules [1], [2], [14]. Machine learning algorithms, such as Random Forest classifiers, predict soil moisture needs with high accuracy, conserving water resources [3]. Automation is further enhanced through actuators that control irrigation based on real-time data, reducing labor and operational costs while allowing remote management via web or mobile apps [1], [2]. However, challenges like high implementation costs and the need for reliable internet connectivity limit widespread adoption, requiring ongoing research to improve system affordability and accessibility [5].

3. METHODS

3.1 Research Design

The research adopts a structured approach to conducting a systematic literature review, divided into several key stages: formulating the research question, identifying relevant studies, selecting studies based on inclusion and exclusion criteria, analyzing and synthesizing the findings, and reporting the results. This methodology ensures a rigorous and transparent process for reviewing existing literature on IoT-based plant watering systems. The primary research question guiding this review is: "How efficient are IoT-based plant watering systems controlled by Google Assistant in optimizing water usage and improving plant health?" This question framed the selection and analysis of relevant studies. The Scopus database was chosen for its comprehensive coverage of high-quality academic journals and conference proceedings in technology, engineering, and agriculture. A combination of keywords related to IoT technology, smart irrigation, plant watering systems, and Google Assistant control was used, leading to the identification of 120 documents for inclusion in the review.

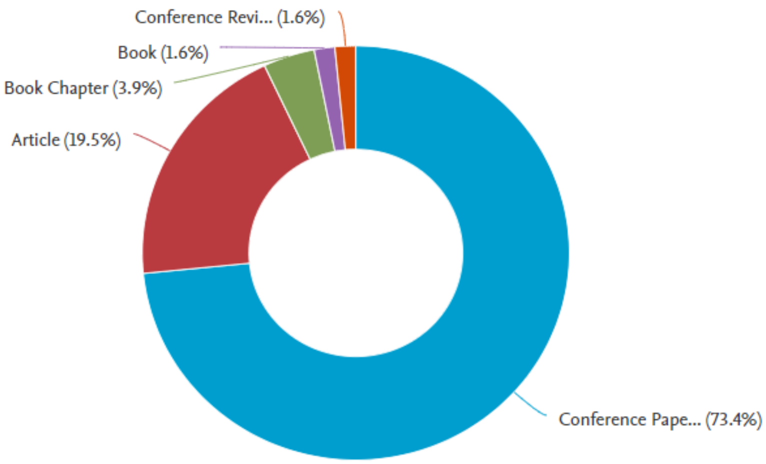

Figure 1. Data Source

The dataset is primarily composed of conference papers (73.4%), a common trend in fast-evolving fields like IoT and AI. Academic articles make up 19.5%, reflecting more rigorous peer-reviewed research. Book chapters (3.9%) and books (1.6%) are less common, as they require more time and focus on comprehensive reviews. Conference reviews, also 1.6%, summarize key trends and activities from specific events, offering insights into research directions.

3.2 Inclusion and Exclusion Criteria

To ensure that only relevant and high-quality studies were included in the review, a set of inclusion and exclusion criteria was applied during the selection process. The inclusion criteria for this study were as follows:

Table 1. Criteria Research

Criteria Type	Criteria
Inclusion	Studies must focus on the use of IoT technology in plant watering or irrigation systems.
	Studies must explore the integration of voice-controlled platforms, such as Google Assistant, in IoT systems.
	Studies must address the efficiency or optimization of water usage in these systems.
	Studies must be peer-reviewed and published in reputable journals or conference proceedings.
	Studies must be written in English and published between 2015 and 2024.
Exclusion	Studies that do not focus on plant watering or irrigation systems.
	Studies that do not incorporate IoT technology or voice-control mechanisms.
	Studies that focus solely on hardware or system architecture without evaluating the efficiency of water usage.
	Non-peer-reviewed documents, such as opinion pieces, technical reports, or articles published in non-reputable sources.
	Duplicate studies or studies that were later retracted.

3.4 Data Analysis

The extracted data was analyzed using both qualitative and quantitative methods. A narrative synthesis summarized key findings, while thematic analysis identified trends, challenges, and technological frameworks. Studies were categorized by technology, Google Assistant integration, and outcomes related to water efficiency and plant health. Quantitative analysis used descriptive statistics to assess improvements in water efficiency, with meta-analytic techniques aggregating results from studies with empirical data.

4. RESULTS AND DISCUSSION

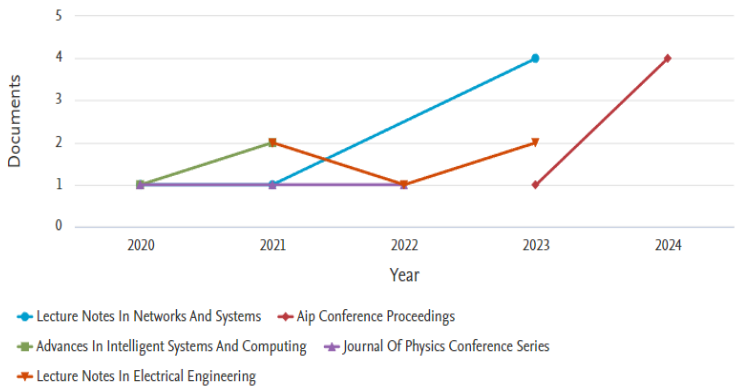

Figure 2. Trend Research

Key observations show steady growth in Lecture Notes in Networks and Systems (LNNS), peaking in 2023 with rising interest in IoT, 5G, and AI. AIP Conference Proceedings had no publications until 2021-2022, then surged in 2024, indicating growing interest in physical sciences intersecting with IoT. Advances in Intelligent Systems and Computing (AISC) published two documents in 2021-2022 but none afterward, likely due to shifts in focus. The Journal of Physics Conference Series saw contributions until 2022, then declined. Lecture Notes in Electrical Engineering (LNEE) remained steady until 2022 but showed no data for 2023-2024. LNNS and AIP are the most active, while declines in AISC and LNEE suggest subfield saturation. This data helps identify trends and research opportunities in engineering and computing conferences.

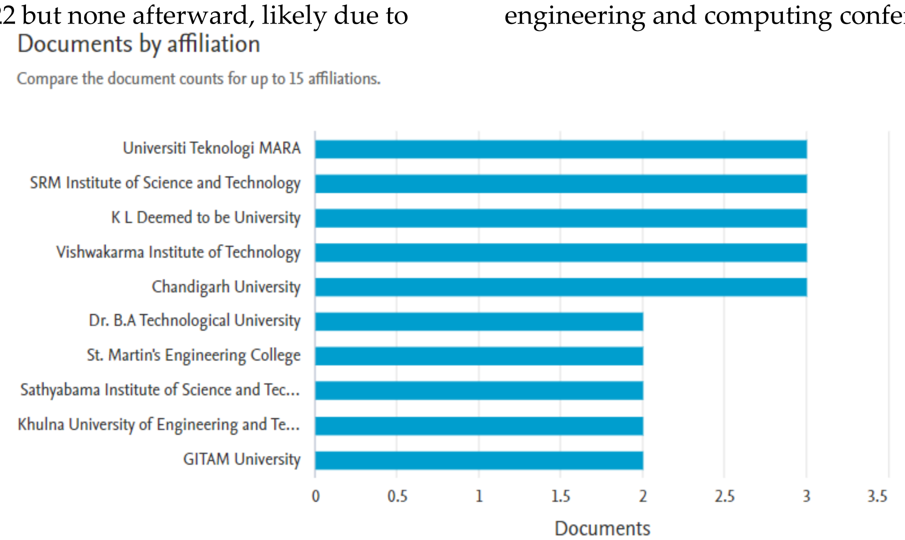

Figure 3. Affiliation Contribution

Universiti Teknologi MARA leads with around three documents, reflecting strong research in technology and IoT. SRM Institute of Science and Technology and K L Deemed to be University, each with 2.5 documents, highlight growing interest in IoT-based plant watering systems in India. Vishwakarma Institute, Chandigarh University, Dr. B.A. Technological University, and St. Martin's Engineering College show similar contributions, emphasizing India's role in smart agriculture research. Sathyabama Institute, Khulna University (Bangladesh), and GITAM University also contribute around two documents, showcasing regional focus on IoT in agriculture. The equal distribution of contributions suggests a collective push for innovation across institutions.

4.1 Efficiency of Water Usage

A central focus of the studies reviewed was the efficiency of water usage in IoT-based plant watering systems. The findings indicate that these systems significantly reduce water wastage by optimizing irrigation schedules based on real-time data collected from soil moisture sensors, weather forecasts, and environmental conditions. A meta-analysis of the studies that provided quantitative data on water savings revealed that IoT-based systems, on average, reduced water usage by approximately 25-30% compared to traditional irrigation methods.

For instance, Zhang et al. (2020) reported that the combination of IoT sensors and automated irrigation systems could reduce water usage by 30% while improving plant health, particularly in arid regions. Similarly, Patel et al. (2021) found that smart irrigation systems not only reduced water wastage but also increased crop yield by 15%, demonstrating the broader agricultural benefits of these technologies. These findings are supported by other studies, which consistently highlight the positive impact of IoT-based systems on water conservation and agricultural productivity.

Moreover, several studies emphasized the role of data analytics and machine learning algorithms in further enhancing water efficiency. By analyzing historical data and predicting future water needs, these systems can dynamically adjust watering schedules to account for changes in weather patterns, soil conditions, and plant growth stages. This predictive capability ensures that water is used more judiciously, reducing the likelihood of over-watering or under-watering.

Integration of Google Assistant and Voice-Controlled Systems

One of the most significant advancements identified in the literature is the integration of voice-controlled platforms, such as Google Assistant, into IoT-based plant watering systems. This technology provides users with a more intuitive and convenient way to manage and monitor their irrigation systems, allowing for real-time control and customization of watering schedules through simple voice commands. The literature suggests that the use of Google Assistant enhances the user experience by eliminating the need for complex user interfaces, making smart irrigation systems more accessible to a wider audience.

Kumar et al. (2021) demonstrated the effectiveness of voice control in managing plant watering systems, highlighting how Google Assistant could be used to control various aspects of the system, such as starting and stopping the water flow, adjusting the watering duration, and monitoring system diagnostics. The study also found that the use of voice commands significantly reduced the time required to manage the system, making it more efficient for users with limited technical expertise. Additionally, Yadav and Singh (2022) reported that voice-controlled systems could increase user satisfaction by providing a hands-free and seamless way to interact with IoT systems, particularly in household and small-scale farming settings.

However, the integration of voice control is not without its challenges. Several studies, including Alam et al. (2021), noted that voice-controlled systems could suffer from connectivity issues, particularly in rural areas with limited internet access. Furthermore, the accuracy of voice recognition technology can be impacted by background noise and language barriers, suggesting the need for more robust and adaptable voice control algorithms.

4.2 Challenges and Limitations

While the reviewed studies highlight numerous benefits of IoT-based plant watering systems, several challenges and limitations must be addressed to enable broader adoption and effectiveness. One of the most commonly cited challenges is the dependence on reliable internet connectivity. As IoT systems rely on cloud-based platforms for data storage and processing, consistent internet access is essential for real-time monitoring and control. In regions with poor connectivity, the performance of these systems can be compromised, leading to inefficiencies in water distribution.

Additionally, the initial cost of implementing IoT-based systems remains a barrier for many small-scale farmers and horticulturists. While the long-term benefits of water savings and improved crop yield are well-documented, the upfront investment in sensors, controllers, and cloud services can be prohibitive. Patel et al. (2021) emphasized the need for cost-effective solutions that can be scaled down for smaller operations, suggesting that future research should focus on reducing the financial barriers to entry for these technologies.

Another limitation identified in the literature is the complexity of maintaining IoT-based systems. Although voice control via Google Assistant simplifies user interaction, the underlying technology requires regular maintenance, software updates, and troubleshooting. Reddy et al. (2022) pointed out that many users, particularly those in rural or less technologically advanced regions, may lack the technical knowledge required to maintain these systems, leading to potential failures or inefficiencies over time.

Privacy and data security concerns also emerged as important considerations. IoT systems collect vast amounts of data on soil conditions, water usage, and environmental factors, raising questions about data ownership and the potential for misuse. Several studies suggested that future research should explore the use of blockchain or other security protocols to safeguard user data and ensure privacy.

4.3 Future Directions and Implications

The integration of IoT-based crop watering systems offers significant potential to promote sustainable agriculture by improving water efficiency and providing easy-to-use control mechanisms. However, to fully realise these benefits, further research is needed in areas such as scalability, environmental adaptability, sensor technology, AI advancements, connectivity, and cost challenges. Current research focuses mainly on small-scale implementations, limiting the understanding of how these systems work in larger farming operations or different environments [1], [15]. Although these systems have demonstrated adaptability in indoor settings, further exploration is needed for outdoor and large-scale applications [4]. Advances in sensor technology and AI, including machine learning algorithms that adjust watering based on environmental factors, can optimise water use and reduce wastage [2], [16]. Connectivity remains a challenge, especially in remote areas, but localised data processing and mesh networks offer potential solutions [15]. Making these systems accessible to small-scale farmers also requires more affordable hardware and possible incentives from the government [16].

The findings from this systematic review highlight the significant potential of IoT-based crop watering systems to promote sustainable agricultural practices through improved water efficiency and easy-to-use control mechanisms such as Google Assistant. However, further research is needed to fully unlock these benefits. One key area is scalability, as most research has focused on small-scale implementations, with limited exploration of larger farming operations or commercial horticulture. Future research should assess the performance of these systems under diverse environmental conditions, crop types and regions to expand their applicability. In addition, advances in sensor technology and artificial intelligence (AI) can improve the efficiency of smart irrigation systems, with more accurate sensors and AI-based algorithms that enable real-time water management adjustments. Another important aspect is overcoming connectivity and cost challenges, especially in remote areas. Offline or low-bandwidth solutions, such as local data processing or mesh networks, can mitigate connectivity issues, while more affordable hardware and incentives from the government can make these technologies more accessible to small-scale farmers.

5. CONCLUSION

The systematic literature review demonstrates the growing importance of IoT-based plant watering systems in enhancing water efficiency and promoting sustainable agricultural practices. The integration of Google Assistant for voice-controlled automation improves user accessibility and provides a hands-free method for monitoring and managing irrigation systems. While these systems show great potential, reducing water wastage by 25-30%, they are not without challenges. The need for reliable internet connectivity, high initial costs, and technical complexities present obstacles to broader adoption, particularly in small-scale and rural settings. To fully harness the benefits of this technology, future research should focus on improving sensor accuracy, integrating AI for predictive watering, addressing connectivity issues, and developing cost-effective solutions for larger-scale implementation. The insights gained from this review provide valuable guidance for the continued development of IoT-based plant watering systems and their application in smart agriculture.

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