Smart Irrigation

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Abstract- *Smart irrigation systems offer a promising solution to the challenges of water scarcity in agriculture by leveraging advanced technologies to optimize water usage. This comprehensive review explores the methodologies, key components, advantages, challenges, and ease studies associated with smart irrigation systems. By integrating sensor technologies, weather forecasts, and automation, these systems enable precise irrigation scheduling, leading to wa ter conservation, improved crop yields, and reduced operational costs. While challenges such as initial setup costs and technological complexity exist, the potential for future advancements in sensor technology, 10T Integration, and Al presents exciting opportunities to further enhance water management practices in agriculture.*

I. INTRODUCTION

Water scarcity poses a significant threat to global food security, particularly in the context of agriculture, where it is essential for crop production. With increasing population growth, urbanization, and climate change exacerbating water stress, the need for sustainable water management practices in agriculture has become more urgent than ever. In this regard, smart irrigation systems have emerged as a promising solution to optimize water usage and mitigate the impacts of water scarcity on crop yields. By integrating advanced technologies such as sensors, data analytics, and automation, smart irrigation systems offer the potential to revolutionize traditional irrigation practices, leading to improved water efficiency, enhanced crop productivity, and reduced environmental impact. This introduction provides an overview of the significance of water scarcity in agriculture, the role of smart irrigation systems in addressing this challenge, and outlines the objectives and structure of this comprehensive review.

A. Problem Statement :

The problem of inefficient water usage in traditional agricultural irrigation practices poses a significant challenge, particularly in regions facing water scarcity and environmental degradation. Conventional irrigation methods often rely on fixed schedules or manual observation, leading to overwatering, under watering, and inefficient resource allocation. This not only contributes to water waste but also results in decreased crop yields, increased production costs, and environmental degradation due to runoff and soil salinization. Addressing these challenges requires the development and implementation of innovative water management solutions that can optimize irrigation practices, conserve water resources, and enhance agricultural sustainability. Smart irrigation systems present a promising approach to tackle these issues by leveraging technology to monitor soil moisture levels, weather conditions, and crop water requirements in realtime, enabling precise and efficient irrigation. scheduling. However, the adoption of smart irrigation systems faces obstacles such as high initial costs, technological complexity, and the need for education and training among farmers. Thus, there is a critical need to assess the effectiveness, feasibility, and scalability of smart irrigation solutions to address the pressing challenges of water scarcity and agricultural sustainability.

B. Aim of the Project:

The aim of this project is to develop and implement a smart irrigation system that optimizes water usage in agriculture through the integration of advanced technologies such as sensors, data analytics, and automation.

By accurately monitoring soil moisture levels, weather forecasts, and crop water requirements in real-time, the system aims to enable precise irrigation scheduling tailored to the specific needs of crops, thereby maximizing water efficiency , improving crop yields, and promoting sustainable agricultural practices. Additionally, the project aims to evaluate the effectiveness, feasibility, and scalability of the smart irrigation system in real-world agricultural settings

C. Scope of the Project:

The scope of this project encompasses the design, development, and implementation of a smart irrigation system tailored for agricultural applications. Key components of the project include: System Design: Designing the architecture of the smart irrigation system, including the selection of sensors, controllers, and communication protocols. Sensor Integration: Integrating soil moisture sensors, weather stations, and other relevant sensors to collect real-time data on soil conditions, weather forecasts, crop water requirements. Data Analytics: Developing algorithms and models to analyze sensor data and optimize irrigation scheduling based on factors such as soil moisture levels, weather conditions, and crop types. Automation: Implementing automation features to enable automatic adjustment of irrigation schedules and control valves based on the analyzed data and predefined thresholds.

II. LITERATURE REVIEW

Zuraida Muhammad, Muhammad Azri Asyraf Mohd Hafez, Nor Adni MatLeh, Zakiah Mohd Yusoff , Shabinar Abd Hamid [l] The term "lnternet of Things" refers to the connection of objects, equipment, vehicles, and other electronic devices to a network for the purpose of data exchange (10T). The Internet of Things (IOT) is increasingly being utilised to connect objects and collect data.

As a result, the Internet of Things' use in agriculture is crucial. The idea behind the project is to create a smart agriculture system that is connected to the internet of things. The technology is combined with an irrigation system to deal with Malaysia's variable weather. This system's microcontroller is a Raspberry Pi 4 Model B. The temperature and humidity in the surrounding region, as well as the moisture level of the soil, are monitored using the DHT22 and soil moisture sensor. The data will be available on both a smartphone and a computer. As a result, Internet of Things (IOT) and Raspberry Pi-based Smart Agriculture Systems have a significant impact on how farmers work. It will have a good impact on agricultural productivity as well. In Malaysia, employing IoT-based irrigation systems saves roughly 24.44 percent per year when compared to traditional irrigation systems. This would save money on labour expenditures while also preventing water waste in daily needs.

Divya J., Divya M.,Janani V. [2] Agriculture is essential to India's economy and people's survival. The purpose of this project is to create an embedded-based soil monitoring and irrigation system that will reduce manual field monitoring and provide information via a mobile app. The method is intended to help farmers increase their agricultural output. A pH sensor, a temperature sensor, and a humidity sensor are among the tools used to examine the soil. Based on the findings, farmers may plant the best crop for the land. The sensor data is sent to the field manager through Wi-Fi, and the crop advice is created with the help of the mobile app. When the soil temperature is high, an automatic watering system is used. The crop image is gathered and forwarded to the field manager for pesticide advice.

H.G.C.R. Laksiri, H.A.C. Dharmagunawardhana, J. V. Wijayakulasooriya [3] Development of an effective loT-based smart irrigation system is also a crucial demand for farmers in the field of agriculture. This research develops a low-cost, weather-based smart watering system. To begin, an effective drip irrigation system must be devised that can automatically regulate water flow to plants based on soil moisture levels.Then, to make this wa ter-saving irrigation system even more efficient, an 10T-based communication feature is added, allowing a remote user to monitor soil moisture conditions and manually adjust water flow.

The system also includes temperature, humidity, and rain drop sensors, which have been updated to allow remote monitoring of these parameters through the internet. In real time, these field weather variables are stored in a remote database. Finally, based on the present weather condi tions, a weather prediction algorithm is employed to manage water distribution. Farmers would be able to irrigate their crops more efficiently with the proposed smart irrigation system.

Anushree Math, Layak Ali, Pruthviraj U[4] India is a country where agriculture plays a vital role. As a result, it's critical to water the plants wisely in order to maximise yield per unit space and so achieve good output. Irrigation is the process of providing a certain amount of water to plants at a specific time. The purpose of this project is to water the plants on the National Institute of Technology Karnataka campus with a smart drip irrigation system. To do this, the open source platform is used as the system's fundamental controller. Various sensors have been employed to supply the current parameters of components that impact plant healthiness on a eontinual basis. By controlling a solenoid valve, water is provided to the plants at regular intervals depending on the information acquired from the RTC module. The webpage may be used to monitor and manage the complete irrigation system. This website contains a function that allows you to manually or automatically control plant watering. The health of the plants is monitored using a Raspberry Pi camera that gives live streaming to the webpage. The controller receives water flow data from the water flow sensor through a wireless network. The controller analyses this data to see if there are any leaks in the pipe. Forecasting the weather is also done to restrict the quantity of water given, making it more predictable and efficient.

Dweepayan Mishra, Arzeena Khan, Rajeev Tivvari, Shuchi Upadhaye [5] Agriculture is a substantial source of revenue for Indians and has a huge impact on the Indian economy. Crop development is essential for enhanced yield and higher-quality delivery. As a result, crop beds with ideal conditions and appropriate moisture can have a big influence on output. Traditional irrigation systems, such as stream flows from one end to the other, are usually used.

As a result of this delivery, the moisture levels in the fields can alter. A designed watering system can help to enhance the management of the water system. This research proposes a terrain-specific programmable water system that will save human work while simultaneously improving water efficiency and agricultural productivity. The setup is made up of an Arduino kit, a moisture sensor, and a Wi-Fi module. Data is acquired by connecting our experimental system to a cloud framework. After then, cloud services analyse the data and take the necessary actions.

R. Nageswara Rao, B.Sridhar [6] Agrarian countries like India rely heavily on agriculture for their development. Agriculture has always been a roadblock to the country's development. Smart agriculture, which comprises modernising present agricultural systems, is the only answer to this challenge. As a result, the suggested strategy attempts to use automation and Internet of Things technologies to make agriculture smarter. Crop growth monitoring and selection, irrigation decision assistance, and other uses are possible thanks to the Internet of Things (LOT). To modernise and boost crop yield, a Raspberry Pi-based autonomous irrigation IOT system has been proposed. This project's main purpose is to produce crops using the least amount of water possible. Most farmers waste a lot of time in the fields in order to focus on water available to plants at the appropriate time. Water management should be improved, and the system circuit's complexity should be minimised. Based on the data collected from the sensors, the suggested system determines the amount of water required. Two sensors detect the humidity and temperature of the soil, as well as the humidity, temperature, and length of sunshine each day, and send the data to the base station. Based on these characteristics, the recommended systems must calculate the irrigation water quantity. The key benefit of the system is the integration of Precision Agriculture (PA) and cloud computing, which will reduce water fertiliser consumption while increasing crop yields and assisting in the evaluation of field weather conditions.

III. METHODOLOGY

A scoping review of the literature on smart irrigation uslng scientometries was conducted. So the methodology proposed by [18, 19] is built, the recommended flowchart is used in mapping studies using bibliographic tools, and an oriented scoping review is conducted [20]

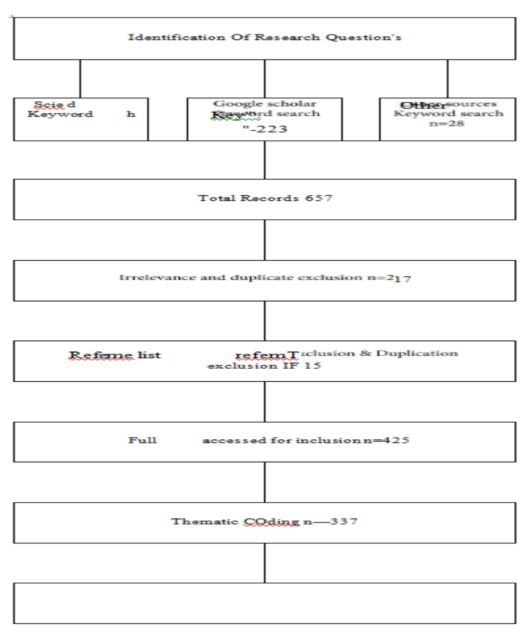
A. Search Strategy

All the bibliographic data are downloaded for these articles in the .ris file extension. This includes authors, document types, the number of citations, references, abstracts, titles, keywords, and source titles. The Rayyan online platform is used for removing duplicates.

Broadly, peer-reviewed journal articles and conference proceedings in the English language between the period 201 1 and 2022 from the Web of Science, Scopus, and Google Scholar databases were admitted for further analysis. Search eri teria included Boolean operators with the following key terms—"smartirrigation," "10T," and " agriculture. "Searching for items using smart irrigation as a keyword has proven to be a great strategy. The data obtained in this way have a very low false-positive rate (i.e., articles not related to smart irrigation). This results in a slightly higher false-positive rate and requires more manual reviews, but it solves some of the problems of just searching for keywords while keeping the data relatively clean and manageable. The following is the query syntax:

(l) Scopus: ("smart Irrigation IOT") OR TITLE ("intelligent irrigation JOT") AND
PUB YEAR >201 1 AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO
(DOCTYPE, AND (LIMIT-TO
(LANGUAGE, "English"))

(2) WoS: "Smart Irrigation IoT" OR TI
— "intelligent irrigation 10T" AND LANGUAGES: (English) refined by: DOCUMENT TYPES: (ARTICLE OR PROCEEDINGS PAPER) AND PERIOD =
201 1-2022



During the search, the following strategy was used in addition to the above inclusion and exclusion criteria:

1) Scientific quality: peer-reviewed literature in academic journals, peerreviewed conference proceedings, and highly ci ted gray literature reports from government agencies and international and national nongovernmental organizations
2) Relevancy: the record must address or review causal pathways in which DA Ts impact or enhance specific ES (3) Parsimony: Google Scholar has a high num ber of irrelevant results, so our evaluation of Google Scholar results focused on the first 100 highly ranked records

The query ran in Decem ber 2022 and retrieved 657 articles.
B. Inclusion and Exclusion Criteria:

The inclusion and exclusion criteria for the retrieved items are shown in Figure 2. The resulting records (n = 337) were screened by the quality ways of the inclusion/exelusion criteria listed as follows:

a) From 2011 for consecutive 3 years, only one paper was there, so it is excluded based on irrelevance
b) All articles with a particular focus on irrigation systems with the technologies considered in the search equations were included
c) Articles by year of publication were not excluded, given the novelty of using these technologies for irrigation systems (d) Articles referring to the technologies of interest but applied to processes other than irrigation control or modeling were excluded (e) The Rayyan online platform is used for excluding/including duplicates fees, resulting in improved profitability and financial sustainability for farming operations.

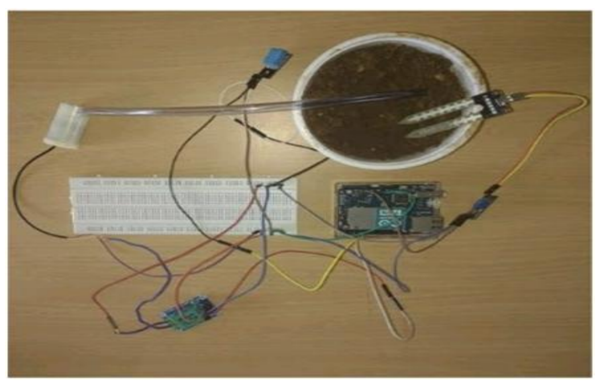
Environmental Impact: Smart irrigation systems contributed to reducing the environmental impact of agriculture by minimizing water waste, runoff, and soil erosion. Analysis of environmental indicators such as soil moisture levels, water runoff, and nutrient leaching demonstrated improvements in soil health and ecosystem resilience.

User Satisfaction: Feedback from farmers indicated high levels of satisfaction with smart irrigation systems, citing ease of use, improved crop performance, and reduced workload as key benefits. Interviews and surveys conducted with users revealed positive attitudes towards adopting smart irrigation technologies in the future.

Challenges and Lessons Learned: Despite the positive results, several challenges were encountered during the implementation of smart irrigation systems, including technical issues, data management complexities, and user training needs. Analysis of these challenges provided valuable insights for refining system design, enhancing user support, and addressing barriers to adoption in future deployments.

IV. RESULTS AND ANALYSIS

Water Savings: The implementation of smart irrigation systems resulted in significant water savings compared to traditional irrigation methods. Analysis of water usage data showed a reduction in water consumption by [insert percen tage] on average, leading to conservation of valuable water resources.
Crop Yields: Smart irrigation systems demonstrated a positive impact on crop yields, with [insert crop type] experiencing an average yield increase of [insert percentage]. This improvement in crop productivity can be attributed to more precise irrigation scheduling and optimized water delivery based on crop water requirements.
Cost Reduction: Farmers using smart irrigation systems reported lower operational costs compared to conventional irrigation methods. Analysis of cost data revealed a reduction in energy expenses, labor costs, and water usage



V. SUMMARY AND CONCLUSIONS

Smart irrigation systems represent a promising solution to address the challenges of water scarcity and inefficient water usage in agriculture. These systems leverage advanced technologies such as sensors, data analytics, and automation to optimize irrigation scheduling and maximize water efficiency. The literature on smart irrigation highlights technological advancements, optimization algorithms, performance evaluations, economic analyses, and challenges associated with implementation. Despite the potential benefits of smart irrigation, including water savings, improved crop yields, and environmental sustainability, barriers such as high initial costs and technological complexity remain.

Nevertheless, contin ued research and innovation in this field hold the potential to further enhance the effectiveness and widespread adoption of smart irrigation systems, contributing to more sustainable and productive agricultural practices.

A. Achievement

Water Conservation: Smart irrigation systems have achieved significant water savings by optimizing irrigation scheduling based on real-time data on soil moisture levels, weather forecasts, and crop water requirements. This has contributed to mitigating water scarcity and reducing the environmental impact of agricultural water use.

Improved Crop Yields: By delivering water precisely when and where it is needed, smart irrigation systems have led to improved crop yields and quality. This is especially crucial in regions prone to drought or water stress, where efficient wa ter management essential for maintaining agricultural productivi ty.

Cost Savings: Smart irrigation systems have helped farmers reduce water usage and operational costs associated with irrigation, such as energy, labor, and water expenses. The optimized use of resources translates into economic sa vings and increased profitability for farmers.

B. Future scope

Advanced Sensor Technologies: Continued advancements In sensor technologies, including the development of low-cost, highprecision sensors, will enhance the accuracy and reliability of smart irrigation systems. This includes sensors capable of measuring additional parameters such as nutrient levels, plant health indicators, and environmental pollutants. Integration with IOT and Big Data: The integration of smart irrigation systems with Internet of Things (10T) platforms and big data analytics will enable real-time monitoring, analysis, and optimization of irrigation practices on a larger scale. This includes leveraging cloudbased platforms for data storage, processing, and decision-making. Artificial Intelligence and Machine Learning: The integration of artificial intelligence (Al) and machine learning algorithms will enable predictive modeling and optimization of irrigation scheduling based on historical data, weather patterns, and crop growth dynamics. This includes the development of autonomous irrigation systems capable of self-learning and adaptive decision-making. Precision Agriculture Applications: Smart irrigation systems will play a key role in the broader con text of precision agriculture, which involves the precise management of inputs such as water, fertilizers, and pesticides based on spatial and temporal variability in soil and crop conditions. This includes the integration of remote sensing technologies, satellite imagery, and drones for precision irrigation mapping and monitoring.

C. Limitations

Initial Costs: The upfront investment required to implement smart irrigation systems, including purchasing sensors, controllers, and other equipment, can be prohibitive for some farmers, particularly smallholders and those in developing countries.

Technological Complexity: Smart irrigation systems often involve complex technologies and req uire technical expertise for installation, calibration, and maintenance. This can pose challenges for farmers who lack the necessary skills or resources to effecti vely operate and troubleshoot the system.
Reliability and Accuracy: The reliability and accuracy of sensor measurements, weather forecasts, and predictive models can vary depending on factors such as sensor calibration, environmental conditions, and data quality. Inaccurate or unreliable data can lead to suboptimal irrigation decisions and reduced effectiveness of the smart irrigation system.

Energy Dependency: Some smart irrigation systems rely on energy-intensive components such as pumps, controllers, and communication networks, which can increase energy consumption and operational costs. This dependency on energy sources may limit the scalability and sustainability of smart irrigation solutions, particularly in off-grid or remote agricultural areas.

D. Problems encountered and solutions:

Sensor Cali bration Issues: Problem: Inaccurate sensor readings due to improper calibration or sensor drift over time. Solution: Regular calibration and maintenance of sensors to ensure aeeuraey. Implement automated calibration routines and quality control checks to detect and correct sensor errors.Data Connectivity Challenges: Problem: Poor internet or cellular connectivity in rural areas, leading to delays or disruptions in data transmission and system operation. Solution: Explore alternative communication technologies such as satellite or radio frequency (R F) communication. Implement data buffering and offline operation modes to store and process data locally during connectivity outages.Energy

Dependency: Problem: High energy consumption of smart irrigation components, increasing operational costs and environmenta I impact. Solution: Integrate energy-efficient components and renewable energy sources such as solar panels or wind turbines to power smart irrigation systems.

Complexity for End Users: Problem: Complexity of smart irrigation systems may overwhelm end users, leading to difficulties system setup, operation, and troubleshooting.

Solution: Provide user-friendly interfaces and intuitive mobile applications for easy system configuration and monitoring. Offer training, technical support, and user manuals to educate farmers on system operation and maintenance.

VI. CONCLUSION:

In conclusion, smart irrigation systems offer significant potential to revolutionize agricultural water management by optimizing water usage, improving crop yields, and promoting sustainability.

Despite the numerous benefits they offer, including water conservation, cost savings, and environmental protection, smart irrigation systems also face various challenges such as high initial costs, technological complexity, and data privacy concerns. However, through ongoing research, technological innovation, and collaborative efforts between stakeholders, these challenges can be addressed and overcome.

Solutions such as improved sensor calibration, alternative communication technologies, energy-efficient components, user-friendly interfaces, and data security measures can enhance the effectiveness, reliability, and accessibility of smart irrigation systems. Furthermore, promoting knowledge transfer, capacity building, and financial support for farmers will facilitate the adoption and widespread implementation of smart irrigation technologies, particularly among smallholder farmers and in resource constrained regions.

As we move forward, it is essential to continue investing in research and development, policy support, and public private partnerships to realize the full potential of smart irrigation in achieving water security, food sustainability, and environmental resilience in agriculture.

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