AI Powered Irrigation

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Abstract

The integration of artificial intelligence in irrigation is transforming contemporary agriculture by optimizing crop yields, conserving water resources, and promoting sustainable farming practices. Traditional irrigation systems often lead to water inefficiencies and misdistribution, which can harm the environment. AI-driven solutions, including machine learning algorithms and Internet of Things (IoT) sensors, enable real-time monitoring of soil moisture levels, weather changes, and crop requirements, ensuring that water is delivered precisely when and where it is needed. By adapting irrigation strategies to reflect evolving environmental conditions, this technology reduces water usage while enhancing both crop health and overall productivity. AI-enabled irrigation presents a scalable solution to address the increasing global demand for food and the challenges posed by water scarcity. Additionally, the use of data from drones and satellites further enhances the effectiveness of this innovative approach. This study presents a brief overview of the use of artificial intelligence in the irrigation system.

Keywords: Automatic Irrigation, Artificial intelligence, Deep Learning, Machine learning.

1. Introduction

Irrigation systems powered by artificial intelligence and deep learning represent cutting-edge solutions to the challenges posed by traditional irrigation methods. Typically, these older systems rely on fixed watering schedules or direct measurements, which often result in water wastage and uneven or inadequate water application. Furthermore, they do not account for varying crop needs in real-time, leading to either excessive water usage or under-irrigation, both of which can adversely affect crop yields and resource sustainability. These methods are

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labor-intensive, costly, and difficult to implement on a large scale, particularly in areas with limited water resources [6-8].

Deep learning, a subset of artificial intelligence, offers a transformative shift by enabling irrigation systems to make intelligent decisions based on data. This technology allows for the collection of extensive information from sensors, weather forecasts, and satellite imagery, thereby optimizing irrigation schedules and providing flexible water delivery that considers current soil moisture levels and plant health[9-11]. In essence, the use of artificial intelligence addresses the shortcomings of traditional watering methods, producing solutions that are more accurate, environmentally sustainable, and cost-effective in meeting the demands of modern global agriculture. The study presents a brief overview of the existing works that use AI to improve the irrigation process and discusses the advantages offered by the AI methods over the conventional methods [12-15].

2. Related Work

Harini S et al. [1] The authors present an innovative approach to modern irrigation practices by integrating AI technologies. the research highlights how AI can enhance irrigation efficiency through real-time data analysis. By utilizing sensors to monitor soil moisture levels, weather conditions, and crop requirements, these smart systems aim to optimize water usage and ensure that crops receive the precise amount of water needed for healthy growth. The authors discuss several benefits of implementing AI-driven irrigation systems, including significant water conservation, improved crop yields, and reduced operational costs. However, they also identify challenges such as the need for reliable data sources and potential barriers to technological adoption among farmers. Ultimately, the research advocates for continuous development in this field, emphasizing that AI-powered irrigation solutions promote sustainable agricultural practices and address water scarcity issues in farming.

Maira Sami et al. [2] It discusses the development of an advanced irrigation management system that utilizes deep learning techniques to enhance water usage efficiency in agriculture. The study focuses on creating a model that integrates various sensor data, such as soil moisture, temperature, and weather conditions, to predict irrigation needs accurately. By utilizing machine learning algorithms, the system aims to optimize water application schedules, reducing waste and promoting sustainable agricultural practices. The study discusses the development of an advanced irrigation management system that utilizes deep learning techniques to enhance water usage efficiency in agriculture. The study focuses on creating a model that integrates various sensor data, such as soil moisture, temperature, and weather conditions, to predict irrigation needs accurately. By utilizing the machine learning algorithms, the system aims to optimize water application schedules, reducing waste and promoting sustainable agricultural practices. The research presents a comprehensive framework that combines data collection from sensors with deep learning methodologies, demonstrating significant improvements in irrigation timing and water conservation. The results indicate that the proposed model can adapt to varying environmental conditions, ensuring crops receive the optimal amount of water. This innovation not only supports farmers in improving yields but also addresses broader environmental concerns related to water scarcity and resource management in agriculture.

Youness Tace et al. [3] The review explores the integration of Internet of Things (IoT) and machine learning technologies to enhance agricultural irrigation practices. The primary objective is to develop a system that optimizes water usage, reduces wastage, and ensure the effective growth of crops. The proposed system utilizes IoT sensors to collect real-time data on soil moisture, temperature, humidity, and weather conditions. This data is transmitted to a central platform for analysis and processing. Machine learning algorithms are applied to predict water requirements based on environmental factors, such as weather forecasts and historical data. By continuously learning from incoming data, the system can adapt to changing conditions, providing precise irrigation schedules that meet the needs of different crops. The journal emphasizes the potential for machine learning models, such as regression analysis and decision trees, to predict and optimize irrigation patterns. The integration of IoT and machine learning reduces the need for manual intervention, allowing for remote monitoring and automated control of irrigation systems. The proposed solution is not only cost-effective but also environmentally sustainable, as it minimizes water waste and supports precision agriculture. The journal highlights the effectiveness of the smart irrigation system in improving crop yield, conserving water, and reducing energy consumption, making it a promising approach for modernizing agriculture. In conclusion, the research demonstrates how IoT and machine learning can be utilized to create intelligent irrigation systems that enhance agricultural efficiency, promote sustainability, and optimize resource usage.

Zouizzaet al. [4] This explores the development and implementation of an advanced irrigation system powered by artificial intelligence (AI) to optimize water usage in agriculture.

The study proposes a system that integrates AI with IoT (Internet of Things) sensors to collect real-time data on soil moisture, weather conditions, and crop requirements. This data is processed and analyzed by AI algorithms to generate precise irrigation schedules, ensuring that water is applied efficiently based on the specific needs of the crops and environmental conditions. The AI system leverages machine learning techniques to predict and adapt irrigation patterns, continuously improving its accuracy by learning from historical data and real-time sensor inputs. This allows the system to adjust to changing weather patterns, soil conditions, and crop growth stages, ensuring that water is used optimally without wastage. The system can also be automated, reducing the need for manual intervention and offering farmers greater control over irrigation practices, even remotely. The journal highlights the potential benefits of such a system, including reduced water consumption, improved crop yields, and lower operational costs. Additionally, the use of AI in irrigation helps mitigate the risks associated with over-irrigation or under-irrigation, leading to better crop health and more sustainable farming practices. In conclusion, the study demonstrates how AI-driven irrigation systems can significantly enhance water use efficiency in agriculture, offering a smart, sustainable solution to address the growing challenges of water scarcity and climate change.

Tae Hoon Kim et al. [5] It focuses on improving irrigation strategies in legume cultivation to optimize water use and enhance crop yields. It highlights the challenges of traditional irrigation methods, which often lead to water wastage and inefficient crop growth due to uneven water distribution and poor management practices. The study proposes a precision irrigation approach, utilizing advanced technologies such as soil moisture sensors, weather forecasting, and automated irrigation systems to deliver precise amounts of water to legume crops based on real-time soil conditions and climatic factors. The goal is to enhance water use efficiency (WUE), ensuring that legumes receive the right amount of water at the right time, thereby reducing water waste and supporting sustainable agricultural practices. The research emphasizes the importance of accurate data collection and analysis in precision irrigation systems. By incorporating tools like remote sensing, IoT devices, and machine learning algorithms, farmers can monitor soil moisture levels and predict irrigation needs more accurately. The study also discusses the role of soil health and the specific water requirements of different legume varieties, which can vary due to their unique growth patterns and water stress tolerances. This study demonstrates that precision irrigation, when combined with advanced technology, can significantly improve water use efficiency in legume farming. This approach not only helps conserve water but also improves crop yield, reduces costs, and supports sustainable farming practices in regions facing water scarcity. Table 1 shows the summary of the related works.

Table 1. Summary of Related Works

Related Works	Application Focused	Advantage of the Algorithm used	Limitations of Algorithm used
1	The paper focuses on the use of AI technologies for optimizing irrigation practices in agriculture. The AI system monitors soil moisture, weather conditions, and crop needs to manage water usage efficiently.	Water Conservation: Optimizes water usage, reducing waste. Improved Crop Yields: Ensures that crops receive the right amount of water at the right time. Operational Cost Reduction: Automates irrigation, reducing labor and resource costs.	Dependence on Reliable Data: The accuracy of the system relies on the quality of the data from sensors and weather forecasts. Adoption Barriers: Farmers may face difficulties in implementing AI technologies due to cost, infrastructure, or technological knowledge limitations.
2	The study focuses on developing an irrigation management system using deep learning techniques to predict irrigation needs by integrating sensor data (soil moisture, temperature, and weather conditions).	Improved Water Usage Efficiency: The system accurately predicts irrigation needs, reducing water waste. Sustainable Agriculture: Promotes sustainable farming practices by optimizing water application. Adaptability: The system can adapt to varying environmental conditions, ensuring optimal water distribution.	Data Dependence: The performance of the system heavily relies on the quality and accuracy of the sensor data. Complexity of Implementation: Integrating multiple sensors and deep learning models can be complex and may require significant technical expertise.
3	The paper focuses on integrating IoT and machine learning to develop an intelligent irrigation system that optimizes water usage and	Sustainability: Minimizes water waste and supports environmentally sustainable farming practices.	Data Dependence: The system relies heavily on the quality and accuracy of IoT sensor data and historical data for predictions.

	improves crop growth by predicting water needs based on real-time data and environmental factors.	Remote Monitoring and Automation: Reduces the need for manual intervention, enabling remote monitoring and automated irrigation control. Improved Crop Yield: Optimizes irrigation, contributing to better crop growth and higher yields. Cost-Effectiveness: The system is cost-effective due to the reduction in water and energy usage.	Complexity of Implementation: Integrating multiple IoT sensors and machine learning models can be complex and require significant technical resources. Need for Continuous Learning: Machine learning models require continuous learning from new data, which might need regular updates to adapt to changing conditions
4	The study focuses on an AI-powered irrigation system integrated with IoT sensors to optimize water usage in agriculture by providing precise irrigation schedules based on real-time data	Efficient Water Usage: AI algorithms process real-time data and adapt irrigation schedules, ensuring water is applied optimally and without wastage. Adaptability to Changing Conditions: The system continuously learns from historical data and real-time inputs, allowing it to adjust to changing weather patterns, soil conditions, and crop growth stages.	Data Dependency: The system's effectiveness depends on the accuracy and reliability of IoT sensor data and environmental inputs. Complexity in Implementation: Developing and integrating AI algorithms with IoT sensors can be technically challenging and may require significant resources for deployment and maintenance.
5	The study focuses on improving irrigation strategies for legume cultivation by using advanced technologies such as soil moisture	Enhanced Water Use Efficiency (WUE): Algorithms predict irrigation needs based on real-time data, ensuring legumes receive the right	Dependence on Accurate Data: The system relies on the accuracy of sensors, weather data, and machine learning

	sensors, weather forecasting, and automated irrigation to optimize water use and enhance crop yields.	amount of water, thus reducing waste. Improved Crop Yield: By providing precise water application tailored to the specific needs of different legume varieties, the system promotes healthy growth and better yields.	models, which may be affected by errors or inaccuracies in data collection. Complexity of Integration: The implementation of precision irrigation requires integrating multiple technologies, which can be complex and resource-intensive for farmers.

3. AI Architecture

AI-powered irrigation systems are typically comprised of four major subsystems: the sensing unit, the processing unit, the subscriber unit, and the actuation unit. The sensing unit incorporates sensors to provide the measurement of environmental factors such as soil moisture, temperature, humidity, and weather. All data is sent to the control unit, which through some AI algorithms, makes judgments regarding crop types or growth stages to calculate, predict, and even modify the irrigation required and even provide optimization of water use on the farm. The subscriber unit is basically the smartphone or a central unit that gives real-time outputs and allows users to handle the irrigation system in direct physical control. Finally, the actuation unit carries out the irrigation commands by controlling valves, pumps, and sprinklers to provide the right quantity of water to the crops for efficient and precise irrigation.

3.1. AI-Powered Irrigation System Architecture [16]

The automated irrigation system powered by artificial intelligence merges different expanses of IoT devices as well as Machine learning algorithms for effective installation of water in crops. Such a solution skeleton includes a number of components namely: the Raspberry Pi (CPU), the receiver node, the subscriber unit, the actuation unit, and the sensing unit. These components, demonstrate a fully autonomous intelligent irrigation system that can assess environmental conditions, forecast the irrigation needs, and distribute water resources with minimum human intervention.

3.2. Persistence Unit and Raspberry Pi

The second fundamental concept would be the persistence unit which is the system's operational data storage usually a database or cloud in which all of the sensor data including soil moisture, soil temperature, soil humidity, and historical figures of irrigation are stored. These values are necessary for models aimed at estimating irrigation requirements using machine learning techniques. The Raspberry Pi, integrated within the central processing unit, is employed in the field to monitor a variety of sensors, including soil moisture sensors and weather stations.

3. 3. Receiver Node and Subscriber Unit

The receiver node is an important processing unit that works between the Raspberry Pi and the physical systems (such as irrigation valves and actuators). It receives commands or decisions from the Raspberry Pi pertaining to the irrigation schedules and the operation of the irrigation valve, performs decision-making based on real-time sensor data, and then translates these decisions into formats understandable by respective systems. The system manages communication with subscriber units, which may include basic mobile devices or remote servers that receive system updates. It delivers notifications regarding system faults identified during automatic diagnostics and provides a manual control option for farmers through a manual override mechanism. This functionality ensures that all relevant information regarding irrigation practices is available to various stakeholders in real-time.

3.4. Actuation Unit and Motor-Driven Pumps

The actuation unit is responsible for physically managing the irrigation system based on commands received from the receiver node. Typically, it consists of motor-driven pumps, solenoid valves, and various actuators designed for controlling water flow. When the AI system predicts the need for irrigation, the receiver node sends signals to activate the motor-driven pumps, which draw water from reservoirs or other sources, directing it towards the field. Solenoid valves are then opened or closed according to an established irrigation schedule. The actuation unit operates solely when necessary, leveraging a feedback loop with the AI's decision-making processes to minimize water use and promote optimal crop health. The operation of the pumps can be monitored and regulated in real-time at each solenoid valve, specifically at every watering point linked by distributors along the lateral lines.

3.5. Sensing Unit

The Sensing Unit includes all the sensors deployed in the field to gather data necessary for the AI-driven irrigation system. These sensors measure important parameters like soil moisture, temperature, humidity, light intensity, and sometimes even weather data like rainfall or wind speed. The sensing unit continuously monitors these environmental variables and sends the data to the Raspberry Pi and receiver node for processing. Soil moisture sensors, in particular, play a key role, in helping the system determine when the soil is too dry and requires irrigation. Weather data, often sourced from external APIs or local weather stations, can also be factored into the AI model to adjust irrigation schedules based on anticipated rainfall or temperature fluctuations. Together, the sensing unit ensures that the irrigation decisions made by the AI system are based on accurate, real-time environmental data.

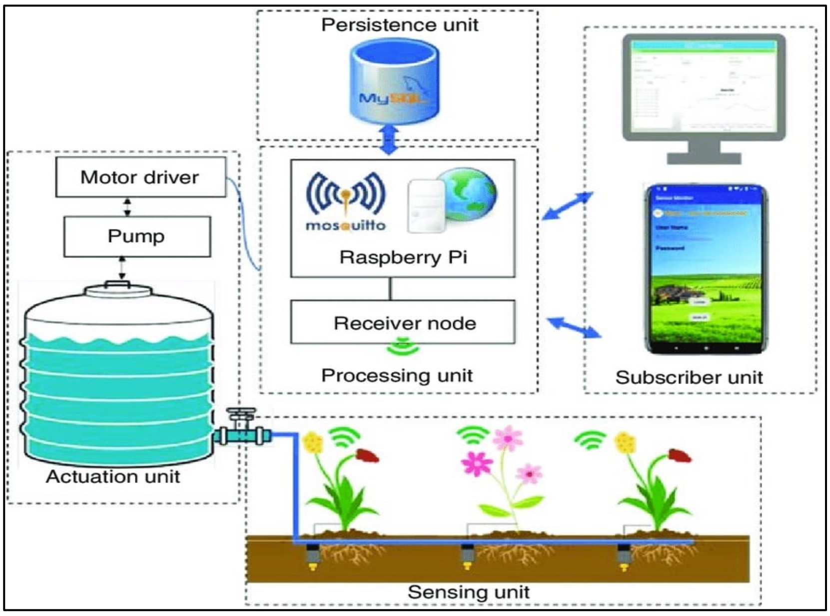

Figure 1. Architecture of AI Irrigation [16]

4. AI Algorithms

In AI-powered irrigation, the performance of many algorithms can be judged through key metrics such as accuracy, efficiency, and scalability. For instance, Decision Trees (DT), offer moderate accuracy along with computational efficiency, making them best suited for smaller, simpler data sets. However, they easily suffer from overfitting and do not scale with large, complex data well. Support Vector Machines (SVM), by contrast, tend to yield higher accuracy, especially in high-dimensional space, though they are computationally intensive and not scalable for huge datasets. They are excellent in finding non-linear patterns but are less effective in real-time applications due to their higher training and testing time.

The use of NNs, however, is excellent for precision as well as the ability to deal with complex, nonlinear relationships, but it comes at a cost in high computation usage and longer training times. Its capability to scale well with larger data sets makes it unsuitable in systems where transparency is sought after. KNN is simple to implement and has a good understanding, achieving good accuracy for small datasets. However, KNN suffers from large data as it fully depends upon distance measurement between points. It is very time-consuming and inefficient for real-time decision-making.

Finally, Random Forest combines the benefits of decision trees- offering high accuracy, being robust, and generalizing and has fewer computational requirements when compared to deep neural networks. RF scales well into very large datasets and offers moderate levels of interpretability through feature importance analyses. On the whole, a combination of accuracy, efficiency, and scalability makes RF very effective in AI-powered irrigation systems where diverse environmental information is necessary to ensure reliable working at varying conditions. Table 3 illustrates the observations from the existing work.

Table 2. Observation of Existing Work

Algorithm	**Observations**
Decision Tree [1]	No simulation was carried out, the model was expected to provide water conservation, improved crop yields, and operational cost reduction.
Long Short-Term Memory (LSTM)-based neural networks (with neural sensors) [2]	RMSE 2.35% for smart irrigation
K-Nearest Neighbors (K-NN) [3]	KNN Accuracy - 98.3%, RMSE-0.12
Neural Network (NN) [3]	NN Accuracy -97.2%, RMSE-0.16

Naïve Bayes (NB) [3]	NB Accuracy - 97%, RMSE- 0.17
Support Vector Machine (SVM) [3]	SVM Accuracy -96.7, RMSE- 0.17
Logistic Regression (LR) [3]	LR Accuracy -96.2, RMSE- 0.19
AIDSII (web app) developed using CNN-LSTM [4]	Addresses the key requirements of agricultural irrigation, such as water supply and irrigation timing, by controlling the irrigation scheduling function.
CNN and RNN [5]	Total Crop Yield – 1150 kg Water Use Efficiency - 0.004 (kg/l)

5. AI vs Conventional Methods

The traditional ways of irrigation mainly rely on fixed schedules, manual observation, and basic environmental cues like temperature or rainfall to decide when and how much water should be applied. These systems work, but they tend to lead to inefficient water usage, over-irrigation, or under-irrigation due to the lack of real-time data and adaptability. It also tends to disregard soil moisture content, the needs of the plants, and weather forecasts, thus resulting in suboptimal water management and wastage.

The integration of AI into irrigation systems represents a significant advancement in real-time, data-driven decision-making. AI-powered systems can incorporate sensors to monitor soil moisture, predict weather conditions, and assess plant health. Utilizing machine learning algorithms, these systems accurately forecast irrigation needs. By continually analyzing environmental variables, AI can optimize water distribution, resulting in reduced water consumption and enhanced crop yields. Additionally, these systems automatically adjust their irrigation schedules based on real-time data, ensuring that each plant receives the appropriate amount of water at the right time, eliminating the guesswork associated with traditional methods.

The true transformation brought about by AI integration in irrigation lies in its capacity to adapt to dynamic conditions and operate efficiently on a large scale. By optimizing water usage and encouraging sustainable farming practices, particularly through waste reduction and enhanced water conservation. AI-driven irrigation systems can forecast future irrigation requirements based on historical data, weather patterns, and evolving climate conditions. Furthermore, AI empowers farmers with the capability to manage irrigation remotely, allowing for better oversight and management tools that enhance productivity, conserve resources, and positively impact the environment.

6. Discussions

AI powered irrigation systems are much better compared to traditional systems. These systems collect data and use programs that tell the best way to use water resources. AI irrigation systems automatically configure irrigation schedules based on several factors including weather conditions, soil moisture levels, and the requirements of specific crops. This is important because it helps in conserving water, reducing losses, and improving the crops yield as well as farming practices.

AI-adjusted irrigation water systems make the most efficient use of water, giving it its major benefit. Real-time AI systems can make alterations in an instant when variables such as weather, moisture, and crop stages shift. This helps ensure that irrigation is more efficient, preventing excess watering or scantness. In addition to that, which is important for drought areas, AI can dramatically lower water consumption in regions where water is in short supply making this method extremely effective in regions that are susceptible to drought.

Many domestic users rely on automatic irrigation systems that operate on fixed timers, which can be inefficient as they do not adjust to changes in environmental conditions. This can lead to water wastage, underdeveloped crops, or even damaged soil, all due to an inconsiderate watering approach. The Table 3 below depicts the comparison between traditional and AI-powered irrigation.

Table 3. Comparison of Traditional and AI-powered Irrigation

Features	Traditional irrigation method	AI-Powered Irrigation method
Technology	Manual or basic automated systems (e.g., sprinklers, canals)	Advanced AI algorithms, sensors, and IoT devices
Efficiency	Low efficiency, irrigation is based on fixed schedules	High efficiency, adjusts watering schedules based on weather, soil moisture, and plant needs
Water usage	Often wasteful, over or under-irrigation common	Optimized water usage, reduces waste by adjusting to real-time needs
Cost of installation	Low initial setup cost (can be higher in manual systems)	High initial cost for AI infrastructure, sensors, and software
Sustainability	Less sustainable, uses more water and energy	More sustainable, conserves water, reduces energy consumption
Accuracy of irrigation	Can lead to over-irrigation or under-irrigation	Very accurate, ensures each area gets the right amount of water
Adaptability	Not adaptable to changing weather or soil conditions	Highly adaptable, can adjust to weather changes, droughts, and varying soil conditions

7. Conclusion

The study states that AI-based smart irrigation systems are constructive technologies that can save agriculture up to 30% of water, boost crop production by 20%, and reduce energy costs. The developments in such technologies can make the agricultural sector efficient, productive, and sustainable contributing to a food-secured world even in the next generations. In addition, it also demonstrates how artificial intelligence can change the entire agriculture mechanism. To further enhance agriculture, by managing water, energy, and fertility, the principles of AI, IoT sensors and real-time systems can be incorporated into irrigation system. The intervention of artificial intelligence in food production methodologies is anticipated to yield significant positive implications for the practice of sustainable agricultural systems, the environment, and food security.

References

[1] Harini S,Shobana A,Sapna S,Vedhashree R,Prabhakaran M “Smart Irrigation Powered By Artificial Intelligence (AI)”International Journal Of Creative Research Thoughts, Volume 12, Issue 4 April 2024, 987-993.

[2] Sami, Maira, Saad Qasim Khan, Muhammad Khurram, Muhammad Umar Farooq, Rukhshanda Anjum, Saddam Aziz, Rizwan Qureshi, and Ferhat Sadak. "A deep learning-based sensor modeling for smart irrigation system." Agronomy 12, no. 1 (2022): 212.

[3] Tace, Youness, Mohamed Tabaa, Sanaa Elfilali, Cherkaoui Leghris, Hassna Bensag, and Eric Renault. "Smart irrigation system based on IoT and machine learning." Energy Reports 8 (2022): 1025-1036.

[4] Zouizza, Mohamed, Mohamed Lachgar, Younes Zouani, Hamid Hrimech, and Ali Kartit. "AIDSII: An AI-based digital system for intelligent irrigation." Software Impacts 17 (2023): 100574.

[5] Kim, Tae Hoon, and Ahmad Ali AlZubi. "AI-enhanced precision irrigation in legume farming: Optimizing water use efficiency." Legume Research 47, no. 8 (2024): 1382-1389.

[6] Zhao, Haoteng, Liping Di, Liying Guo, Li Lin, Chen Zhang, Eugene Genong Yu and Hui Li. “Optimizing Irrigation Scheduling Using Deep Reinforcement Learning.” 2023 11th International Conference on Agro-Geoinformatics (Agro-Geoinformatics) (2023): 1-4.

[7] Gurrapu, Sai, Nazmul Sikder, Pei Wang, Nitish Gorentala, Madison Williams, and Feras A. Batarseh. "Applications of Machine Learning For Precision Agriculture and Smart Farming." In FLAIRS. 2021.

[8] Goyal, Manish Kumar, Sachidanand Kumar, and Akhilesh Gupta. "AI for Water Conservation." In AI Innovation for Water Policy and Sustainability, Cham: Springer Nature Switzerland, 2024. 17-29.

[9] Mohammed, Maged, Hala Hamdoun, and Alaa Sagheer. "Toward sustainable farming: implementing artificial intelligence to predict optimum water and energy requirements for sensor-based micro irrigation systems powered by solar PV." Agronomy 13, no. 4 (2023): 1081.

[10] Pandey, Prabhat, and Sudhir Agarwal. "A Low Cost Smart Irrigation Planning Based On Machine Learning and Internet of Things." Available at SSRN 4414709 (2023).

[11] Kashyap, Pankaj Kumar, Sushil Kumar, Ankita Jaiswal, Mukesh Prasad, and Amir H. Gandomi. "Towards precision agriculture: IoT-enabled intelligent irrigation systems using deep learning neural network." IEEE Sensors Journal 21, no. 16 (2021): 17479-17491.[12] Li, X., & Chen, Y, "AI-Powered Irrigation System Using Soil Moisture Prediction Models," IEEE IoT Journal, vol. 8, 1232-1242,2022

[12] Yamuna Bee,L.Lakshana,K.Ishwarya,J.Durgadevi “AI Based Smart Irrigation System Using Hybrid Ensemble Model”, International Journal of Creative Research Thoughts, Volume 10, Issue 5 May 2022, 799-828

[13] Krishna, M., A. Vinitha, S. Ravinder, and G. Akhilesh. "SMART IRRIGATION SYSTEM USING RASPBERRY PI." Turkish Journal of Computer and Mathematics Education (TURCOMAT) 11, no. 3 (2020): 2686-2695.

[14] Jha, Kirtan, Aalap Doshi, and Poojan Patel. "Intelligent irrigation system using artificial intelligence and machine learning: a comprehensive review." Int. J. Adv. Res 6, no. 10 (2018): 1493-1502.

[15] Khriji, Sabrine, Dhouha El Houssaini, Ines Kammoun, and Olfa Kanoun. "Precision irrigation: an IoT-enabled wireless sensor network for smart irrigation systems." Women in Precision Agriculture: Technological Breakthroughs, Challenges and Aspirations for a Prosperous and Sustainable Future (2021): 107-129.