Smart Irrigation Models Based on IoT: A Review

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Abstract: Agriculture is backbone of any country which play important role in overall growth and GDP of the country. But agriculture is run with traditional methods since long ago. Now, some technologies have been introduced to make agriculture more effective and automated. IoT technology is one the best technologies which is introduced to agriculture for the automation of the various functions used in agriculture. A thorough study has been performed to evaluate uses of IoT technology in automation of agriculture. Research papers related to agriculture and IoT have been studied and reviewed starting from inception of integration of agriculture and IoT. It has been found from the available literature that most of the studies used three or four sensors to make automated irrigation system. But there is a scope of integration of more sensors so that more accurate information can be collected and consider to make irrigation system more effective.

Introduction:

Agriculture is the cornerstone of India's economy, with the majority of its population relying on farming for livelihood. As a predominantly rural country, India's agricultural practices are deeply tied to the monsoon seasons, which historically have dictated crop growth and productivity. The dependency on rainfall has increasingly become a vulnerability, as the monsoon rains have become erratic, unpredictable, and insufficient to sustain agricultural needs. This climatic uncertainty, coupled with the rising global demand for food and limited water resources, has highlighted the urgent need for efficient and sustainable agricultural practices. The primary challenge faced by Indian farmers is managing water resources efficiently, as irrigation plays a crucial role in supplementing the natural water supply. Traditional irrigation methods have been widely used in agriculture, but they often lack precision, leading to water wastage, inefficient resource utilization, and adverse environmental impacts. Over-irrigation can lead to soil erosion, waterlogging, and nutrient leaching, while under-irrigation can stress crops and reduce yields. These inefficiencies are exacerbated by factors such as climate change, which causes unpredictable weather patterns and fluctuating water availability. As a result, farmers face significant challenges in managing their irrigation practices effectively. Irrigation is managed manually, where farmers turn on water pumps and irrigate their fields at scheduled intervals, often without any real-time understanding of soil moisture content. This approach leads to the overuse or underuse of water, both of which are detrimental to crop health and overall productivity. Over-irrigation wastes water, increases costs, and can lead to waterlogging, while under-irrigation stunts crop growth, leading to lower yields. With rising concerns about water scarcity, especially in regions where groundwater levels are depleting rapidly, such inefficiencies in water management need to be addressed urgently to ensure the sustainability of agriculture. To overcome this problem, smart irrigation is emerging as an innovative solution to these water management challenges. Unlike conventional systems, smart irrigation technologies use data-driven insights to optimize water usage based on real-time environmental conditions. By leveraging modern technologies such as sensors, wireless communication, and data processing platforms, smart irrigation systems can ensure that crops receive the appropriate amount of water exactly when they need it, thereby minimizing waste and promoting sustainable farming practices. The increasing pressure to conserve it necessitates the development of advanced irrigation systems that can provide more precise, timely, and efficient irrigation. The emergence of the Internet of Things has opened new doors for revolutionizing irrigation practices. IoT refers to a network of interconnected devices that communicate and exchange data to create a more efficient and automated system. In agriculture, IoT-based solutions enable smart irrigation systems that reduce human intervention while optimizing water usage. By integrating sensors, software, and connectivity, IoT technology enables real-time monitoring of various environmental parameters such as soil moisture, temperature, and humidity, directly influence crop growth. These devices can collect and share data, helping farmers make informed decisions about irrigation, resulting in water and energy conservation. IoT refers to a network of interconnected devices, sensors, and systems that communicate and exchange data in real-time. These devices can collect, analyse, and transmit information, enabling the automation of processes and providing valuable insights to enhance efficiency. In the context of agriculture, IoT-based solutions are used to implement smart irrigation systems, which significantly reduce the need for human intervention while optimizing water usage. These systems rely on a network of sensors placed in the soil and surrounding environment to monitor critical parameters that influence crop health, such as soil moisture, temperature, humidity, and even light levels.

In view of the above many researchers integrated IoT to make the irrigation system smart so that irrigation may be effective without any wastage of water and over irrigation which results in improvement in crop quality and quantity. Some of the researches have been depicted below.

Background:

The term Internet of Things (IoT) was coined by Kevin Ashton[1]who is a British technology pioneer in 1999. It is the concept of connected devices dates back to the early days of radio and television. He believed Radio Frequency Identification (RFID) was a prerequisite for the IoT primarily as an inventory tracking solution. In 2002-2003, Walmart and the US Department of Defence were the first large organizations to embrace Ashton's model of tracking inventory using tagging, RFID, and the IoT[2].

Ring a doorbell that links to your smartphone, provides an excellent example of the Internet of Things being used at home. Ring signals you when the doorbell is pressed, and lets you see who it is, and to speak with them.The Ring doorbell was developed in 2011 by Jamie Siminoff[3] because he wanted to see who was at his door while he was in the garage, working. He couldn't hear the doorbell from the garage and kept missing deliveries[3].

In 2012, the Swiss Federal Office of Energy started a pilot program called "Smart City Switzerland." They brought representatives from universities, business, and public administration together to discuss new ideas for the urban environment. Smart City Switzerland has over sixty projects underway and supports new scientific partnerships and innovation. (Smart City Switzerland has evolved into something quite impressive.)[4.]

In the year 2013, the IoT had become a system using multiple technologies, ranging from the Internet to wireless communication and from micro-electromechanical systems (MEMS) to embedded systems[2]

Smartphones are part of the IoT, and have become an important communications tool for many individuals. In 2015, they joined the IoT with a high degree of enthusiasm from marketers. The sensors within these devices are monitored by marketing departments, who send out certain promotions based on the customer and the product's location[.5].

Then, it was thought that this technology can be used in different fields for automation. In 2016, IoT was introduced in agriculture mainly focused on irrigation system. Some important work related to integration of IoT in irrigation system of agriculture have been presented and reviewed as under.

Review of Literature:

Masaba, K. et. al (2016)[6] worked on a smart irrigation system for improved water energy efficiency, this irrigation systemidentifies specific areas to irrigate and it uses environmental information to determine when and where irrigation is required.The system is comprised of microcontroller, sensors and integration of water pumps with the decision make system. A truth table is developed to help the system determine the necessity to irrigate based on the collected environment information and sensors narrow down the location that requires irrigation and the decision-making system activates sprinklers, water is given to dry locations of the fieldresults efficient water use. The temperature, humidity and moisture, makes it possible to adjust the system according to the needs of a particular location. Several such smart irrigation systems can be placed in a farm field and each area remains self-sufficient. This kind of decentralization reduces the complexity of the irrigation system making it more manageable.

Nasiakou, A. et. al. (2016)[7] worked on a smart energy for smart irrigation. It reduces the cost of irrigation by utilizing techniques, methods and practices that are common to the smart energy systems. A software platform that couples the smartness of the irrigation systems with the smartness of the energy systems is designed, implemented and evaluated. The resulting simulation engine allows large scale and very detailed experimentation where irrigation experts specify energy effective configurations that lead to the reduction of the irrigation cost through smart utilization of Renewable Energy Sources.

Priyadharsnee, K & Rathi, S (2017)[8] worked on an IoT based smart irrigation system to address the issues in agriculture and increase the quality and that can detect soil moisture, crop growth that can be assigned an IP address and effectiveness of agricultural production.The system was found capable to reduce the efforts of farmers and provides high yield. It also conserves water for irrigation by locating the sensor at the right position above the soil level. This work has shown that plants can still sustain at low moisture level when the temperature is moderate.

Gori, A. et. al (2017)[9] worked on a smart irrigation system using IoT to detect the moisture content of the soil and depending on it sprinkle water.This entire information is sent to the user's mobile phone. The smart irrigation system implemented is cost effective for optimizing water resources for agricultural production, system is used to switch on/off the water sprinkler depending on the soil moisture levels thereby making the process simpler to use.

Naik, P.K. et al. (2018)[10] worked on automation of irrigation system using IoT to save water and time using various sensors like temperature, humidity, soil moisture sensors which senses the various parameters of the soil and based on soil moisture value land gets automatically irrigated by ON/OFF of the motor. These sensed parameters and motor status was displayed on user android application.

Ashwini, B.V.(2018)[11] worked on a smart irrigation system using IoT for surveillance of crop field. System is micro control based and is operated from remote location through wireless transmission so there is no need to concern about irrigation timing as per crop or soil condition. Sensor is used to take reading of soil like soil moisture, temperature, air moisture and decision making is controlled by user by using microcontroller. The data received from sensors are sent to server database using wireless transmission. The irrigation is automated when the moisture and temperature of the field is reduced. The farmer is notified with the information regarding field condition through

mobile periodically. This system is more useful in areas where there is scarcity of water and is worth efficient with satisfying its requirements.

Singh, S.S (2019)[12] worked on a smart irrigation system using IoTwhich is economical and have great impact on irrigation system. The system controlled in two modes first is manual and second is automatic control for controlling the operation of water pump for irrigation. The pump is controlled by using Atmega328P IC which is programmable in nature using relay as switch and taking the feedback from soil moisture sensor and rain sensor for controlling the water pump. The manual control is done by using HTML webpage by BOLT IoT module. The system worked as designed and planned, it optimally controls the water pump and highly reduced the electricity consumption by 30% and the production is increased by 17.23% because of controlled water supply.

Premalatha, C. (2019)[13] worked on an automatic smart irrigation system using IoT to provide an automatic irrigation system that saves time and money. With the automated technology of irrigation, the human intervention can be minimized. Whenever there is a change in humidity of the soil, the sensor senses the humidity change and irrigates the field automatically, it makes use of simple IoT technology and is economic making it feasible even in economically backward areas, integration is reduce the number of other hardware components used in the system thereby reducing the total cost of the system and continuously send the data on the cloud accessed using Bluetooth on Android App and if there is no internet present, the farmer is control the system through the App that is the Semiautomatic system.

Himavamshi, S. et. al. (2019)[14] worked on a smart irrigation using IoT to maintains the desired soil moisture level to Arduino and it acts as a control unit based on the sensed values, water is supplied to the plant which can help us to avoid overirrigation and under irrigation. Water sensor is used to sense the amount of water still available in the tank and information from the two soil moisture sensors are regularly updated to the web page using WIFI module and message alert is sent to the user. Sensor values are uploaded to the thingspeak channel to generate graphs for analysis, the same is viewed in-app and motor can be controlled. Real-time update to the cloud helps to view the current water condition in the plant.

Singh, K. et. al (2019)[15] worked on an IoT based approach for smart irrigation system applicable to multiple crop cultivation. It uses Data Science to implement real-time analytics of the collected data. Multiple sensors are deployed in the field to create an on-field dataset into the cloud system. The cloud system scraps the required data from the meteorological center and compares it with the on-field data set. The analysis is then done using the concepts of data science to determine the amount of water to be released according to each crop type in the field.

Kalyani, A. et al. (2020)[16] worked on an IoT based smart plant watering system.They proposed an automation of farm activities that was transform agricultural domain from being manual and static to intelligent and dynamic leading to higher production with lesser human supervision. In this work, a system is developed to monitor crop-field using sensors (soil moisture) and automate the irrigation system. These sensors are connected to AurdinoUNO which receive the sensor data and transmit it. The micro controller analyses the sensor data and determine the amount of water needed for irrigation. The amount of water required for the field is based on the type of crop, duty and delta. By using web application, the data is read from the web server and analysed and then control commands is sent to the micro controller through internet.

Gayathri, M. et.al (2021)[17] worked on a smart irrigation system based on IoT using drip irrigation where the water was allowed to drip slowly to the roots of plant either from above the soil surface or buried into the surface so that the water is placed directly into the root zone and minimize evaporation. It uses temperature sensor, soil humidity sensor to collect and monitor field information and also uses float switches to monitor ground water level through web page. When the field gets dry and ground water level falls down, it notifies through SMS. This provides a solution for the problems in developing a smart farming system. The System has high efficiency and accuracy in fetching the live data of fields such as soil moisture level and temperature including the ground water level.

Kumar, S. et.al. (2023)[18] worked on an automatic irrigation system based on IoT using real time input data foragri environment to reduce the man power in the fields which reduce the physical presence all the time. The system is used with ATMEGA32 processor in the implementation of sensor module and other communication environment. The system offers a complete, low cost, powerful and user friendly way of real-time monitoring and remote control of agri field.

Priyanka, M. et. al (2023)[19] worked on an IoT based smart irrigation system using a network of sensors and actuators that collect data on soil moisture, temperature, humidity, and weather conditions and is transmitted to a central control unit that uses algorithms to make decisions about when and how much water to be irrigated and designed to be energy-efficient and cost effective, using a regular power source to operate. It reduces water wastage and conserves water resources, resulting in improved crop yields and reduced costs, the system is scalable and expanded to cover larger areas or multiple fields, the proposed IoT-based smart irrigation system is a significant improvement over traditional irrigation systems, providing a sustainable and efficient solution for agriculture and the system's scalability, energy-efficiency, and customizability make it a viable option for farmers looking to adopt new technology to system provides real-time monitoring of the soil moisture level, temperature, humidity, and rainfall, enabling farmers to make informed decisions about their irrigation systemsand improve crop.

Kumar, P. (2023)[20] worked on a smart irrigation using machine learning and IoT that uses watering systems with a simple route based on the IoT for remotely controlling water pumps and keep eyes on robotic systems. Technology advancements and improvement are utilized in this ongoing project. The sensors are connected to the network so that it can collect information and send it to the cloud and thus as a result of the method's improved capacity to conjugate the real world with computerbased structures, financial advantage will improve. This can lead to substantial cost savings and environmental benefits, such as reduced water waste and improved water resource management.

Sasi Kumar, G. et. al (2023)[21] worked on smart irrigation system using IoT. In thissoil moisture are detected by soil moisture sensors and irrigation is automated using IoT.System is most economical for underdeveloped places because it is very cost effective. Based on the soil moisture content, the sensor detects and sends signals to the node MCU, it activates the motor. When the plants receive enough water, the motor automatically switch off, it alerted about the soil's moisture content through mobile phone.This system can be converted into a smart system that forecasts worker activities, rainfall patterns, harvest times, and animal intruders in the field, and then communicates the information using advanced technology such as IoMT, allowing agricultural systems to become self-contained and better yield.

Ranjan, S. et. al (2023)[22] worked on a smart irrigation system using IoT consist of sensors, controllers, and a cloud-based platform that collects real-time data about soil moisture content, weather conditions, and plant water requirements, data is analyzed and used to regulate water supply to the crops, resulting in reduced water consumption and significant savings in water resources. Field experiments have shown that smart irrigation systems can increase crop yields by 25% and reduce water consumption by 40%. This system is designed to be automated and allows users to monitor and control the irrigation process remotely through a smartphone app or a web interface, making it easy for farmers or gardeners to manage their irrigation systems from anywhere, at any time, it helps to conserve water by using only the required amount of water and preventing over-watering, leading to a significant reduction in the cost of irrigation, the potential for large-scale deployment and can benefit farmers worldwide, making it a powerful tool to optimize irrigation processes, conserve water, and improve crop yields.

Kurundkar, S. et.al (2024)[23] worked on an IoT enabled smart irrigation system for precision of farming using microcontroller to operate in Automatic and Manual mode. In automatic mode all the control of the system is handed to the AT89c51 Microcontroller, Soil moisture sensor connected to the AT89c51 MCU is used to sense the moisture in the soil and the motor is actuated accordingly. If the rain is detected by the Rain sensor, the motor is automatically turned off to avoid the access water in the farm. In manual mode, the motor can be turned on and off with the help of an Android app that is connected to the ThingSpeak IoT cloud. The temperature and humidity values from the Dht11 sensor in the farm area are also shown on the app interface. The system sends and reads the data from the cloud with the help of ESP8266.

Manjula, A. (2024)[24] worked on a smart irrigation system using IoT which reads the values using sensors and waters the pants based on those values and send notification as well as email to the owner for a certain interval of time depending on the owner specification.These are remotely monitor values by using mobile application or web application, its save manpower, leading to a cost effective solution for efficient water management in agriculture, this system harnesses the power of a microcontroller to monitor and control irrigation process, ensuring optimal water usage, greater efficiency, accuracy, and environmental management in agricultural practices through the continued evolution and implementation of smart irrigation systems based on IoT.

Nanthakumar, G. et. al. (2024)[25] worked on an IoT based smart irrigation system using artificial intelligence, it improve water utilization in agriculture, this research suggests a comprehensive system that includes buzzers, LCD displays, relays, water pumps, soil moisture sensors, AI algorithms, and water pumps, at the centre of the system evaluates data collected in real time from field-installed soil moisture sensors, they gather information on the soil's moisture content, which offers important insights into the real water needs of the crops after analysing this data, the AI programme decides how best to schedule irrigation, system integration with a relay is intended to regulate when a water pump is activated.. Important details like irrigation status, soil moisture levels, and AI-driven suggestions are conveyed through the display, with the help of this function, farmers may monitor the system's performance and make well-informed judgements and a buzzer is incorporated to deliver auditory notifications in the event of crucial occurrences, such low soil moisture levels or system faults.A number of benefits are provided by the suggested AI-driven water management system, including improved agricultural output, water conservation, and operational effectiveness. Water scarcity and resource optimisation in irrigated fields are addressed by the system, which offers a comprehensive precision agriculture solution by utilising the capabilities of IoT devices, soil moisture sensors, relays, water pumps, buzzers, and LCD displays.

Ali, A. et. al. (2025)[26] worked on smart irrigation technologies and prospects for enhancing water use efficiency for sustainable agriculture, it explores the fundamentals and processes of smart irrigation, such as open- and closed-loop control, precision monitoring and control systems, and smart monitoring methods based on soil data, plant water status, weather data, remote sensing, and participatory irrigation management.

Conclusion

From the literature survey from starting integration of IoT with agriculture till date it is found that different sensors are used to collect the environmental conditions information like temperature, humidity, moisture content of soil etc. These sensors collect relevant data and send the data to microcontroller through network which is used to automate the irrigation system. It has been found from the available literature that most of the studies used three or four sensors to make automated irrigation system. But there is a scope of integration of more sensors so that more accurate information can be collected and consider to make irrigation system more effective. Therefore, it is recommended to use more sensors which can collect more data and smart or automated irrigation system can be made more effective.

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