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From Traditional to Technology: A Comprehensive Analysis of Traditional and Smart Irrigation Strategies

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***Abstract*— Agricultural water management is critical for guaranteeing long-term agricultural production and dealing with the mounting challenges brought by climate change and water scarcity. This study article examines old and modern irrigation technologies in depth, highlighting their merits and demerits. Furthermore, the study investigates the requirements and benefits of implementing smart irrigation systems to optimize water usage and boost agricultural productivity. The article explores the need for smart irrigation systems, which make use of cutting-edge technology such as the Internet of Things (IoT), sensors, and data analytics. The advantages of smart irrigation systems over traditional approaches, including precise water distribution, real-time monitoring, and reduced water waste are discussed thoroughly. Furthermore, a survey of several research publications and projects on smart irrigation systems is presented, wherein various existing smart irrigation techniques are studied in depth. These studies cover a wide range of regions, crop kinds, and implementation methodologies to get a thorough understanding of smart irrigation's global relevance.**

***Index Terms*— Agriculture, Smart Irrigation, flood and furrow irrigation, drip and sprinkler irrigation, IoT, sensors.**

I. Introduction

Irrigation, the controlled application of water to cultivate crops, is a fundamental agricultural practice that transcends the whims of weather and rainfall. In countries like India, where agriculture plays a pivotal role in sustaining livelihoods and the majority of the population relies on it for their sustenance, irrigation assumes a position of paramount significance. Unlike regions blessed with consistent year-round rainfall, a substantial part of India's landscape is marked by intermittent and insufficient rainfall. However, the demands of agriculture remain constant, with crops requiring water even in the absence of natural rainfall. Thus, irrigation emerges as the default solution when nature's provisions fall short, functioning as a catalyst for strengthening agricultural productivity.
Beyond the immediate need for crop hydration, irrigation contributes to the preservation of soil fertility and facilitates the preparation of land for cultivation. Ensuring a consistent flow of water, it safeguards the essential elements necessary for crop growth, aiding in the sustenance of soil quality and agricultural practices. Furthermore, in a nation facing the pressing challenge of meeting the demands of a growing population, high crop yields are paramount. Irrigation, coupled with the "green revolution," stands as the key aspect of agricultural endeavors in the country. Recognizing the overarching importance of irrigation, it is vital to acknowledge its multifaceted contributions. Firstly, it serves as a vital mechanism to augment crop output in regions where natural rainfall is

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scanty. Secondly, irrigation has been instrumental in reclaiming vast tracts of fallow land, bringing them into productive cultivation. Moreover, irrigation has facilitated the cultivation of previously fallow land, expanding the agricultural landscape significantly. Additionally, it acts as a stabilizing force, ensuring consistent output and yield levels, thereby providing economic stability to farmers. Furthermore, the implementation of irrigation systems improves the availability of water resources, thereby increasing the income of farmers and the overall agricultural economy. However, it is important to note that the benefits of irrigation are reliant upon careful management. Over-irrigation can have adverse consequences, leading to water logging, inhibited germination, elevated salt concentrations in the soil, and even uprooting of crops due to excess moisture. Hence, it is imperative to employ optimal irrigation practices to harness its full potential and avert potential pitfalls. [1]
In light of these considerations, this survey paper delves into the multifaceted realm of irrigation, with a specific focus on the emergence of smart irrigation techniques, as an exploration of innovations that promise to enhance the efficiency and sustainability of this vital agricultural practice.

A. Traditional Methods of Irrigation

Traditional methods of irrigation refer to age-old techniques that have been used by farmers for centuries to supply water to their crops. These methods have been passed down through generations and were developed before the advent of modern irrigation technologies. Some common traditional methods of irrigation include:
Flood Irrigation: This is one of the oldest and simplest methods where water is allowed to flow over the soil surface, covering the fields like a flood. It is commonly used in flat or gently sloping terrain.
Furrow Irrigation: In this method, small channels or furrows are made between crop rows, and water is allowed to flow through these furrows, providing a controlled supply of water to the plants' root zones.
Basin Irrigation: In basin irrigation, the field is divided into small basins, and each basin is flooded with water. This method is suitable for crops that require a lot of water and is often used in orchards and vineyards.
Traditional Well Irrigation: In regions where groundwater is easily accessible, wells are dug, and water is drawn manually or using animals to irrigate the fields. This method has been practiced for centuries in many parts of the world.
Tank Irrigation: Water is stored in large tanks or reservoirs during the rainy season. This stored water is then used to irrigate fields during dry periods. Tank irrigation is common in areas with erratic rainfall patterns.
Lift Irrigation: In lift irrigation, water is lifted from a water source, such as a river or canal, using pumps and then transported to fields through pipelines. This method is suitable for areas where water sources are at a lower elevation than the fields.

Positive Aspects of Traditional Irrigation Systems

Low Cost: Traditional irrigation methods are often cost-effective to implement, requiring minimal investment in infrastructure and equipment. This accessibility makes them viable options for small-scale farmers with limited resources.
Simple Technology: Traditional irrigation systems are simple to understand and operate, making them accessible to farmers without specialized training. Local communities can maintain and repair these systems with local resources and knowledge.
Environment Friendly: Some traditional methods, such as flood and furrow irrigation, promote natural groundwater recharge and can reduce the need for chemical fertilizers, promoting environmentally sustainable practices.
Adaptability: Traditional methods can be adapted to suit specific crops, terrains, and water availability, providing flexibility to farmers in different regions and climates.

Negative Aspects of Traditional Irrigation Systems

Water Wastage: Traditional methods like flood irrigation can lead to significant water wastage due to uneven distribution and evaporation of water. This inefficiency becomes a critical concern, especially in regions facing water scarcity
Soil Erosion: Improperly managed traditional irrigation systems can lead to soil erosion, degrading the quality of arable land over time. This erosion can result from the force of water flow in flood irrigation or inadequate drainage systems.
Limited Control: Traditional methods offer limited control over the amount and timing of water delivery. This lack of precision can result in overwatering or underwatering, affecting crop health and yield.
Land Degradation: Over time, certain traditional methods can lead to the salinization of soil due to excessive irrigation, rendering the land infertile and unsuitable for cultivation.

Dependency on Weather: Traditional irrigation heavily relies on natural water sources such as rivers and rainwater. In times of drought or erratic rainfall, these systems may fail, leaving crops vulnerable to water stress.
In summary, while traditional irrigation methods have their advantages, they also come with significant challenges, particularly in terms of water efficiency, environmental impact, and scalability. As agriculture evolves, there is a growing need to integrate modern, sustainable irrigation technologies to address these limitations and ensure food security in the face of changing climate patterns and growing population demands.

B. Modern methods of irrigation

Modern methods of irrigation use advanced technologies to efficiently and effectively distribute water to crops, optimizing agricultural productivity. Some of the prominent modern irrigation methods include:
Drip Irrigation: Drip irrigation involves the slow and precise application of water directly to the root zone of plants, usually through a network of pipes, tubing, valves, and emitters.
Sprinkler Irrigation: Sprinklers distribute water over the crops in the form of droplets, simulating natural rainfall. Different types of sprinklers include fixed, rotating, and oscillating systems.
Center Pivot Irrigation: This is a form of sprinkler irrigation where equipment rotates around a pivot point, creating a circular irrigated area. It is commonly used for large, circular fields.
Laser Land Levelling: Laser technology is used to level the land, ensuring a uniform surface for irrigation. This improves the efficiency of water distribution and reduces water wastage.
Subsurface Drip Irrigation: Similar to traditional drip irrigation, the pipes or tubing are buried underground. This method is particularly useful in arid regions with high evaporation rates.

Positive Aspects of Modern Irrigation Methods

Water Efficiency: Modern irrigation systems, such as drip and sprinkler irrigation, are designed for efficient water use by delivering water directly to the root zone, minimizing wastage through evaporation and runoff.
Increased Crop Yields: Precision in water application and the ability to tailor irrigation to specific crop needs contribute to improved crop yields and overall agricultural productivity.
Energy Savings: Some modern systems, like drip and subsurface drip irrigation, require less energy for water distribution compared to traditional methods, leading to energy savings.
Flexibility and Adaptability: Modern irrigation methods are adaptable to various terrains and can be used for a wide range of crops. They offer flexibility in terms of application and can be adjusted based on specific crop requirements.
Fertigation Integration: Integration of irrigation with fertilization (Fertigation) allows for simultaneous application of water and nutrients, enhancing nutrient management and promoting optimal plant growth.
Reduced Soil Erosion: Controlled and localized water application helps minimize soil erosion, contributing to soil conservation and sustainable agricultural practices.

Negative Aspects of Modern Irrigation Systems

Initial Cost: The installation of modern irrigation systems, such as drip or sprinkler systems, can have a high initial cost. This may pose a barrier to adoption, especially for small-scale farmers with limited financial resources.
Maintenance and Technical Skills: Modern systems may require regular maintenance and technical expertise for optimal performance. Farmers may need training to operate and troubleshoot these systems effectively.
Dependency on Infrastructure: Modern irrigation systems often depend on infrastructure like pumps, pipes, and emitters. Any failure in this infrastructure can disrupt the irrigation process and affect crop health.
Risk of Over-Irrigation: Without proper monitoring and control, there is a risk of over-irrigation, leading to water logging, nutrient leaching, and potential damage to crops.
In conclusion, while modern irrigation systems offer numerous benefits, addressing the associated challenges and ensuring proper implementation are crucial for maximizing their positive impact on agricultural sustainability and productivity.

C. Smart Irrigation

In the preceding section, we explored both traditional and modern irrigation methods, outlining their respective advantages and disadvantages. Throughout this discussion, it became evident that both types of irrigation systems operate without smart monitoring and control of water resources and fertilizers. Notably, they function as open-loop systems, lacking feedback mechanisms related to soil parameters, environmental conditions, and crop health. To address these limitations and enhance the intelligence of irrigation systems for informed water management based on soil parameters and crop health monitoring, the integration of sensors, IoT technology, and Machine

Learning algorithms is commonly recommended. This section provides a concise review of smart irrigation systems.

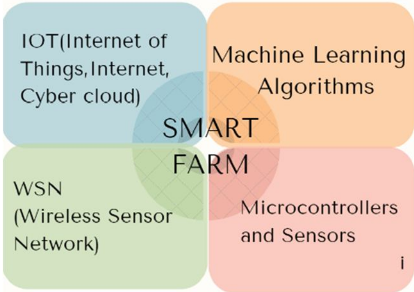

Figure 1. Structure of Smart Irrigation

Smart irrigation refers to the use of advanced technologies and data-driven systems to optimize the management of water resources in agriculture. There are several compelling reasons for the adoption of smart irrigation practices. A few of them are discussed below:

Water Conservation: Smart irrigation systems use real-time data and sensors to determine the water needs of crops precisely. This targeted approach minimizes water wastage, ensuring that crops receive the optimal amount of water for their growth without over-irrigation.

Energy Efficiency: By automating irrigation processes based on accurate data, smart irrigation systems can optimize energy use in pumping and water distribution. This leads to energy savings and lower operational costs for farmers.

Improved Crop Yields: Smart irrigation allows for precise control over the timing and amount of water delivered to crops. This precision enhances plant growth, leading to improved crop yields and quality.

Environmental Sustainability: By minimizing water wastage, runoff, and the use of unnecessary chemicals, smart irrigation systems contribute to environmental sustainability. It helps protect water resources and reduces the risk of soil erosion and nutrient leaching.

Remote Monitoring and Control: Smart irrigation allows farmers to monitor and control the irrigation process remotely. This flexibility enables quick adjustments based on real-time data, weather conditions, and other factors, reducing the need for physical presence in the field.

Fertigation Integration: Some smart irrigation systems can integrate with fertigation, allowing farmers to apply water and nutrients simultaneously. This improves nutrient management and promotes optimal plant nutrition.

Data-Driven Decision-Making: Smart irrigation systems collect and analyze data on soil moisture, weather patterns, and crop conditions. This data-driven approach enables farmers to make informed decisions, leading to more effective and sustainable water management.

Risk Reduction: Smart irrigation systems can take into account weather forecasts, helping farmers mitigate the risks associated with extreme weather events. For example, adjusting irrigation schedules in anticipation of rain can prevent overwatering.

In summary, smart irrigation offers a holistic approach to water management in agriculture, combining technology, data, and automation to address water scarcity, enhance agricultural productivity, and promote sustainable farming practices.

II. Survey Of Existing Smart Irrigation Technologies

This comprehensive literature review delves into several studies exploring innovative approaches to automated irrigation systems, each emphasizing advancements in water usage efficiency and sustainable agricultural practices. The study by [2] introduces a solar-powered automatic irrigation system that utilizes solar panels to extract water from a borewell, subsequently directing it to a ground-level storage tank. This system dynamically regulates the tank's outlet valve based on sunlight intensity, showcasing a forward-thinking approach to irrigation optimization. However, identified limitations include reliance on batteries for energy storage, raising concerns about degradation and associated costs, as well as the overall system cost attributed to high-capacity batteries and converters. In [3], the significance of SMART irrigation within the framework of Sustainable Development Goals (SDGs) is underscored, employing the Internet of Things (IoT) and sensory systems. The study advocates for automated irrigation systems as pivotal in water conservation, emphasizing their role in minimizing water usage.

While the integration of IoT and automation enhances overall efficiency, challenges such as increased project costs due to cloud storage for data analysis and ensuring reliable Internet connectivity in agricultural settings are acknowledged. Authors in [4] propose a monitoring system designed to address over-irrigation, soil erosion, and crop-specific irrigation. This solution involves a distributed wireless sensor network (WSN) transmitting data to a centralized server, where machine learning (ML) algorithms predict irrigation patterns based on crop types and weather conditions. Acknowledged limitations include the accuracy dependence on proper setup installation, extensive training requirements for ML algorithms, and the influence of Support Vector Regression (SVR) model parameters on prediction accuracy.

The implementation of a smart irrigation system incorporating temperature, humidity, and soil moisture sensors, governed by fuzzy logic, is explored in [5]. Despite promising advancements, limitations include the system's inability to predict harvest time, anticipate animal intrusion, or monitor nutrient levels. Additionally, the fuzzy logic model is tailored for crops suitable for summer growth, potentially requiring adjustments for other crops.

The study in [6] suggests an automated irrigation system with strategically positioned sensors for soil moisture, temperature, and water flow. The system, adaptable for small gardens, nurseries, or greenhouses, automates the pumping motor based on soil moisture levels. The study highlights data collection for graph generation and analysis, contributing to a CSV dataset. Utilizing PC-based LabVIEW, NI myRIO, IoT, and GSM, [7] calculates relative humidity for irrigation based on soil conditions. While providing detailed information on irrigation practices, limitations include the need for user training, potential constraints in weather forecasting accuracy, and challenges associated with project expansion.

Authors in [8] introduce an electronic system for water pump control based on soil moisture levels, validated through MULTSIM simulation software. The automated system enhances water management efficiency but is limited by the use of discrete components, introducing potential adaptability and scalability constraints. In [9], a proposed technique utilizes various sensors to assess critical soil measurements, with an Arduino microcontroller processing and transmitting data through a Zigbee network. While aiming to minimize equipment costs through Thing Speak cloud server integration, limitations include a focus on soil wetness, neglecting other crucial factors, and challenges related to the limited range of Zigbee modules and dependence on strong internet connectivity.

Lastly, the utilization of embedded technology to characterize soil attributes is presented in [10], focusing on suggesting suitable crops based on analyzed soil data. While emphasizing precision, the system acknowledges the crucial role of sensor accuracy and maintenance, as well as potential challenges associated with internet connectivity in rural areas.

A. Research Gaps

Research on smart irrigation systems has made significant strides, but several gaps and areas for further investigation remain. Some notable research gaps include:

The current smart irrigation system operates as an open-loop system, where irrigation decisions are predetermined based on soil parameters. The system is designed to activate the pump and water the land according to the specified soil conditions. However, it lacks a closed-loop feedback mechanism, as feedback from the soil is not considered when deactivating the motor. The irrigation process is initiated based on preset criteria, but adjustments or interruptions to the watering schedule do not occur in response to real-time soil feedback, reflecting the open-loop nature of the system.

The current irrigation system cannot regulate water flow through the pipes. Once the pump is activated, the watering of the farm occurs at a fixed rate without adjustments based on the soil conditions or environmental factors. The system operates without dynamically adapting the flow of water according to real-time feedback from the soil or the surrounding environment.

There is a need for more advanced and adaptive optimization algorithms that can dynamically adjust irrigation schedules based on real-time data, considering factors like weather forecasts, plant growth stages, and soil conditions, remains a research priority.

While current systems utilize soil moisture, temperature, and humidity sensors, there is potential for further integration of advanced sensor technologies. Research could explore the incorporation of sensors that measure nutrient levels, plant health, and other relevant parameters to provide a more comprehensive understanding of the irrigation needs of crops.

Enhancing the user interface and accessibility of smart irrigation systems is essential. Research could focus on developing user-friendly applications and interfaces that cater to the varying technological literacy of farmers, facilitating seamless interaction with the system.

III. SMART IRRIGATION SYSTEM FOR EFFICIENT MANAGEMENT OF WATER AND CROP

A proposed intelligent irrigation system integrates IoT and WSN technologies to monitor and analyze diverse parameters, including soil moisture, pH levels, humidity, and temperature. This innovative system enables precise control over the volume and duration of water supplied to the soil. Implementation involves deploying soil moisture level sensors at specific intervals on various slope levels, facilitating the determination of soil moisture requirements. Through the analysis of seasonal conditions, environmental changes, and the availability of water and power supply, a customized water supply schedule is devised. This schedule is designed to meet the specific soil water and pH level requirements of a particular crop within a defined land area, ensuring optimal irrigation management.

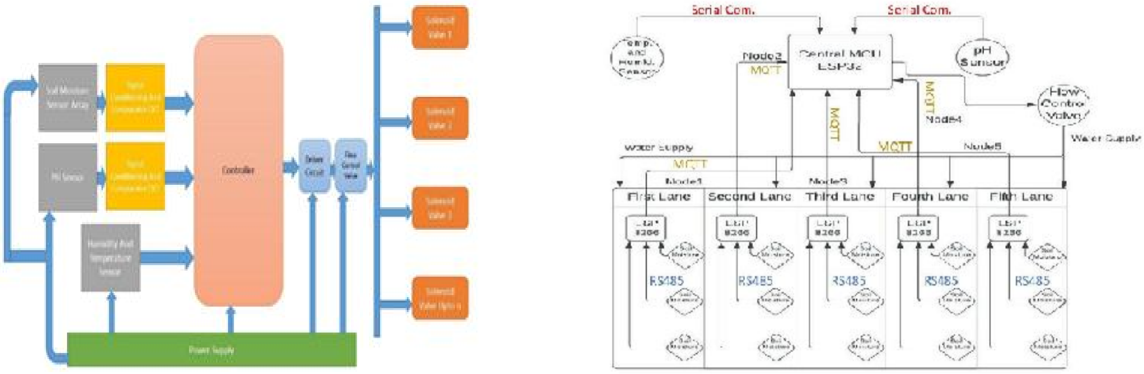

Figure 2: Detailed diagram of Smart Irrigation System

A. Proposed Methodology

The proposed work involves dividing the farm into five sectors, with each sector housing a single Microcontroller Unit (MCU) designated as a slave node. These slave nodes are responsible for collecting moisture level data from all deployed sensors within their respective sectors.

The master MCU will then gather data from the slave MCUs and other environmental sensors connected to it using the MQTT protocol. To establish communication between the master and slave nodes, a local area network will be implemented, with each node assigned a unique IP address for communication purposes.

To address range limitations, a shortest path algorithm will be developed to identify the nearest slave node for efficient communication with the master node. Additionally, a cooperative communication protocol will be implemented among slave nodes, enhancing data transfer to the nearest node.

Following data reception, the master MCU will conduct predictive analysis to determine the optimal volume and timing for water distribution. Subsequently, the master MCU will operate Flow sensors and Solenoid valves based on the decision. It will identify slave nodes with varying soil moisture levels and make irrigation decisions accordingly. Regions with nodes exhibiting low moisture levels will receive a higher water supply, and vice versa.

To enhance system power efficiency, the slave nodes will be configured in sleep mode, with the master MCU periodically waking them for data collection

IV. CONCLUSION

In conclusion, integrating soil moisture, nutrient levels (N, P, K), and humidity monitoring in a smart irrigation system signifies a significant advancement in precision agriculture. This new way of doing things helps us use water better, make crops grow more, and take care of the environment while farming. By using live information from a group of sensors, the clever irrigation system can figure out exactly how much water and nutrients the plants need. This smart system uses its intelligence to customize watering schedules and the amount of water for each plant. This helps plants get the right amount of moisture and nutrients they need for healthy growth and better crop production.

Farmers can look at both the moisture in the soil and the nutrients in the soil at the same time. This helps them not waste water and make sure the soil has the right amount of nutrients. This not only saves important water resources but also helps decrease the use of fertilizer and its effects on the environment. Moreover, by adding information about humidity, we can better understand how plants lose water through transpiration. This helps us improve the way we water plants and reduce waste water. Moreover, using smart irrigation systems could be very important in dealing with the problems caused by climate change and the lack of water worldwide. As the need for farming increases, it is important to use technology to make sure water is used efficiently. This will help guarantee that there is enough food and economic stability for farming communities all around the world.

To sum up, combining technology that tracks soil moisture, nutrient levels, and humidity in a smart irrigation system can help achieve efficient water usage, improve crop yield, and promote environmentally friendly farming practices. This new way of doing things helps farmers have better control over water and could change how farming is done. It will make farming more sustainable and better for the planet. So, the Smart Irrigation system we will create will check different things like how wet the soil is, the acidity of the soil, how damp the air is, and how hot or cold it is. Based on this information, it will adjust how much water is given to the soil and for how long.

Interest of Conflict

The authors do not have any interest in conflicts

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