Optimizing Irrigation In India: Balancing Iot And Non-Iot Paradigms

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Abstract - *This review explores India's irrigation landscape, where only 36.7% of crop land is reliably irrigated, with groundwater constituting 65% of irrigation. Emphasizing the importance of enhancing irrigation practices, the paper navigates the evolving precision agriculture domain, considering both IoT and non-IoT methodologies. Non-IoT approaches are highlighted for their potential cost-effectiveness, reduced maintenance, and lower environmental impact. Machine learning is identified as a promising avenue for creating sensor-free irrigation systems. The paper identifies research gaps, urging exploration of alternative pathways in irrigation optimization. Comparative evaluations include AI applications in agriculture, diverse uses of IoT, a WSN-based soil moisture system, a cloud-based IoT plant monitoring system, an economic model for irrigation, and solutions for drought-affected areas. It anticipates a shift in irrigation management towards economic goals and a broader definition of optimal irrigation, emphasizing social benefits and the need for advanced models and analytical techniques.*

Key Words: **IoT, Non-IoT, Irrigation, Agriculture, Wireless sensors, Artificial Intelligence, Cloud systems, Economic model, Irrigation management.**

1.INTRODUCTION

1.1 Background

Irrigation in India consists of a network of large and minor canals originating from Indian rivers, groundwater well-based systems, tanks, and other rainwater collection installations for agricultural use. The largest of these is the groundwater system [1]. In 2013-14, only roughly 36.7% of total crop land in the nation was reliably irrigated [2], with the remaining 2/3 relying on monsoons [3]. Groundwater provides 65% of irrigation in India [4]. At 39 million hectares (67% of its total irrigation), India has the world's largest groundwater well equipped irrigation system (China with 19 mha is second, USA with 17 mha is third) [1] (Fig.1). Irrigation currently covers only around 51% of the agricultural land farming food crops. The remainder of the region is reliant on rainfall, which is frequently inconsistent and unexpected. For a country as dependent on agriculture as India, it is of paramount importance to improve irrigation practices.

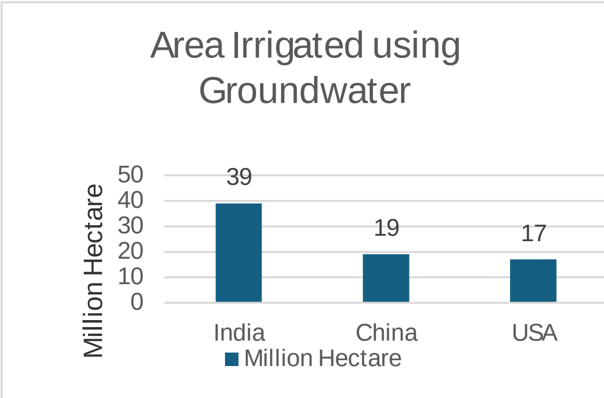

Fig – 1: Top countries with area irrigation in million hectares

1.2 Motivation and Objectives

In the ever-evolving landscape of precision agriculture, the pursuit of optimizing irrigation practices has witnessed notable strides, often propelled by technological advancements such as the Internet of Things (IoT). Within this context, our review paper endeavours to offer a thoughtful synthesis and reflection on the body of work related to irrigation optimization, recognizing the nuanced contributions of both IoT and non-IoT paradigms.

This review aims to unravel the intricacies surrounding methodologies for optimizing irrigation, paying due respect to the methodologies, successes, and challenges inherent in systems that operate independently of IoT integration. In doing so, we adopt a stance, acknowledging that the path less travelled may harbour insights and possibilities worthy of exploration.

A key focal point of this review is the identification and illumination of the existing research gap within the irrigation optimization domain. While IoT solutions have undeniably left a significant mark, we posit that alternative approaches may hold overlooked potential. Throughout this paper, our intent is to underscore the often-unnoticed advantages of non-IoT methodologies—emphasizing their potential cost-effectiveness, reduced maintenance requirements, and a lower environmental impact, particularly in terms of electronic waste generation. In particular, machine learning may be a promising technology to create a sensor free irrigation management system.

We recognize that the field of irrigation optimization is vast, and our understanding is but a modest contribution to a broader conversation. By adopting this perspective, we hope to foster a collective interest in exploring alternative pathways, thereby nurturing a holistic understanding of irrigation optimization that extends beyond the prevalent use of IoT-based solutions. Through this modest review, we extend an open invitation to scholars and practitioners alike to join us in navigating these unexplored territories, envisioning a future where irrigation optimization is not only technologically advanced but also mindfully considers economic considerations and environmental responsibility.

2. COMPARISON AND EVALUATION OF PREVIOUS WORKS/ METHODS

2.1 Artificial Intelligence in Agriculture

The primary focus of this paper is to conduct an extensive examination of the diverse applications of Artificial Intelligence in agriculture [5]. The integration of Artificial Intelligence (AI) into agriculture has catalyzed a transformative revolution, addressing and mitigating numerous challenges faced by the agricultural sector. This cutting-edge technology has proven instrumental in safeguarding crop yields amidst the complexities arising from climate change, population growth, employment concerns, and food security issues.

One pivotal application pertains to precision irrigation, weeding, and spraying facilitated by AI-driven sensors embedded in robotic systems and drones. This technological synergy aims to optimize resource usage by curbing excessive water, pesticide, and herbicide utilization. Furthermore, it plays a crucial role in soil fertility maintenance while concurrently streamlining manpower utilization, ultimately enhancing overall productivity and elevating the quality of agricultural outputs.

This paper meticulously surveys the extensive body of work conducted by researchers in the field, providing a comprehensive overview of the current state of automation in agriculture. Particular emphasis is placed on the development of automated weeding systems employing robots and drones. The exploration encompasses various soil water sensing methodologies and delves into two distinct automated weeding techniques. Moreover, the implementation of drones in agriculture is thoroughly examined, encompassing the diverse methods employed for spraying and crop monitoring.

In essence, this paper serves as a holistic exploration of the multifaceted applications of AI in agriculture, providing insights into the present landscape of automation and the advancements made in weeding systems, soil water sensing, and drone technology for precision farming.

Table 1 has some of the notable examples from the paper.

2.2 IoT in Agriculture

The author of the literature under review provides an extensive overview of all the different studies done in the area of IoT monitoring in agriculture[6]. The writer uses examples from several regions, including China, Malaysia, Thailand, and others, to show the variety of IoT's agricultural applications. The assessment provides information on prospective IoT uses in agriculture which could have a big impact on farmers and the sector as a whole.

The author lists number of open-source software for agricultural farm management. Using these freely available tools, farmers can increase their output and reduce labor costs. The author also list number of IoT sensors, their power consumption and communication distance for easy comparison. The review also examines the difficulties encountered in the field, such as problems with data management, infrastructure, and technology standards. If these difficulties can be resolved, it will speed up and improve the use of IoT monitoring in agriculture.

2.3 Wireless Sensor Network for Soil Moisture Monitoring

The authors of this paper offer a comprehensive exploration into the practical implementation of a Wireless Sensor Network (WSN)-based soil moisture monitoring system [7] (Fig 2). Designed with the specific goal of prolonging the system's operational lifetime, the WSN is meticulously crafted to be battery-operated. The integration of the Exponentially Weighted Moving Average (EWMA) event detection algorithm is a pivotal aspect of this system. Notably, the algorithm generates events solely when predetermined threshold conditions are met, ensuring a judicious use of resources. During periods when the threshold conditions are not fulfilled, the sensor nodes transition into a power-efficient sleep state, thereby conserving energy.

The significance of this work is underscored by its potential for further expansion and refinement. A noteworthy avenue for extension involves the incorporation of multiple sensor modules. By exploring the integration of additional sensor modules, this research paves the way for a more intricate and nuanced understanding of soil moisture dynamics. Such expansions could contribute to a more holistic approach to environmental monitoring and offer valuable insights into optimizing resource utilization in agricultural contexts. The subsequent sections of this paper delve into the intricatetechnical details, methodologies, and findings of this WSN- based soil moisture monitoring system, providing a robust foundation for future research endeavors and practical applications.

Table - 1: Examples of artificial intelligence in agriculture [5]

No.	ALGORITHM	METHOD OF EVATRANSPORATION	OTHER TECHNOLOGIES	ADVANTAGES/RESULTS	REFERENCES
1	PLSR and other regression Algorithm	Evapotranspiration model	Sensors for Data collection, IOT Hardware Implementation	Increased Efficiency And Economic Feasibility	Choudhary et al.(2019)
2	Artificial Neural Network based control system	Evapotranspiration model	Sensors for measurement of soil, temperature, wind speed etc.	Automation	Umair and Usman(2010)
3	Fuzzy Logic	FAO Penman-Monteith Method	----	Optimization	Kia et al. (2009)
4	ANN (Multilayer neural model)	Penman-Monteith Method	----	Evaporation decreased due to schedule and saving observed in water and electrical energy	Karasekreter et al. (2013)
5	Fuzzy Logic	------	WSN, ZigBee	Evaporation results verification. Can be applied to home garden and grass	Al-Ali et al. (2015)
6	ANN (Feed Forward, Backpropagation	------	----	Optimization of water resource in a smart farm	Dela Cruz Et al. (2017)
7	Fuzzy Logic Controller	Penman-Monteith Method	Wireless Sensors	Drip irrigation prevents wastage of water evaporation	Arvind et al. (2015)
8	Machine Learning Algorithms	-------	Sensors, ZigBee, Arduino Microcontroller	Prediction and tackles drought situations	Arvind et al. (2017)

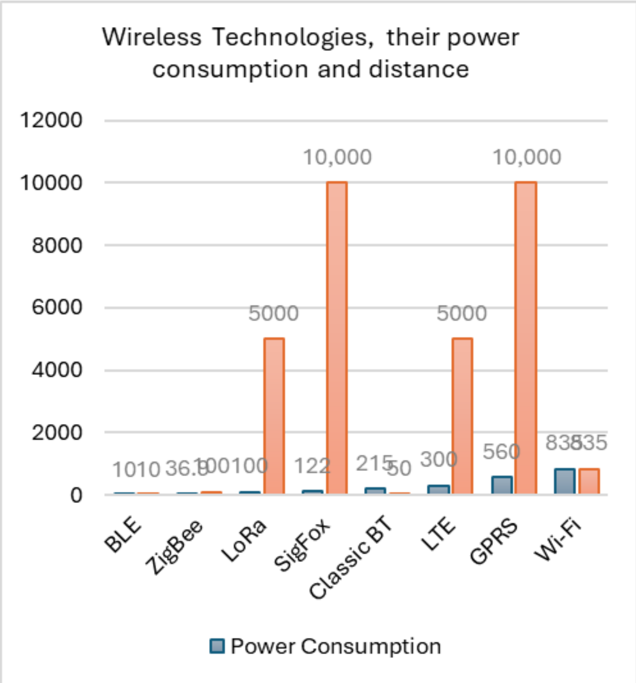

Fig – 2: Comparison of power consumption and range

2.4 Cloud based Plant Monitoring System

This literature presents the development of an automated plant monitoring and data storage system, with a specific emphasis on the implementation of a cloud-based Internet of Things (IoT) plant monitoring framework [8]. The central objective of this paper is to highlight the utilization of the ThingSpeak cloud platform for the purpose of seamlessly storing data collected from various sensors onto the cloud. This system offers a comprehensive solution for real-time monitoring, ensuring efficient data management and accessibility in the context of plant growth and environmental conditions. The subsequent sections delve into the technical aspects and functionalities of this innovative cloud based IoT plant monitoring system, providing insights into its design, implementation, and potential applications within the realm of precision agriculture.

2.5 Economic Model for Improving Irrigation

Based on an economic efficiency criterion, an optimization model has been presented to carry out water distribution planning in complex deficient agricultural water resources systems [9]. To tackle the issue, it is divided into three separate subsystems, each with varying levels of resolution.

The model offers the best irrigation water volumes and flows for irrigation areas generated from each reservoir, changes in the storage quantities they hold, and network flows. The combined economic functions for every irrigation region are produced by the model, and the best distribution of land and water resources for each crop in the cropping pattern, while accounting for cropping pattern, area-specific limits, land and water limitations, and optimized water production functions for each crop. Each crop's water timing and production functions are determined by taking into account the crop's sensitivity to water stress throughout its phenological phases, reference evapotranspiration and effective precipitation, irrigation uniformity, and water application distribution.

The most effective optimization strategies have been highlighted by comparing non-linear approaches. For the purpose of resolving water allocation issues, non-linear approaches work better than linear ones.

A sensitivity analysis of every parameter used in the planning of water allocation can be performed by the model. Economic analysis can be used to examine the effects of various meteorological and economic situations, modifications to irrigation techniques, and modernization of transportation and storage infrastructure.

2.6 Irrigation Solutions for Drought Affected Areas

There are several aspects to managing water scarcity in irrigated agriculture. These have to do with the nature of the current issues as well as the xeric regime, which is the source of water scarcity. The deficit irrigation results reported in this paper demonstrate that related solutions exhibit distinct economic responses during droughts and become more challenging or even impractical to implement in comparison to non-drought conditions [10]. A broader consensus on concepts and performance indicators would be beneficial in order to develop irrigation water management policies that are appropriate in the face of water scarcity. Policies should generally work to reduce the non-beneficial uses of water, especially those that are associated with water consumption and the portion of diverted water that is not reusable. But in order to properly explore these ideas—primarily for basin and system-scale planning and management—appropriate procedures must be created.

The goal of supply management, which is to increase delivery flexibility and dependability, is crucial to the effectiveness of decreased demand management since decisions made off-farm have an impact on the scheduling and management of farm irrigation systems. Saline fluids and wastewaters must be appropriately controlled for their effects on human health and the environment before being added to the irrigation supply. The degree of treatment of the effluents, the crops cultivated, the farming techniques, and the irrigation techniques all have an impact on wastewater reuse. The primary concerns might be with monitoring, specifically with regard to crop limitations in wastewater-using areas and the proper selection of appropriate irrigation techniques and procedures. Similar to this, management and careful selection of irrigation techniques and monitoring are essential for the safe use of salt water.

Adopting deficit irrigation and enhanced farm irrigation systems can reduce demand. A better level of irrigation uniformity is closely correlated with the improvement of irrigation systems. Better design, attentive maintenance, suitable irrigation equipment selection, and increased field evaluation are all implied by this. Improved homogeneity creates the opportunity to use low-quality waters with less environmental impact and to achieve higher efficiency. The review has demonstrated that because a wide range of factors affect irrigation performance, the economic effects of upgrading irrigation are not well understood.

Generally speaking, the most limited resource in places of water shortage is water rather than land. In these circumstances, maximizing the return per unit of water rather than the return per unit of land can be more advantageous. This appears to be the case for the supplemental watering of cereals, but other important considerations should also be made, such as the amount of fertilizer applied and the timing of sowing. However, when supplemental irrigation is taken into account, the quantity of rainfall that is available has a significant impact on the economic outcomes at the farm level. The review also demonstrates that, in typical climates, deficit irrigation of certain crops may be possible, but not in drought-prone areas, as demonstrated by the potato crop as an example. In places where water is scarce, irrigation schedules that maximize water production and farm profitability must follow certain principles.

2.7 A Shift in Mindset for Irrigation Management

It is anticipated that in the upcoming decades, the primary goal of irrigation will change from the physiological goal of increasing crop yields per unit of land to a new economic goal of maximizing net returns to irrigation [11]. This could be called, to put it simply, an "optimization" paradigm. Lower irrigation depths and lower yields per unit of irrigated land are typically associated with optimization. However, farm profitability will rise as running costs are decreased and water is freed up for other fruitful uses. When return flows from irrigation would otherwise be irretrievably lost, additional water may become available to other off-farm purposes.

Optimal management practices should still be expected to benefit farmers and other water users through lower production costs, better water distribution, and less environmental impact, even in cases where irrigation return flows are nearly totally recovered. A broader definition of optimal irrigation from a social standpoint would be the maximization of all benefits, which would include non-financial advantages such the preservation of water quality, food security, job growth, and population relocation. The optimization method will be more difficult than the current standard irrigation practices. Crop-water production functions and specific cost functions that are now not taken into account in irrigation planning or scheduling will need to be included in irrigation planning. Salinity is frequently a major problematic element. Analysts will typically have to handle a variety of goals and a broad range of potential approaches. They may also need to take uncertainty and the potential for increased financial risk into account. These kinds of intricate assessments will require more advanced physical models and rely on operations research analytical techniques.

3. RESULT

Table 2 is a comparison of the various methodologies discussed above:

Table – 2: Comparison of all discussed methodologies

No.	PAPER	TECHNOLOGIES/ALGORITHMS USED	REFERENCE
1	Implementation of Artificial Intelligence in Agriculture for Optimization of Irrigation and Application of Pesticides and Herbicides	Various ML algorithms have been discussed, like, Fuzzy Logic and ANN	[5]
2	IoT Enabled Plant Soil Moisture Monitoring Using Wireless Sensor Networks	Wireless Sensor Network, Exponentially Weighted Moving Average (EWMA) event detection algorithm	[7]
3	IoT Based Intelligent Agriculture Field Monitoring System	IoT sensors (soil moisture and temperature sensors), Cloud infrastructure	[8]
4	Optimization Model for Water Allocation in Deficit Irrigation Systems	Economic optimization model	[9]
5	Irrigation Management under Water Scarcity	Improvement in various irrigation techniques have been discussed	[10]
6	A paradigm shift in irrigation management	Various irrigation techniques have been discussed in the paper	[11]

4. CONCLUSION

In concluding our comprehensive review of various methodologies for irrigation optimization in agriculture, it becomes evident that the field is teeming with diverse approaches, each contributing uniquely to the overarching goal of resource-efficient and sustainable water management. As we reflect on the extensive body of work explored in this paper, a notable observation emerges—the conspicuous absence of non-IoT methodologies, particularly those that leverage Machine Learning (ML) without direct reliance on sensors.

While IoT-based solutions have rightfully garnered attention for their efficacy in real-time data acquisition, it is crucial to acknowledge the research gap pertaining to non-IoT methodologies in the realm of irrigation optimization. Notably, ML algorithms that operate independently of sensor input present an intriguing avenue for exploration. These methodologies, which often draw from historical data, climatic patterns, and soil characteristics, offer a pragmatic alternative, particularly in scenarios where sensor deployment might be economically or logistically challenging.

By underscoring the scarcity of non-IoT methodologies, our aim is to stimulate future research endeavors in this direction. The potential of ML-driven approaches without sensor reliance is substantial, offering not only cost-effective alternatives but also circumventing the challenges associated with sensor maintenance, deployment, and electronic waste generation. This void in the literature prompts a call for nuanced investigations into the untapped potential of data-driven irrigation optimization methods that operate outside the conventional IoT paradigm.

In essence, this review serves as a humble testament to the rich tapestry of methodologies that have evolved to enhance irrigation practices. By accentuating the absence of non-IoT methodologies, particularly those rooted in ML, we hope to inspire researchers, practitioners, and policymakers to delve into unexplored realms. The future of irrigation optimization may well hinge on embracing diverse, sensor-independent approaches that harness the power of data-driven insights to propel agriculture toward a more sustainable and efficient future.

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