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A Study On IOT and Big Data for Irrigation Automation and Yield Optimization

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1. Introduction

1.1 Research Background

Farmers rely on irrigation systems to supply the water demands of their crops, especially those grown in greenhouses. However, there are a number of common factors that limit output in many agricultural areas, including inadequate water resource utilization and poor irrigation scheduling. To reduce the likelihood of crop damage, farmers can adjust irrigation schedules based on sensed data such as moisture, light, and temperature **(Roopaei, Rad, & Choo, 2017).** As an example, soil sensors may monitor changes in soil temperature, moisture, nitrogen, and carbon levels, as well as water flow patterns over the landscape. Strawberry and other sensitive crops can be monitored, optimized, and controlled precisely in this way, allowing farmers to maximize crop productivity without sacrificing product quality.

Assuming that there is already some network infrastructure in place that can support the collection and delivery of all this data is a frequent method to gathering massive amounts of agricultural data. In most cases, data is sent to the cloud, which serves as the secondary system responsible for processing, analyzing, and managing the field actuation devices. The deployment of field devices at the network edge lacks the processing capacity of the cloud, so migrating all computing duties to the cloud has shown to be an efficient data processing method. Typically, a wideband cellular network like LTE serves as the backbone for systems that are enabled by the Internet of Things (IOT). Another option could be to use more regional wideband infrastructures, such WiFi, in Smart Irrigation Network (SIN) settings. Any method that depends only on international cloud providers to supply smart irrigation services is bound to fail in two key respects. One consideration is that data traffic demand might exceed the bandwidth of wideband wireless networks, especially in more remote locations. However, if SIN owners and operators solely use globally deployed clouds, they run the risk of losing control of their data when it is transferred to data centers without their knowledge or consent. Furthermore, catering to the farmer's needs for storage and calculation capacity might greatly affect the cost of information and communication technology services. If this cost were to be decreased, more of the farmer's earnings could be reinvested into the core production process. Thus, data kept at the network's periphery results in faster reaction times, better processing and action, less strain on the backhaul network, and stronger data ownership assurances (Shi, & Dustdar, 2016).

Smart irrigation management, upon which this study is based, is an attempt to solve the major problems that contemporary agriculture faces by making use of technology and data-driven methods. Our goal is to help create more efficient and environmentally friendly agricultural production systems by learning more about irrigation methods and coming up with real-world solutions.

1.2 Evolution of Irrigation

Using reference data from four distinct eras, beginning in 1970 and ending in the current day, we trace the development of irrigation. Figure 1 shows the progression.

Between 1970 and 1985, academics focused on irrigation optimization due to the scarcity of water and the rise of automatic control systems **(Sidhu, et al., 2021).** The demand for water began to surge in the late 1970s due to the exponential rise in population and the depletion of natural resources, prompting the implementation of water use information and efficiency measures. Because of this situation, improving the irrigation method became essential. A number of variables, including weather, the evapotranspiration crop canopy, and the stress day index (SDI), were recognized as crucial for optimizing irrigation. Data storage on the web and Internet-based control systems were made possible by the general use of the Internet after 1989. An easy and powerful technology for environmental monitoring has begun to emerge: wireless sensor networks (WSNs) **(Gamal, et al., 2021).** Agricultural uses of WSNs have led to the development of new sensors and actuators..

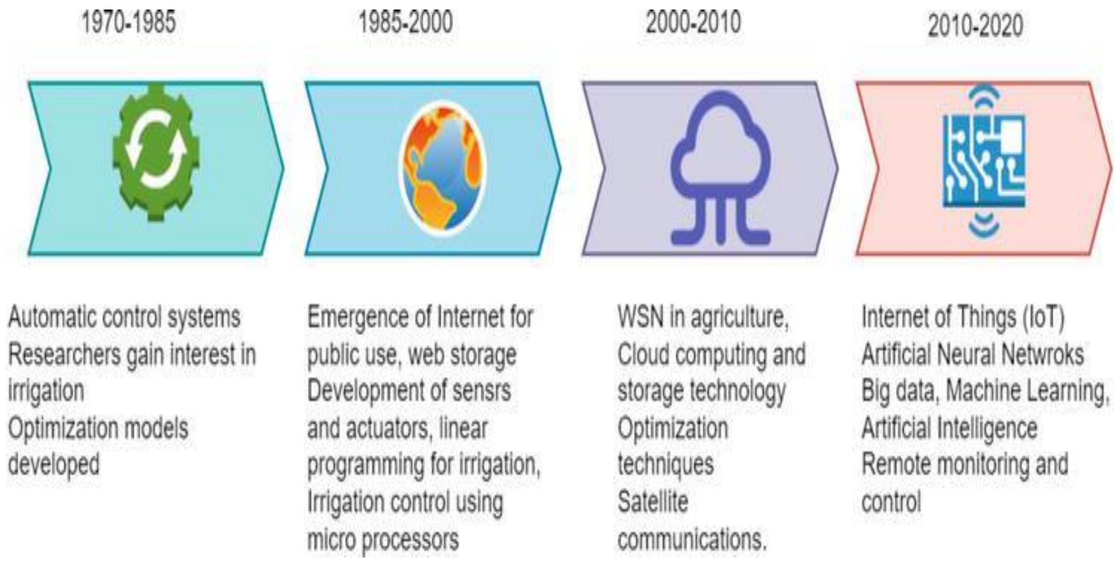

Figure 1.1: Evolution of irrigation from 1970 to present.

1.3 Factors to Be Considered for Effective Irrigation

There are a number of ways to water crops, or features of irrigation systems, depending on how the water is applied or used. Surface, drip, or sprinkler irrigation, as well as localized and subsurface irrigation, are common categories. The method of surface irrigation involves saturating the land with water. Less water is used in drip or sprinkler irrigation because the water is applied drop by drop or sprinkled like artificial rain. On the other hand, localized irrigation targets specific areas on the surface, and subsurface irrigation reaches the root zone of the crop (Gong, et al 2020). The kind of irrigation optimization done depends on a lot of things. Also, the quantity of rainfall, soil type, irrigation technique, crop, and location all play a role in how these factors interact. Among the many critical aspects influencing irrigation optimization are the following: Moistness of the soil. 2. The pH level. Conductivity of electrical current. 4. Metrics for crop growth... 5-Climate statistics. 6. Plant the canopy. 7. According to Abou-Shady, Siddique, and Yu (2023), evapotranspiration exists. The complexity of irrigation makes it difficult to set up properly, so it's smart to calculate how much water will be needed and then find the best way to water it by creating an optimization strategy that accounts for all of the variables.

Architecture or Deployment Models for IoT in Agriculture Irrigation Management

A remote monitoring system based on the Internet of Things employs a variety of methodologies for a variety of applications, and hence the design and deployment patterns are diverse. There is no one-size-fits-all approach to IoT architecture. Consolidation of the Internet of Things architecture is based on a three- or four-layer architecture.

Three-Layer and Four-Layer Architectures

The common architecture is the three-layer architecture represented in Figure 1.2, comprising the physical, network and application layers **(Harsha, Mohammed, & Arra, 2022).**

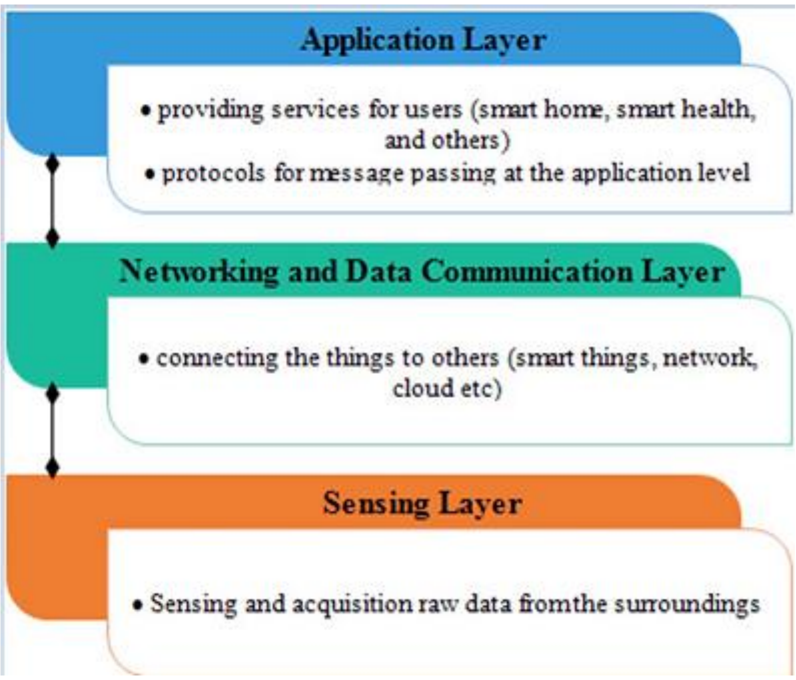

Figure 1.2: Three -layer architecture.

i) The sensor and actuator layer (physical layer) has the sensors and actuators connected to it, allowing sensing to gather information from the environment and to control the actuators

ii) The network layer (data management layer) connects other devices, servers, and things in the IoT application. This layer is sometimes called the communication layer, as it merges some of the functions, such as data aggregation and preprocessing.

iii) The application layer delivers application-driven services or functions to the end users. The functions and process differ based on the application in which it is used, such as smart homes, smart cities, and smart agriculture.

In the four-layer architecture the service layer is added to the three-layer architecture, and the service layer classifies the data for the application layer. The data are classified based on applications such as visualization, security, storage, communication services, and analytics. The service layer is accountable for the creation and management of services needed for applications. It acts as a middleware for the application and network layer, and is responsible for maintaining the services registry for discovery of services, API (application programming interface), and composition of services. Reliability management is also taken care of by the service layer.

Water management

Despite its scarcity, water is essential for all forms of life on Earth. However, water use has been dramatically altered due to rising populations and changing weather patterns over the past few decades, driving greater demand (Minhas, et al 2020).The agricultural resources are dwindling at a frightening rate; consequently, old ways of doing things need to give way to new ways of making the most of what we have. The agricultural sector relies mostly on soil and water. India has a cultivable area of over 55%, or over 183 million hectares, and irrigation uses up over 80% of the country's water resources, according to a report on Aquastat by the Food and Agriculture Organization [FAO]. The artifacts of the Indus Valley Civilization have revealed the beginnings and trajectory of irrigation in India. The practice of irrigation has evolved and changed over the course of thousands of years. Complex irrigation techniques or irrigation management are needed to supply the crop with the right amount of water at the right time (Gloria, et al 2020). In order to meet the enormous demand for food caused by the world's rapidly expanding population, it is crucial to find a solution to the problem of water use efficiency (WUE) and improve crop output through the implementation of appropriate irrigation management (FAO, 2001). (Das, et al., 2021). Optimisation of irrigation systems is crucial for satisfying the demand for raw materials. Since the 1970s, irrigation optimization has grown in popularity and has been in a constant state of evolution. Irrigation optimization could be achieved through the use of control-theory based automatic irrigation technology in precision agriculture. AquaCrop-Open Source is a MATLAB-based model for crop simulation. As one of the water-driven crop models, AquaCrop takes into consideration the many ways in which water stress affects transpiration. AquaCrop is a purpose-built simulation model for herbaceous crop types that can mimic their water needs, growth rates, biomass production, and harvestable yield. Numerous variables, such as weather, available resources, planted crops, evapotranspiration, stress coefficient, crop coefficient, electrical conductivity, and countless more, must be considered while optimizing irrigation systems. The diverse problem statements associated with irrigation contribute to the difficulty of optimization in this domain. In contrast to a dynamic irrigation model, which yields great accuracy, a static one leaves little room for improvisation. The implementation of dynamic irrigation optimization is made easier by available technologies like the internet of things (IoT), machine learning, and decision support systems hosted in the cloud. A growing number of agricultural organizations are implementing state-of-the-art data management systems and technological advancements. Nevertheless, regional differences exist in the technologies that are embraced. The technologies that farmers are most likely to use include soil samples, computers with fast Internet connectivity, yield maps, and sensors to monitor yields. Yields could be increased by 70% with the help of new technology. Developing an irrigation management application requires careful consideration of when and how much water should be applied. Improving irrigation management apps is much more feasible with the use of machine learning and models of artificial neural networks **(Shen, et al., 2022).**

Smart homes, smart waste management, smart agriculture, smart industry and retail, etc. are just a few examples of the incredibly abundant applications that fall under the banner of the Internet of Things (IoT). Internet of Things (IoT) capabilities are not limited to being essential in industry 4.0; they also extend to smart farming. In the context of smart agriculture, the work detailed in this thesis also takes into account an Internet of Things (IoT) application for adaptive irrigation.

Crop water needs estimation

The currently available water resources are slowly vanishing which creates more dependency and calls for efficient irrigated farming. It is thus exceedingly important that the farming sector contributes to prevent worsening of this water scarcity situation by making best use of the technological advances. People from the sector must be made aware regarding this issue and should be made to move towards more water efficient methodologies to cope up with water scarcity. As a solution, execution of data driven decision making could assist to curb water requirement in agriculture. One of the important factors while estimating crop water needs is the surrounding ambient conditions and the soil. To accomplish this, usage of sensors is a key solution. Information from these sensors can be used to form decision making models. However, the systems that rely solely on the climatic conditions are vulnerable to sudden changes, so soil related factor also needs to be taken into account. These changes imply, sudden surge in temperatures, occurance of sudden rainfall in non-rainy seasons, i.e. the unplanned sudden changes in current weather conditions.

To compute the crop water requirements, the potential or reference evapotranspiration $(ET_0)$is mentioned by the Food and Agriculture Organization of the United Nations (FAO) and is a key variable. Normally expressed in mm/ time, ET_0 defines the rate at which water is lost from a cropped surface, i.e. a combination of evaporation from soil surface and transpiration from the plant leaves, stems, flowers, etc. (grass taken as reference) in units of water depth. Figure 1.3 portrays a similar scenario which shows evapotranspiration as a combination of the evaporation and transpiration. Crop evapotranspiration (ET_c) as the name suggests, is the evapotranspiration from crops under ideal soil water conditions. It can be related to ET_0 using a factor k_c given by Equation (1.1),

$$ET_c = k_c \times ET_0 \ldots (1.1)$$

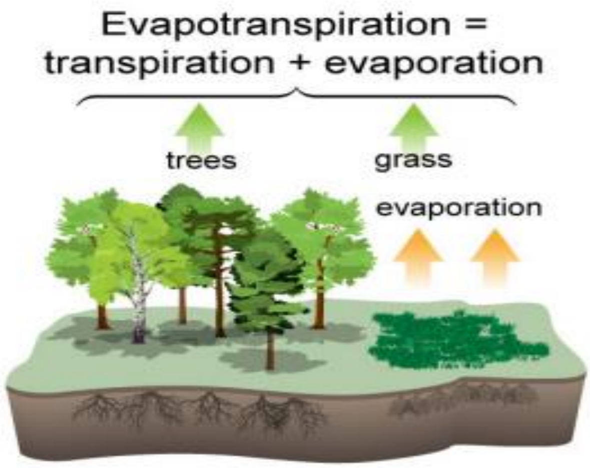

Figure 1.3: Evapotranspiration explanation diagram

where, k_c: crop coefficient that depends upon plant properties and is used in predicting the crop evapotranspiration. There are radiation, temperature, pan co-efficient based methods to compute the crop evapotranspiration. Thus, to improve food production and efficiently utilize water resources it is essential to incorporate latest technology trends with traditional methods of farming. The ever advancing technology has made rapid growth in digitization that in turn has made Internet a basic human necessity. Only if there were systems that were intelligent and knew everything about the different devices based on the gathered data (via the machines) without any human assistance life would be easier. Section 1.2 presents one such technology made for human assistance.

Technology assistance

This section explores the technological advancements that have been used in the work presented in this thesis. It starts with the introduction to Internet of Things, followed by its architecture, application domain, the protocols used for data communication and the basic neural network which is the decision making model employed in the system.

Internet of Things

The increasing advances in technology has led to a tremendous growth in the capabilities of internet enabled devices. This internet connectivity makes communication and device operability possible with minimum effort. One such technology, the Internet of Things (IoT) has made human life much more comfortable and effortless. To put in simple words, IoT is something which allows various internet enabled devices to communicate on their own without any human intervention. A future evaluation of Internet, the IoT, is referred to as a system of inter-related computing devices, objects, things, animals, people, etc. that has the capability to share information over a network without human involvement. It can be seen from Figure 1.4 that, in IoT the user can connect to any internet enabled device anytime and from anywhere in the world. IoT extends its application to a wide horizon of applications some of which include,

- Smart home: where the ACs, fans, etc. are controlled by these devices and not by the human,

- Smart health: where the devices with the patients send the stats to the doctor without the person actually measuring and sending it
- Smart agriculture: where smart systems take care of irrigation machinery automatically harvests after end of growth cycle, etc

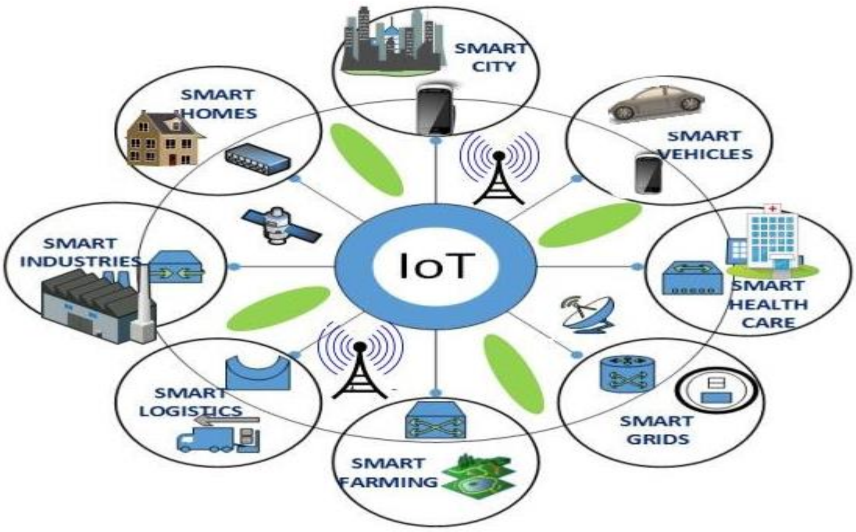

Figure 1.4: Internet of Things representation: Anything, anytime and anywhere

IOT architecture

For every concept to be employed there has to be a well-defined reference architecture. The general structure of an IoT architecture can be seen from Figure 1.4. It initially starts with the requirement i.e. what type of application is required and what sort of services need to be provided using it. After this is decided, sensors that pertain to that service and match the technical needs are chosen. These sensors sense data and this data is communicated over the network. The transferred data is then used at the other end for analysis, predictions, suggestions, decision, etc. A five layered IoT structure is shown in Figure 1.5 and the layers are further briefly explained.

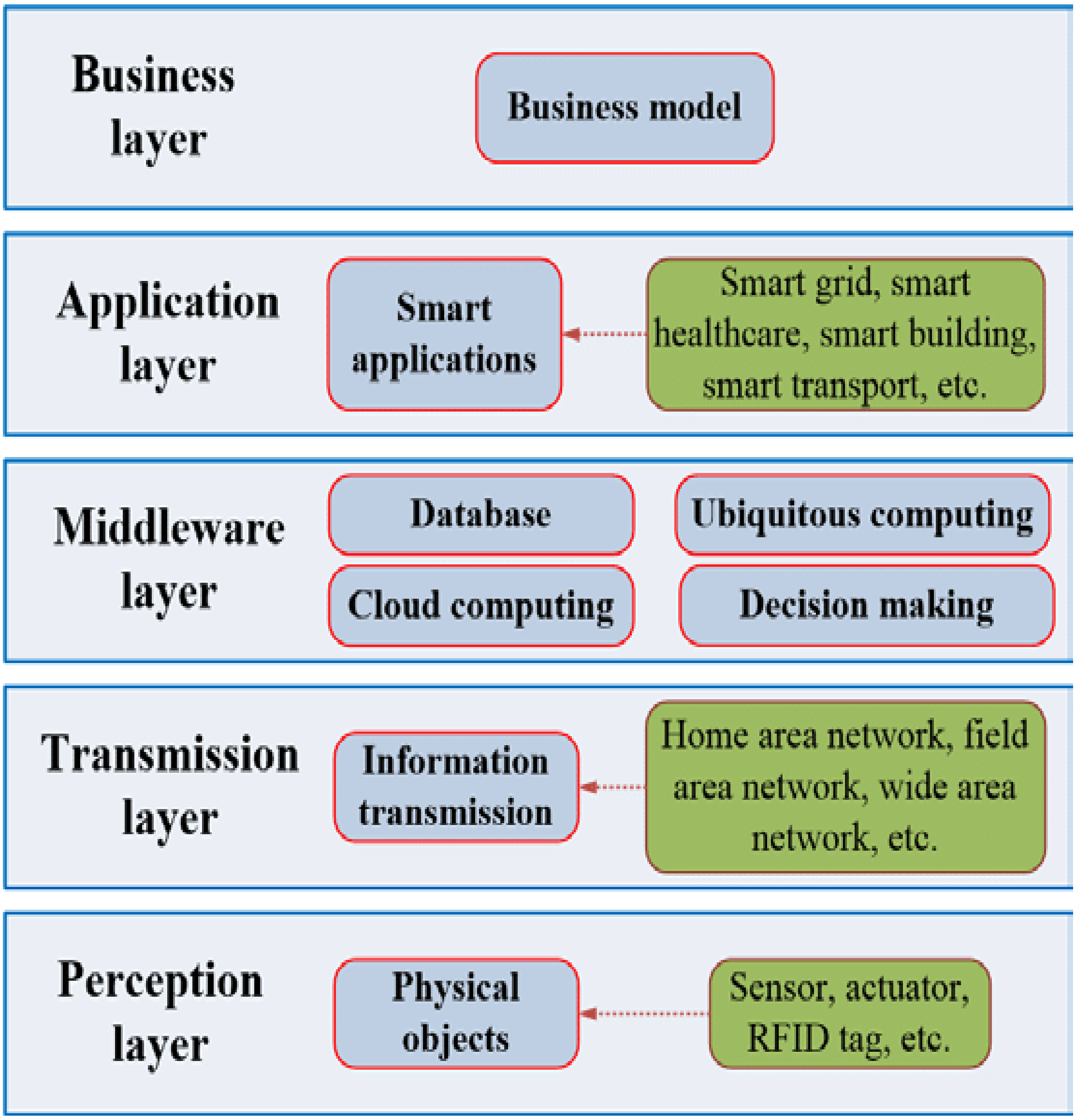

Figure 1.5: A five layered IoT structure

1) Device/perception layer: It senses data from the physical world and transfers it to the next layer. The data can be fetched using a camera in case of any image or video processing application, RFID when there is a need to keep a track of products in a mall or at the billing counter, sensors like accelerometer, hygrometer, moisture sensor, etc.

2) Network layer: The data fetched at the perception layer is sent using this layer via a gateway, and this data is transferred so that it can be further used in any application. Both wired and wireless modes of communication can be used for this purpose.

3) Middleware Layer: It is this layer through which there is proper service management and a link to the database. The middleware layer takes information from the network layer, stores it in the database, performs processing and then takes decision as per the obtained results.

4) Application layer: The end user sits at this layer. In general the IoT device/ system is designed as per the application required by the user. A variety of applications exist such as: e-health, power management, smart parking systems, smart agriculture, etc. The application layer comprises of the custom applications that is actually making use of the data from the devices.

5) Business Layer: The overall management of an IoT system is done by this layer. It keeps a track of the applications and services provided by the system, and based upon the data it gets from the application layer it builds models, graphs, etc.

1. Literature Review

The study by **Ayaz et al. (2019)** discusses the possibilities and anticipated difficulties of using wireless sensors and the Internet of Things (IoT) in agriculture. The Internet of Things (IoT) and the communication methods used by wireless sensors in agricultural applications are examined in depth. This article details the various agricultural sensors that are now on the market and their respective uses, such as in monitoring crop health, watering, and the identification of insects and other pests. The article explains how this technology aids farmers all the way through the crop life cycle, from planting seeds to harvesting, packaging, and shipping. The article also discusses additional beneficial uses of UAVs, such as agriculture production optimization, and their potential for crop surveillance. Highlighted as appropriate are state-of-the-art IoT-based systems and platforms utilized in agriculture. Lastly, we draw attention to possible research obstacles and present and future trends of the Internet of Things (IoT) in agriculture based on this comprehensive assessment.

According to Nawandar and Satpute (2019) "A large portion of India's GDP and the livelihoods of the majority of its citizens are derived from agriculture. Because of this, water is a precious resource that must be protected utilizing cutting-edge methods. Internet of Things (IoT) capabilities are not limited to being essential in industry 4.0; they also extend to smart farming. In this proposal, we aim to build an intelligent system for smart irrigation that is both affordable and efficient. With the help of the Internet of Things (IoT), the system's gadgets may communicate and collaborate autonomously. Among its features are an admin mode for user engagement, a one-time setup for irrigation schedule estimation, intelligent support based on neural networks, and the ability to monitor data remotely. To showcase the outcomes of the suggested system—which encompasses an irrigation schedule, neural net decision-making, and remote data viewing—a representative crop test-bed has been selected. A neural network gives the gadget the brains it needs by taking into account the data coming in from the sensors right now and hiding the irrigation schedule so it can water efficiently. The user can stay updated on the status of the crop from afar thanks to the system's utilization of MQTT and HTTP. Because of its portability, low cost, and intelligence, the proposed system is ideal for greenhouses, farms, and similar environments."

Monteleone et al. (2020) "investigates the factors that propel PA adoption within the Agriculture 4.0 framework. Factors influencing PA adoption in the context of Agriculture 4.0 and a model of irrigation operations management are given as a consequence of a multimethod approach. In order to investigate the interrelationships of the variables in irrigation planning, six different simulation scenarios are run. The empirical results enhance our comprehension of Agriculture 4.0 and broaden the scope of the Internet of Things (IoT) in the PA area. By combining the views of PA, the Internet of Things (IoT), and operational management, this study adds to the ongoing conversation around Agriculture 4.0. Taking into account the farmer's potential decision to implement multiple IoT sensing technologies for data collecting, this research further emphasizes the crucial significance of the Internet of Things.”

Li et al. (2020) “In developing nations, where agriculture and weather play a disproportionate role in the economy, the idea for this review study originated. Profitability in production farming hinges on making the correct operational decision at the right moment based on current conditions and previous records. The goal of precision farming is to increase agricultural yields while decreasing negative impacts on the environment by managing soil and crops in a way that is uniquely suited to each area. In order to remotely measure environmental factors in an agricultural field, this review paper focuses on the creation of an automated irrigation system that uses portable wireless sensor networks and decision support algorithms. Soil moisture, temperature, humidity, and light intensity are some of the ecological factors that are captured via radio satellite, mobile phones, sensors, internet-based connectivity, and microcontrollers. Internet of Things (IoT) technology allows the data collected by the sensors to be transmitted straight to a server in the cloud. Anywhere across the globe, users with an internet-connected device can see them. Modern agriculture is becoming more efficient and productive because to the development of sensor-based applications, which in turn reduces costs.”

Pornillos et al (2020) “These days, people are more likely to depend on devices that have some kind of autonomous control feature. The agricultural sector is one area that could benefit from this technology. A smart irrigation control system was developed by the researchers to aid in water conservation and reduce human labor. This system makes use of wireless sensor networks and an Internet-of-things platform in the form of a customized server. The study's aims were to compare the water consumption of a smart irrigation control system to that of a traditional irrigation method, as well as to ascertain the system's accuracy and functioning through the use of both experimental and developmental methodologies. In this investigation, the Wemos D1 Mini served as the primary microcontroller. The significance of the experiment's results was assessed using a T-test, a statistical method. A more efficient irrigation system that makes good use of all its parts is the result of careful planning and execution of a wireless sensor network based on microcontrollers. In regards to its sensing capabilities and precision, the system is reliable. The research showed that plants are automatically and adequately supplied with their water needs.”

Jamroen et al (2020) “Improvements in agricultural irrigation that increase crop yields while decreasing water consumption have recently attracted a lot of attention. On the other hand, conventional irrigation systems use a lot of water and power to plan when to irrigate. In this research, we provide a smart irrigation scheduling system that makes use of a cheap WSN and is based on fuzzy logic. When determining when to irrigate crops, the fuzzy logic system considers the variability of soil water and crop yields. By combining canopy temperature, solar irradiance, and vapor pressure deficit, the theoretical crop water stress index (CWSI) can be used to evaluate the water status of plants. Additionally, the water status of soil can be determined by analyzing the soil moisture content, which is measured by a capacitive soil moisture sensor. Consequently, the irrigation scheduling method is made more accurate by incorporating these two variables. The experimental setup validates the proposed irrigation scheduling system and compares it to traditional irrigation systems already in use to investigate how well it performs. With this system in place, farmers may expect a 22.58% gain in crop yield with a 59.61% drop in water use and a 67.35% drop in electrical energy consumption. The experimental findings demonstrate that the suggested irrigation scheduling system is both efficient and successful in terms of water and energy usage, as well as in terms of precise irrigation scheduling. The last step in confirming the proposed irrigation scheduling system's economic advantage is to do the cost analysis."

In the study of Hapsari et al (2020) "The issue of irrigation monitoring remains a challenge for Indonesian agriculture. Droughts hit the fields during the dry season, and floods hit during the wet season. Due to the remote nature of many farmland areas, farmers could benefit from an automated system that keeps tabs on water supply. To fix issues with the monitoring system, a wireless sensor network is a good choice of technology. Every monitoring node in this research is equipped with a water level sensor, pump, XBee Pro S2C, and an Arduino Nano. An automation irrigation module and a monitoring module make up the system, and they're linked through the master-slave communication arrangement between Xbee Pro S2C at every node. In order to gauge performance, the system ran through multiple scenarios. All performance parameters can be appropriately given to the user and adjusted to the real conditions in the farm field based on the testing result. It takes only 5-10 seconds for the latency between nodes."

Champness et al. (2020) "assess the present state of automated gravity surface irrigation in rice, pinpoint possible technical factors that have hindered the widespread use of the limited systems that have been developed so far, and list the extra features that an irrigation system needs to save water in commercial-scale systems, whether the water is ponded or not. Further study is needed to identify the best parameters for scheduling irrigation during non-ponded periods and to establish thresholds that are specific to regions and varietals. Only then can automation's potential economic, social, and environmental benefits be fully realized. Irrigation practices that greatly decrease irrigation water input and paddy GHG emissions could be widely adopted if the research and technical limitations mentioned in this chapter are filled."

(Kumari & Sharma 2121) "Connected devices and systems that can exchange data and instructions across a network are known as the "Internet of Things" (IoT). The agricultural sector, which has the potential to feed 10 billion people by 2050, relies heavily on IoT services. The foundation of agriculture is irrigation systems, which maximize crop productivity by decreasing water wastage and optimizing water usage for individual crops. This study presents an intelligent irrigation system (IIS) that uses sensors (soil moisture, pH, and flow) to monitor a paddy crop field. The system is built on the idea of the internet of things (IoT). Soil condition data is wirelessly transmitted to a web server database in order to determine the amount of water that is required. The authors employ the idea of a dashboard to store data in the suggested server database; the database controls the irrigation pump for farms via the HTTP protocol. The Internet of Things (IoT) can activate and deactivate water pumps, allowing for the monitoring of soil conditions depending on parameters such as soil-like wetness and water flow amount. A free and open-source server called "000webhost" was utilized to build the dashboard in question. Due to its reliance on water for its survival and development, this study has focused on rice, a paddy crop. The experimental results demonstrate that this technology outperforms the current traditional and uninspiring method of irrigation."

2. Statement of Research Problem

India and other developing countries' economies rely heavily on agriculture, which is why it is essential to global food security. Nevertheless, there are still obstacles to overcome when it comes to improving agricultural output, particularly in the areas of water resource management and increasing crop yields. Suboptimal use of water resources and output losses are consequences of inefficient irrigation practices, which are frequently exacerbated by inaccurate and unreliable real-time data. Agricultural management is already complicated due to the unpredictability of weather conditions, which is especially true in India.

This study aims to tackle multiple important problems. Firstly, a major obstacle is the lack of current data necessary for optimal irrigation methods, which leads to poor management of water resources. Harvest quality and quantity are both affected by the amount of water applied due to this deficit, which can be too much or too little. The second issue is that small and medium-sized farmers in India face a lack of access to modern technology, which makes it hard for them to use data-driven irrigation strategies that are efficient. These technologies include things like Internet of Things (IoT) sensors and big data analytics.

Moreover, data-driven precision farming is lacking since it is not yet obvious how to best use internet of things (IoT) and big data technologies to automate irrigation and maximize crop yield. The intricacies of many crop varieties and the vagaries of climate make this disparity all the more noticeable. Finally, issues with sustainability continue to arise because of the prevalence of unsustainable irrigation practices that are fueled by decisions that are not based on facts. Conventional irrigation systems waste a lot of water and energy, so finding a long-term solution to these problems will need creative thinking.

3. Objectives of Research Work

1) To improve the crop yield by introducing IOT technology and Big Data in agriculture
2) To decrease the crop wastage in agricultural sector
3) To increase the crop productivity with efficient and effective water usage

4. Scope and Significance of the Study

The scope of our work encompasses the application of smart farming techniques specifically targeted at irrigation management for crops. By leveraging the latest technological advancements, particularly in IoT (Internet of Things) and data-driven decision-making, our research aims to address the critical need for efficient water utilization in agriculture.

1) **Smart Irrigation Technologies:** Our research focuses on exploring and implementing smart irrigation technologies that utilize IoT sensors, data analytics, and automation systems to monitor and optimize water usage in agricultural fields.

2) **Integration of Traditional Methods with Modern Technology:** We seek to integrate traditional irrigation methods with modern technology to enhance their efficiency and effectiveness. This includes the deployment of IoT sensors for real-time monitoring of soil moisture levels, weather conditions, and crop health.

3) **Data-Driven Decision Making:** Our research emphasizes the importance of data-driven decision-making in irrigation management. By collecting and analyzing data from various sources, including IoT sensors and weather stations, we aim to develop algorithms and models that enable informed decision-making regarding irrigation scheduling and water allocation.

4) **Optimization of Crop Yields:** The ultimate goal of our work is to optimize crop yields while minimizing water wastage and resource utilization. By implementing smart irrigation techniques and utilizing data analytics, we aim to achieve higher productivity and profitability for farmers while ensuring sustainability in agricultural practices.

The study holds significance in promoting efficient utilization of resources, particularly water, by leveraging IoT sensors to monitor soil moisture levels and weather conditions in real-time, enabling precise irrigation scheduling and reducing water wastage.

5. Limitations (Exclusions) Of The Study

While researching smart irrigation management for farms, a number of limitations become apparent. First, in the event of technological breakdowns or connectivity challenges, the accuracy of data and the capacity to make sound decisions could be jeopardized because smart irrigation systems are highly dependent on the availability and dependability of applicable technology. Also, small-scale farmers would have trouble affording the upfront costs of Internet of Things (IoT) sensors and data analytics platforms, which could slow down their adoption. Because sensitive agricultural information could be at risk from unauthorized access or breaches, data privacy and security are also major concerns. Another barrier to efficient exploitation of IoT data and analytics platforms is the potential lack of technical skills among farmers and practitioners when it comes to interpreting and leveraging findings. Study results are subject to unpredictability and ambiguity due to environmental factors such shifting climatic patterns and severe weather occurrences, which further hamper smart irrigation system efficiency. In addition, the study's results could not be applicable to other agricultural settings due to limitations in the sample size and participant representation.

6. Research Methodology

The study's research methodology centres on gathering primary data using a questionnaire survey directed at farmers, agricultural specialists, and irrigation management stakeholders. Before creating the questionnaire, a comprehensive analysis of pertinent literature was done to determine the most important variables linked to increasing crop production, lowering crop waste, and raising crop yields through the use of IoT and big data in agriculture.

The purpose of the questionnaire was to compare attitudes and perspectives regarding IoT technology and Big Data in agriculture, as well as to include relevant aspects found in the literature research. Reaching out to stakeholders who were already using these strategies proved difficult, given the novelty of trends, patterns, and variances in crop yields and irrigation practices. In order to accomplish the research goals and determine if those goals have been met, it was determined that both primary and secondary data were required.

The aim of the research is to take an exploratory approach by doing a thorough inquiry prior to identifying specific issues. The investigation covers a wide range of IoT technologies and Big Data in agricultural processes. The analysis method takes into account the nature of the research by combining qualitative and quantitative approaches. While qualitative methods focus on understanding how Big Data and IoT technology are seen and used in the agricultural industry, quantitative methods are used for data surveys. This coordinated strategy guarantees the accomplishment of research goals and promotes a comprehensive grasp of the research topic.

7. Chaptalization

Chapter 1: Introduction

Introduces the study's background, problem statement, objectives, scope, and significance. Discusses Internet of Things (IoT), irrigated crop, precision agriculture, smart irrigation, water management system.

Chapter 2: Literature Review

Reviews literature aimed at summarizing the current state of the art regarding smart irrigation systems, and identified gaps.

Chapter 3: Research Methodology

A description of the IoT and big data for irrigation automation is provided in the present section various methodological approaches that can be implemented. Following the presentation of the philosophy, methodology, and study methods, the decision to conduct the study is then justified. The procedure for gathering data, determining the population, and selecting samples is segmented in precise detail. The ethical questions that were established have been responded. In conclusion, the shortcomings of the methodological approach as well as the insights of the research were discussed.

Chapter 4: Results and Evaluation

In this chapter, the findings and analysis of the data that was gathered during the research process will be presented. The analysis will be commenced with the qualitative research, the data interpretation has been performed with the concept of the framework.

Chapter 5: Conclusion and Future Directions

Summarizes the research work, discusses limitations, and outlines opportunities for future enhancements. Concludes with final remarks.

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