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Smart Agriculture: Self-Monitoring Irrigation System using Sensor

Dr. Pradnya Muley
MCA Department, PES's Modern College of Engineering
Pune, Maharashtra, India

Mr. Prathamesh Pravin Sakore
MCA Department, PES's Modern College of Engineering
Pune, Maharashtra, India

Mr. Tushar Naresh Puntambekar
MCA Department, PES's Modern College of Engineering
Pune, Maharashtra, India

Mr.Tushar Muley
Software Engineer, Smiths Detection
Bangalore, India

Abstract: The proposed system of using drip irrigation with the help of IoT and soil moisture sensors has several advantages over traditional irrigation methods. By directing water directly to the roots, it helps to reduce water wastage and optimize crop growth. The use of IoT technology and soil moisture sensors also allows for more efficient and precise irrigation scheduling, helping to conserve water resources and reduce energy costs.

The soil moisture sensors provide real-time data on soil moisture levels, which can be used to automate the irrigation process. The sensors can be connected to a central control unit, which can then be programmed to automatically turn on or off the motor, based on the data collected by the sensors. This eliminates the need for manual intervention and ensures that the plants receive the right amount of water at the right time.

The proposed system can help farmers save water, reduce energy costs, and optimize crop growth, making agriculture more sustainable and efficient.

Keywords: Smart Irrigation, IoT, Agriculture, Self-Dependent, Sensor

1. Introduction

Irrigation is the process of artificially supplying water to land or crops to help them grow. This can be done using different techniques, such as surface irrigation, sprinkler irrigation, or drip irrigation, depending on the water source, the type of crop, and the terrain.

The goal of irrigation is to provide the right amount of water to crops at the right time, to improve their growth, quality, and yield. Irrigation is an important practice in agriculture, as it helps to increase crop productivity and ensure food security [11].

There are several types of irrigation methods used worldwide, depending on the availability of water, soil type, crop type, and local conditions.

2. Literature Review

In recent years, several innovative approaches have been proposed to revolutionize the field of precision agriculture through the use of Internet of Things (IoT) technologies. One such notable contribution was made by Channe et al., who presented a ground-breaking multidisciplinary model for precision agriculture [6]. Their model introduced numerous applications aimed at enhancing crop production processes and providing real-time information to farmers, vendors, and government representatives. By leveraging IoT technology, Channe et al. enabled online agriculture data analysis, established an agricultural cloud infrastructure, facilitated agribusiness operations, and incorporated soil and weather analysis and predictions into their system. Moreover, their model featured a mobile application designed to empower farmers with valuable insights into fertilizer utilization, soil analysis, and future agricultural needs [6].

In 2017, the emergence of the FIGARO (Flexible and precise irrigation platform to improve farm scale water productivity) project further propelled advancements in precision agriculture. With a primary focus on freshwater irrigation management and production optimization, FIGARO presented a comprehensive decision support system. This system relied on an array of sensors, sophisticated software, and cloud computing capabilities [6]. Additionally, field experts were actively involved in the project to ensure optimal decision-making in irrigation practices.

Expanding on the potential of IoT-enabled precision agriculture platforms, Popovic et al. conducted a case study that explored the integration of various sensors, IoT protocols, and analytical tools for ecology monitoring and precision agriculture. Their research shed light on the diverse range of possibilities for leveraging IoT technologies in this domain.

Taking a slightly different approach, Kamilaris et al. proposed a theoretical framework known as SWAMP, which aimed to enable IoT-enabled smart farming. By harnessing the power of semantic reasoning and real-time stream processing, SWAMP provided farmers with accurate and actionable information for decision-making. This framework marked a significant advancement in facilitating efficient and data-driven agricultural practices [6].

Another noteworthy contribution was made by Jaiganesh et al., who presented an elegant farming model based on IoT principles. Their model leveraged mobile devices, information processing systems, and cloud services to collect, process, and store agricultural data. Additionally, they introduced the concept of an "Agro Cloud" module, designed specifically to cater to the unique needs of the agricultural sector [6].

In the realm of greenhouse management, Li et al. proposed an IoT-based system that incorporated various Android applications, sensors, communication protocols, and hardware. Their system offered a comprehensive suite of control functions, allowing farmers to regulate temperature, humidity, and lighting conditions within the greenhouse. Furthermore, the system encompassed monitoring capabilities and even featured weather forecasting functions to aid farmers in making informed decisions.

Addressing the specific requirements of small-scale farms, Kiani and Seyyedabbasi proposed a sensor and IoT-based monitoring system. This system continuously tracked crucial parameters such as temperature, humidity, and soil moisture, enabling efficient scheduling of irrigation, harvesting, and cultivation plans. By leveraging IoT technologies, farmers could optimize their resource utilization and maximize productivity.

In their research, Nurellari and Srivastava tackled the challenge of energy efficiency in agriculture field monitoring systems. They developed an IoT-enabled wireless sensor network that effectively provided farmers with vital information on moisture levels, salinity, and soil temperature. This resourceful system not only optimized agricultural practices but also minimized energy consumption, contributing to sustainable farming methods.

Collectively, these pioneering studies and projects have significantly contributed to the advancement of IoT-based precision agriculture. By harnessing the power of IoT technologies, researchers and practitioners continue to explore new avenues for improving crop production, resource management, and decision-making processes in the agricultural sector.

3. History And Evolution

In recent years, there have been notable advancements and innovations in self-dependent irrigation systems, particularly driven by technological developments and a growing focus on sustainable agriculture. Here are some key trends and examples:

3.1 Precision Irrigation: Precision irrigation technologies utilize sensors, weather data, and automation to optimize water delivery based on specific crop needs and soil conditions. These systems can monitor soil moisture levels, weather patterns, and plant requirements in real-time, allowing for precise irrigation scheduling and reducing water waste. They can be implemented through drip irrigation [4], micro-irrigation, or specialized sprinkler systems.

3.2 Sensor-Based Systems: Sensor technologies have played a significant role in enhancing irrigation efficiency. Soil moisture sensors, for instance, measure the moisture content in the soil and provide data that helps determine when and how much water to apply. These sensors can be integrated into automated systems that adjust irrigation schedules accordingly, ensuring plants receive adequate moisture while minimizing water consumption [1].

3.3 Remote Monitoring and Control: The emergence of Internet of Things (IoT) technology has facilitated remote monitoring and control of irrigation systems [5]. Farmers can access and manage their irrigation systems through smartphone apps or web interfaces. They can remotely monitor soil moisture levels, control irrigation schedules, and receive alerts or notifications about system performance. This real-time monitoring and control enable farmers to make timely adjustments, conserve water, and optimize crop health.

4. Features

Self-dependent irrigation systems typically encompass a range of features and capabilities that enable efficient and sustainable water management for agricultural purposes. Here are some key features commonly associated with self-dependent irrigation systems:

4.1 Sensor-Based Monitoring: Self-dependent irrigation systems often incorporate sensors to monitor critical parameters such as soil moisture levels, temperature, humidity, and weather conditions. These sensors provide real-time data to inform irrigation decisions and optimize water usage [7].

4.2 Automated Irrigation Scheduling: These systems leverage sensor data and advanced algorithms to automate irrigation scheduling based on crop water requirements, soil conditions, and weather forecasts. Automated scheduling reduces human intervention and ensures timely and precise water delivery to plants.

4.3 Water Conservation and Efficiency: Self-dependent irrigation systems prioritize water conservation by minimizing water wastage. They achieve this through accurate and targeted water application, avoiding over-irrigation and reducing runoff or evaporation losses [8].

4.4 Precision Water Delivery: These systems enable precise water delivery by utilizing technologies such as drip irrigation or micro-irrigation. Water is directly applied to the root zones of plants, minimizing water contact with non-target areas and reducing weed growth [6].

5. Impact On Society

Self-dependent irrigation systems have a significant impact on society, particularly in the agricultural sector. Here are some of the key impacts of these systems:

5.1 Improved Food Security: Self-dependent irrigation systems contribute to improved food security by enhancing crop productivity and reducing the risk of crop failure due to water scarcity. By providing a reliable and controlled water supply, these systems help ensure a stable and sufficient food production, even in regions with erratic rainfall patterns or water scarcity.

5.2 Increased Agricultural Productivity: Self-dependent irrigation systems enable farmers to optimize water usage and irrigation scheduling based on crop requirements. By providing the right amount of water at the right time, these systems enhance crop growth, yield, and quality. This, in turn, leads to increased agricultural productivity, allowing farmers to generate higher incomes and contribute to economic development [8].

5.3 Water Conservation and Environmental Benefits: These systems promote water conservation by minimizing water wastage and reducing excessive irrigation [5]. By precisely delivering water to plant root zones and avoiding runoff and evaporation losses, self-dependent irrigation systems help conserve water resources. This has positive environmental impacts, such as preserving local water sources, reducing pressure on water systems, and mitigating the depletion of groundwater reserves.

5.4 Sustainable Resource Management: Self-dependent irrigation systems support sustainable resource management practices. By incorporating sensors, data analytics, and automated control mechanisms, these systems optimize resource allocation and reduce the use of fertilizers, pesticides, and energy. They promote efficient use of water and other inputs, minimizing environmental impact and preserving natural resources for future generations [7].

6. Methodology

Self-dependent irrigation systems incorporate various technologies to optimize water usage, automate irrigation processes, and improve overall efficiency. Here are some key technologies commonly used in self-dependent irrigation systems:

6.1 IoT (Internet of Things): IoT technology forms the backbone of self-dependent irrigation systems. It enables connectivity and communication between different components, such as sensors, controllers, and cloud platforms. IoT facilitates real-time data collection, analysis, and remote monitoring, allowing farmers to make informed decisions about irrigation management [9].

6.2 Sensors: Sensors play a crucial role in self-dependent irrigation systems by collecting data on various environmental parameters. Soil moisture sensors measure soil moisture content, helping determine irrigation requirements. Weather sensors provide real-time data on temperature, humidity, and rainfall, enabling precise water scheduling based on weather conditions. Other sensors, such as solar radiation sensors or leaf wetness sensors, may also be used to gather relevant data.

6.3 Automation and Control Systems: Automation and control systems in self-dependent irrigation systems automate the irrigation process, reducing human intervention and optimizing water delivery. These systems incorporate programmable controllers that receive data from sensors and use algorithms to determine when and how much water to apply. Automated valves, pumps, and actuators are also utilized to regulate water flow and distribution.

I. Architecture

The architecture of a self-dependent irrigation system typically involves multiple components working together to monitor, control, and optimize irrigation processes. Here is a high-level description of the architecture:

Sensors: The system incorporates various sensors to collect real-time data on environmental parameters such as soil moisture, temperature, humidity, and weather conditions. Soil moisture sensors are particularly important as they provide information on the moisture content in the soil, enabling precise irrigation scheduling [3].

Block Diagram Of The Current Prototype

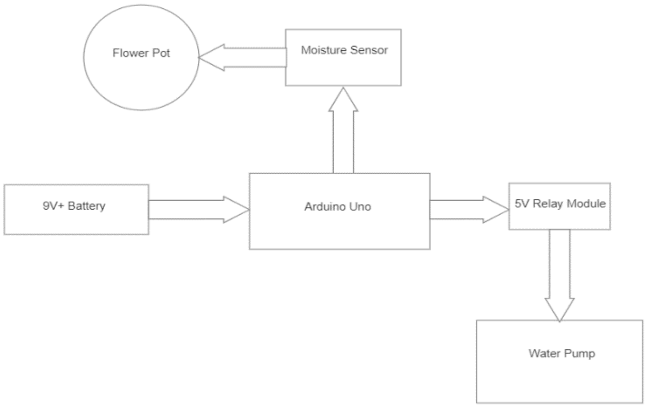

Fig. 1.1

Controllers: Controllers receive data from the sensors and perform analysis and decision-making based on predefined algorithms and models. They determine the irrigation requirements by considering factors such as soil moisture levels, weather conditions, and crop needs. The controllers also regulate the operation of valves, pumps, and actuators to control water flow and distribution.

Circuit Diagram of The Current Prototype

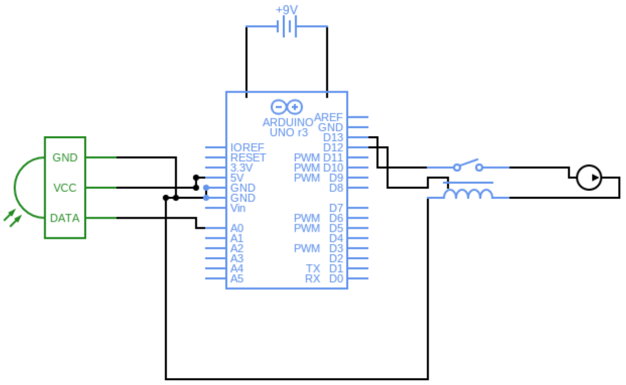

Fig. 1.2

Energy Management and Power Source: Energy management techniques and energy-efficient components are incorporated into the system to optimize energy usage. This may include the use of low-power sensors, controllers, and actuators. Additionally, renewable energy sources such as solar power can be utilized to power the system, reducing reliance on non-renewable energy sources.

The architecture of a self-dependent irrigation system is designed to collect accurate data, analyse it, and make informed decisions for irrigation management. It leverages sensors, communication networks, controllers, cloud platforms, data analytics, and user interfaces to optimize water usage, improve crop productivity, and facilitate efficient and sustainable irrigation practices.

II. IoT Components

Arduino Uno Board: The Arduino Uno is a popular microcontroller board based on the ATmega328P chip. It provides a simple and affordable platform for prototyping and creating electronic projects. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, USB connection for programming and power, and a range of compatible shields and modules. The Arduino Uno is widely used due to its ease of use, extensive community support, and compatibility with a variety of sensors and actuators, making it suitable for both beginners and experienced makers [1].

Fig. 1.3

Moisture Sensor With LM393 Driver: The Moisture Sensor with LM393 Driver is a module designed to detect soil moisture levels. It utilizes the LM393 voltage comparator chip for precise measurement. The sensor has two probes that are inserted into the soil, and based on the conductivity of the soil, it provides an analog output signal that can be read by a microcontroller. The LM393 driver helps convert the analog signal into a digital signal for easy interpretation. This moisture sensor module is commonly used in various applications, including agriculture, gardening, and automated irrigation systems [1].

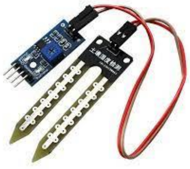

Fig. 1.4

5v Relay Module: The 5V relay module is an electronic switch that allows low-voltage control signals, such as those from microcontrollers or Arduino boards, to control higher voltage and current devices [3]. It is typically powered by a 5V power source and features an input control signal, usually a digital signal, to trigger the relay. The module consists of a relay, a driver circuit, and supporting components, providing isolation between the control circuit and the load. It is commonly used in home automation, robotics, and industrial applications to control devices like lights, motors, and appliances using low-voltage control signals.

Fig. 1.5

III. Working Principle

The system consists of several key components: a soil moisture sensor, an Arduino microcontroller, a relay module, and a water pump. The soil moisture sensor is placed in the soil near the plant's root zone and measures the moisture content of the soil.

The Arduino microcontroller acts as the brain of the system. It collects data from the soil moisture sensor and compares it with the predefined moisture thresholds set in the code uploaded to the microcontroller. These thresholds determine when the plants need watering.

Based on the moisture level readings, the microcontroller makes decisions on whether to activate or deactivate the water pump. When the soil moisture falls below a certain threshold, indicating that the plants require watering, the microcontroller sends a signal to the relay module [2].

The relay module acts as a switch and is connected to the water pump. Upon receiving the signal from the microcontroller, the relay module turns on the water pump, allowing water to be delivered to the plants. The water pump can be connected to a water source, such as a reservoir or a water supply system.

The water pump continues to operate until the moisture level in the soil reaches the desired threshold, indicating that the plants have received sufficient water. At this point, the microcontroller sends a signal to the relay module to turn off the water pump, conserving water and preventing over-watering.

The system can be customized to include additional features and sensors. For example, temperature and humidity sensors can be incorporated to provide more comprehensive data for optimizing plant growth. These sensors can help adjust the watering schedule based on environmental conditions.

To summarize, this automated watering system offers numerous benefits. It ensures that plants receive water precisely when needed, avoiding under or over-watering. By conserving water and optimizing plant growth, the system promotes sustainable and efficient water usage. It is particularly useful in areas with limited water resources or when manual watering is impractical or inconvenient. The system can be expanded and customized to meet specific requirements, making it a flexible solution for various plant irrigation needs.

7. Advantages

Self-dependent irrigation systems offer several advantages over traditional irrigation methods. Here are some key advantages:

7.1 Water Conservation: Self-dependent irrigation systems enable precise water management by using real-time data on soil moisture, weather conditions, and crop needs. This allows for optimal water usage, minimizing wastage and reducing water consumption. Water conservation is crucial in areas facing water scarcity or where water resources need to be managed sustainably.

7.2 Increased Efficiency: By automating the irrigation process and utilizing advanced technologies, self-dependent irrigation systems improve overall system efficiency. They ensure that water is delivered directly to the root zone of plants when needed, eliminating water loss due to evaporation or runoff. This efficient water delivery promotes better plant growth and reduces water and energy wastage [12].

7.3 Improved Crop Health and Yield: Self-dependent irrigation systems help maintain optimal soil moisture levels, ensuring that crops receive adequate water for healthy growth. Consistent and precise irrigation prevents under-watering or over-watering, reducing the risk of plant stress, disease, and yield loss. Proper water management contributes to higher crop yields and improved crop quality.

7.4 Labor and Time Savings: Traditional irrigation methods often require manual monitoring and adjustment, which can be labour-intensive and time-consuming. Self-dependent irrigation systems automate the process, reducing the need for constant manual intervention. Farmers can remotely monitor and control the irrigation system, saving time and effort while ensuring efficient water delivery.

Self-dependent irrigation systems offer significant advantages in terms of water conservation, efficiency, crop health, labour savings, flexibility, data-driven decision making, and environmental sustainability. These systems play a crucial role in sustainable agriculture, helping farmers optimize water resources, enhance crop productivity, and ensure long-term agricultural viability.

8. Disadvantages and Limitations

While self-dependent irrigation systems offer numerous advantages, they also have certain disadvantages that should be considered. Here are some potential drawbacks of self-dependent irrigation systems:

8.1 Initial Cost: Implementing a self-dependent irrigation system can involve a significant upfront cost. The purchase of sensors, controllers, pumps, and other necessary equipment, as well as the installation and setup expenses, can be a financial burden for some farmers or landowners.

8.2 Complexity: Self-dependent irrigation systems require technical knowledge and expertise to design, install, and operate effectively. Farmers may need to learn new skills or rely on specialized professionals for system setup and maintenance. The complexity of the system can be a barrier for those who are not familiar with technology or lack the necessary training.

8.3 Maintenance and Reliability: Like any technological system, self-dependent irrigation systems require regular maintenance to ensure proper functioning. Sensors may need calibration or replacement, and controllers may require firmware updates or troubleshooting. Failure of any component can lead to irrigation inefficiencies or crop loss, emphasizing the need for timely maintenance and reliable operation [5].

8.4 Power Dependency: Many self-dependent irrigation systems rely on a stable and uninterrupted power supply to operate effectively. Power outages or disruptions can impact the system's functionality, leading to potential irrigation gaps or system failure. Backup power sources or alternative energy solutions may be necessary to mitigate this dependency.

8.5 Data Accuracy and Calibration: The accuracy and reliability of sensor data can sometimes be a challenge in self-dependent irrigation systems. Sensors may require periodic calibration to ensure accurate measurements, and environmental factors such as soil variability or sensor placement can affect data accuracy. Regular monitoring and calibration are essential to maintain the system's accuracy and make informed irrigation decisions.

8.6 Lack of Flexibility: Self-dependent irrigation systems typically operate based on pre-programmed settings or algorithms. While they offer automation and optimization, they may not provide the flexibility needed to adapt to sudden changes or specific crop requirements. Adjusting irrigation schedules or strategies may require manual intervention or reprogramming the system [11].

8.7 Compatibility and Integration: Integrating self-dependent irrigation systems with existing farm management systems or infrastructure can be challenging. Compatibility issues may arise when trying to connect different sensors, controllers, or software platforms. Integration with other data management systems or decision support tools may require additional effort and investment.

It's important to evaluate these disadvantages against the potential benefits and specific requirements of your irrigation needs. Proper planning, training, and regular maintenance can help mitigate these challenges and ensure the successful implementation and operation of self-dependent irrigation systems.

9. Applications

Self-dependent irrigation systems have a wide range of applications across various sectors. Here are some common applications:

9.1 Agriculture: Self-dependent irrigation systems are extensively used in agricultural settings to optimize water usage, improve crop yield, and reduce labour requirements. These systems ensure that crops receive the right amount of water based on their specific needs, leading to improved plant health, increased productivity, and water conservation.

9.2 Horticulture and Landscaping: Self-dependent irrigation systems are utilized in horticultural and landscaping applications, such as gardens, parks, golf courses, and greenhouses. They automate the irrigation process, ensuring that plants, flowers, and turf receive optimal water supply for growth and aesthetics. These systems can be programmed to deliver water at specific times and in varying quantities based on plant types and environmental conditions.

9.3 Urban Water Management: Self-dependent irrigation systems play a crucial role in urban water management. They are employed in public spaces, such as parks, sports fields, and roadside plantations, to provide efficient and controlled watering. By using sensors and automated control, these systems help conserve water resources, reduce runoff, and minimize water wastage in urban environments.

9.4 Smart Home Gardening: With the rise of smart homes and connected devices, self-dependent irrigation systems find applications in home gardening. These systems enable homeowners to automate the watering of their indoor and outdoor plants. By integrating with IoT platforms and mobile apps, users can remotely monitor and control the irrigation process, ensuring the health and vitality of their plants [11].

9.5 Green Roofs and Vertical Gardens: Self-dependent irrigation systems are employed in green roofs and vertical gardens, where space is limited. These systems ensure that plants on rooftops or vertical structures receive sufficient water for growth and insulation benefits. They allow for precise watering, minimizing water usage and preventing water runoff from these unique gardening environments.

9.6 Water Scarcity Regions: In regions with water scarcity or limited access to water resources, self-dependent irrigation systems offer significant benefits. These systems allow farmers and gardeners to optimize water usage and maximize crop yield while using minimal water resources. By employing smart irrigation techniques and data-driven decision-making, water can be allocated more efficiently, ensuring sustainable agricultural practices.

9.7 Remote Agricultural Areas: In remote agricultural areas, where manual irrigation management may be challenging due to distance or lack of resources, self-dependent irrigation systems prove to be highly beneficial [11]. These systems can be remotely monitored and controlled, allowing farmers to manage their irrigation operations effectively and optimize water usage without physically being present in the field.

The applications of self-dependent irrigation systems are diverse and continually expanding. By combining automation, data analysis, and efficient water management, these systems provide sustainable and optimized solutions for irrigation needs across various sectors.

10. Future

Advancements in technology and the Internet of Things (IoT) are likely to enable the integration of irrigation systems with Android apps for monitoring and control purposes. This integration would provide farmers and users with the convenience of managing their irrigation systems remotely through their smartphones or tablets.

By incorporating sensors such as NPK sensors (to measure soil nutrient levels), temperature sensors, humidity sensors, and other relevant sensors, the irrigation system can gather comprehensive data about the soil and environmental conditions. This data can then be transmitted to the Android app in real-time, allowing users to access and analyse it.

With this information at their disposal, the Android app can provide valuable insights and recommendations regarding the water and fertilizer requirements of the soil. By analysing the data collected from the sensors, the app can determine the specific needs of the soil, taking into account factors such as soil type, nutrient levels, temperature, and humidity.

Based on these findings, the Android app can suggest customized watering schedules and fertilizer application plans for optimal plant growth. It can provide notifications and alerts to the user, indicating when the soil moisture levels are too low or when specific nutrients need to be replenished. Users can then remotely control the irrigation system through the app, initiating watering cycles or adjusting the irrigation settings as per the recommendations.

This integration of advanced sensors, data analysis, and remote control through an Android app would promote efficient water and resource management. Farmers and users can make informed decisions based on real-time data, ensuring that the irrigation system is precisely tailored to the specific needs of the soil and crops. This would result in optimized resource utilization, reduced water wastage, improved crop yields, and potentially cost savings.

The future integration of irrigation systems with Android apps would offer enhanced convenience, flexibility, and efficiency in managing irrigation operations. It would empower users with real-time information and enable them to make informed decisions for better agricultural practices.

11. Conclusion

11.1 Efficient Water Usage: Smart irrigation systems utilize various sensors such as soil moisture sensors, weather sensors, and evapotranspiration sensors to collect real-time data on soil moisture levels, weather conditions, and plant water requirements. By analysing this data, the system can determine the optimal amount of water needed and deliver it precisely to the plants. This ensures that plants receive the right amount of water without wastage, reducing water consumption and conserving this valuable resource.

11.2 Water Conservation: By providing water only when and where it is needed, smart irrigation systems significantly reduce water wastage. Traditional irrigation methods, such as overhead sprinklers, can result in water runoff and evaporation, leading to inefficient water usage. With smart systems, water is targeted directly at the root zone of plants, minimizing losses due to evaporation and ensuring maximum water absorption [2].

11.3 Energy Savings: Smart irrigation systems often incorporate efficient water pumps and controllers, allowing for optimized water distribution and reduced energy consumption. By using sensors and automation, the system can operate the water pump only when necessary, saving energy and reducing operational costs.

11.4 Time and Labour Savings: Manual irrigation requires significant time and labour investment, especially in large agricultural or landscaping areas. With a smart irrigation system, the process is automated, eliminating the need for manual operation. The system can be programmed to follow specific schedules or respond to real-time data, saving time and freeing up labour resources for other important tasks.

11.5 Plant Health and Growth Optimization: Smart irrigation systems enable precise control over the watering process, ensuring that plants receive the appropriate amount of water at the right time. This promotes healthy root development, efficient nutrient uptake, and overall plant growth. By avoiding overwatering or under watering, the system helps prevent plant stress, diseases, and root rot, leading to improved plant health and increased crop yield.

11.6 Remote Monitoring and Control: Many smart irrigation systems offer remote monitoring and control capabilities, allowing users to access and manage the system from anywhere using mobile apps or web interfaces. This provides flexibility and convenience in monitoring and adjusting irrigation schedules, especially for users managing multiple sites or those who are frequently on the move.

11.7 Data-Driven Insights and Decision Making: Smart irrigation systems collect and analyse data from various sensors, providing valuable insights into soil moisture trends, weather patterns, and plant water requirements. This data can be used to optimize irrigation schedules, make informed decisions on water allocation, and adapt to changing environmental conditions. By utilizing data-driven decision making, users can maximize irrigation efficiency and achieve better overall crop and plant management [13].

To summarize the topic, smart irrigation systems offer a range of benefits including efficient water usage, water conservation, energy savings, time and labour savings, improved plant health, and data-driven decision making. These systems are becoming increasingly popular in agriculture, landscaping, and even residential settings, as they provide a cost-effective and sustainable solution for irrigation needs.

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