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IOT- BASED SMART IRRIGATION MONITORING FOR CROP YIELD OPTIMIZATION

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Abstract :

The traditional irrigation system often results in inefficient water usage, which directly affects crop productivity. This study proposed an IoT-based smart irrigation monitoring system design to optimize crop yield while minimizing water wastage. The system employs an ESP32 microcontroller, Soil moisture sensors, Temperature and humidity sensors, and cloud integration to monitor and control irrigation in real time. The data from the sensor is transmitted via Wi-Fi to the cloud platform. Where farmers can access live field conditions through a smartphone application, based on the soil moisture threshold, and the system can automatically trigger irrigation to maintain optimal conditions for crop growth. The prototype was tested on multiple crop samples, demonstrating improved water efficiency and healthier crop growth. The experimental results indicate that the system not only reduces manual intervention but also contributes to better crop yield optimization through smart water management, making it a practical solution for precision agriculture.

Keywords: Internet of Things, Smart irrigation, Crop yield optimization, Precision agriculture, ESP32, Sensors.

1. Introduction

The IoT-based smart irrigation monitoring and controlling system interconnection of number of devices through the internet, describing the Internet of Things. Every object is connected through a unique identifier so that data can be transferred without human-to-human interaction. It allows establishing solutions for better management of natural resources. The smart object embedded with sensors enables interaction with the physical and logical worlds according to the concept of IoT [1]. The farmers are suffering from the low yield of crops. Though the right crop selection is the main key to maximizing crop yield by doing soil analysis and considering meteorological factors, the lack of knowledge about soil fertility and crop selection is the main reason for low crop production. In the changed current climate, farmers having primitive knowledge about conventional farming are facing challenges in making sagacious decisions on crop selection. The selection of the same crop in every seasonal cycle results in low soil fertility [2]. The IoT-based smart crop field monitoring and automation irrigation system that issues concerning

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agriculture have always been hindering the development of the country. The solution to this problem is smart agriculture by modernizing the current traditional methods of agriculture. To make agriculture smart using automation and IoT technology. IoT enables various applications for crop growth monitoring, selection, and irrigation decision support [3].

IoT technology has emerged as a significant pathway in innovative agricultural techniques. The low capacity of these IOT nodes has faced energy limits and complicated routing methods. Due to the growing global population and increasing food demand, smart agriculture is playing a more vital role. [4]. Enhancing crop yield and growth prediction using a smart irrigation system and ML. The smart irrigation yield optimization of a smart irrigation system to improve crop yield and growth prediction.

The irrigation methods, such as furrow irrigation, overhead sprinkler system, and manual watering, are analyzed for their inherent inefficiencies and especially in precision and resource management. The real-time sensor that monitors soil moisture, temperature, humidity, and nutrient levels, enabling precise and automated irrigation tailored to the specific needs of crops [5]. The design and optimization of an IoT-based smart irrigation system in the field of agriculture, and the development of an efficient IoT-based smart irrigation system are similarly valuable requirements for farmers. The low-cost IOT weather-based smart irrigation system has been developed. The water-efficient irrigation system is given IoT-based communication capabilities to remotely monitor soil moisture conditions and to manually control water supply by a remote user [6].

The environmental remote sensing and prediction model for an OIT smart irrigation system based on an enhanced wind-driven optimization. The IOT has revolutionized several applications and industries. Smart agriculture and irrigation are among these industries that have witnessed tremendous advances in how environmental and agriculture-related data are remotely sensed, collected, presented, and analyzed. The smart irrigation system based on IOT and ML to provide farmers with an efficient way to remotely sense the environmental and agricultural-related parameters such as air temperature, pressure, humidity, and soil moisture [7].

The irrigation water management has attracted strategies and their effect on water savings and crop yield. The irrigation water management of crucial to guarantee water and water, food security worldwide. The smart irrigation system is applied for the rational use of water in agricultural fields and for maximizing crop yield. The high demand for water resources is decreasing, and the adverse environmental impact of irrigation by assessing the soil moisture content and crop water stress index. The smart irrigation technologies are discussed their effect on water saving, yield, and crop quality. The analysis of prominent highlighted that the water use is efficient based on soil moisture, crop growth, and quality [8]. The precision irrigation of water-saving technology under a changing climate for enhancing the water efficiency of crop yield and environmental footprints. The water is considered one of the vital natural resources and factors for performing short and long-term agriculture practices on earth. Globally, the most available freshwater resources are utilized for irrigation purposes in agriculture. The world regions are facing an extreme water shortage problem that can worsen if not managed properly [9].

The smart irrigation management for improving water productivity under climate change in drylands. The major constraints to agricultural productivity are traditional irrigation scheduling methods and associated challenges, efforts, and progress [10]. The novel energy management scheme in IoT enables a smart irrigation system using optimised intelligent methods. The growing population, increasing food demand, and smart agriculture are becoming more vital. The (IOT) Internet of Things technology towards precision agriculture to enable intelligent irrigation systems using a deep learning neural network [11]. Precision agriculture has gained substantial attention due to the ever-growing world population's demand for food and water. Farmers will need water and will be able to meet this demand. The availability of both resources and farmers' needs requires a solution that changes the way they operate. The precision irrigation solution to deliver bigger and better profitable yield with fewer resources [12]. The adaptation of weather conditions based on the enabled smart irrigation technique in precision agriculture mechanisms. Precision agriculture is the mechanism to control land productivity and maximise revenue, and reduce the impact on the surroundings by automating the complete agriculture process. The farm is generating necessary action throughout the whole course of farming. The irrigation system precisely manages water value using a neural network-based prediction of soil water requirements [13]. The smart irrigation system for precision agriculture on an IoT platform. Agriculture in future farming technology is a key enabling factor towards sustainable agriculture. The IOT transforms traditional practices such as irrigation into a modern solution of precision agriculture. It describes the operation of the IOT node that is utilized in the platform.

This fabricates and validates a rectenna module for radiofrequency energy harvesting [14]. The smart IoT-driven precision agriculture and land mapping, crop prediction, and irrigation system. The smart IoT-based suitable agriculture land and crop selection, along with an irrigation system using agriculture mapping with precision agriculture. The model is used for healthy vegetation and the effectiveness of advanced computational technology in enhancing agricultural resource management. In the design of smart IoT-based suitable agriculture land and crop selection with an irrigation system using agriculture [15].

2. Materials And Methods

2.1 System Architecture

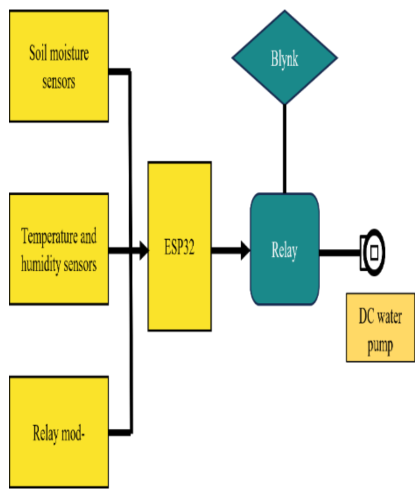

Figure 1: Block diagram of the proposed system

The proposed system architecture is designed to monitor soil conditions and optimise crop yield through automated irrigation. The consists of an ESP32

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microcontroller, a soil moisture sensor, a temperature and humidity sensor, a relay, and DC water pumps. The IoT-based smart irrigation monitoring for crop yield optimisation. The soil moisture sensor and temperature sensor meter unit is monitoring and controlling of waste monitoring sensor. The soil moisture sensor measures water content and temperature, and the humidity sensor provides data crucial for crop growth. And the smart control is based on the soil represented in Figure 1.

2.2 Main Circuit of the system

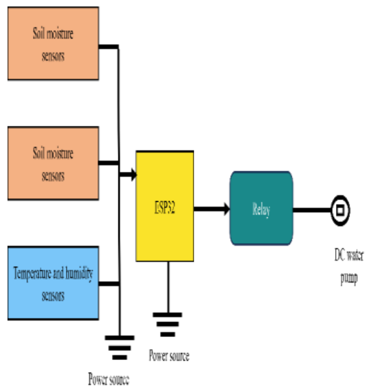

Figure 2: Circuit diagram of the proposed smart irrigation system

The above Figure 2 represents the main circuit connection of the proposed IoT-based smart irrigation system. The setup includes an ESP32 microcontroller, a Soil moisture sensor, a Temperature and humidity sensor, relay modules, and DC water pumps. The ESP32 serves as the control and communication hub, managing both data acquisition and irrigation activation. The circuit operates with two power sources, one dedicated to the ESP32 and sensor modules. The other to relay and DC water pumps. The soil moisture sensor is connected to an analogue input pin of the ESP32 and allowing continuous monitoring of soil moisture levels. The ESP32 processes the sensor data and, based on the predefined threshold, sends control to the relay module. The relay module acts as a switching interface between the ESP32 and DC water pumps. The soil moisture value drops below the optimal level, and relay is energised to activate the corresponding water pumps. When the soil moisture reaches the desired value, the relay automatically turns off the pump to prevent over-irrigation.

2.3 System algorithms

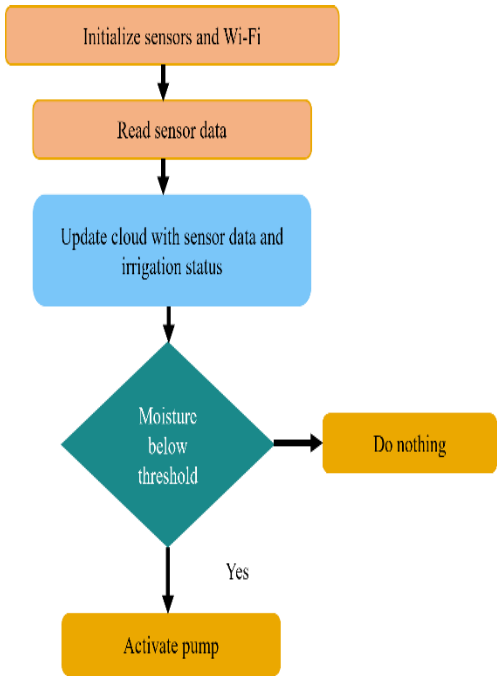

Figure 3: Flowchart of the smart irrigation monitoring algorithm

The ESP32 microcontroller in the proposed system is programmed using the Arduino IDE, and the Blynk IOT platform is utilized for cloud communication and remote monitoring. The Blynk library allows real-time visualization of sensors, irrigation status, and notifications through user user-friendly smart interface. The main algorithm to control irrigation automatically, based on soil moisture readings and environmental data. The optimisation of water usage supports

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maximum crop yield. The initialisation of the ESP32, the Soil moisture, temperature, and humidity sensor, and establishing wifi connection. To read the soil moisture, temperature, and humidity values from the sensor. Update the Blynk cloud with live sensor reading and irrigation pump status. The notification is sent to a user through a mobile application when the soil moisture drops below the threshold, Figure 3. The comparison of the current soil moisture value against a predefined threshold of soil moisture. Control irrigation by activating and deactivating the relay module based on soil moisture content.

2.4 System Overview

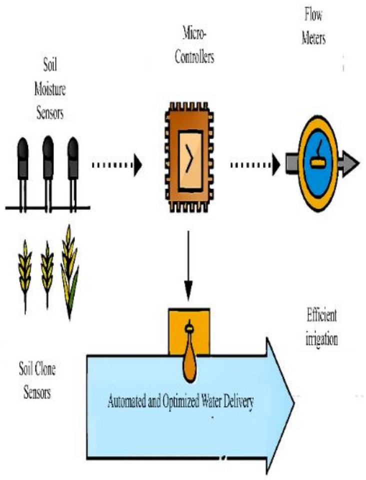

Figure 4: Primary goal of the smart irrigation system

The main objective of this intelligent irrigation system is to automate and optimise water distribution over agricultural fields based on advanced Internet of Things (IOT) technologies. By incorporating soil moisture sensors, flow meters, and microcontrollers, the system dynamically observes environmental conditions and responds accordingly based on crop requirements. This minimises water wastage, increasing crop health and reducing manual intervention, making irrigation intelligent and effective.

The smart irrigation system is meant to transform conventional farming by integrating automation and accuracy into water management. Through the exploitation of IOT technologies. It converts irrigation from a manual schedule-based activity into an adaptive data-driven system. These changes are imperative in the fight against the issue of water scarcity, inconsistent soil conditions and time-consuming field work.

At the centre of the system are soil moisture sensors constantly monitoring levels of hydration in various zones of the field. The sensors offer detailed information about soil conditions, allowing the system to know precisely when and where water is required. This precision prevents both overwatering and underwatering, which are prevalent problems in traditional irrigation.

Ultrasonic and electromagnetic flow meters are crucial in measuring water consumption. They confirm that the amount of water supplied is equal to the amount required for a specific crop type and soil type. This not only enhances accuracy in irrigation but also aids in long-term water saving measures through recording consumption habits Figure 4.

Microcontrollers like the ESP32 are the brain of the system, which processes sensor readings and carries out control instructions. If soil moisture is below a set threshold, the microcontroller turns the relay module on, which subsequently turns the water pump on. The closed-loop automation provides timely irrigation without intervention.

Apart from the local management, the system is integrated with cloud platforms such as AWS or Azure for remote monitoring, logging data and predictive analysis. The farmers and stakeholders may access dashboards for visualizing performance, receiving notifications and modifying parameters in line with user-defined seasonal trends and growth stages of crops. This connectivity facilitates wiser decision-making and scalable farm operations.

Essentially, the system represents a combination of environmental perception, intelligent control and cloud-based monitoring, providing a sustainable, effective and future-proofed solution for contemporary agriculture.

Scope: The intelligent irrigation system is deployed strategically across a 5-hectare farm landscape, segmented into several zones carefully to provide for crop diversity and soil heterogeneity. This zoning strategy, based on modules, permits precise control over delivery so that every section receives water to meet unique agronomic requirements.

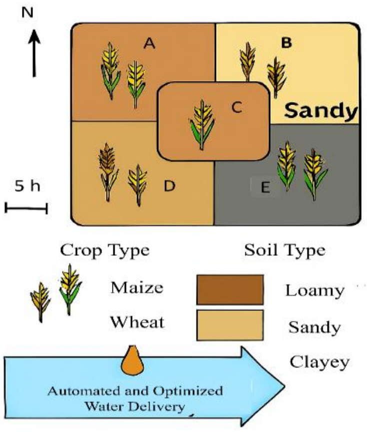

Figure 5: Scope and Zoning

Maize and wheat, the two major crops grown in this field, possess different physiological characteristics and water requirements. Mize generally needs more frequent and deeper watering during the vegetative and tasseling phase, while wheat needs controlled irrigation at germination and grain filling. The mapping of these crop zones allows the system to implement differentiated irrigation schedules that are in harmony with each crop's growth cycle.

The soil composition underlying the site creates another level of complexity Figure 5. Zones have differing textures, loamy, sandy and clayey, each affecting water retention, infiltration and nutrient mobility. Loamy soils provide moderate retention, and sandy soils dry rapidly and have a greater tendency to become saturated. These variations require a dynamic system that responds to localized soil activity by adjusting irrigation volume and timing Figure 5.

To compensate for this variation, the system incorporates soil water sensors and a meter inside every zone. These monitor the rate of hydration in real-time, allowing for dynamic adjustments in irrigation schedules. This results in a highly effective site-specific water management plan that saves resources and increases crop yield, and promotes sustainable agriculture.

Innovative highlight: What sets this smart irrigation system apart is its effortless integration of real-time environmental sensing, intelligent control schemes and cloud-based analysis. By using multiple depth soil moisture sensors, the system picks up subtle hydration patterns across varied soil profiles. Ultrasonic and electromagnetic flow meters supplements accuracy with their ability to measure water delivery volumes with supplement accuracy with their ability to measure water delivery volumes with excellent precision. In the centre of the system, there is a microcontroller ESP32 that receives sensor data and powers water pumps through relay modules, enabling localised, autonomous irrigation reactions. At the same time, all working data is sent to cloud

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platforms like AWS and Azure, where it is stored, displayed and analysed. This cloud connectivity supports predictive irrigation scheduling, remote system monitoring and easy integration with more extensive farm management software, reimagining traditional irrigation as a data-driven, scalable solution for twenty-first-century agriculture.

2.5 Site selection and deployment

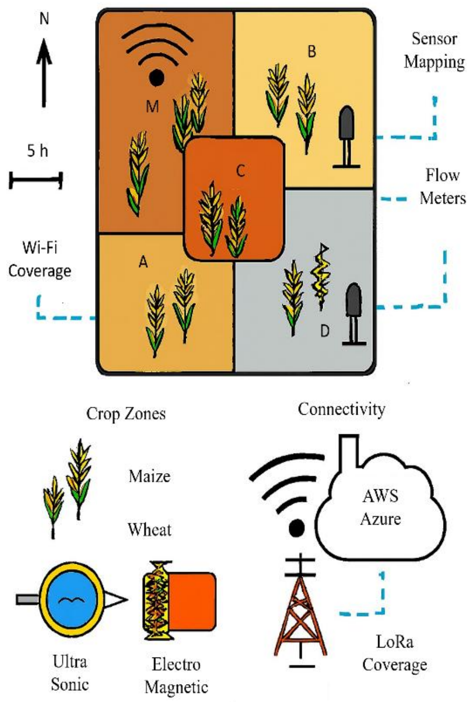

Figure 6: Site selection and deployment strategy

Rollout of the intelligent irrigation system is initiated with a strategically chosen 5-hectare farm topography, divided into unique crop zones solely for maize and wheat. This zoning approach is an implementation of the varied water needs, growth periods and nutrition demands of each crop, enabling specific irrigation regimes that optimise yield and resource utilisation. Segmentation also optimises modular system control, which makes localised adjustments possible depending on real-time field conditions Figure 6.

Soil heterogeneity on the site introduces an additional complexity to deployment planning. Zones contain a combination of loamy, sandy, and clayey textures, each with an effect on water retention, infiltration rates, and sensor sensitivity. Loamy soils provide well-balanced moisture retention, sandy soils ned more watering because they drain quickly, and clayey soil retains water for longer but is prone to saturation. This heterogeneity requires an adaptive sensor network that can pick up local soil dynamics and provide feedback to adaptive irrigation logic.

To make this happen, sensor mapping is done with accuracy. Soil moisture sensors are positioned strategically at several depths in every zone to track hydration levels in real time. Flow meters, both electromagnetic and ultrasonic, are positioned on irrigation lines to record water delivery amount and confirm system performance. These sensors supply data to the ESP32 microcontroller, which processes data and activates irrigation events through relay modules and water pumps. Connectivity planning provides seamless data transfer throughout the entire field. Wi-fi connectivity is implemented in areas with high signal availability, and LoRa for long-range communication supporting remote monitoring, predictive analysis and interoperability with large farm management systems.

Sensors:

At the heart of the system are soil moisture sensors, which give the system real-time feedback on hydration levels in various zones within the field. These sensors are installed at various depths to detect vertical moisture gradients, enabling the system to react not only to surface drought but also to subsurface

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water availability. Such detailed insight is vital to optimising irrigation timing and quality, particularly in fields with diversified soil textures Figure 7.

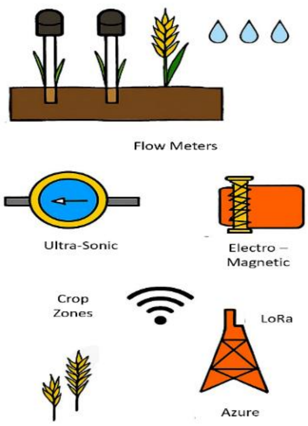

Figure 7: Soil Moisture Sensors

In addition to the moisture sensors, there are flow meters that monitor the volume and rate of water transmitted into the irrigation lines. Both ultrasonic and electromagnetic flow meters use magnetic fields and conductive fluid characteristics. Combined, they allow for precise water delivery and performance benchmarking per zone.

Microcontroller

At the core of the smart irrigation system is the ESP32 microcontroller, which is responsible for all field-level operations as the central processing unit. This is a small yet powerful device that comes with a dual-core processor, which allows it to work on several tasks at a time, such as sensor data reading, logic calculation and communication protocol without delay and performance jam.

One of the most impressive features of the ESP32 is its integrated WiFi and Bluetooth connectivity, which enables easy interfacing with local networks and remote cloud platforms Figure 8. This feature allows for real-time transmission of sensor data to centralized dashboards and cloud analytics engines, making it possible for remote monitoring and control from anywhere in the world.

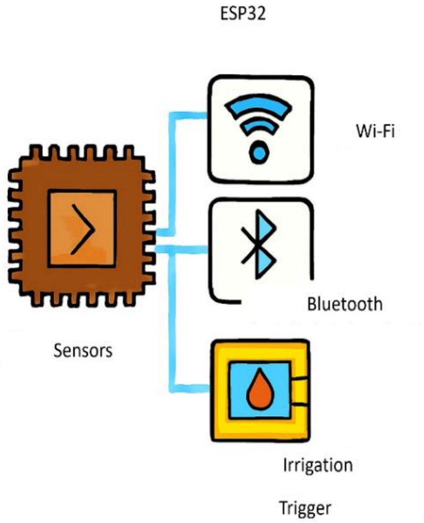

Figure 8: Micro-controller architecture

The microcontroller is made to read threshold logic from soil moisture and water flow data. Once hydration levels dip below set thresholds, the ESP32 activates the relay module to turn on the water pump. This process is done locally to provide an instant response without cloud latency important for time-critical irrigation events.

Actuation

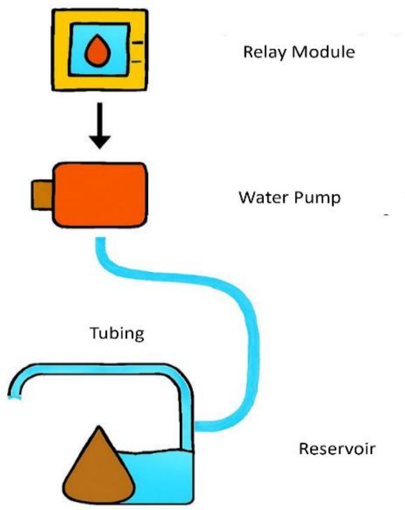

Figure 9: Actuation architecture

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After sensor data is processed by the ESP32 microcontroller and it finds that irrigation is necessary, the actuation process is started with a control signal sent to the relay module. The relay acts as an electrical switch, turning the water pump on and off in accordance with preset soil moisture levels. The modular control system makes zone-specific irrigation possible, providing water only where and when it is needed, reducing waste and over-irrigation Figure 9.

The water pump is the mechanical energiser of the irrigation by relaying the pump pressurises water and forces it through an array of flexible tubing spread out over the field. The tubing system is designed to provide consistent pressure and flow even in uneven land and mixed crop zones.

In order to provide an even distribution, the tubing design is designed for the lowest pressure loss and optimum outlet location. This ensures that each field section and plant pot gets the right amount of water based on its location from the pump. The system also has provisions for drip and sprinkler accessories. Where applicable, based on crop and irrigation method.

The coupled together the relay, pump and tubing together becomes a responsive, efficient actuation chain. When coupled with intelligent sensor data and microcontroller logic, this infrastructure supports precision irrigation based on the specific water needs of any crop and soil condition, enabling sustainable agriculture and scalable deployment.

2.6 Data processing infrastructure

Edge node

The edge node is the on-site data processing centre in the smart irrigation system. It is provisioned with a quad-core processor and is responsible for performing real-time computation functions like sensor data parsing, threshold check and irrigation decisions. The local minimises latency and allows for quick response to field condition changes.

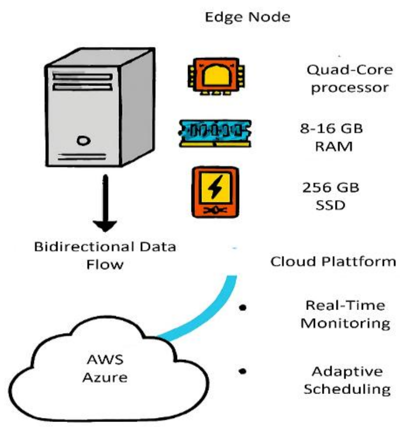

Figure 10: Data processing infrastructure

To facilitate buffering and short-term analysis, the edge node is equipped with 8-16 GB of RAM. The memory size enables the system to buffer high-frequency sensor inputs temporarily and provide localised trend analysis even in the case of temporary disconnection from the cloud Figure 10.

For relentless logging and offline capability, the node features a 256 GB SSD. The historical sensor data, irrigation events and system diagnostics are stored on this solid-state drive for retrospective analysis and network outage continuity. The synchronised cached data can be uploaded to the cloud upon restoration of connectivity.

Cloud platform

The system comes pre-integrated with cloud infrastructure like AWS and Azure, which offers centralised storage, big data analysis and remote control features. Sensor data and system logs are sent to the cloud for permanent storage, visualisation, and predictive modelling.

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An important aspect of such infrastructure is bidirectional data transfer. The edge node transmits data to the cloud but also receives updates, configuration changes and control commands. This facilitates real-time monitoring and adaptive irrigation scheduling according to weather forecasts, growth stages of the crop and user settings.

The edge cloud architecture collectively guarantees strong, scalable and smart data management, enabling precision agriculture and informed decision-making for deployment environments.

2.7 Workflow logic

Trigger chain

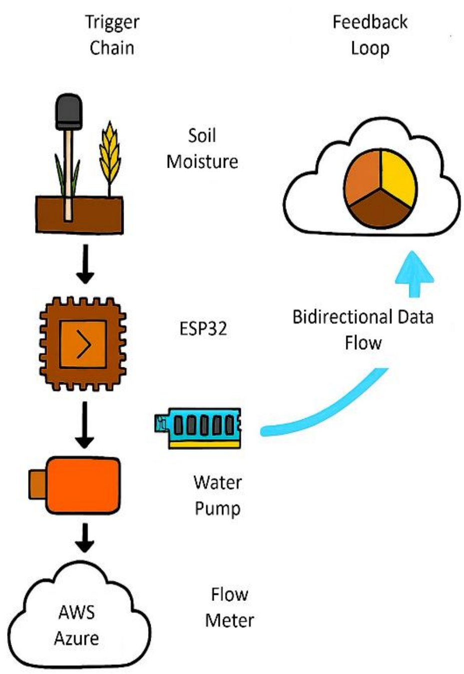

Figure 11: logical workflow architecture

The irrigation is started by a sequential trigger chain within the system. When soil moisture drops below a preset limit, the sensors embedded in the soil sense this decrease and send input to the ESP32 microcontroller. Having received this signal, the ESP32 switches to the ESP32 microcontroller. Having received this signal, the ESP32 switches on the relay module, which then supplies power to the water pump. Water is then distributed through a series of flexible tubing to the assigned crop areas. As water is irrigated, flow meters track the quantity and speed of water delivery, and the data is accurate and confirms system performance. All operational information, such as sensor readings and flow rates, is logged to the cloud for analysis Figure 11.

The irrigation cycle starts when the soil moisture sensor identifies that hydration levels have fallen below a set threshold. Such sensors placed at various depths in the domains of crops monitor soil constantly and relay live information to the system computer core.

After this input, the ESP32 microcontroller compares the data with predetermined logic. If the moisture level is low, it provides a signal to the relay module, an electronic switch. The relay switch on the water pump and the irrigation process are initiated module, an electronic switch. The relay switch on the water pump and the irrigation process are initiated.

Water is pulled from a central reservoir and dispersed using a system of flexible tubing set up on the field. The tubing distribution system is used to ensure focused delivery to individual zones of the crop, cutting down on waste and maximizing hydration according to crop type and soil type.

As water passes through the system, flow meters using ultrasonic and electromagnetic sensors measure delivery volume and rate. These measurements confirm that the proper quality of water

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actually flows to every zone, giving the system a performance standard for efficiency.

Lastly, all operational information, such as sensor values, pump operation, and flow rates, is sent to cloud hosting environments like ASW and Azure. All this information is stored for analysis, which allows for remote monitoring, historical tracking, and inclusion in predictive irrigation models.

Feedback loop

A side reactive control, the system has a dynamic feedback mechanism. Data stored in the cloud is monitored to detect irrigation patterns, crop response and environmental trends. Based on historical data as well as forecasting models of weather forecasts, crop growth phases, the system revises future irrigation schedules. Adaptive logic allows more intelligent water management to save resources and improve crop health, making irrigation more than a static ritual but a responsive data data-driven process.

The feedback mechanism converts irrigation into an active adaptive process from a reactive one. After sensor and flow data are stored in the cloud, it is processed to reveal trends in crop hydration, environmental factors and irrigation efficiency. By blending historical data with forecast models such as weather reports and crop growth phases, the system knowingly adjusts upcoming irrigation schedules.

This ongoing learning process facilitates adaptive logic, making the system refine water delivery as field conditions change. Irrigation becomes more accurate and efficient, minimising the waste of resources while optimising crop health and yield. The feedback loop guarantees that each irrigation decision is guided by both historical performance and expected outcome, making the system data-driven.

2.8 Visualisation and monitoring Dashboard

The system includes a real-time dashboard interface presenting principles operational parameters like soil moisture levels, flow rate, and irrigation status across crop zones. This aggregate view enables users to observe field conditions, system performance and irrigation events in overview, enabling timely interventions and informed decision making Figure 12.

The dashboard is the system core monitoring interface offering real-time insight across such as soil moisture, water flow rate and irrigation status across various crop zones. It consolidates sensor data and system activity into an easily understood, visual format, usually employing gauges, graphs, and zone maps, enabling users to evaluate field conditions at a glance. This supports rapid decision-making, anomaly identification and effective resource management, making the dashboard a critical tool for operational control and strategic planning.

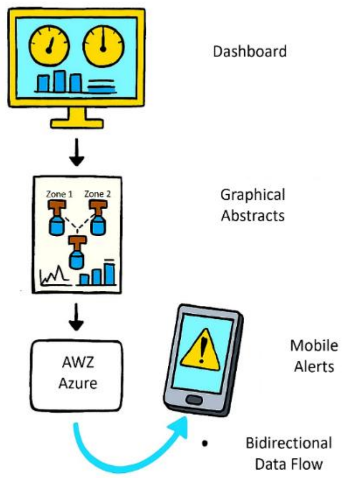

Figure 12: Visualization and monitoring

Graphical abstracts

Graphical abstracts are critical in condensing sophisticated system architecture into visual forms that are understandable. Such schematic diagrams are meant to simplify major elements of the smart irrigation system, such as sensor location, microcontroller function, data flow path, and actuation into visual forms easy to comprehend. Graphical abstracts close the gap between engineering complexity and stakeholder comprehension by summarizing technical processes into basic sketches Figure 13.

Every abstract is customised to emphasise particular elements of the system. The deployment zone diagram, for instance, reveals how the flow meters and soil moisture sensors are arranged over maize and wheat fields of different soil types. Architecture schematics demonstrate how sensors, relay modules, and a cloud platform are connected to the ESP32 microcontroller. Data flow visual map the path from sensing at the field level to analysis in the cloud and back via feedback loops, focusing on two-way communication and adaptive scheduling

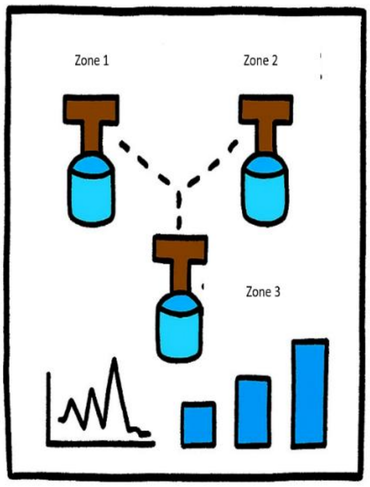

Figure 13: Graphical module architecture

These images are particularly useful for stakeholder communication, whether in scholarly writing, policy reports and corporate presentations. They enable researchers, policymakers, and field technology to easily understand system behaviour, deployment strategy and performance logic, improving transparency, collaboration, and informed decision-making.

2.9 Scalability and impact

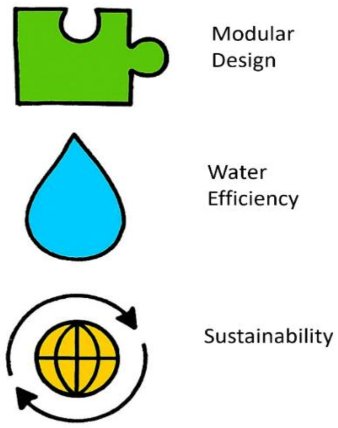

Figure 14: scalability and impact

Modular design

The system is designed with a modular architecture supporting easy expansion on a large farm or compatibility with varying crop types. Every aspect, sensors, microcontroller, pumps, and data nodes can be duplicated and remapped without touching the underlying logic Figure 14. The phased deployment is enabled by this flexibility, and farmers can expand deployment is enabled by this flexibility and farmer can expand operations as per budget, land holdings and crop rotation patterns. Whether deployed on small pieces of land or multi-hectare farms, the system is consistent in its performance and responsiveness.

The system's modular design accommodates scalable deployment. All units' sensors, microcontroller, and pump function in isolation but are easily integrated into the larger network. The user can thus begin with a minimal system and add in increments as operational requirements expand without having to redesign.

This structure also accommodates crop-specific adjustments. The modules may be designed to meet the irrigation requirements of various crops, soil types and planting densities. For example, maize area can use a deeper moisture sensor and low pressure drip system. The modular design allows for these differences without sacrificing system integrity.

Also, modularity makes maintenance and upgrades easy. Bad components may be substituted one at a time, and new technologies like powerful sensors and AI-based controllers may be added without affecting the existing infrastructure. This minimises downtime and future-proofs the system against changing agricultural needs.

Essentially modular design keeps the system flexible, affordable and robust, making it appropriate for smallholder farms and large commercial farms alike.

water efficiency

The precision irrigation is a key to the impact of the system. Through real-time soil moisture feedback and verified flow rates, the system reduces overwatering and runoff. Flow meters provide precise volume control, and sensor-activated actuation irrigates only the zone needing hydration. This yields substantial water conservation, particularly in areas of scarcity and seasonality. The efficiency of the system not only saves resources but also saves energy from pumping and distribution.

Precision delivery

At the centre of the system, water saving technology is its precision irrigation algorithms. Soil humidity sensors constantly check moisture levels throughout the crop area, and irrigation only occurs when predetermined thresholds are exceeded. This focused method ensures that water is supplied precisely where and when it's required, preventing blanket irrigation and eliminating excess runoff.

Accurate delivery is a fundamental element of effective water management within the system. It is based on real-time steady monitoring of soil hydration levels through embedded sensors that are strategically distributed over zones of the crop. These sensors identify hydration deficiencies if moisture has dropped below a specified threshold. It is only when these requirements are satisfied that the system triggers irrigation, focusing on limited zones instead of sprinkling water everywhere. Such a limited application ensures that every plant gets the appropriate quantity of water runoff and maintains soil health. Through matching water supply with localised demand by the crop and the system enjoys high efficiency and promotes sustainable agriculture.

Flow validation

To supplement moisture sensing, flow meters are installed along irrigation lines to detect the amount and rate of water delivery. These meters, ultrasonic and electromagnetic, ensure that the proper volume of water arrives in each zone. This is monitored properly, but also carried out with volumetric precision, avoiding overwatering and facilitating performance benchmarking.

Flow validation prevents water delivery from being both inaccurate and wasteful. Ultrasonic and electromagnetic flow

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meters are mounted on irrigation lines to quantify the volume and rate of water supplied to every crop zone. They verify that the system provides the right amount of water as dictated by the microcontroller logic. The real-time feedback avoids overwatering, detects anomalies and enables performance benchmarking, making the system more dependable and resource aware.

Resource conservation

This flow-validated, sensor-actuated system is responsible for tremendous water saving, particularly where water is scarce and subject to seasonal fluctuations. The system saves groundwater by preventing over irrigation and optimising delivery, lowering surface runoff and safeguarding soil structure. It also reduces energy runoff and safeguards soil structure. It also reduces energy demands for pumping and distribution, resulting in lower operational expenses and a lower carbon footprint.

Adaptive efficiency

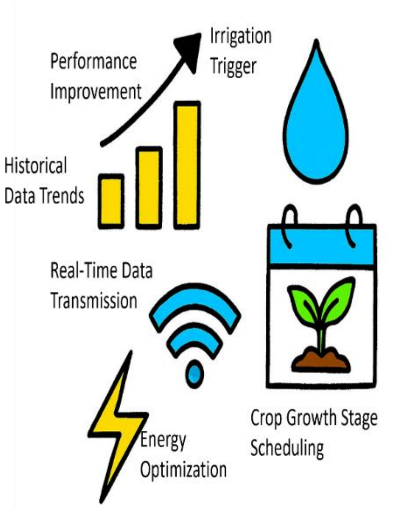

Figure 15: Adaptive efficiency architecture

The system learns and improves over time. It gathers data from past irrigation events and combines it with predictions such as upcoming weather and how crops are growing. Using this information, it adjusts when and how much water to deliver. This indicates the system becomes smarter with each cycle and saving more water and matching irrigation to what the crop actually needs. It helps farmers use resources wisely and grow healthy crops and even when conditions change Figure 15.

Water preservation

The system uses smart sensors to check how wet the soil is. It only turns on the water when the soil is too dry and only in the area that needs it. The flow meter makes sure the right amount of water is used. This helps to save water by avoiding overwatering and protects the underground water source. It is especially helpful in places where water is limited and during dry seasons.

Runoff reduction and soil protection

When too much water is used during irrigation, it can flow over the surface area instead of soaking into the soil. This is known as runoff, and it can wash away the top layer of soil and important nutrients that crops need to grow. The smart irrigation system avoids this limitation by using sensors to check soil moisture and only watering when needed and in the right amount. This helps to keep soil strong, healthy and full of nutrients, which means better crops and less damage to the land over time.

Energy efficiency

The system saves energy by using water wisely. It turns on the pump only when the soil actually needs water, and flow meters make sure the right amount is delivered. This means less electricity or fuel is used to run the pump. It is especially helpful for farms that use solar power and do not have regular access to electricity. By avoiding waste, the system lowers energy costs and helps protect the environment.

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Climate impact

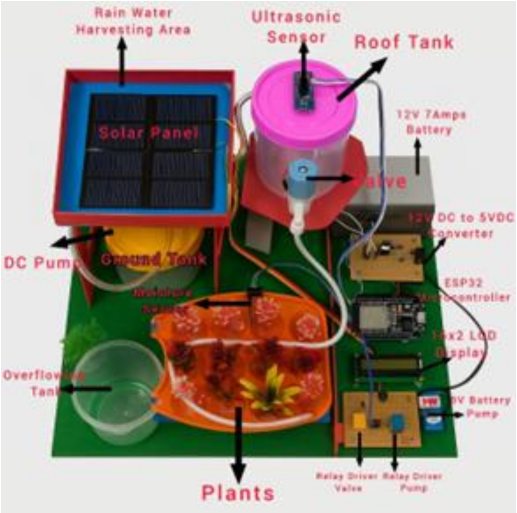

Figure 16: climate impact Architecture

The smart irrigation system helps to protect the environment by using less water and energy. This means fewer greenhouse gases are released, which lowers the carbon footprint of farms. It also supports climate-resilient farming, which helps farmers adjust to changing weather and growing conditions. Using data to guide irrigation and the system makes farming more sustainable and better prepared for future climate challenges Figure 16.

water savings through sensor-driven logic

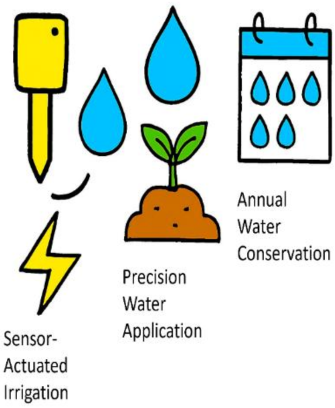

Figure 17: Water saving through sensor-driven logic

The system uses a smart soil moisture sensor to check how wet the soil is. If the soil is dry and the system turns on the water only in the area that needs it. This avoids wasting water and makes sure plants get just the right amount. It is especially helpful in places where water is limited and during dry seasons because it saves every drop and keeps the crop healthy Figure 17.

3. Results and Discussion

3.1 Prototype of the system

The below Figure 18 represents a prototype of the IoT-based smart irrigation system. The steps include an ESP32 microcontroller as the central unit, a soil moisture sensor, a relay module, DC water pumps, and wifi Wi-Fi-enabled connection to the Blynk cloud. The system can monitor and irrigate multiple plants. When the soil moisture level drops below the threshold, the SP32 activates the corresponding relay to power the DC pump, delivering water to the plants. The moisture level is achieved, and the pump automatically switches off, ensuring optimal water usage and energy efficiency.

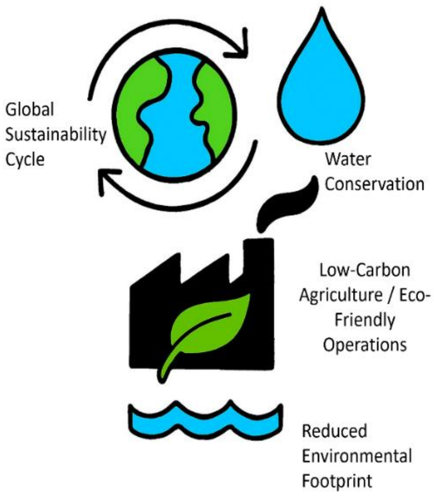

Figure 18: Prototype of the IoT-based irrigation monitoring system

3.2 Output from cloud server using Blynk cloud

The Blynk cloud platform provides real-time visualisation of the system performance through both desktop and mobile interfaces. This interface allows users to remotely monitor live soil moisture level, pump activity, and system status. The readings from the soil moisture sensor are automatically transmitted to the Blynk cloud via the ESP32 wifi module Figure 19. It indicates dry soil when the moisture level drops, prompting automatic irrigation. The representation of moderately moist conditions when the reading is measured in an irrigation is nearing the threshold. To indicate sufficient moisture when the level exceeds, to ensure the irrigation stops automatically to prevent overwatering.

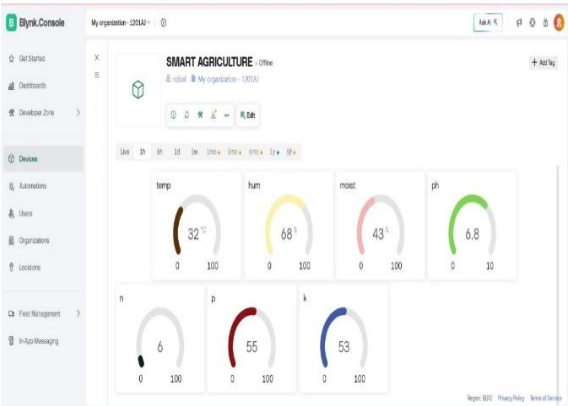

Figure 19: Blynk cloud console dashboard

Parameter	Note	Values score	Purpose
Temperature	Sensor reading	32 degrees Celsius	Temperature affects plant growth
Humidity	Humidity values	68 percentage	Air humidity and plant comfort
Moisture content	Soil moisture	43 percentage	It denotes wet or dry
Ph level	Soil pH level	6.8	To measure soil acidity
Nitrogen(N)	Nitrogen level	6	To measure the soil nutrient sensor
Phosphorus (P)	Phosphorus level	55	Fruit production
Potassium (K)	Potassium level	53	Improves plant strength and water retention

Table 1: Blynk cloud sensor parameter reading

The above Figure 19 represents a Blynk cloud console dashboard for a smart agriculture in IOT system. It is used to monitor and display real-time agricultural parameters. At the top of the smart agriculture is the offline status of the IOT device. The ESP32 is not currently transmitting live sensor data to the cloud. These allow users to view sensor data trends over different time periods of historical data. The Blynk cloud integration of data from the sensor is sent to the cloud of Wifi using an IOT controller of ESP32. The automated threshold values can trigger automation to turn on the water pump if the soil moisture is less than 40%. This Blynk dashboard acts as a remote monitoring and control panel for precision agriculture, as represented in **Table 1**. The real-time feedback on environmental soil conditions helps farmers. To reduce water wastage by automated irrigation. To maintain nutrient-balanced and optimized crop growth based on live data.

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3.3 Blynk push notification

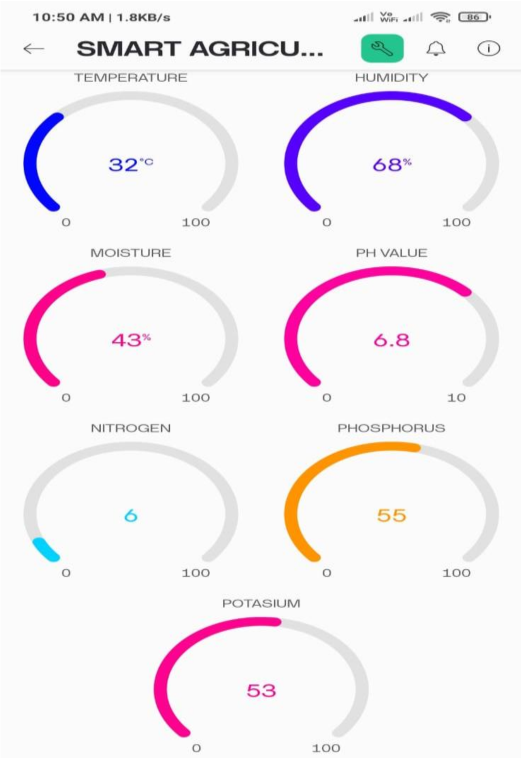

Figure 20: Blynk mobile dashboard to display real-time smart agriculture sensor readings

The developed IoT-based irrigation system is integrated with the Blynk cloud platform, which sends real-time push notifications to the user's smartphone. When the soil moisture level drops below the predefined threshold. This ensures the farmers are immediately informed about critical soil conditions without the need for manual checking in the field. The soil moisture percentage falls below the threshold. The EPS32 microcontroller automation eliminates the need for manual operation and ensures timely watering of the crop. To promote better yield and efficient water management, Figure 20. The automatic control and user received a Blynk push notification indicating the soil current condition and system irrigation response.

The following **Table 2** represents the Blynk mobile dashboard interface for a smart agriculture system. To display real-time sensor readings collected from the IoT-based smart farming setup. The temperature of 32 degrees Celsius indicates the current environmental temperature around the plant. The optimization of plant growth to soil moisture of 43% of water in the soil. pH value of 6.8 displays soil acidity near the neutral pH level of 6.5 to 7. The nitrogen content of 6 is essential for leaf development. The phosphorus value of 55 indicated the importance for root growth and flowering. The potassium of 53 helps to strengthen the plant and improve disease resistance.

Parameter	**Symbol**	**Measured values**	**Unit**	**Interpretation**
Temperature	T	32	Degree Celsius	Temperature for plant growth
Humidity	H	68	Percentage	Air moisture for healthy plants
Moisture	M	43	percentage	Above 35% threshold
pH value	pH	6.8	Zero	Suitable for most crops
Nitogen	N	6	percentage	Moderate nitrogen level
Phosphorus	P	55	Percentage	Plant development
Potassium	K	53	percentage	Balanced level for growth

Table 2: Real-time sensor reading from the Blynk mobile dashboard

3.4 Evaluation of the system

The proposed IoT-based smart irrigation system was tested using five potted plants, each equipped with an individual soil moisture sensor. The prototype was evaluated over a period of one week, analyzing its performance in maintaining optimal soil moisture and regulating irrigation frequency according to weather variations. Each sensor continuously monitored the moisture content of the soil, and irrigation was automatically controlled through the relay and pump mechanism. The data collection was analyzed based on the number of irrigation cycles per day. The plants were placed outdoors under a shaded area to ensure sunlight exposure while being protected from direct rainfall **Table 3**. During sunny conditions, the plant requires two irrigation cycles per day to maintain adequate soil moisture. The cloud of irrigation frequency was reduced to once per day. During the rainy period the irrigation is required on per daily basis.

Periods	**Climatic condition**	**Average percentage**	**Irrigation times**	**Observation**
1 day	Sunny	28	2	The soil dried quickly due to the heat
2 day	Sunny	30	2	Consistent water loss
3 days	Sunny	27	2	The previous day was under high temperatures
4 days	Cloudy	45	1	One irrigation required
5 days	Rainy	70	1	Irrigation triggered once

Table 3: System performance evaluation

4. Conclusion

The proposed smart agriculture monitoring and irrigation system using the ESP32 microcontroller and Blynk IOT cloud successfully monitors soil moisture and the irrigation system. The system continuously collects real-time data on temperature, humidity, soil moisture, pH, and essential nutrients like N, P, K, which are displayed on both the web and mobile interface. Based on sensor feedback, the delay module intelligently controls the water pump that ensure an optimal soil moisture level to prevent water wastage. Through continuous testing and the result system demonstrated reliable performance across varying weather conditions, automatically adjusting the irrigation cycle based on soil moisture threshold. The integration of Blynk push notifications allows users to stay informed about their plants' condition without manual supervision. The IoT-based irrigation system promotes efficient water usage. To enhance crop productivity and reduce the need for manual intervention, and serves as a cost-effective and scalable solution for sustainable agriculture and precision farming applications.

5. Reference

1. S. B. Saraf and D. H. Gawali, "IoT-based smart irrigation monitoring and controlling system," 2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), Bangalore, India, 2017, pp. 815-819, doi: 10.1109/RTEICT.2017.8256711.

2. Ikram, A., Aslam, W., Hama Aziz, R. H., Noor, F., Mallah, G. A., Ikram, S., Ahmad, M. S., Abdullah, A. M., & Ullah, I. (2021). Crop Yield Maximization Using an IoT-Based Smart Decision. Journal of Sensors, 2022(1), 2022923. https://doi.org/10.1155/2022/2022923
3. R. N. Rao and B. Sridhar, "IoT-based smart crop-field monitoring and automation irrigation system," 2018 2nd International Conference on Inventive Systems and Control (ICISC), Coimbatore, India, 2018, pp. 478-483, doi: 10.1109/ICISC.2018.8399118.
4. Asif Irshad Khan, Fawaz Alsolami, Fahad Alqurashi, Yoosef B. Abushark, Iqbal H. Sarker, Novel energy management scheme in IoT-enabled smart irrigation system using optimized intelligence methods, Engineering Applications of Artificial Intelligence, Volume 114,2022,104996, ISSN 0952-1976,https://doi.org/10.1016/j.engappai.2022.104996.M. Shilpa et al., "Enhancing Crop Yield and Growth Prediction Using IoT-Based Smart Irrigation Systems and Machine Learning Algorithms," 2024 Second International Conference on Networks, Multimedia and Information Technology (NMITCON), Bengaluru, India, 2024, pp. 1-5, doi: 10.1109/NMITCON62075.2024.10698825.
5. H. G. C. R. Laksiri, H. A. C. Dharmagunawardhana and J. V. Wijayakulasooriya, "Design and Optimization of IoT-Based Smart Irrigation System in Sri Lanka," 2019 14th Conference on Industrial and Information Systems (ICIIS), Kandy, Sri Lanka, 2019, pp. 198-202, doi: 10.1109/ICIIS47346.2019.9063272.
6. Ala' F. Khalifeh, Abdullah Alqammaz, Ahmad M. Khasawneh, Laith Abualigah, Khalid A. Darabkh, Zinon Zinonos, An environmental remote sensing and prediction model for an IoT smart irrigation system based on an enhanced wind-driven optimization algorithm, Computers and Electrical Engineering, Volume 122, 2025, 109889, ISSN 0045-7906, https://doi.org/10.1016/j.compeleceng.2024.109889.
7. Touil, Sami, Amina Richa, Meriem Fizir, Jesus E. Argente Garcia, and Antonio F. Skarmeta Gomez. "A review on smart irrigation management strategies and their effect on water savings and crop yield." Irrigation and Drainage 71, no. 5 (2022): 1396-1416.19 June 2022 https://doi.org/10.1002/ird.2735
8. Lakhiar, I.A.; Yan, H.; Zhang, C.; Wang, G.; He, B.; Hao, B.; Han, Y.; Wang, B.; Bao, R.; Syed, T.N.; et al. A Review of Precision Irrigation Water-Saving Technology under Changing Climate for Enhancing Water Use Efficiency, Crop Yield, and Environmental Footprints. Agriculture 2024, 14, 1141. https://doi.org/10.3390/agriculture14071141
9. Ahmed, Z., Gui, D., Murtaza, G., Yunfei, L., & Ali, S. (2023). An Overview of Smart Irrigation Management for Improving Water Productivity under Climate Change in Drylands. Agronomy, 13(8), 2113. https://doi.org/10.3390/agronomy13082113
10. Vellela, Sai Srinivas and Varshini, K. and Jeevana, M., and Kadheer, S. K. and Kumar, T. Pavan, IoT-Based Smart Irrigation and Controlling System

E-ISSN: 3107-5843
International Journal of Advanced Engineering and Management System
Volume 01, Issue 02, July-September 2025, pp. 40 - 59

(February 17, 2024). IoT-Based Smart Irrigation and Controlling System, International Journal for Modern Trends in Science and Technology, 2024, 10(02), https://ssrn.com/abstract=4739212

11. Khan, A. I., Alsolami, F., Alqurashi, F., Abushark, Y. B., & Sarker, I. H. (2022). Novel energy management scheme in IoT-enabled smart irrigation system using optimized intelligence methods. Engineering Applications of Artificial Intelligence, 114, 104996. https://doi.org/10.1016/j.engappai.2022.104996
12. P. K. Kashyap, S. Kumar, A. Jaiswal, M. Prasad and A. H. Gandomi, "Towards Precision Agriculture: IoT-Enabled Intelligent Irrigation Systems Using Deep Learning Neural Network," in IEEE Sensors Journal, vol. 21, no. 16, pp. 17479-17491, 15 Aug.15, 2021, doi: 10.1109/JSEN.2021.3069266.
13. Keswani, B., Mohapatra, A.G., Mohanty, A. et al. Adapting weather conditions based IoT enabled smart irrigation technique in precision agriculture mechanisms. Neural Comput & Applic 31 (Suppl 1), 277–292 (2019). https://doi.org/10.1007/s00521-018-3737-1
14. A. D. Boursianis et al., "Smart Irrigation System for Precision Agriculture—The AREThOU5A IoT Platform," in IEEE Sensors Journal, vol. 21, no. 16, pp. 17539-17547, 15 Aug.15, 2021, doi: 10.1109/JSEN.2020.3033526.
15. Saha, G., Shahrin, F., Khan, F. H., Meshkat, M. M., & Malek Azad, A. A. (2025). Smart IoT-driven precision agriculture: Land mapping, crop prediction, and irrigation system. PLOS ONE, 20(3), e0319268. https://doi.org/10.1371/journal.pone.0319268