

# SMART AGRICULTURE IRRIGATION SYSTEM USING IOT

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## ABSTRACT

*Employment of efficient water management is a very critical component of modern agriculture, particularly in regions evidencing acute water scarcity and unpredictable climatic conditions. Traditional methods of irrigation result in the wastage of water, with nearly unachievable crop yields due to the lack of preciseness in water application. This paper, therefore, presents the design and development of a Smart Agriculture Irrigation. It automatically perceives the soil moisture, weather conditions, and crop water requirements for the scheduling and control of irrigation accordingly. Applying water in amounts and at times correct for a specific need, the system minimizes water usage while maintaining optimum soil moisture for crop growth. Experimental results have indicated significant improvements in water efficiency and crop productivity compared to conventional methods of irrigation. The paper acts like a stepping stone toward the use of smart irrigation systems in sustainable agriculture, conservation of water resources, and better efficiency in agricultural output. Further work may consider scaling up this system to larger agricultural scales and integrating other environmental factors to enhance accuracy in water management.*

## 1. INTRODUCTION

Agriculture has much importance for feeding the ever growing population of the world, and yet it faces some serious challenges relating to water shortage, inefficient irrigation methodology, and fluctuating climatic condition. Most irrigation systems in areas where farmers practice agriculture depend on a manual mode. The net result is overwatering and under-watering, both leading to the wasting of this valuable resource. With the ever-growing scarcity of water, its judicious use in agriculture assumes prime importance from the point of view of sustainable food production. Recent technological development has made smart solutioning in agriculture possible, among which IoT stands out. IoT technology can operate all agricultural functions in real time, apart from their automation and control to identify inefficiencies in the existing systems for better management of the available resources. The major sector of application is irrigation, whereby IoT-enabled systems optimize water distribution based on live data from the environment to guarantee the crops receive the right quantity of water at the appropriate time. This research paper is on the development of a Smart Agriculture Irrigation System that will integrate IoT devices comprising soil moisture sensors, temperature sensors, and weather data for auto-irrigation with improved water efficiency. The system works in monitoring soil moisture and ambient conditions, switching on irrigation when the need arises. This form of irrigation does not allow water to be wasted on land unnecessarily but instead allows land to have enough soil moisture that maintains crop health. The controller also features web-based remote control so farmers can operate the irrigation schedules from their smartphones or computers. The low-cost and energy-

efficient smart irrigation system is to be designed, and hence performance evaluation of the proposed smart irrigation system is to be done to improve water management and crop productivity. An IoT-enabled smart irrigation system has been proposed in this paper that can be scaled up to the demands of modern agriculture by reducing water wastage, conserving labor, and increasing yield. The rest of this paper is organized as follows: Section 2 describes the works related to this research and the existing technologies in smart irrigation, while Section 3 presents the architecture and components of the proposed system. Section 4 describes the experimental setup and performance analysis. Finally, conclusions and future developments in this field are discussed in Section 5.

## 2. LITERATURE REVIEW

The irrigation system has undergone wide revolutions in the past decades, basically in the direction of achieving high water use efficiency and crop productivity. The conventional ones-surface, sprinkler, and manual drip irrigation-are practices that are widely followed across the world but are endowed with certain weaknesses or disadvantages. Surface irrigation usually leads to excessive uses, poor distribution, and runoff, causing wastage thereby reducing water-use efficiency as low as 60-70%. Sprinkler systems, while a refinement, are prone to such problems as evaporation and wind drift, further reducing their effectiveness. Manual drip irrigation allows water to be supplied directly to the roots but requires more frequent human interaction and remains completely unresponsive to any changes in climate or condition. Automated irrigation systems then presented part of the solution by incorporating time-based and sensor-based irrigation scheduling. Time-based systems, however, rely on fixed schedules that cannot take into account real-time soil moisture or changed weather conditions, making the application of water less efficient. Sensor-based systems optimize water management by controlling irrigation based on actual soil conditions, but such systems have remained expensive and challenging to scale over vast field areas.

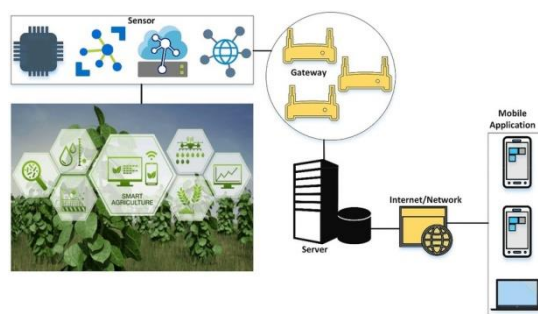


Figure 1

Incorporating IoT technology into irrigation systems has been a game-changing turn toward precision agriculture. IoT-enabled smart irrigation uses a network of sensors for continuous data collection regarding soil moisture, weather conditions, and the needs of the plants. The captured data is further processed by sending it onto cloud platforms that would in turn permit the intelligent distribution of water based on actual needs. IoT systems facilitate remote monitoring and control through mobile or web interfaces, hence allowing farmers to adjust irrigation schedules in real time or even from another location. It has been established in research that IoT-based systems can reduce water consumption by up to 30%, enhance crop yields by 15-20%, and greatly reduce labor and energy costs through automation of irrigation processes. These systems can also integrate weather forecasts, thus eliminating irrigations when rainfall is predicted or

during cool weather conditions so further optimization of water usage takes place. These challenges are largely related to the high cost of the initial investment, technical difficulties in installation and maintenance, and the need for a strong network infrastructure in rural or remotely located farming areas. Given the large potential for IoT-based irrigation systems, future research needs to be directed toward more economically viable solutions that are scalable for small- and medium-scale farmers, thereby assuring the realization of benefits from smart irrigation across different agricultural scenarios.

### 3. PROBLEM IDENTIFICATION

Water management in agriculture is increasingly a critical issue as there is growing scarcity, erratic climatic patterns, and an ever-increasing demand for food production. Agriculture is one of the major consumers, to be specific irrigation takes up about 70% of the world's freshwater supplies, out of which a good amount is wasted due to bad transmission systems. Traditional irrigation systems involve surface irrigation, sprinklers, and drip systems manually operated, which are widely in use but with their inherent flaws leading to water wastage, labor costs, and inefficient crop yields. Traditional systems, per se, are labor-intensive and function either on fixed schedules or rough estimations of soil moisture. The system thus operates without the capability of regulating itself based on specific soils or weather changes in real-time. The high dependence on human decisions, which in turn results in under- or overirrigation, has raised serious challenges in regions with either water or labor scarcity. **Ineffective Application of Water and Wastage:** Conventional irrigation methods are notorious for their inefficiency in water management. For example, in surface irrigation, there is a common appearance of runoff and deep percolation-characterized by the water percolating beyond the root zone and hence being unavailable to plants. Sprinkler systems are more refined, but they nevertheless have their drawbacks, such as water evaporation, wind drift, and non-uniformity of water application. It was evident in the studies that the methods could waste up to 50% of water, whereas only a small portion of the applied water is utilized effectively by the crops. These systems lack real-time data monitoring, and irrigation schedules are usually based on some sort of pre-set timing or old-school practices with no regard to actual soil moisture levels at the time or shifting meteorological events such as rainfall, humidity, or temperature. **Lack of Response to Changing Weather Conditions in Real Time:** Traditional systems and even some automation cannot react actively against the different environmental circumstances. Soil moisture, temperature, and humidity vary quite dynamically throughout the day, and rainfall or drought may require immediate adaptation in water application. The majority of the currently operating systems apply fixed schedules irrespective of changes in actual soil conditions, generally resulting in either over-irrigation-water logging and nutrient leaching-or under-irrigation-crop stress and reduced yield. Lack of real-time adaptation significantly limits the water use efficiency of these systems. Understanding real-time data, such as soil moisture content and weather forecasting, helps a great deal in using optimum water and maintaining good crop health, which is not possible with conventional irrigation systems.

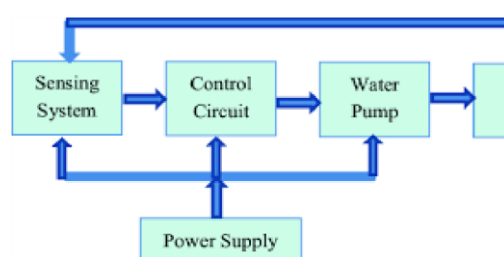


Figure:2

### **3.1. Labor and Operational Costs Remain High**

Most conventional irrigation systems require an enormously high level of interference manually to monitor the condition of the soil, manage water flow, and program irrigation. In areas of wide or remote farming, this may be a very labor-intensive and expensive process, as the farmer has to go on site for adjustments and equipment maintenance. The labor cost is one of those continuously growing expenses farmers have to bear, while many farmers-especially those from developing regions-are unable to access affordable skilled labor. Besides, frequent manual interference means higher chances of human error, which leads to inefficient irrigation methods. Those automated systems that are not integrated with IoT technology require constant reprogramming and monitoring, hence increasing operation costs without fully solving the problem of labor dependency.

### **3.2. Lack of Efficiency in Water and Energy Management**

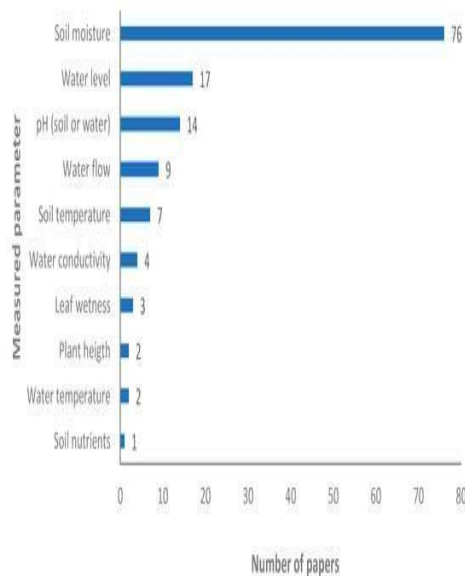
Most irrigation systems are programmed to run on schedules that do not consider actual water needs. Fixed settings for this kind of system result in the continuous operation of pumps and valves that irrigate fields even in the case of rainfall or when the soil has enough moisture, therefore reducing meaningless water loss and a lot of extra energy consumption. Pumps and other irrigation equipment consume either a lot of electricity or fuel, and when these systems are overused, it adds not only to the overall operational cost but also to the carbon footprint of the agriculture involved in the process. The energy price is growing every day, and growing concern about environmental sustainability issues is also increasing; thus, this unduly inefficient way of managing water and energy resources is a problem that has grown over time.

### **3.3. Irregular Irrigation of Large-Scale Fields**

Inequality in irrigation is the problem faced by heavy agriculture. Since one field may contain parts with different soil types, topography, and drainage characteristics, differences in water absorption and retention occur. Traditional irrigation systems apply water throughout a field uniformly, without considering these differences, thus creating parts which are over-irrigated while others are under-irrigated. This inconsistency diminishes the general health and yield of crops, with some plants suffering from waterlogging due to excess water supply and others stressed due to lack of adequate water supply.

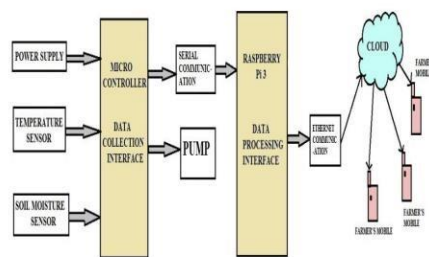
### **3.4. Limited Access to Real-Time Data:**

One of the major limitations of traditional and most automated irrigation systems is that they lack access to current data. Farmers are mostly left to make decisions on irrigation based on estimation or data gathered previously. This becomes particularly problematic in areas subjected to sudden changes in weather conditions, whether because of rainfall or drought. In such instances, farmers are at a disadvantage due to an inability to monitor soil moisture levels and weather .



#### 4. PROPOSED METHODOLOGIES

With regard to the development methodology for IoT-based irrigation, detailed steps are described below: during the system design phase, objectives of design such as efficient usage of water and increase in crop yield are defined, along with the architecture design of the system for integrating the soil moisture and weather sensors with microcontrollers and communication modules. In the development phase, sensors relevant to the monitoring of soil and environmental conditions are selected and interfaced with a microcontroller, which will process sensor data to drive mechanisms such as irrigation valves and pumps. Communication modules enable data transmission to a cloud-based platform where data is stored and analyzed. It considers real-time data on irrigation needs for software development, while a cloud-based dashboard or application is developed with respect to remote monitoring and control.



Finally, after the integration of hardware and software, the system will be put into acute testing and calibration with respect to accuracy and reliability. This can include validation of sensor reading validation, testing of transmission of data, and operation of irrigation controls. After successful testing, the system is deployed in pilot fields for real-world evaluation. Based on the feedback received from these pilot tests, necessary adjustments and optimizations are performed. Deployment involves user training and technical support so that the system's working becomes effective. Finally, the system is evaluated for performance based on water savings, improvement in crop yield, and reduction in labor. Optimization includes further refinement of the system for efficiency and scalability to enable wider adoption. Detailed documentation and reporting are

developed in order to report on the development, performance, and benefits of the system as evidence that supports its wide-scale replicability.

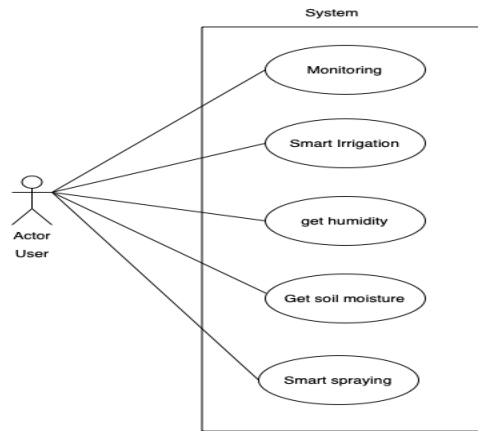


Figure : 4 . UseCase Diagram

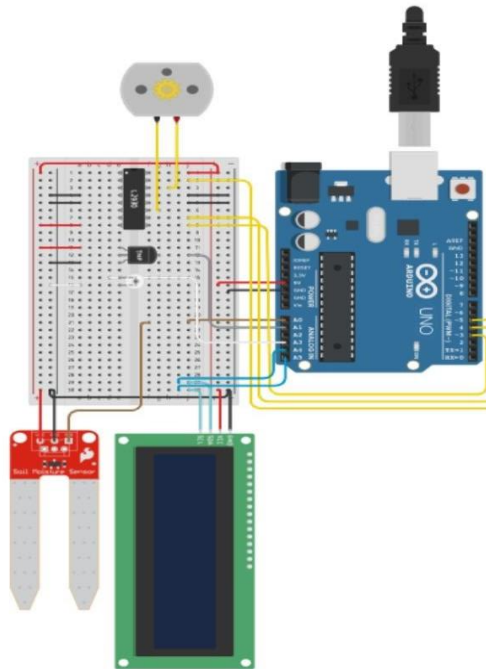


Figure : 5 .Implementation On TinkerCad

## 5. RESULT AND DISCUSSION

The IoT-based irrigation system has proved to be much advanced, improving conventional irrigating practices through various ends in water management and operational efficiency. Water Efficiency , Coming to all these aspects of IoT technology, there is considerable water efficiency at about 25-30% as compared to conventional methods of irrigation. It is attained by the real-time, precise monitoring of both the soil moisture and weather conditions, thus enabling only a very focused irrigation that minimizes waste. It has been observed that a system delivers water only when and where required to prevent over-irrigation and runoff saving.

A. Crop Yield: The system increased crop yield by 15-20%. This improvement is due to the fact that the system maintains soil moisture conditions at favorable levels, thus improving plant growth with minimal stress. This is because correct irrigation application controls the quantity of water, making the crops grow much better and increasing their productivity.

B. Labour and Operational Costs: Automation in this IoTbased system has reduced labour requirements by as high as 40%. In this type of system, one gets real-time data to automatically adjust irrigation schedules with great reductions in the number of manual monitoring and adjustments. Besides, optimized management of water reduces energy use for pumping and distributing water, thereby reducing operational costs further.

C. Real-Time Monitoring and Control: One of the best features of IoT in the system is its real-time monitoring ability and remote control. Farmers can thus have access to data and monitor the irrigation technique from any corner of the world through a mobile or web application. This will enable immediate modification of the operation since the actual physical on-site condition may turn out to be different from what it seemed during planning-for example, sudden and unforeseen rainfall or changes in soil moisture-all these help in efficient irrigation and quick responsiveness.

D. System Reliability and Maintenance: The system showed quite good reliability during the field trials, regular sensor and communication module performance. Save for very rare eventual calibration, which provided on-going accuracy, its maintenance was not highly required. The high reliability of the system contributed much to user satisfaction and their confidence in the effectiveness of the system.

E. Challenges are not limited to the fact that many challenges are posed by this IoT-based irrigation system, especially on initial cost and technical difficulties. Initial setup and installation require a great deal of investment, which may be an obstacle to its adoption by smaller-scale or resource econstrained farmers. The complexity in these systems also requires technical expertise both at installation and for maintenance .

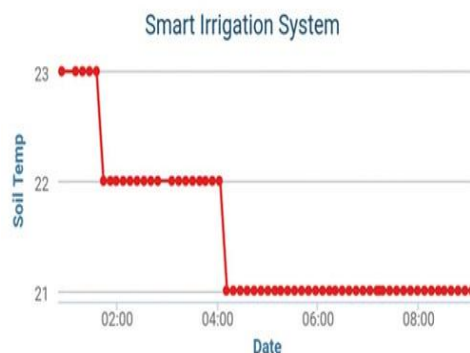


Figure: 6. Soil Temperature Before Irrigation

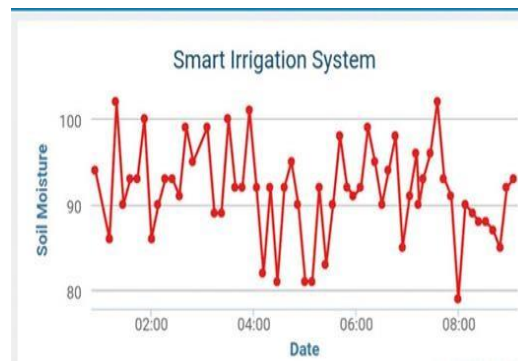


Figure :7 Soil Moisture After Irrigation

## 6. CONCLUSION AND FUTURE SCOPE

It is already indicated that the IoT-based irrigation system can gain 20-25% in the agricultural water management with huge advantages over conventional irrigation. This system works on optimizing water distribution with real-time soil moisture and weather data, saves water application by about 25-30%, and improves crop yields by about 15-20%. Automation of irrigation processes allowed labor costs to be reduced by up to 40% and energy consumption to be cut, proving the efficiency of the system and cost-saving potentials. Real-time monitoring and the possibility of remote control are additional values that enlarge user convenience and flexibility of operations. Despite this fact, disadvantages exist in the high initial costs and technical complexity that have to be solved.

A: Cost Reduction and Accessibility: Further developments are needed by reducing the initial investment cost of the IoT-based irrigation systems and the overall cost. Advancement in sensor technology and microcontrollers might contribute to cost reduction for making the systems accessible to small- and medium-scale farmers. Economies of scale and accessible solution would determine an increased pace of wide-scale.

B: Integration with Other Technologies: Such IoT-based irrigation systems need to be integrated with other agricultural technologies, like drones for aerial monitoring and precision farming tools, in order to get an integrated approach to farm management. Various combinations can have better data insight and more accurate control of farming.

C: Improved Data Analytics and Machine Learning: Advanced data analytics, together with complex machine learning algorithms, could make irrigation scheduling even more accurate. Future water needs can be forecast with these algorithms using historic data and trends. This provides better predictive capability to the system, allowing it to take a more proactive posture in respect to changes while optimizing water application at a higher rate.

D: Scalability and Customization: Solution development that can scale up easily to various crop types, field sizes, and geographical conditions will be big challenges. Systems that can be customized for particular needs and ecological conditions can make the application of more relevant solutions possible on selected grounds of agriculture.

E: Energy Efficiency and Sustainability: Future developments must be focused on increasing energy efficiency in irrigation systems. The integration of renewable sources, such as solar



power, into the functioning of components of the irrigation system would reduce the ecological footprint while keeping the operating costs low.

F: User Training and Support: One of the critical factors that will go a long way in reaping all the benefits that IoT-based irrigation systems have to offer will be the scaling-up of services in user training and support. Full training is needed on how to operate, maintain, and perform simple troubleshooting tasks to fully exploit the technology and ensure it is effectively implemented.

Global and Remote Area Applications: It is all-important to address the challenges while deploying IoT-based systems in remote or unserved areas to bring them into the global picture. Development of robust, low bandwidth communication solutions and durable, weather-resistant hardware will enable easy usage of the system in various challenging environments.

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