# RENEWABLE ENERGY INTEGRATION USING CLOUD & IOT BASED SMART AGRICULTURE

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*Abstract*— **The introduced system uses IoT devices connected to a cloud network to manage irrigation water automatically in order to boost agricultural sustainability. A collection of environmental sensors combined with soil moisture and temperature and humidity and rainfall and water level instruments enables real-time monitoring capability. The microcontroller operates this data to automatically adjust irrigation and drainage procedures. The water pump operation starts automatically when soil moisture reaches a particular threshold and when there is no recent rainfall to ensure proper water conservation. When conditions become too moist the drainage gate automatically activates to drain extra water thus avoiding waterlogged conditions. Users can access real-time data monitoring through local displays of LCDs and a cloud platform interface. Farmers can utilize mobile and web applications to control the system. Serious issues, such as low water levels in tanks or the incorrect amount of humidity in the air, trigger alarms from the system so that prompt action may be performed. By let individuals manage IoT technology immediately and access them from great distance, it increases the usefulness of the systems. The automated system uses solar electricity and other green energy sources. This reduces the company's dependence on conventional power grid infrastructure and increases its sustainability. The system improves natural farming practices as well as reduces the demand for water, human labor, and food production. The system might one day acquire more sensors and machine learning algorithms to assist in optimizing the irrigation operation.**

**Keywords— Smart agriculture, IoT-based irrigation, cloud monitoring systems, renewable energy, automated farming.**

## I. INTRODUCTION

Smart agriculture uses new technologies like the Internet of Things (IoT), cloud computing, and green energy to solve big problems in farming today, like wasteful use of resources and protecting the environment. The automatic irrigation system tries to make an IoT and cloud-based dynamic tracking system that makes the best use of irrigation water by analyzing environmental parameters. Using traditional irrigation methods can lead to situations where there is too much or too little water, which hurts crop yields and damages the ground. This system uses real-time sensor data and computerized decision systems to give exact irrigation controls that help to save resources. The system design is made up of a microcontroller that acts as the main processor and gets information from a number of sensors. Soil moisture sensors help show how much water is in the soil, which helps farmers decide if they need to water. Soil moisture sensors keep track of external factors that affect how much water is needed; temperature and humidity sensors do the same thing; rain sensors turn on to stop watering when it's not needed. The system's water level monitors keep an eye on reservoirs and water tanks to make sure there is always water for irrigation. The microprocessor system looks at sensor data to decide when to turn on the water pump. This keeps water from being wasted through over-irrigation. It has settings that let it open a drainage gate to keep crops from getting too wet and hurt.

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The Internet of Things (IoT) makes the system more useful by letting things be monitored and controlled from afar using cloud services. Real-time data from sensors is sent by the system to the cloud, where farms can access it through a web-based or mobile app. IoT technology helps farmers make better decisions because it lets them take care of their land from anywhere. Real-time analyzing data can be seen on the site's LCD screen, which lets decisions be made right away. Problems with devices, low water levels, and high soil moisture cause notices to be sent when the system identifies problems. These notices are based on basic system events. An automatic alarm system sends farmers alerts through their app or email so they can act quickly and fix problems before they hurt the system's performance or the health of their crops. It will be run by a system that uses solar power and other green energy sources.

Cutting off power to normal electricity networks helps the system run in a way that doesn't harm the environment. In the same time, the execution keeps farming methods that are good for the earth and lowers operating costs. This connected system, made possible by IoT, cloud technology, and renewable energy sources, greatly boosts agricultural output by lowering the need for manual labour and promoting sustainable water use, which leads to better crop production and longer-lasting agricultural profits. agricultural sustainability

## II. RELATED WORK

Study by Tahat M.M. et al. (2020) [1] look into the need for healthy land for long-term farming. To protect soil fertility and the long-term health of ecosystems, the study finds that using fewer chemicals, integrated nutrient control systems, and organic substance treatments are all good ideas. The paper says that organic changes along with integrated nutrition methods that use few chemicals help to keep the soil fertile and protect ecosystem services. The writers look at how soil bacteria improve plant health as part of the nutrient cycle. Scientists are using study methods to try to show that long-term methods of managing soil can protect animal species even when climate change happens.

Karthikeyan L et al. (2020) [2] wrote a study paper saying that remote tracking technology was used in farmland to make food security better. Tracking technology from afar lets people see how crops are growing, guess how much they will produce, and handle tools for watering [2]. The study uses satellite data, UAVs, and multispectral cameras to check the health of plants and predict how pests and diseases will destroy crops, along with environmental factors.

Li L. and B. Wang wrote a study in 2021 [3] about how deep learning algorithms could help find plant diseases and make the visual diagnostic identification process better [3]. The main focus of the piece is on convolutional neural networks (CNNs), which are being looked at for their growing potential to find disease markers in picture collections. Scientists say that automated detection systems can help find illnesses earlier and cut down on crop loses, which leads to more crops being grown.

This paper by Hasan A.S.M.M. et al. (2021)[4] discusses deep learning techniques for locating weeds in agricultural land. The authors examine three algorithms—YOLO, Faster R-CNN, and SSD—to evaluate their performance in tasks involving locating weeds in images[4]. Because they reduce the cost of herbicides, reduce the demand for labor, and improve crop output, automated weed control systems are required.

Turkoglu M.O., et al. (2021) [5] conducted research that resulted in the development of a novel crop mapping method using time-series photographs. The proposed approach corrects accuracy problems while classifying several kinds of crops using multi-scale label systems. The study demonstrates how satellite pictures and neural networks may be combined to examine temporal trends, hence improving categorization outcomes. All components of agricultural monitoring—large-scale observation, yield forecasting, and resource management analysis—the technique is applied to.

This paper discusses by the people of Ullo, S. L., and Sinha, G. R. (2020)[6] for advancements in smart environmental monitoring systems using IoT and sensors, focusing on their applications in agriculture[6]. The study highlights how IoT-enabled systems provide real-time data on soil moisture, temperature, humidity, and other parameters essential for precision farming. These systems integrate low-power sensors, wireless communication, and cloud- based analytics to optimize resource use and enhance productivity.

Building a earlier studies by Bozzi, R., et al.(2022) [7] review the examines the role of precision livestock farming technologies in improving the efficiency and sustainability of pasture-based systems. The study focuses on tools for monitoring animal welfare, feed intake, and environmental impacts. Technologies like GPS tracking, wearable sensors, and automated data analysis are explored for optimizing grazing patterns and reducing resource waste.

This study reviews by the de Souza, J. S. & dos Reis, J. G. M. (2022) [8] to technologies for monitoring animal welfare, focusing on IoT devices and sensor-based systems. It explores parameters like body temperature, movement, and heart rate to assess health and stress levels. The authors discuss applications of smart collars, RFID tags, and environmental sensors in livestock management.

The 2021 study by Friha O., et al. [9] offers a comprehensive examination of every IoT application for smart farming. The study examines the latest LPWAN, edge computing, and blockchain-based platforms enhancing security solutions. IoT applications that use resources more effectively and create long-lasting structures help to increase agricultural accuracy.

V. P. Kour and S. Arora (2020)[10] examining tracking gadgets that can be interacted with and robotized systems, and the paper investigates how the Internet of Things can be applied in modern agriculture. The article discusses three methods of monitoring environmental, watering, and crop growth. This article discusses how IoT functions by cooperating with artificial intelligence and applying machine learning to examine vast volumes of data and forecast how things will operate. The study demonstrates how an IoT system may cooperate with artificial intelligence, machine learning, and big data analytics to produce judgments more likely to succeed

## III. PROPOSED SYSTEM

The technology offers autonomous irrigation capabilities by connecting to the cloud and internet of things (IoT), therefore supporting sustainable agriculture and improving water management. This system is made up of a microprocessor, environmental sensors, a water pump, and a drainage gate. They together create a cloud platform that determines when to irrigate plants using real-time environmental data. The major objective is to consume less water, which is accomplished by monitoring significant variables such soil moisture, temperature, humidity, rainfall, and water reserve assessments. The principal processor that receives data from the sensors to determine when to water and how to operate the water pump is the microcontroller. When the soil wetness level falls below a specified level and no rain is detected, the microcontroller activates the water pump. The system, as part of its job, checks to see whether the soil is sufficiently wet or whether it has rained recently to prevent watering plants when it's not required. It maintains the soil in good condition and saves water.

A draining gate controls the amount of water stored and keeps the system from getting too wet. The water level sensors in the storage tanks keep an eye on the current water levels to make sure there is enough water for the plants. The technology lets people know when the water level in a storage tank drops below a certain level. When sensor readings show high soil moisture levels or too much water in the system, the drainage gate opens immediately to let the extra water out, protecting the plants from harm. The system has two separate functions that let it handle drainage and watering. These functions work together to provide precise water modulation, which stops either too much or too little moisture.

The system works by sending measurements in real time to a cloud platform that is connected to the Internet of Things. This lets operators handle and keep an eye on the system from anywhere. Farmers can use a mobile app or an online platform to access the technology, which lets them keep an eye on irrigation activities, check environmental factors, and receive system alerts from anywhere. The cloud shows the same data for watching from afar (see Fig. 1), but an LCD panel on the system shows real-time system performance data. Farmers always have access to important information through this function, which helps them make smart decisions about how to best handle their crops and irrigation plans.

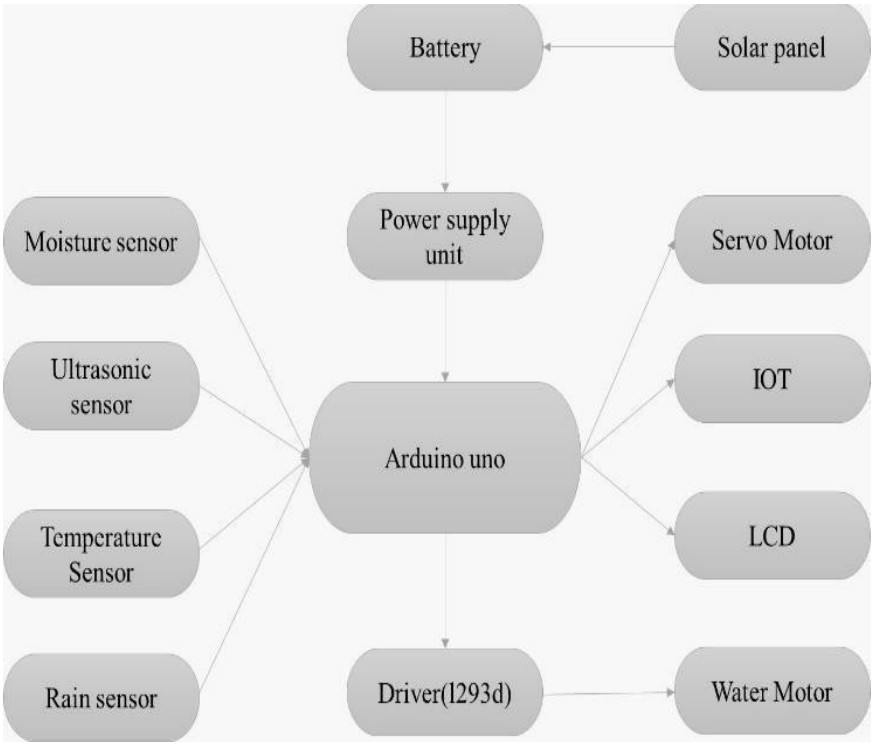


Fig. 1: System Architecture

An alert automation method let users know when important system conditions happen, like low water levels or high land water levels, as well as when there are problems with equipment. The technology instantly sends alerts to farmers' email addresses and mobile phones, so they can act quickly before crop health and system performance are negatively affected. The system sends farmers instant alerts so they can act quickly and make sure the watering system keeps working and gets better.

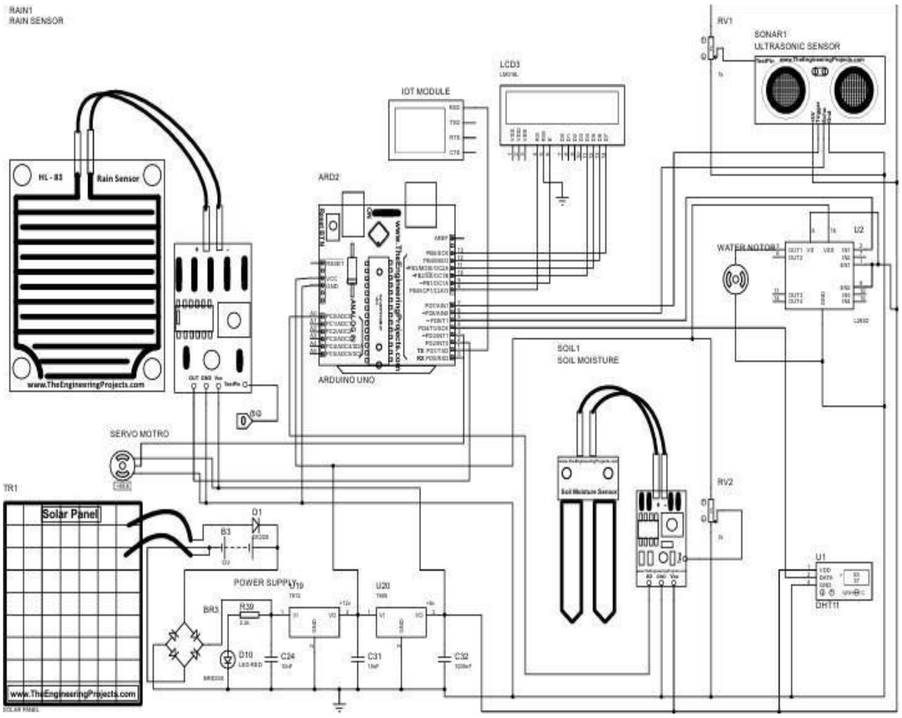


Fig. 2: Circuit Diagram

Operations may be maintained for a long period using the proposed system, which relies exclusively on renewable energy sources such solar electricity. The system's solar panels are shown in Figure 2. The water pump, drainage gate, sensors, and microprocessor are powered by these panels. This arrangement allows for less power from conventional energy sources. This combination of green energy helps farming practices that are beneficial for the environment and helps to maintain systems operating even in distant locations lacking access to the power grid. Because it has adjustable characteristics, the technique developed can be applied to a broad spectrum of crop kinds and field sizes. The irrigation system needs to work better when sensors keep an eye on a number of weather factors and machine learning algorithms make predictions based on past data. This adaptable solution uses Internet of Things (IoT) systems, automation technologies, renewable energy, and cloud-based infrastructure to deal with the world's limited water resources and provide an environmentally friendly and efficient way to farm

## IV. METHODOLOGY AND TECHNOLOGIES USED

### METHODOLOGY

#### *A. Sensor Data Acquisition*

Environmental sensors use data from moisture meters, temperature instruments, humidity sensors, rain detectors, and water level sensors to figure out what's going on in the field in real time. After the microcontroller unit gets communication, it processes the data that came from it. Farmers can stop over-irrigating and waste less water by making sure they make accurate decisions and act quickly by constantly watching. Feedback from processed sensor readings helps farmers make automatic irrigation plans that help plants grow in the best way possible. This kind of system application makes the best use of resources while reducing the need for operational human intervention to achieve water use efficiency based on specific environmental factors.

The microcontroller's processing sequence uses limits that have already been set to figure out what sensor data means so it can make operational decisions. The computer in the system turns on the water pump when it senses that the ground is dry and there has been no rain. According to the system, the water pump shuts-off when it detects saturated wetness or rains, since too much water wastes electricity. The drainage gate has an automatic system that draws water that is higher than what is recommended for the soil's water level. This is good for crop health.

#### *B. IoT-Based Remote Monitoring*

The system leverages IoT to transmit real-time data to the cloud platform. The mobile application combined with web interface allows farmers to review sensor information while they track system functions from any location. Remote monitoring features in the system let farmers maintain control of several fields from any location. Real-time system updates allow users to make quick actions that lead to early preventive measures. The IoT enables farmers to modify irrigation sequences while evaluating natural conditions which triggers alerts for vital equipment issues so the system performs optimally even with physical user absence.

#### *C. Alert Mechanism and Automation*

The system functions with automatic alert technology which produces alarms through sensor-detected urgent system conditions. Automated notification systems deliver alerts to the farmer’s mobile device or email whenever the water reaches critical low levels or when sensor detectors show abnormal moisture content. The system technology sends warnings promptly to enable prompt corrective actions which protects crops from harm and preserves system functionality. Through its alert system the device maintains operational and efficient performance which enables direct responses to irregular conditions to preserve irrigation management quality across all operational scenarios.

### TECHNOLOGY

#### *A. Microcontroller (ESP32/Arduino)*

The system's control unit operates as the microcontroller which merges sensor data with necessary execution elements. Through its functionality the microcontroller triggers both water pump activation and drainage gate operation for different environmental parameters. Multiple sensor inputs processed through the microcontroller achieve efficient water management operations by performing dynamic control of irrigation processes. The system achieves optimal performance and accurate irrigation decisions because of its low electricity consumption together with its IoT module. The outcomes from the proposed IoT based automatic irrigation system present major enhancements for water management along with decreased need for human labor and improved crop production. Soil moisture along with temperature and humidity and rainfall and water levels are monitored in real time using Fig 2 to only carry out irrigation when needed and prevent unnecessary water loss.

#### *B. Environmental Sensors*

The system uses diverse sensors involving soil moisture and temperature along with humidity and rainfall and water level sensors to track environmental factors. The measurement of soil water content depends on soil moisture sensors while temperature and humidity sensors evaluate environmental situations. Rain sensors prevent additional watering operations and water level monitoring devices maintain constant access to water reservoirs. The system obtains immediate data from these sensors. The system depends on sensor measurements to generate decisions about irrigation. The system achieves better soil maintenance through precise and dependable components which lower the waste of resources.

*C. IoT and Cloud Platform*

The IoT modules provide simple data transfer capabilities which allow the microcontroller to exchange information with the cloud platform for distant operational control. Real-time updates from sensors and system statuses move to the cloud platform through which farmers obtain information using mobile applications or web interfaces. The integration of cloud services enables users to access historical data and develop trends for forecasting decisions that lead to better outcomes. The IoT platform maintains system flexibility which enables compatibility across multiple agricultural sites as well as remote irrigation system oversight independently from any location.

*D. Renewable Energy Integration*

Solar panels active in the system enable renewable power generation thus eliminating conventional power requirements while supporting sustainable operations. The solar-powered operation enables operation without interruption even when farmers work in isolated agricultural sites without electricity access. The system lowers operational expenses while being environmentally sustainable because it implements renewable energy. Solar energy enables the efficient operation of the microcontroller along with sensors, water pump, and drainage gate through its power supply. The solar-powered operating system brings environmental benefits at cost savings and perfects sustainable agricultural practices.

## V. RESULT AND DESCUSSION

The results of the proposed IoT-based automatic irrigation system demonstrate significant improvements in water management efficiency, reduced manual intervention, and enhanced crop yield. Figure 3 shows the real-time monitoring of soil moisture, temperature, humidity, rainfall, and water levels ensures that irrigation is performed only when necessary, minimizing water waster. The comparison of various parameters and their threshold is shown in Table 1.

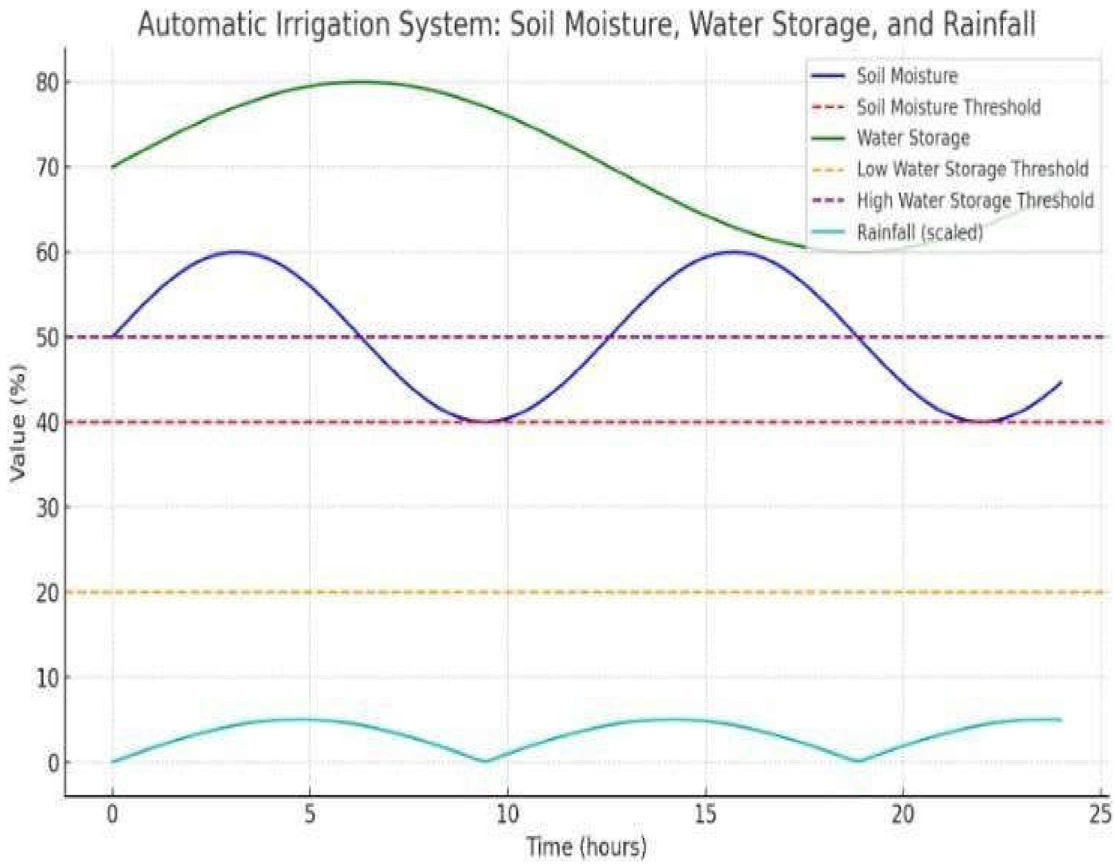


Fig. 3: Result Comparison graph

TABLE 1: Comparison of various parameters of the this work

| Condition | Action | Threshold Values | Remarks |
|---|---|---|---|
| Soil moisture is low and no rain | Turn on the water pump to water the crops | Soil Moisture: Below 40% | Water is provided when soil is too dry. |
| Soil moisture is low and rain detected | Do not turn on the water pump (water is enough) | Rainfall: ≥ 1mm | No watering if it's already raining. |
| Soil moisture is enough | Do not turn on the water pump (no need for watering) | Soil Moisture: Above 60% | No watering if the soil is moist enough. |
| Water storage is low | Send an alert to refill the water tank | Storage Level: Below 20% | Alerts the user when water supply is running low. |
| Water storage is high | Continue normal operation without alerts | Storage Level: Above 50% | System works normally when there is enough water. |
| Too much water in the field | Turn on drainage to prevent waterlogging | Water Level in Field: Above 15cm | Prevents excess water from gathering around the plants. |
| Soil moisture is good and no rain | System stays off (no action needed) | Soil Moisture: 50%-60%,<br>Rainfall: 0mm | System does nothing when conditions are already fine. |

The multi-cycle irrigation observation period indicates the system controls soil moisture at optimal levels while avoiding both excessive and inadequate water supply. The automatic water pump system turns on to deliver hydration to crops when soil moisture reaches its threshold while rainfall measurement confirms dry conditions. The system performs effectively to block excess irrigation under conditions where rainfall occurs or when soil moisture reaches suitable levels thus preventing wasted water usage

Farmers can run and keep an eye on their irrigation system from anywhere using cloud tools that include IoT technology. Real-time data The web interface mobile app shows real-time data visualizations that keep users up to date on the state of the system and the environment.

With this feature, farmers can make good choices and act right away, even if they're not at the farm. Built-in warning systems let farmers know when important things happen in the system, like when the water level is too low or too high, so they can fix the problem before it hurts their crops or the whole system breaks down.

Its useful features help the system manage how well it stores water. The system is made up of water level monitors that keep checking the level of the storage tank until they see it drop below certain levels. This tracking tool keeps the irrigation cycle going even when there isn't enough water. The device's drainage gate system keeps crops from getting too much water by automatically letting out water above the safe soil wetness levels. This keeps the soil from getting too wet while keeping its good conditions.

The research also indicates that the system performs effectively under various weather circumstances and can modify the kinds of watering depending on present sensor data. Including renewable solar energy in the system guarantees its constant operation and lessens the need on conventional power lines. This durable approach not only helps farmers save money but also promotes environmentally friendly farming practices. Because it is meant to be scalable, the approach can be modified to suit various crop kinds and field sizes. This makes the approach effective in many other agricultural contexts.

The innovative approach increases farmers' crop production, reduces the requirement of water, and optimizes irrigation. Smart farming results from combining renewable energy, cloud software, and the Internet of Things (IoT). Because it monitors in real time, makes decisions automatically, and sends out fast alerts, the system controls irrigation quite well. This eliminates many major issues in contemporary agriculture.

## VI. CONCLUSION

Studies show that the system stays stable in a variety of weather conditions and can change its mind about when to water based on what sensors are reading at the moment. Using renewable solar energy makes sure that the system always works well and cuts down on the need for regular power lines. A long-term view helps farmers save money and encourages them to work in ways that are good for the environment. Users can change the system to handle different types of crops and fields of different sizes by using scalable design elements. This means that the system can be used in a wider range of farming settings.

The new way makes irrigation better, increases crop yield, and uses less water. When you combine IoT with cloud technologies and clean energy, you get a stable, long-lasting framework for smart agriculture. The system handles irrigation well by keeping an eye on things in real time, using automated decision algorithms, and sending out quick alerts. This talks about some of the most important problems in modern agriculture.

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