

# **GREEN INTELLIGENT AGRICULTURE IRRIGATION SYSTEM USING SOLAR PANEL**

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## **ABSTRACT**

*Agriculture is one of the most important aspects for economic growth and food security. Conventional irrigation practices are prone to overuse of water and high energy consumption. To overcome these challenges, this paper presents a Green Intelligent Agriculture Irrigation System using Solar Panels for the sustainable farming applications. The proposed system integrates solar photovoltaic technology, soil moisture sensors and automated control mechanisms for optimizing irrigation efficiency. Soil moisture sensors provide continuous monitoring of soil conditions and transmit real-time data to a microcontroller-based control unit that automatically controls water flow according to the crop requirements. The irrigation system is powered by solar energy, reducing reliance on conventional electricity and lowering operating costs. The smart irrigation approach enhances water conservation, improves energy efficiency and increases crop productivity while supporting the environmentally. The intelligent irrigation approach enhances water conservation, improves energy efficiency, and increases crop productivity while supporting environmentally sustainable agricultural practices. The proposed system contributes toward eco-friendly agriculture by reducing water wastage, carbon emissions, and energy consumption in modern farming environments.*

## **RESEARCH GAPS IN PREVIOUS STUDIES:**

Although several researchers have developed smart irrigation systems using sensors, and solar energy, significant research gaps still exist. Many existing systems focus mainly on either water conservation or energy management, but very few integrate both renewable energy and intelligent irrigation in a cost-effective and scalable manner. Previous studies also lack efficient real-time monitoring and adaptive decision-making capabilities for varying soil and climatic conditions. Some earlier irrigation systems require continuous internet connectivity and advanced infrastructure, making them unsuitable for rural and remote agricultural areas. In addition, high installation and maintenance costs remain a major challenge for small-scale farmers. Several studies have highlighted limitations related to sensor accuracy, power management, and system reliability under different environmental conditions

**Keywords:** *Smart Irrigation<sup>1</sup>, Solar Panel<sup>2</sup>, Agriculture Automation<sup>3</sup>, Soil Moisture Sensor<sup>4</sup>, Renewable Energy<sup>5</sup>, PH Sensor and TDS Sensor<sup>6</sup>, Sustainable Farming<sup>7</sup>.*

## 1. INTRODUCTION

Agriculture is one of the most significant sectors contributing to economic development, employment generation, and food security across the world. With the rapid increase in population and the growing demand for food production, efficient utilization of water and energy resources has become essential for sustainable agricultural development. Traditional irrigation methods such as flood irrigation and manual watering systems often lead to excessive water consumption, uneven water distribution, and high energy usage, resulting in resource wastage and environmental degradation. Water scarcity is becoming a major global concern due to climate change, irregular rainfall patterns, and overexploitation of groundwater resources. According to the Food and Agriculture Organization (FAO), agriculture consumes nearly 70% of the world's freshwater resources, emphasizing the need for intelligent irrigation systems that can optimize water utilization)

Recent advancements in smart agriculture and Internet of Things (IoT) technologies have enabled the development of automated irrigation systems capable of monitoring environmental conditions in real time. Soil moisture sensors, temperature sensors, and microcontroller-based systems are increasingly being used to improve irrigation efficiency and crop productivity. Intelligent irrigation systems can automatically regulate water flow based on soil moisture conditions, thereby reducing water wastage and minimizing human intervention. In addition to water conservation, energy consumption is another critical issue in modern agriculture. Conventional irrigation systems primarily depend on grid electricity or diesel-powered pumps, which increase operational costs and contribute to environmental pollution. Renewable energy sources, particularly solar photovoltaic (PV) systems, provide an eco-friendly and sustainable alternative for powering agricultural irrigation systems. Solar-powered irrigation systems reduce dependence on fossil fuels, lower greenhouse gas emissions, and support sustainable farming practices

Several researchers have proposed smart irrigation models integrating sensors and automation technologies; however, many existing systems focus mainly on either irrigation control or renewable energy utilization. Limited studies provide a complete integration of solar-powered energy systems with intelligent irrigation control mechanisms in a low-cost and efficient manner. Furthermore, many previous systems face challenges related to high installation costs, poor adaptability to varying environmental conditions, and lack of autonomous operation capabilities. To overcome these limitations, this paper presents a Green Intelligent Agriculture Irrigation System using Solar Panels for sustainable and efficient farming. The proposed system integrates solar photovoltaic technology, soil moisture sensors, automated water control mechanisms, and microcontroller-based monitoring systems to optimize irrigation processes. Soil moisture sensors continuously monitor soil conditions and automatically regulate irrigation according to crop requirements. Solar energy is used to power the entire system, reducing electricity dependency and operational expenses. The proposed intelligent irrigation approach aims to improve water conservation, enhance energy efficiency, increase crop productivity, and promote environmentally friendly agricultural practices.

## 2. LITERATURE REVIEW

Several researchers have contributed significantly to the development of smart irrigation systems for sustainable and precision agriculture. The integration of renewable energy sources, Internet of Things (IoT) technology, wireless sensor networks (WSN), cloud computing, and artificial intelligence (AI) has improved irrigation efficiency, water conservation, and energy management in modern farming systems. A solar-powered irrigation system integrated with IoT technology was developed to automate irrigation processes based on soil moisture conditions. In this system, soil moisture sensors continuously monitored the water content in the soil and transmitted data to a microcontroller for automatic irrigation control. The system used solar photovoltaic panels as the primary energy source, reducing dependency on conventional electricity and lowering operational costs. Experimental results demonstrated significant improvements in water conservation, energy efficiency, and crop productivity. The study concluded that combining renewable energy with smart monitoring technologies can provide sustainable agricultural solutions for rural farming areas.

Researchers also proposed intelligent irrigation systems using Wireless Sensor Networks (WSN) and cloud-based monitoring technologies to optimize agricultural operations. In these systems, multiple sensors such as soil moisture sensors, temperature sensors, and humidity sensors were deployed across agricultural fields to collect environmental data in real time. The collected data was transmitted wirelessly to cloud servers where farmers could monitor field conditions remotely through mobile or web applications. Automated irrigation control mechanisms enabled precise water distribution according to crop requirements, thereby reducing water wastage and improving irrigation scheduling. The research highlighted that cloud-enabled smart irrigation systems enhance decision-making capabilities and support precision agriculture practices. Another study focused on smart irrigation techniques based on moisture sensing and automated water control systems. The proposed system utilized soil moisture sensors connected to a microcontroller that automatically switched water pumps ON or OFF depending on soil conditions. This approach minimized unnecessary irrigation and optimized water usage. Researchers observed that automated moisture-based irrigation systems significantly reduced human intervention, improved irrigation accuracy, and conserved groundwater resources. The study also emphasized that sensor-based automation is highly beneficial for areas experiencing water scarcity and irregular rainfall patterns.

Recent studies on Artificial Intelligence (AI)-based irrigation systems have emphasized the importance of integrating renewable energy sources and real-time monitoring technologies for precision agriculture. AI algorithms were used to analyze environmental data such as soil moisture, weather conditions, crop type, and temperature to predict irrigation requirements accurately. Machine learning models improved irrigation scheduling by providing intelligent decision-making capabilities and adaptive control mechanisms. Researchers reported that AI-driven smart irrigation systems can maximize crop yield, reduce water consumption, and improve energy utilization efficiency. Furthermore, the integration of solar-powered systems with AI technologies supports environmentally sustainable farming practices by minimizing carbon emissions and reducing reliance on fossil fuels.

In addition, several researchers have explored the use of IoT-enabled precision agriculture systems that combine sensor technologies, data analytics, and automation. These systems provide farmers with real-time field monitoring, remote irrigation management, and predictive analysis for crop health assessment. The literature indicates that smart agriculture technologies contribute significantly toward sustainable farming by enhancing resource utilization, improving productivity, and reducing environmental impact. However, many existing systems still face challenges related to high implementation costs, limited scalability, sensor reliability, and dependence on stable internet connectivity. Therefore, there is a growing need for low-cost, energy-efficient, and autonomous irrigation systems that can operate effectively in rural and remote agricultural regions.

### 3. OBJECTIVES OF THE PROPOSED RESEARCH

The primary objective of this research is to develop a **Green Intelligent Agriculture Irrigation System using Solar Panels** for sustainable and efficient farming applications. The proposed system aims to integrate renewable energy, smart sensing technologies, and automated irrigation control mechanisms to improve agricultural productivity while conserving natural resources.

The specific objectives of the proposed research are as follows:

1. **To design and develop a solar-powered intelligent irrigation system** that utilizes solar photovoltaic energy to operate irrigation components and reduce dependence on conventional electricity sources. The use of renewable energy helps minimize operational costs and environmental pollution.
2. **To implement soil moisture sensing technology** for real-time monitoring of soil conditions and automatic control of water supply according to crop water requirements. This objective aims to optimize water utilization and prevent unnecessary irrigation.
3. **To integrate microcontroller-based automation and IoT technologies** for efficient monitoring and control of agricultural irrigation systems. The integration of IoT enables remote monitoring, data collection, and intelligent decision-making for precision agriculture applications.
4. **To improve water conservation and energy efficiency** by developing an automated irrigation mechanism that minimizes water wastage and reduces energy consumption during agricultural operations.
5. **To enhance crop productivity and sustainable farming practices** through the application of smart irrigation technologies capable of maintaining optimal soil moisture conditions for healthy crop growth.
6. **To develop a low-cost, reliable, and eco-friendly irrigation solution** suitable for rural and remote agricultural areas where access to electricity and advanced irrigation infrastructure may be limited.
7. **To reduce human intervention in irrigation management** by implementing intelligent automated control systems capable of operating autonomously based on environmental conditions and sensor data.

The proposed research intends to provide an efficient, sustainable, and intelligent agricultural irrigation framework that supports precision farming, resource conservation, and environmentally friendly agricultural development.

## 4. PROPOSED SYSTEM

### A. System Architecture;

The proposed system consists of the following major components:

- Solar Panel
- Battery(0-12v)
- Solar Charge Controller
- Microcontroller (Arduino/uno)
- Soil Moisture Sensor (name)
- TDS and PH Sensor
- 16x2 LCD display screen
- Water Pump (DC)
- Relay Module
- Water Storage Tank

### B. Working Principle:

The proposed **Green Intelligent Agriculture Irrigation System using Solar Panels** operates by integrating solar energy, soil moisture sensing technology, microcontroller-based automation, and communication for efficient irrigation management. The system is designed to provide sustainable and intelligent irrigation with minimal human intervention while conserving water and energy resources. Initially, the **solar photovoltaic (PV) panel** converts sunlight into electrical energy through the photovoltaic effect. The generated electrical energy is supplied to a **solar charge controller**, which regulates the charging process and stores energy in a rechargeable battery. The charge controller protects the battery from overcharging and ensures stable power supply to the irrigation system components. The stored solar energy is used to operate the microcontroller, sensors, IoT module, and water pump, thereby reducing dependence on conventional electricity sources and supporting environmentally sustainable agricultural practices. The **soil moisture sensor** is installed in the agricultural field to continuously monitor the moisture content of the soil. The sensor detects variations in soil water levels and generates corresponding electrical signals. These signals are transmitted to the **microcontroller unit**, which acts as the central processing and control unit of the system. The microcontroller continuously compares the sensed moisture value with a predefined threshold value stored in the program memory.

When the soil moisture level falls below the predefined threshold, indicating insufficient water content in the soil, the microcontroller sends a control signal to the **relay module**. The relay functions as an electronic switching device that activates the **water pump** automatically. Water is then supplied to the agricultural field through the irrigation system to maintain adequate soil moisture conditions required for healthy crop growth.

The irrigation process continues until the soil moisture sensor detects that the moisture level has reached the desired threshold value. Once sufficient moisture is achieved, the microcontroller automatically deactivates the relay module, which switches OFF the water pump. This automated control mechanism prevents over-irrigation, reduces water wastage, and improves irrigation efficiency.

## 5. HARDWARE COMPONENTS:

### A. Solar Panel

The **solar panel** is one of the most important components of the proposed irrigation system. It converts solar radiation into electrical energy using the photovoltaic effect. The generated electrical energy is used to operate the irrigation system components such as the microcontroller, sensors, relay module, and water pump. Solar panels provide a renewable and eco-friendly energy source, reducing dependence on conventional electricity and minimizing operational costs in agricultural applications. The integration of solar photovoltaic systems in irrigation significantly improves energy efficiency and supports sustainable farming practices.

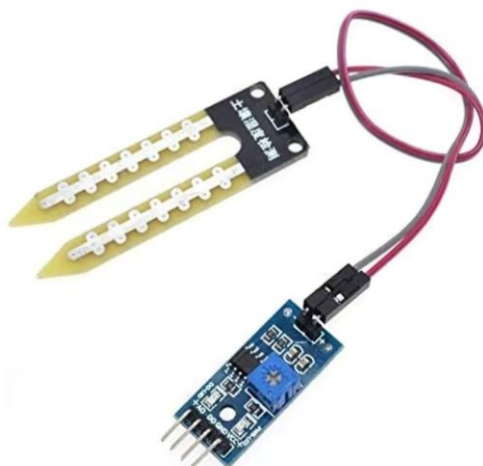


**Figure 1.1 Solar Panel**

Solar panels are particularly beneficial in rural and remote agricultural areas where access to electrical power is limited. The energy generated by the solar panel is stored in rechargeable batteries through a solar charge controller, ensuring continuous system operation even during low sunlight conditions

### B. Soil Moisture Sensor

The **soil moisture sensor** is used to measure the water content present in the soil. It continuously monitors soil moisture conditions and provides real-time data to the microcontroller. The sensor operates by detecting variations in electrical conductivity or resistance caused by the presence of moisture in the soil. When the soil becomes dry, the sensor sends signals indicating low moisture levels, enabling the irrigation system to initiate watering automatically.



**Figure 1.2 Soil Moisture Sensor**

The use of soil moisture sensors helps optimize water utilization, reduce water wastage, and improve irrigation efficiency. These sensors play a crucial role in precision agriculture by maintaining appropriate soil moisture conditions required for healthy crop growth. Automated irrigation based on soil moisture sensing also reduces manual intervention and improves agricultural productivity.

### **C. Microcontroller(Arduino Uno)**

The **microcontroller** acts as the central processing and control unit of the proposed irrigation system. It receives input signals from the soil moisture sensor, processes the collected data, and controls the operation of the irrigation system based on predefined programming instructions. Popular microcontrollers such as Arduino, UNO are commonly used in smart irrigation systems due to their low power consumption, flexibility, and ease of interfacing with sensors and communication modules



**Figure 1.3 Microcontroller(Arduino Uno)**

The microcontroller continuously compares the sensed soil moisture values with the threshold value stored in memory. When the soil moisture level falls below the required limit, the microcontroller activates the relay

module to switch ON the water pump. Once adequate soil moisture is achieved, the controller automatically switches OFF the pump. This intelligent automation improves irrigation efficiency and conserves both water and energy resources.

#### D. Relay Module

The **relay module** functions as an electronic switching device used to control the operation of the water pump. Since the microcontroller operates at low voltage and cannot directly drive high-power electrical devices, the relay module acts as an interface between the controller and the water pump. When the microcontroller sends a control signal, the relay either completes or disconnects the electrical circuit of the pump.



Figure 1.4 Microcontroller(Arduino Uno)

The relay module enables safe and efficient switching operations while protecting the microcontroller from high current and voltage loads. It plays a critical role in automating irrigation processes and ensuring reliable system performance in agricultural environments.

#### E. Water Pump



Figure 1.5 Microcontroller(Arduino Uno)

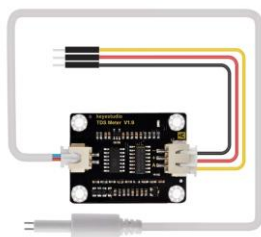
The **water pump** is responsible for supplying water to the agricultural field during irrigation. The pump is automatically activated when the soil moisture level drops below the predefined threshold value. It draws water from a water source such as a tank, reservoir, or bore well and distributes it to crops through irrigation pipelines or sprinklers.

#### F. TDS-Sensor

A highly innovative feature of this project is the repurposing of a TDS (Total Dissolved Solids) sensor to indirectly measure and monitor soil mineral content. Direct measurement of solid soil minerals via electronic

probes is scientifically unfeasible without complex lab equipment. However, an indirect electrochemical proxy method can be utilized.

The methodology operates on the principle of electrical conductivity (EC). Essential soil minerals, salts, and applied fertilizers exist as soluble chemical compounds. When the automated DC pump irrigates the dry soil, the supplied water acts as a solvent. The solid minerals dissolve into the water, creating a conductive soil solution or 'leachate'. The TDS sensor probes are structurally inserted into the plant's root zone. The sensor works by applying a small electrical voltage between its two electrodes and measuring the resulting current flow through the damp soil. Since dissolved minerals consist of highly conductive ions (such as calcium, magnesium, potassium, and nitrates), a higher concentration of these beneficial minerals facilitates greater electrical conductivity. The sensor's signal conditioning board converts this EC reading into a TDS value, measured in parts per million (ppm).



**Figure 1.6 TDS-Sensor**

Therefore, a high TDS reading indicates nutrient-rich soil. Conversely, if the TDS value drops significantly after irrigation, it acts as a direct indicator that the soil is severely depleted of soluble minerals—either due to continuous root uptake or nutrient leaching (where water washes nutrients below the root zone). This indirect correlation allows for immediate, low-cost monitoring of soil fertility.

The experimental setup definitively proved that utilizing a TDS sensor to gauge soil mineral content is a highly viable, low-cost agriculture tech solution. The indirect electrochemical method (measuring leachate conductivity) accurately reflected the addition of commercial fertilizers (showing a sharp increase in ppm) and simulated nutrient leaching (showing a drop in ppm). The localized alert system proved essential; by immediately displaying warnings when TDS values fell below the critical threshold, the system removes the guesswork from fertilization, allowing users to apply nutrients only when chemically necessary.

### **G. PH-Sensor**

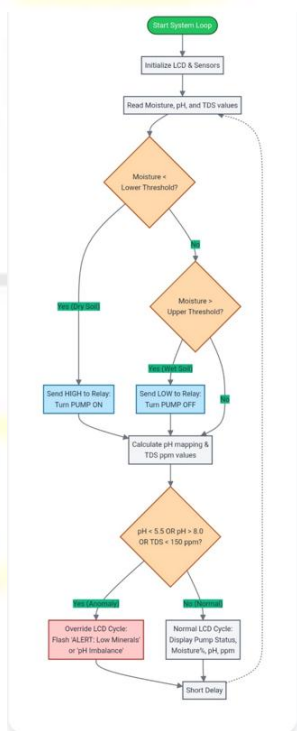
The sensor is used in this system to monitor the acidity or alkalinity of the soil. Soil pH is an important factor in agriculture because it directly affects nutrient availability, fertilizer effectiveness, and crop growth. Different crops require different pH ranges for proper development. The pH sensor continuously measures the hydrogen ion concentration present in the soil and converts it into an electrical signal that can be processed by the Arduino Uno microcontroller.



**Figure 1.7 TDS-Sensor**

In this project, the pH sensor is placed in the soil near the root zone of the crop. The sensor sends real-time pH values to the microcontroller, which displays the readings on the LCD screen. The system continuously compares the measured pH value with predefined safe limits. If the soil becomes too acidic or too alkaline, the system automatically generates an alert message such as “ALERT: SOIL TOO ACIDIC” or “ALERT: SOIL TOO ALKALINE.” This helps users identify unsuitable soil conditions and take corrective actions to maintain proper soil health. The integration of the pH sensor improves the intelligence and efficiency of this system. Along with the soil moisture sensor and TDS sensor, the pH sensor helps provide complete monitoring of agricultural conditions. By maintaining proper soil pH levels, the system supports better nutrient absorption, healthier plant growth, and improved agricultural productivity. Therefore, the pH sensor plays an important role in transforming the project from a basic irrigation system into an advanced smart farming solution.

**6. Control Logic and Alert Algorithm**



**Figure 1.8 Control Logic and Alert Algorithm**

The Arduino Uno is programmed with a continuously executing C++ loop that governs the system's autonomous behavior. The logic follows a strict sequence of operations:

**1. Irrigation Control:** The microcontroller reads the analog value from the soil moisture sensor. If the value falls below a predefined lower threshold (indicating dry soil), the Arduino sends a HIGH signal to the relay module. This closes the circuit, powering the DC pump and delivering high-pressure water. Once the moisture level surpasses the upper threshold (indicating optimal saturation), the relay is deactivated, and the pump stops, preventing waterlogging.

**2. Diagnostic Processing:** Simultaneously, the Arduino samples analog data from the pH and TDS sensors. The raw voltages are mapped and calibrated to accurate pH and ppm values using predefined algorithms.

**3. Data Visualization:** The 16x2 LCD screen continuously refreshes, cycling through the current state of the system. It displays: Pump Status (ON/OFF), Moisture (%), pH level, and Mineral content (TDS ppm).

**4. Anomaly Detection and Alerts:** To protect the crops, safety thresholds are hardcoded into the system. If the pH level strays outside the optimal range (e.g., falls below 5.5 or rises above 8.0), or if the TDS mineral level drops below a critical baseline (e.g., <150 ppm, indicating severe nutrient depletion), the standard LCD display cycle is immediately overridden. The screen flashes a high-priority warning message: 'ALERT: Low Minerals' or 'ALERT: pH Imbalance'. This localized alert prompts the user to apply fertilizers or pH adjusters manually.

## 7. SOFTWARE IMPLEMENTATION

The system software is developed using embedded programming for sensor monitoring and pump control operations.

### Algorithm

1. Start the system.
2. Read soil moisture sensor data.
3. Compare sensor value with threshold level.
4. If moisture is low:
5. Turn ON water pump.
6. Else: Turn OFF water pump.
7. Repeat the process continuously.

## 8. ADVANTAGES OF THE PROPOSED SYSTEM

- Conserves water resources.
- Uses renewable solar energy.
- Reduces electricity consumption.
- Minimizes human intervention.
- Provides automatic irrigation control.
- Enhances crop productivity.
- Eco-friendly and sustainable.

## 9. APPLICATIONS

- Smart Agriculture
- Precision Farming
- Greenhouse Irrigation
- Drip Irrigation Systems
- Remote Agricultural Areas
- Urban Farming

## 10. RESULTS AND DISCUSSION:

The proposed **solar-powered intelligent irrigation system** demonstrated significant improvements in water management, energy efficiency, and agricultural productivity. The system successfully automated irrigation operations by continuously monitoring soil moisture conditions and supplying water only when required. This intelligent irrigation mechanism minimized unnecessary watering and optimized water utilization in agricultural fields. Experimental observations indicated that the automated irrigation approach reduced water wastage compared to conventional manual irrigation methods. The proposed system also improved **crop health and productivity** by maintaining consistent soil moisture levels required for healthy plant growth. Proper irrigation scheduling prevented both over-irrigation and under-irrigation, which are major causes of reduced crop yield and soil degradation. Researchers have reported that precision irrigation systems contribute to improved crop quality, enhanced agricultural productivity, and better resource management.

## 11. CHALLENGES

- High initial installation cost.
- Dependence on sunlight availability.
- Sensor maintenance requirements.
- Limited technical awareness among farmers.

## 12. Future developments may include:

- Artificial Intelligence-based irrigation prediction.
- Weather forecasting integration.
- Drone-assisted crop monitoring.
- Machine learning for optimized water management.
- Fully autonomous smart farming systems.

## 13. CONCLUSION

The proposed **Green Intelligent Agriculture Irrigation System using Solar Panels** provides an effective and sustainable solution for modern agricultural irrigation challenges. The system successfully integrates solar photovoltaic technology, soil moisture sensors, microcontroller-based automation. By continuously monitoring soil moisture conditions and automatically controlling water supply, the system minimizes water wastage and ensures efficient irrigation according to crop requirements.

The utilization of solar energy as the primary power source reduces dependence on conventional electricity and fossil fuels, thereby lowering operational costs and supporting environmentally friendly agricultural practices.

The integration of renewable energy with intelligent irrigation contributes significantly toward energy conservation, reduction of greenhouse gas emissions, and sustainable farming development. Experimental observations demonstrated that the automated irrigation system improves water-use efficiency, enhances crop health, and reduces manual intervention in agricultural operations. The efficient management of irrigation activities, supporting precision agriculture and smart farming applications.

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