Integrated Water and Energy Management System for Smart Agriculture

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Abstract - Agriculture in India faces significant challenges such as water scarcity, irregular rainfall, and increasing energy costs. Traditional irrigation methods often result in water wastage and high dependency on electricity. This paper presents an integrated smart agro-infrastructure system that combines rainwater harvesting, filtration, solar energy, and drip irrigation. The system collects rainwater using gravity flow, stores it in a tank, and filters it before use. A solar-powered pump distributes water through a drip irrigation network, ensuring efficient water utilization. Soil moisture sensors are incorporated to automate irrigation and prevent overwatering. The proposed system reduces manual effort, conserves water, and minimizes energy consumption. The experimental model demonstrates improved irrigation efficiency and sustainable farming practices. This approach provides a cost-effective and eco-friendly solution for modern agriculture.

Key Words: Smart Agriculture, Rainwater Harvesting, Drip Irrigation, Solar Energy, Sustainable Farming

1. INTRODUCTION

Agriculture plays a crucial role in the economic development of India. However, traditional farming practices face challenges such as water scarcity, irregular rainfall, and high energy consumption. Conventional irrigation methods often lead to inefficient water use and increased operational costs.

Smart agriculture integrates modern technologies such as rainwater harvesting, drip irrigation, and renewable energy systems to improve productivity and sustainability. This study proposes an integrated system that combines these technologies into a single efficient agricultural infrastructure.

2. LITERATURE REVIEW

Previous research has focused on individual technologies such as rainwater harvesting, drip irrigation, and solar-powered irrigation systems.

- Rainwater harvesting systems improve water availability but lack automation.
- Drip irrigation systems reduce water usage by up to 40% but require continuous monitoring.
- Solar-powered irrigation systems reduce electricity costs and provide renewable energy for pumping. However, their efficiency depends on sunlight availability and they are typically used with groundwater or stored water sources.

However, most existing systems are not integrated. This study proposes a combined system that enhances overall efficiency and sustainability.

3. METHODOLOGY

The proposed system consists of the following components:

3.1 Rainwater Harvesting

Rainwater is collected from the agricultural field using gravity flow through channels and stored in a primary tank.

3.2 Filtration Unit

Collected water is filtered using layers of stones, gravel, and mesh to remove impurities.

3.3 Storage System

Filtered water is stored in a secondary tank for irrigation purposes.

3.4 Solar Power System

Solar panels generate electricity to operate the water pump, reducing dependency on conventional power sources.

3.5 Drip Irrigation System

Water is supplied directly to plant roots through drip pipes, minimizing water wastage.

3.6 Sensor-Based Automation

Soil moisture sensors monitor moisture levels and automatically control irrigation.

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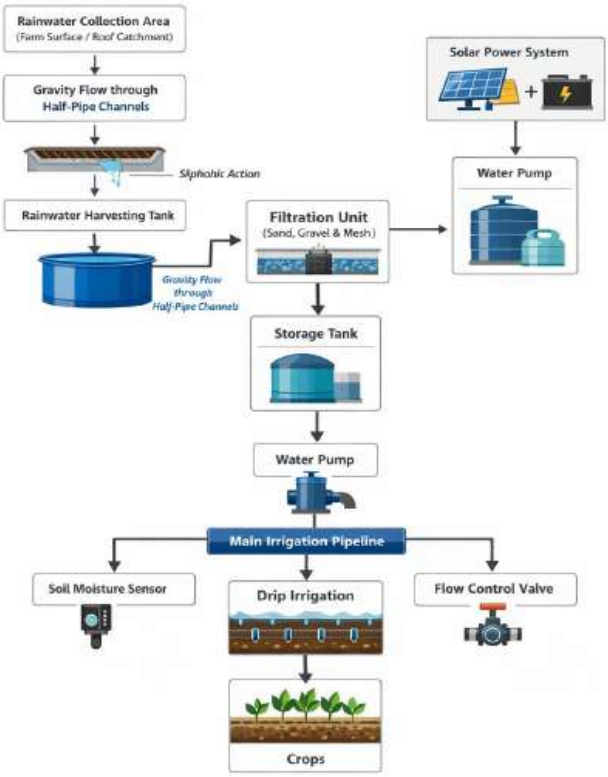

Smart Irrigation (use of Renewable Energy)

4. DESIGN CALCULATIONS

Based on agricultural land area of 5 acres:

- Rainfall (Solapur): 550 mm
- Runoff coefficient: 0.4
- Rainwater available: 4,451.7 m³
- Daily water requirement: 1,01,175 liters
- 2-month requirement: 60 lakh liters

Tank Design

- Size: 40 m × 38 m × 4 m

Pump Calculation

- Power required ≈ 1 HP
- Recommended pump: 2 HP

Solar System

- Required capacity: 2 kW
- Panels: 4 (500W each)

5. RESULTS AND DISCUSSION

The developed model was tested to evaluate system performance.

- Rainwater was successfully collected using gravity flow
- Filtration unit effectively removed impurities
- Solar-powered pump operated efficiently
- Drip irrigation ensured uniform water distribution
- Sensors prevented over-irrigation

The system improved:

- Water efficiency
- Energy savings
- Crop irrigation management

6. ADVANTAGES AND LIMITATIONS

Advantages

- Efficient water management
- Reduced electricity cost
- Automated irrigation system
- Eco-friendly and sustainable

Limitations

- High initial cost
- Requires maintenance of sensors
- Suitable for small-scale implementation

7. CONCLUSION

The integrated smart agro-infrastructure system provides an effective solution for sustainable farming. By combining rainwater harvesting, solar energy, and drip irrigation, the system reduces water wastage and energy consumption. The model demonstrates improved efficiency and can be implemented in real agricultural fields with further enhancements.

ACKNOWLEDGEMENT

The authors would like to thank the Department of Civil Engineering, A.G. Patil Polytechnic Institute, Solapur, for providing support and guidance in completing this project.

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