

SMART IRRIGATION FOR CLIMATE CHANGE ADAPTATION

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ABSTRACT



Climate change poses a significant challenge to agricultural sustainability, particularly in arid and semi-arid regions, where water scarcity is intensifying. Smart irrigation has emerged as a vital solution to enhance water-use efficiency and support climate adaptation in agriculture. By integrating advanced technologies such as the Internet of Things (IoT), sensors, and automated controllers, smart irrigation systems optimize water delivery in real time, minimizing losses due to evaporation and runoff. This article explores various smart irrigation approaches, including plant-, soil moisture-, and weather-based strategies, highlighting their potential to promote resource efficiency, increase crop productivity, and support sustainable agricultural practices.

KEYWORDS: Climate adaptation, Precision agriculture, Smart irrigation, Sustainable farming, Water-use efficiency

INTRODUCTION

The growing impacts of climate change have severely affected agriculture, particularly in water-stressed regions. Rising global temperatures, erratic rainfall patterns, and frequent droughts and floods have diminished water availability and reduced agricultural productivity. Consequently, ensuring efficient water management has become imperative for sustainable farming.

Smart irrigation, an innovative technology-driven approach, offers a solution by optimizing water usage through real-time monitoring and precise delivery. These systems reduce water wastage by minimizing evaporation, deep percolation, and runoff losses (Bwambale et al., 2023). By incorporating sensors, automated controllers, and data analytics, smart irrigation systems enable farmers to make informed decisions, conserve water, and enhance crop resilience. This technology plays a critical role in mitigating the effects of climate variability and promoting food security through sustainable agricultural practices.

SMART IRRIGATION SCHEDULING

Irrigation scheduling refers to determining the optimal time and volume of water application based on factors such as crop water requirements, root zone depth, and soil moisture levels. Smart irrigation integrates digital technologies to automate and streamline this process, enhancing precision and efficiency. The core technologies behind smart irrigation include IoT, artificial intelligence (AI), and automation.

IoT technology connects physical components—such as soil moisture sensors, weather stations, and irrigation systems—into a network that provides real-time data for remote monitoring and control. This connectivity reduces labour dependency and optimizes water management (Vallejo-Gómez et al., 2023). However, challenges such as high initial costs, technological dependency, and regular maintenance requirements must be addressed to maximize the benefits of smart irrigation. Smart irrigation scheduling can be implemented using the following approaches:

- 1. PLANT-BASED APPROACH:** The plant-based approach monitors the physiological responses of plants to determine irrigation needs (Sidhu et al., 2021). Water stress is assessed using direct techniques, such as sap flow, xylem water potential, and leaf water content sensors. Indirect methods, including infrared thermometry, thermal remote sensing, and near-infrared spectroscopy, are also employed. These techniques help calculate cumulative stress degree days, crop water stress index, and crop evapotranspiration, enabling farmers to optimize irrigation timing.
- 2. SOIL MOISTURE-BASED APPROACH:** The soil moisture-based approach uses in-field sensors to measure soil water content in the root zone. Technologies such as time-domain transmission (TDT) sensors, neutron probes, and capacitance sensors assess moisture levels, while satellite imagery can provide large-scale moisture mapping. This approach allows for variable-rate irrigation scheduling by detecting spatial variations in soil moisture content. By comparing sensor data with pre-set moisture thresholds, farmers can automate irrigation (Pramanik et al., 2022).
- 3. WEATHER-BASED APPROACH:** In this approach, weather stations equipped with sensors monitor environmental parameters, including temperature, humidity, solar radiation, wind speed, and rainfall. This data, combined with crop and soil information, is used to estimate the crop's water requirements. Advanced models and predictive analytics guide irrigation scheduling based on both short- and long-term weather forecasts, enhancing water-use efficiency.

KEY COMPONENTS OF SMART IRRIGATION SYSTEMS

Smart irrigation systems comprise several key components that work together to enhance water management efficiency:

1. SENSORS:

- **Soil Moisture Sensors:** Measure soil water content to determine the optimal irrigation time and volume.
- **Weather Sensors:** Track temperature, humidity, solar radiation, rainfall, and wind speed to estimate crop water needs.

2. AUTOMATED IRRIGATION CONTROLLERS:

- These devices automate water application based on real-time data, reducing human error and conserving water.

3. DATA ANALYTICS AND IOT:

- IoT platforms connect sensors, controllers, and cloud systems to provide data-driven insights and enable remote management.

4. WEATHER FORECAST INTEGRATION:

- Predictive models guide irrigation planning by incorporating weather forecasts, improving accuracy in water management decisions.

CONCLUSION

Smart irrigation systems offer a sustainable and efficient solution for managing water resources in agriculture. By utilizing advanced technologies such as sensors, weather forecasting, and automated controls, these systems ensure precise water delivery based on real-time crop needs and environmental conditions. This reduces water waste, lowers energy consumption, and boosts crop productivity. Additionally, data-driven insights from smart irrigation promote better decision-making, supporting sustainable farming practices and enhancing agricultural resilience. As water scarcity and climate variability intensify, adopting smart irrigation is essential for ensuring food security and long-term productivity. However, challenges such as high initial costs, technological literacy gaps, and infrastructure limitations must be addressed for widespread implementation. Future advancements in artificial intelligence and predictive analytics will further enhance irrigation efficiency, making it more adaptive and precise. Ultimately, smart irrigation is a key climate adaptation strategy, promoting water-use efficiency, sustainable agriculture, and resilience to global climate challenges.

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