

Digital Technologies for Precision Water Management

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OPEN ACCESS

Keywords

Precision Irrigation, IoT-based Sensors, Remote Sensing, Water Use Efficiency

How to cite this article:

Sharma, S., Sharma, G. D., Manuja, S., Mansingh, B., Kumari, G. and Dogra, P. 2026. Digital Technologies for Precision Water Management. *Vigyan Varta* 7 (04): 141-144.

ABSTRACT

By enabling effective, data-driven irrigation techniques in agriculture, digital technologies are revolutionising precision water management. Real-time monitoring of crop water requirements and field variability is made possible by tools like remote sensing, IoT-based soil moisture sensors, and GPS-guided systems. By lowering water waste and increasing water-use efficiency, these technologies facilitate site-specific irrigation. Irrigation scheduling and resource optimisation are further improved by integrating artificial intelligence and decision support systems. Precision water management reduces environmental effects, conserves water resources, and boosts crop productivity. It is essential for resolving water scarcity and guaranteeing sustainable agricultural production in the face of shifting climate conditions.

INTRODUCTION

Digital technologies for precision water management are revolutionizing agriculture by enabling efficient and targeted use of water resources. Traditional

irrigation methods are becoming less sustainable due to growing issues like water scarcity, climate variability, and rising food demand. Precision water management

monitors field conditions in real time using sophisticated tools like automated irrigation systems, remote sensing, and soil moisture sensors (Abioye *et al.*, 2022). These technologies reduce waste and increase water-use efficiency by assisting farmers in precisely applying water in accordance with crop requirements.

The integration of technologies such as Internet of Things (IoT), Geographic Information Systems (GIS), and decision support systems allows for data-driven irrigation planning and management. Improved scheduling and control of irrigation practices are made possible by farmers' access to real-time information via mobile applications. In addition to increasing crop productivity, this minimises environmental effects like runoff and nutrient leaching, conserves water, and uses less energy. All things considered, digital technologies are essential to the advancement of climate-resilient and sustainable agricultural systems.

Concept and Principles of Precision Water Management

Site-specific resource management is the foundation of precision water management. It acknowledges that soil characteristics, moisture content, crop growth stages, and microclimatic conditions vary within agricultural fields. Precision approaches customise irrigation techniques to meet the unique needs of various zones within the field, as opposed to applying water evenly throughout.

The key principles are:

- **Right timing:** Irrigation is scheduled based on crop water demand and soil moisture status.
- **Right quantity:** Water is applied in optimal amounts to avoid under- or over-irrigation.

- **Right place:** Water is delivered directly to the root zone to minimize losses.
- **Efficiency and sustainability:** Focus on conserving water while maintaining productivity.

Major Digital Technologies Used in Precision Water Management

1. **Soil Moisture Sensors:** Soil moisture sensors are among the most widely used tools in precision irrigation. They provide real-time information on the moisture status of the soil and measure the amount of water in the soil at various depths (Aivazidou *et al.*, 2021). Using this data, farmers can decide when irrigation is necessary and how much water to use. This helps prevent over-irrigation as well as water stress.
2. **Remote Sensing and Satellite Technology:** Satellites, drones, and aerial imaging systems are used by remote sensing technologies to track soil and crop conditions over wide regions. These systems are able to evaluate variables like soil moisture, evapotranspiration, and vegetation health. Targeted irrigation is made possible by satellite imagery, which aids in the identification of water stress zones within fields.
3. **Internet of Things (IoT):** The Internet of Things (IoT) is a system of interrelated physical objects that can transfer data over a network without requiring human-to-human or human-to-computer interaction. So, in agriculture, IoT based systems incorporate sensors, weather stations as well as and irrigation devices. These systems autonomously check the environmental conditions and manage irrigation systems, automatically ensuring the application of optimal amount of water with least human-input.

4. Geographic Information Systems (GIS):

Commonly, GIS is sought to analyze the spatial variability among agricultural fields. Its applications include mapping soil types, moisture levels and crop conditions. Combining geographic information systems with additional technologies allows farmers to create precise irrigation plans and perform site-specific water management.

5. Decision Support Systems (DSS):

DSSs are systems that combine data from multiple sources such as weather forecasts, soil sensors and crop models to make irrigation scheduling recommendations. Such systems allow farmers to decide when and how much water to apply more effectively.

6. Smart Irrigation Systems:

Automated drip and sprinkler systems include smart irrigation. The systems use real-time data to determine the amount of water that needs to be applied so that crops do not receive more water than needed, reducing waste. It helps to lower the labor requirements while maintaining consistency in irrigation practices.

Benefits of the Digital Technologies in Water Management.

The applications of digital technologies to the field of precise water management have a lot of advantages:

- **Greater efficiency of water-use:** Water is applied in the correct amount and at the time of need.
- **Increased agricultural output:** Correct irrigation results in an improvement of crop growth and better yield.
- **Less water wastage:** Minimizes the wastage of water through runoffs, evaporation and deep percolation.

- **Saving of energy:** The efficient irrigation will save energy used in pumping water.
- **Environmental protection:** Decreases the nutrient leaching and depletion of ground water.
- **Improved decision-making:** Timely decision-making by the management through the real-time information.

Challenges and Limitations

The implementation of the digital technologies has a number of challenges, though they are advantageous:

- **Expensive start up:** Expenses of sensors, equipment and infrastructure may be high.
- **Knowledge gap:** The farmers may not have sufficient expertise to use advanced technologies.
- **Poor internet connection:** IoT-based systems can be affected by poor internet accesses in rural locations
- **Problems in data management:** Processing and analysis of large data can be complicated. Maintenance requirements: Devices need maintenance and calibration.

Future Prospects

The integration of new technologies, which include artificial intelligence (AI), machine learning (ML), and large data analytics, is the future of precision water management. Such technologies are able to forecast the water needs in crops, maximize irrigation times and efficiency of the systems (Brahmanand et al., 2022). These technologies will be more accessible to farmers since they will use mobile applications or cloud-based platforms. This will be continued by government assistance, training, and the implementation of cost reduction measures that will encourage

farmers to adopt digital tools in agriculture (Gupta *et al.*, 2020).

CONCLUSION

The digital technologies are transforming in enhancing water management in agriculture. These technologies can aid in conserving water by allowing precise and efficient and even data-driven irrigation, resulting in increased crop productivity. Not only is precision water management able to deal with the challenges of water scarcity but also helps in the development of agricultural sector sustainably. Policy measures and awareness of the farmers are needed to ensure the wider usage of such technologies to secure the future food security and environmental sustainability

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