

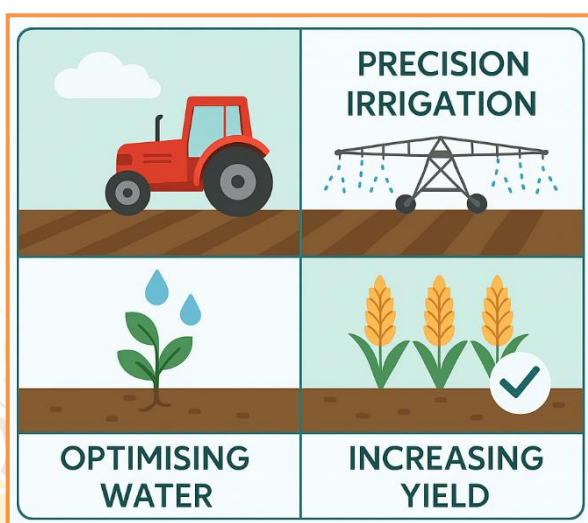
Enhancing Water Use Efficiency through Precision Irrigation in Agriculture

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Water is a biggest gift and blessing for agriculture practices. Real-time irrigation monitoring was crucial in crop understanding and evaluation. Currently every region global wise suffering from water scarcity and shortage due to abrupt climate change behaviour. The Utilisation of precision farming practices includes water saving technology for efficient water management system under such condition will put-forth better solution for farming communities. Through precision irrigation system, the delivery efficiency for crop plants gets maximize, thus promoting better water uptake, plant growth and lied on sustainability in water usage. Through reducing the water usage can aids for future generation farming. Thus, the present study article highlights the key use of potential precision irrigation system in agriculture.



Graphical Abstract

Introduction

Water is a vital resource for agriculture, with farming accounting for nearly 70% of global water withdrawals and up to 95% in some developing countries (Lakhia *et al.*, 2024). Different crops require varying amounts of water for optimal growth, making efficient water use essential. However, water scarcity - whether physical, due to limited natural water availability, or economic, caused by inadequate infrastructure - poses a serious threat to agricultural productivity and food security (Vianny *et al.*, 2022). With the world population expected to reach around 9 billion by 2050, increasing food production with limited water resources is a major challenge. Enhancing water use efficiency through precision irrigation offers a promising solution by applying water more accurately and sustainably, helping to secure food supply while conserving precious water resources.

Importance of water use efficiency

Efficient water use in agriculture is crucial for ensuring long-term food security, environmental sustainability, and resilience to climate change (Panotra *et al.*, 2024). As agriculture accounts for the largest share of global freshwater use, optimizing irrigation and water management practices can significantly reduce water waste, prevent soil degradation, and enhance crop yields (Ali *et al.*, 2025). With increasing water scarcity in many regions,

efficient use helps farmers maintain productivity while preserving water resources for future generations. It also minimizes the energy costs and environmental impacts associated with water extraction and distribution. Ultimately, sustainable water use in agriculture is essential for balancing the needs of people, ecosystems, and the planet.

What is Precision Irrigation?

Precision irrigation is an advanced agricultural technique that involves applying water to crops in the right amount, at the right time, and at the right location using modern technologies. Its goal is to maximize crop yield while minimizing water waste, energy use, and environmental impact. Unlike traditional irrigation methods, such as flood irrigation, which distribute water uniformly across entire fields regardless of crop needs, precision irrigation targets specific areas based on real-time data. Traditional methods often lead to overwatering, runoff, and inefficient use of water, while precision irrigation uses tools like sensors, GPS, and automation to deliver water more accurately and efficiently.

Tools and Technologies Used in Precision Irrigation

To effectively gather and utilize information, those interested in precision farming should become acquainted with the available technological tools. These include hardware, software, and best practices.

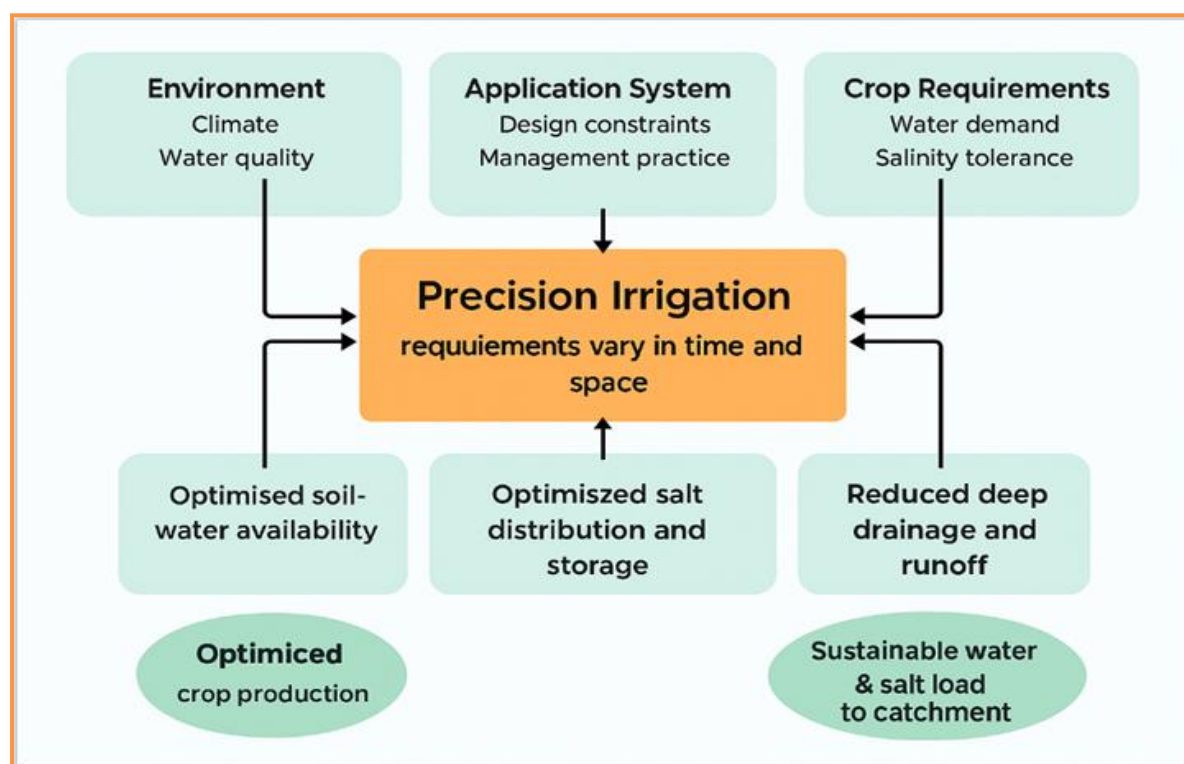


Fig. 1. Input and output of precision irrigation system. (Source: Smith *et al.*, 2021)

Technologies Involved in Precision Irrigation

1. **Soil Moisture Sensors:** These sensors are buried in the ground to track the soil's moisture content. They offer real-time data that helps avoid excessive or insufficient irrigation by determining when and how much water crops require.
2. **Weather Forecasting Tools:** Information on wind, temperature, humidity, and precipitation is provided by sophisticated weather stations and forecasting systems. With this knowledge, farmers can more effectively manage their irrigation schedules and steer clear of watering before the natural rainfall occurs.
3. **Internet of Things (IoT)-Based Irrigation Controllers:** By tying sensors, pumps, and valves together, IoT devices automate irrigation systems. These controllers allow for precise and remote irrigation management by modifying watering schedules and quantities in response to real-time data.

4. Satellite and Drone Imaging: To keep an eye on crop health, soil conditions, and places experiencing water stress, satellites and drones take high-resolution pictures of fields. Farmers may identify field variations and administer water just where necessary with the aid of these photos.
5. Geographic Information Systems (GIS) and GPS Technology: These technologies aid in the mapping of fields and the highly precise guidance of irrigation equipment, guaranteeing precise water application in various zones.
6. Automated pumps and valves: These devices employ sensor data to automatically control water flow and pressure, ensuring that each section of the field receives the proper amount of water.

Benefits of Precision Irrigation

Numerous advantages of precision irrigation help make agriculture more productive and sustainable. It greatly lowers water waste and increases crop yields by supplying the appropriate amount of water at the appropriate time and location. This technique reduces nutrient leaching and soil erosion, helps preserve essential freshwater resources, and saves energy expenditures related to pumping and distributing water (Waqas et al., 2025). Additionally, precision irrigation increases resistance to drought and climate variability by enabling farmers to make data-driven decisions that better adapt to changing weather and soil conditions. In the end, it encourages more ecologically friendly farming methods, lowers input costs, and produces healthier crops.

Challenges and Limitations of Precision Irrigation

Although precision irrigation has many advantages, there are a number of drawbacks and restrictions. Advanced systems like drip networks, automated controllers, and soil sensors can be too expensive for small and medium-sized farmers to install initially. Furthermore, the system necessitates routine upkeep, technical expertise, and accurate calibration -all of which may be deficient in remote or underdeveloped regions. IoT-based systems may not be as effective in some areas due to inadequate internet access and unreliable power supplies. Sensor and imaging data interpretation can also be complicated, necessitating professional assistance or training. The complexity and expense may also be increased by the need for specialized solutions due to variations in crop kinds, soil types, and regional climates. These obstacles may hinder adoption, particularly in poor nations, underscoring the necessity of infrastructure development, funding, and education to increase the effectiveness and accessibility of precision irrigation.

Conclusion

Precision irrigation plays a vital role in transforming agriculture into a more sustainable, efficient, and productive sector. By using advanced technologies such as soil moisture sensors, weather forecasting tools, IoT-based controllers, and remote imaging, farmers can apply water precisely where and when it is needed, significantly reducing waste and improving crop yields. This targeted approach not only conserves freshwater resources but also lowers energy and input costs while minimizing environmental impacts. Although challenges like high initial costs, technical complexity, and infrastructure limitations exist, the long-term benefits make precision irrigation a valuable investment for the future of farming. With greater awareness, support, and innovation, precision irrigation can help ensure food security and environmental sustainability in an increasingly water-scarce world.

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