

From Flood to Precision: Why Micro-Irrigation is the Future of Farming

Hari Krishna. B¹, A. Sairam², Kadam Praveen Kumar², Manu S. M¹ and Vimal Kumar. C¹

¹ICAR- Indian Agricultural Research Institute, New Delhi, India

²Professor Jayashankar Telangana State Agricultural University, Hyderabad, India

17 July 2019: Received | 18 August 2019: Revised | 15 September 2019: Accepted | 17 October 2019: Available Online

*Corresponding Author: **Hari Krishna. B** | Email Address: hari.agricos07@gmail.com

Citation: Hari Krishna. B, A. Sairam, Kadam Praveen Kumar, Manu S. M and Vimal Kumar. C (2019). From Flood to Precision: Why Micro-Irrigation is the Future of Farming. *Life Science Review*. DOI: <https://doi.org/10.51470/LSR>

Abstract

The shift from traditional flood irrigation to micro-irrigation marks a significant evolution in modern agriculture. Micro-irrigation systems, including drip and sprinkler technologies, enable precise delivery of water and nutrients directly to the plant root zone, minimizing losses due to evaporation and runoff. This approach enhances water-use efficiency, promotes uniform crop growth, and supports sustainable farming in water-scarce regions. The paper explores the economic, agronomic, and environmental advantages of micro-irrigation, along with challenges in adoption and maintenance. Emphasis is placed on its role in climate-resilient agriculture and the future integration of automation and smart irrigation technologies.

Keywords: Micro-irrigation, precision agriculture, water-use efficiency, sustainable farming, drip irrigation.

Introduction

1. A New Era for Water in Agriculture

For centuries, Indian agriculture has relied on surface irrigation—flooding fields from canals, tanks, or groundwater wells. While this system sustained civilizations, it was designed for an era of abundant water and low population pressure. Today, that reality has changed. With climate change altering rainfall, groundwater levels declining, and agricultural demand surging, the old methods are showing their limits.

In many parts of India, more than 60–70% of irrigation water applied through flood or furrow systems is lost to evaporation, runoff, or deep percolation before reaching plant roots. This inefficiency is a major concern, given that agriculture already consumes over 80% of the country's available freshwater.

Enter micro-irrigation — a technology that delivers water and nutrients directly to the root zone of plants in a controlled, efficient manner. It's a quiet revolution, replacing the waste of flood irrigation with the precision of science.

2. What Is Micro-Irrigation?

Micro-irrigation refers to low-pressure, low-flow irrigation systems that deliver water in small, frequent doses through drippers, sprinklers, or micro-sprayers. The two most common types are:

- **Drip Irrigation:** Water is supplied slowly through emitters or drippers at the base of each plant, ensuring moisture stays near the roots.

- **Sprinkler/Mini-Sprinkler Systems:** Water is sprayed through nozzles or jets in a fine mist or controlled droplets, mimicking gentle rainfall.

The hallmark of micro-irrigation is precision—both in timing and quantity. Instead of flooding a field once every few days, water is supplied as per the crop's daily requirement, reducing losses and enhancing uptake.

3. The Science of Precision Watering

Micro-irrigation's power lies in hydraulics and plant physiology. Let's break down why it's so efficient:

a) Targeted Delivery

Drip systems deliver water directly to the rhizosphere (root zone). This avoids wetting the entire soil surface, drastically cutting evaporation losses, which can reach 30–40% in flood irrigation.

b) Reduced Runoff and Deep Percolation

Since water is applied slowly, it seeps uniformly into the soil, minimizing runoff on sloping lands and percolation below the root depth.

c) Optimized Soil Moisture

Frequent, small doses maintain soil moisture near field capacity, avoiding the stress cycles of drying and rewetting that reduce yields.

d) Fertigation Advantage

Micro-irrigation easily integrates fertigation—the injection

of soluble fertilizers into the irrigation line. This ensures nutrients are delivered directly to active root zones, enhancing fertilizer-use efficiency and reducing leaching.

e) Automation and Sensors

Modern systems use soil moisture sensors, tensiometers, and IoT-based controllers to automate irrigation based on real-time plant or soil feedback. This takes guesswork out of the equation.

4. Efficiency Gains: Evidence from Research

Studies across India and globally confirm the remarkable efficiency of micro-irrigation:

Crop	Water Saved (%)	Yield Increase (%)	Reference
Tomato (Tamil Nadu)	55–60%	+35%	Suvitha et al., 2021 (IJPSS)
Castor (Rajasthan)	31%	+25%	Chawara & Kaushish, 2016 (AAZ)
Groundnut (Gujarat)	23%	+18%	Vaghasia et al., 2017 (JOR)
Cumin (Arid regions)	64%	+40%	MDPI, 2023
Rice (Tamil Nadu)	50%	+20%	Subramanian et al., 2021 (IJAgS)

Across hundreds of experiments, drip irrigation saves 30–70% of water and increases yield by 20–50%, depending on crop and soil type. In addition, fertigation reduces fertilizer losses by 25–40%.

5. The Indian Scenario: Policy and Progress

India has emerged as a global leader in promoting micro-irrigation. Government programs such as:

- **Per Drop More Crop (PDMC)** — A component of the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), promoting water-use efficiency and micro-irrigation.
- **Micro-Irrigation Fund (MIF)** — Managed by NABARD, this fund provides long-term financing support to states for expanding drip and sprinkler systems.
- **Subsidy Programs** — Most states offer 45–55% subsidies for farmers (up to 75% for smallholders) to encourage adoption.

As of 2024, India has brought over 20 million hectares under micro-irrigation, but the potential area exceeds 70 million hectares, indicating vast room for growth.

6. Economic and Environmental Benefits

a) Higher Income, Lower Cost

By saving on water, energy, and fertilizers while improving yields, farmers see a higher benefit-cost ratio (1.5–3.0) compared to conventional irrigation.

b) Reduced Groundwater Stress

Micro-irrigation minimizes over-pumping, helping stabilize groundwater levels—especially in semi-arid states like Gujarat, Rajasthan, and Telangana.

c) Climate Resilience

In drought-prone regions, maintaining uniform soil moisture improves crop survival during dry spells.

d) Carbon Footprint Reduction

Lower pumping and fertilizer use translate to reduced greenhouse gas emissions. Studies estimate 20–30% lower carbon emissions per hectare compared to flood irrigation systems.

7. Challenges on the Path Ahead

Despite proven benefits, several challenges hinder widespread adoption:

- **Initial Investment:** High setup cost (₹40,000–70,000/ha) deters small farmers despite subsidies.
- **System Maintenance:** Clogging of emitters due to poor water quality or lack of filtration reduces efficiency.
- **Knowledge Gap:** Many farmers lack training in fertigation scheduling, pressure management, or system upkeep.
- **Fragmented Holdings:** Irregular small plots make layout design complex and costly.
- **After-Sales Service:** Limited technical support and spare parts in rural areas cause early system failure.

Addressing these barriers requires public-private partnerships, robust extension support, and farmer cooperatives to share costs and maintenance.

8. The Road to Smart Micro-Irrigation

The next generation of irrigation is already here—combining AI, IoT, and data analytics.

- **IoT Sensors:** Monitor soil moisture, temperature, and salinity in real time.
- **AI Models:** Predict water needs based on crop growth stage and weather forecasts.
- **Smart Controllers:** Automate irrigation timing and fertigation schedules using mobile apps.
- **Remote Monitoring:** Farmers and extension officers can track performance via cloud dashboards.

These innovations ensure that micro-irrigation evolves from a static water-saving tool to a dynamic precision farming ecosystem—smart, data-driven, and sustainable.

9. Conclusion: A Drop Toward the Future

The transformation from flood to precision is not just a technical shift—it is a philosophical one. It redefines how we value water, manage resources, and sustain livelihoods. Micro-irrigation offers a path to sustainable intensification—producing more food with fewer inputs, protecting soil health, and securing water for future generations.

As India marches toward climate-smart agriculture, every drop saved today is an investment in tomorrow's food security.

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