

# Significance of micro-irrigation for feasible and sustainable agriculture: A review



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**Abstract** The aim of this research is to conduct a thorough assessment of earlier studies on the impact of microirrigation on various crop farming scenarios, with a focus on water use efficiency, cost effects and yield enhancement. The depletion of agricultural water supplies and the increasing demand from various sectors demonstrate the need to increase the efficiency of water consumption. India has devised a unique approach to address these problems by using drip and sprinkler irrigation systems as a form of microirrigation. To provide important insights into the revolutionary potential of microirrigation systems, this research aims to shed light on the impacts and economic impact of deploying microirrigation on diverse crops. By addressing the difficulties associated with traditional irrigation techniques, this research aims to enhance the understanding of microirrigation as a strategy for optimising water resources, reducing the ecological footprint, and promoting sustainable farming methods within the distinct framework of agriculture. The resource-based view, which underpins the study's theoretical framework, contends that a sustained competitive advantage may be attained via the strategic utilisation of resources through microirrigation technology. Microirrigation systems are vital resources that affect crop yield, cultivation expenses, and water conservation. In summary, these studies highlight the importance of sustainable irrigation techniques, especially drip and sprinkler irrigation, to address water shortages, improve water usage efficiency, and guarantee the long-term viability of agriculture in India and throughout the world. In order to improve the sustainability of farmers by reducing input costs and increasing profitability, the study will look into how microirrigation might be beneficial. Additionally, it will evaluate these systems' long-term viability in light of shifting climatic circumstances. The objective of this research is to enhance comprehension of how technological improvements might promote resilient agriculture practices by providing a comparative examination of traditional and microirrigation systems.

**Keywords:** drip-irrigation, cost of cultivation, microirrigation, and water use efficiency, sustainable agriculture

## 1. Introduction

Microirrigation has played a major role in addressing the global challenge of water shortages, highlighting the need for various alternative irrigation technologies and sustainable farming practices. The consumption of around 70 percent of the world's freshwater resources by agriculture is contributing to the growing urgency of the problem of water scarcity on a global scale (FAO, 2017). Microirrigation, which uses drip and sprinkler systems, is an innovative replacement for flood irrigation that provides a more accurate and effective method for irrigating crops. This not only results in a substantial increase in crop yield, but it also results in a considerable reduction in weed problems, soil erosion, and cultivation costs, particularly in businesses that demand a significant amount of manpower. The extraction of water from irrigation wells is accomplished by the use of micro-irrigation, which not only consumes less water but also requires less energy (electricity) (Narayanamoorthy, 1995 and 2001).

With a focus on the water shortage issue in the agricultural sector, this study aims to present a thorough analysis of previous research on the use of microirrigation in a variety of crop farming applications. The objective of this study was to investigate the functions of microirrigation systems in current agriculture in depth. It examines how well microirrigation methods work to improve crop yields, lower environmental impacts, and increase water efficiency while supporting sustainable agricultural practices.

As a result of population expansion, a rise in the demand for food, and the consequences of climate change, it is anticipated that by the year 2050, more than half of the world's population will be residing in regions that are experiencing water stress. (2018) According to the World Water Development Report published by UNESCO. Furthermore, in order to reduce the amount of groundwater that is extracted, it is essential to enhance the use of microirrigation worldwide. India offers a plethora of opportunities and challenges given the pivotal role of the agricultural sector in the country's economy. Because it employs approximately 60% of the workforce and makes a considerable contribution to the GDP, the agricultural sector must apply a range of strategies. The India Water Portal promotes contemporary technology adoption, crop diversification, efficient



irrigation techniques such as drip and sprinkler irrigation, effective water management strategies, precision farming, and rural development (Agriculture, India water portal Agriculture | India Water Portal). Microirrigation has emerged as a water-saving irrigation technique that increase crop yield not only in India but also in China. These developments have elevated microirrigation to a significant milestone in China's agricultural modernisation (Li, 2020). According to INCID, 1994; GOI, 2004 DMI expanded from 1500 ha in 1985 to 70,859 ha in 1991-92 and 5,00,000 ha in March 2003. From 1985-86 to 1997-98, the area under SIM expanded from 0.23 mha to 0.67 mha and then to 1.63 mha in 2004-05. Over the past 15 years, micro-irrigation has grown significantly, although its share of the gross irrigated area is still low. INCID (1994) report compared the same crops that were cultivated using the flood method of irrigation, the drip method of irrigation improves crop yield and helps reduce the cost of cultivation. In addition, it helps reduce the amount of water that is consumed throughout the cultivation process. A significant number of studies have been conducted, primarily with the use of experimental data, with the purpose of investigating the impact that the drip technique of irrigation has on the productivity of crops.

## 2. Materials and Methods

The research methodology consists of three steps. A body of knowledge on microirrigation research on various crops was gathered and analysed by analysing the literature. Second, the literature was divided into categories and examined individually to analyse the environmental and economic impacts of microirrigation. The last stage's conclusion addresses the study purpose and is based on the synthesis of data. It offers a thorough analysis of the results and their consequences.

Research, Practical & Social implications: The efficacy and comparative water consumption efficiency of microirrigation systems are the primary focus of this study. Providing support and encouragement for the widespread adoption of microirrigation devices is a practical way to increase water efficiency. Farmers and other stakeholders need to be aware of the drawbacks of conventional flood irrigation, and sustainable water usage methods need to be promoted to address concerns about water scarcity.

## 3. Results and Discussion

### 3.1. Challenges of traditional flood method of irrigation

The traditional flood irrigation technique used in Indian agriculture has high water usage efficiency because of the large conveyance and distribution losses. Although these techniques are widely used, traditional flood irrigation techniques provide severe transportation and distribution issues that can lead to significant water waste. Improving agricultural water usage efficiency is essential as demands from different sectors increase and irrigation water supplies decrease (Madramootoo and Morrison, 2013). Narayanamoorthy (2009, 2010) highlighted the need for demand management approaches to save groundwater and enhance water use efficiency in the agricultural sector, given the growing problems of diminishing irrigation water potential and increasing demands from several different sectors.

### 3.2. Microirrigation as a revolutionary approach

Microirrigation is an innovative approach for Indian agriculture to overcome inefficiencies in conventional techniques. This method represents a calculated move in the direction of maximising water use by combining drip and spray irrigation systems. Together with previous research by Narayanamoorthy (1996, 1997) and Sivanappan (1994), Narayanamoorthy and Deshpande (2013) demonstrated the potential of microirrigation for reducing water-related issues and providing an effective and sustainable method for irrigating crops.

### 3.3. Microirrigation practices for sustainable agriculture

The UN World Water Development Report 2022 highlights the importance of microirrigation techniques in tackling issues that India's agriculture is facing. According to the paper, implementing microirrigation techniques can lead to enhanced soil and water quality, higher prices for farmers, lower input costs, and crop resistance to climate change. It can also increase public investment in agriculture (Agriculture | UN World Water Development Report 2022).

### 3.4. Water and fertiliser conservation

Microirrigation (MI) methods, such as drip irrigation and sprinklers, offer a revolutionary way to manage fertiliser and water in agriculture. According to Dhawan (2002) and Saleth & Amarasinghe (2010), MI systems increase water-use efficiency by 50–90% by providing precise and targeted water to crop root zones. This reduces the environmental impact on water bodies by minimising fertiliser leaching and conserving water resources. According to data from the Government of India, the implementation of MI may result in a 25% decrease in the amount of fertiliser applied, which would minimise cultivation costs and increase farm profitability (Kumar & Palanisami, 2011; Narayanamoorthy, 2010; Pfeiffer & Lin, 2013). MI promotes environmental care and reduces energy usage, which goes beyond economic benefits to support sustainable agriculture. In

other words, using MI systems is a critical tactic for reducing the amount of water and fertiliser used while maintaining the sustainability and profitability of farming operations (Nair, 2023).

### 3.5. Evapotranspiration

Temperature, humidity, wind speed, and drop fineness all affect sprinkler evaporation losses; these factors are further impacted by the pressure and nozzle size of a sprinkler device. The typical amount of evaporation in the sprinkler output is between 2% and 8%. The overall evapotranspiration of a newly sown crop does not exceed its mean rate. Direct evaporation from foliage stops is a substantial cause of water loss, and free water on foliage greatly decreases leaf transpiration. An 85–90% range of water application efficiency is often maintained; (Lenka, 2005).

### 3.6. The economic impact of various irrigation techniques

The positive effect of irrigation systems on operating expenditures has been proven in several studies worldwide. Pumping costs were highest for sprinkler systems and lowest for basin irrigation. Labour costs were higher for irrigation systems with furrows and basins since ridges and dykes had to be constructed in addition to the system's running expenses. In terms of the cost-benefit ratios, okra had values of 1.24, 1.41, 1.01, and 1.52 for spray, drip, basin, and furrow irrigation, respectively, whereas amaranth had values of 1.50, 1.78, 1.22, and 1.55, respectively. With a marginal return of Rs of 1.24 for okra and Rs of 1.52 ha<sup>-1</sup> for amaranth, following spray irrigation, basin irrigation was the least costly technique. Drip irrigation had the highest cost-benefit ratio for amaranth, with Rs values of 1.78 and 1.41 ha<sup>-1</sup> for okra and amaranth, respectively (Okunade et al., 2010).

Compared with flood irrigation, drip irrigation in Maharashtra resulted in power savings of 44% in sugarcane, 37% for grapes, and 29% for bananas, according to findings by Narayanamoorthy (1996 and 2001). Similar findings were reported by Narayanamoorthy's field survey in 2004, which revealed that sugarcane in Pune and Ahmedabad saved 48% and 41% of their electricity, respectively. Drip irrigation systems conserve power, which is one of their key advantages (Andal, 2011). Drip irrigation greatly reduces the number of hours a pump-set needs to run since it uses less water. As a result, the amount of energy required to irrigate a unit area of land has significantly decreased (Narayanamoorthy, 2003).

**Table 1** Economic analysis of drip and furrow irrigation for sweet peppers.

Activity	Furrow Irrigation (\$/HA)	Drip Irrigation (\$/HA)
Labor	7.41	3.7
Land preparation	161	171
Seed	138.3	138.3
Fertiliser	971	349
Pesticides	133.4	89
Irrigation	200.1	122.26
Total cost	3625	3026
Total income	4940	7163
Net income	1315.4	4137
Benefit cost ratio	1.36	2.37

*Source:* Computed from the article Impact of Drip and Furrow Irrigation Methods on Yield, Water Productivity and Fertiliser Use Efficiency of Sweet Pepper (Asif, et.al. 2016).

A comparative economic analysis of two irrigation techniques, furrow and drip, for growing sweet peppers is shown in Table 1. Furrow irrigation costs more labor, fertiliser, pesticide, and water than does drip irrigation. The overall cost of furrow irrigation is \$3625 per hectare, whereas drip irrigation costs \$3026. Despite the lower overall cost, furrow irrigation generates a total income of \$4940 per hectare, with a net income of \$1315.440 per hectare. In contrast, drip irrigation yields a higher total income (\$7163 per hectare) and net income (\$4137 per hectare). A larger benefit-cost ratio (2.37) for drip irrigation than for furrow irrigation (1.36) further suggests that the former is more profitable. This study highlights the possible cost benefits of switching from furrow irrigation to drip irrigation for growing sweet peppers.

### 3.7. Impact of microirrigation on different crops

Numerous studies that have examined how different irrigation techniques affect different crops have also revealed the potential advantages of microirrigation systems such as drip irrigation.

- A study demonstrating the revolutionary impacts of drip irrigation on groundnut production was carried out by Narayanamoorthy et al. in 2020. Compared with conventional flood irrigation techniques, their research revealed a significant 79% increase in groundnut yield and an impressive 36% decrease in water use. Drip irrigation increased farmers' income by reducing labour costs, weeding, and inter-cultivation expenses while also optimising water use.
- The importance of drip irrigation for sugarcane growth is highlighted by Afzal (2023) and Narayanamoorthy (2005). According to their research, drip irrigation not only increases sugarcane output but also saves 41% of electricity. Drip



irrigation is a useful tool in water management techniques for sugarcane farming since it reduces electricity use, which solves concerns about environmental effects and economic sustainability.

- The effects of drip irrigation on cotton farming were studied by Choudary et al. (2016). Their study clarified how supplying accurate water directly to the root zone reduces water waste and maximises moisture availability, which noticeably improves seed cotton output. Drip irrigation works well for cotton growers as a sustainable alternative since it uses less water while increasing production.
- The impact of drip-irrigation on red chili cultivation was investigated by Devika et al. (2016). According to their findings, using drip irrigation resulted in a noteworthy 43% decrease in water use and a corresponding 39% increase in output. This finding illustrates how this technique might improve the economic viability of red chili producers while simultaneously addressing concerns about water shortages.
- Garg et al. (2004) reported that when irrigation was applied at an IW/CPE ratio of 0.7 (four irrigations), the test weight and seed output were considerably greater than when the ratio was applied at an IW/CPE ratio of 0.3 (two irrigations).
- When drip irrigation was scheduled at 0.8 PEF post monsoon season, Patel & Rajput (2008) reported that castor seed output increased by 36% while conserving 25% of water compared with surface irrigation. This study assessed the practicality of drip irrigation for castor plantations.
- Research carried out in Morocco by Kharrou et al. (2011) revealed that switching from surface irrigation to drip irrigation enhanced water productivity by 24% and wheat output by 28%.
- Under different irrigation water regimes, Ad El-wahed & Ali (2013) investigated the impact of sprinkler and drip systems on maize production and water productivity in Egypt. They discovered that drip irrigation greatly increased maize grain output relative to spray irrigation, with corresponding gains in water consumption.
- To compare various drip irrigation levels and flood irrigation for onion seed crops, Sankar et al. (2014) carried out an experiment in Maharashtra. Compared with surface irrigation techniques, drip irrigation at 100% potential evapotranspiration (PE) on a daily basis improved growth metrics and produced more seeds while using less water.
- Drip irrigation is beneficial not only for the crops listed above, but also for potatoes, green chilies, and other agricultural products. Drastic irrigation techniques have been shown to increase yields and save resources by Khan et al. (2001), Patidar et al. (2021), and Okunade et al. (2010). These studies highlight the viability and sustainability of microirrigation systems for a variety of crops economically, reiterating their significance in modern agricultural practices.
- In summary, these investigations highlight the importance of drip irrigation in sustainable agriculture by demonstrating its ability to increase crop output and water productivity in a variety of crops and geographical areas.

#### 4. Final Consideration

This study highlights the profound influence that Microirrigation (MI) systems have on farming methods, which extends much beyond basic resource preservation. Because they promote higher productivity, environmental sustainability, and economic sustainability, MI systems fundamentally alter the nature of agriculture.

The term "increased productivity" first and foremost highlights the fact that microirrigation systems actively improve the productivity and efficiency of agricultural operations in addition to just preserving resources. MI systems increases overall productivity and yields by accurately supplying water to crop roots. This optimises the growing conditions.

The second point is that the term "economic viability" draws attention to the monetary advantages of implementing MI systems. Through careful cost-benefit evaluations, these technologies not only demonstrate their economic viability but also help reduce overall cultivation costs.

The emphasis on "environmental sustainability" also acknowledges the vital role that MI systems play in resolving environmental issues such as resource depletion and water shortages. By lessening the environmental effects of conventional irrigation techniques, microirrigation systems support sustainable water management. The importance of microirrigation systems in addressing these issues is growing as concerns about ecological balance and climate change spread around the world. Futures agriculture is shaped in part by microirrigation systems. Microirrigation stands out as a ray of hope, providing a comprehensive answer, as the globe is struggling with water scarcity and the depletion of natural resources. In addition to serving as effective instruments for resource management, these technologies are seen as essential elements in the transition toward a future in agriculture that is more resilient and sustainable. Agrarian economies are supported by economic sustainability, which guarantees farmers' long-term financial success from their farming activities.

The paper's conclusion, taken as a whole, essentially recognises microirrigation systems as more than just a technological achievement; it recognises them as revolutionary forces reshaping agriculture's future through increased output, feasible economic practices, and protection of environmental sustainability.

#### Ethical Considerations

Not applicable.

## Conflict of Interest

The authors declare that they have no conflicts of interest.

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