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Impacts of Micro-irrigation Technologies in Maharashtra: A Review

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ABSTRACT

Micro-irrigation technologies have been an integral part of modern agriculture. Ranging from 'increased crop yield' to 'improved economic benefit,' such systems have much to offer. However, costly installation procedures and high socioeconomic barriers restrict their diffusion with relatively cheap alternatives. Appropriate policies and innovative approaches enable crossing these barriers only if carefully crafted to meet economic, technological and socio-economic challenges. This review offers an overview of significant strategic policies and new-generation micro-irrigation technologies that would help tap their full potential. Based on previous studies and individual experiences from India, an assessment of the transformative impacts of micro-irrigation has been done. These micro-irrigation technologies are proving highly beneficial for Maharashtra. The main gains that accrued to farmers from the process include reduced costs of cultivation, lesser dependence on chemicals and pesticides, conservation of water resources*and* less expenditure on labor. The above results manifest the contribution or role of micro-irrigation to accelerate sustainable agriculture, which induces a second green revolution imbued with higher productivity, efficiency in resource mobilization and economic prosperity.

Key words: Drip, Impact, Micro-irrigation.

Water scarcity is one of the significant challenges that farmers face in crop production (Joy *et al*., 2021). Water is the most essential and critical input for agriculture. With a view of global concern for food security and environmental sustainability, the demand for irrigation water for crops is intensifying alongside the methods of efficient use of irrigation water (Roja *et al*., 2021). Dealing with the issue of increasing groundwater scarcity and the accompanying exhaustion of groundwater resources in many states calls for a two-pronged strategy that addresses supply and demand in terms of water management. Because it represents nearly 80% of total water use within India, a central targeted effort revolves around reducing the aggregate water demand to make it commensurate with the projected future supplies so that the level of water stress expected to prevail in the country can be limited, according to Kumar (2003).

Tap measures to increase water supply, such as the construction of storage dams, interlinking of rivers, desalination of seawater, artificial recharge of groundwater and rainwater harvesting, can be described as significant and long-term initiatives. On the other hand, a package of demand management options, including water pricing, developing water users' associations and turnover systems, has been implemented since the late 1970s. These measures are targeted at increasing water use efficiency and have become integral parts of the overall approach to managing limited water resources, as Molden *et al*. (2001) put it. Pitcher irrigation, a traditional system of irrigation alternative to the drip method, is a practical innovation of localized irrigation methods (Adhikary *et al*., 2021; Hussain and Guha, 2021). In this respect, drip irrigation emerges as a very effective irrigation method, as Keller and Blisner (1990) noted. Micro-irrigation technologies, therefore, become conflictingly efficient in water savings. Aeroponics is a water-saving farming technique that uses up to 98% less water than traditional farming methods (Sumarni, 2021). On the one hand, the efficiency of these technologies is seen as resulting in a net saving of water and, therefore, provides a solution to water scarcity. Reduced losses through evaporation and inefficiencies of field conveyance and distribution are principal ways water savings increase. In this framework, the state governments in India have been actively promoting the widespread adoption of micro-irrigation technologies. However, the utility of such technologies for farmers may

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differ from the state's objectives. Farmer objectives will be influenced more by parameters enhancing their yield, reducing labor and output quality and the quality required for marketing.

The second viewpoint maintains that although micro-irrigation technologies certainly save water at an individual plot or field level, it might not necessarily result in net water savings at an aggregated level of a watershed or basin level (Molden *et al*., 2001; Narayanamoorthy *et al*., 1997). According to this view, net water savings may be moderate, especially with the phenomenon of return flows, where a significant share of the return flow goes toward recharging underground water sources. Thus, water savings at the basin level will not automatically occur without institutional and economic policy instruments to ensure that the saved water is distributed or allocated equitably. A debate exists on whether micro-irrigation systems save water and energy and improve income and employment opportunities. This fact alone poses challenges and risks to the farming community; the study seeks to address the benefits of micro-irrigation and constraints in adoption.

Impact of micro-irrigation technologies

The literature on the impacts of micro-irrigation technologies advocated that it is a critical technology for achieving the following key objectives. Micro-irrigation is a pivotal technology for water conservation in irrigated agriculture, which is essential to help meet pending water crises (Narayanamoorthy, 2003; Verma, 2004). Micro-irrigation is promoted as a technology for the rural community to increase income and reduce poverty. Another important use is to improve rural households' food and nutritional security, primarily by cultivating vegetables (Upadhyay, 2003; Upadhyay and Samad, 2004). The last important identification is to spread the available water over a larger cropped area, particularly in drought or pre-monsoon season.

Poverty is reduced after adopting micro-irrigation technologies because of increased farm income due to increased areas under cultivation, increased yield, improved quality of output produced, early maturity and reduced cost for many cultivation operations, especially irrigation and weeding. It also helps to secure a country's nutrition by producing and consuming vegetables on the farm, which bridges the dietary gap of the staple, mono-crop diet. Many studies in India mention micro-irrigation technologies that have given way to high returns from farmers' investments, such as those by Dhawan (2002).

The principle access mechanism for demand management is micro-irrigation in the form of drip and sprinkler irrigation that has superior to traditional irrigation for more reasons since it increases water use efficiency, energy savings and then yield increase also, as reported by Kumar and Palanisami (2010). In addition, sprinkler irrigation creates conditions of suitable microclimate for crop growing, contributing to higher crop and water use efficiency (Yang *et al*., 2000; Tianxue *et al*., 2024).

Drip irrigation helps reduce costs in labor-intensive operations like plowing and weeding while addressing the environmental concerns associated with surface irrigation, such as waterlogging and salinity (Narayanamoorthy, 2005). Drip irrigation helps water conservation, increases water-use efficiency, decreases tillage requirement, higher product quality, enhances crop yield and improves fertilizer use efficiency (Qureshi *et al*., 2001; Namara *et al*., 2005). Water-use efficiency is estimated to double in well-designed and managed drip irrigation systems (Sivanappan, 1994). Nevertheless, despite several advantages, only a few states in India, viz.andhra Pradesh, Maharashtra and Tamil Nadu had significant areas under micro-irrigation.

These limited adoptions are attributed to high costs, technological complexity and socio-economic problems like a lack of access to credit, inequitably distributed landholdings and localized cropping patterns. Further, inadequate design of irrigation systems, especially for small and marginal farmers, is a significant factor that restricts the diffusion of micro-irrigation. The element marginal productivity of water and water-use savings motivate farmers to adopt drip irrigation and net returns increase per unit volume of groundwater (Chandrakanth *et al*., 2013).

In the scenario of the deepening of the groundwater market, the failing of irrigation has reported a greater probability of drilling additional wells, especially in the districts of Kolar and Bangalore of Karnataka, thus worsening the negative reciprocity externality, wherein a negative vicious circle, the farmers are caught up in contributing to and losing because of the evil of groundwater over-extraction (Chandrakanth and Arun, 1997).

The impact of micro-irrigation technologies on different crops has been widely explained in several studies and here we evaluate some of these studies, which provide immense insights into the scope of benefits and opportunities connected to these in-depth adoption tools and diverse forms of resultant problems.

Bhaskar *et al*. (2005) - Maharashtra, India

Bhaskar *et al*. (2005) in a study to indicate the effect of micro-irrigation on cotton pulsed, realized increased yield for all crops. Their findings declared that a range between 15% and a remarkable 66% improvement in yield was achieved for cotton, Kastor, groundnut and potato.

Bahinipati and Viswanathan (2016) - Gujarat, Western India

This study assessed the impact of institutions and policies on the diffusion of micro-irrigation and noted the dynamism in Gujarat state. It attributed this to the channeled approach of the state, which used specific variables to target the subsidies, such as the socio-economic status of the farmer and, for this reason, recorded a high uptake rate compared to the others.

Kiruthika (2014) - Tamil Nadu, India

The results by Kiruthika on the determinants of drip adoption by sugarcane farmers pointed out that younger sugarcane farmers and those with offers of extension services were more likely to take up drip irrigation, illustrating aptly the importance of addressing demographic and outreach determinants in the promotion of micro-irrigation technologies.

Palanisami *et al*. (2011) - Nine states, India

The identified obstacles to adopting micro-irrigation include the high technology cost, complexity, socio-economic obstacles such as access to credit and land fragmentation. The study has, therefore, called for reduced capital costs and widened technical know-how.

Reddy *et al*. (2017) - Guntur, Andhra Pradesh

In its account of a study on the evaluation of drip systems in selected villages, it was noted that drip systems proved to have substantial benefits for farmers in terms of increased land area cultivation and operational cost reduction. The survey further said that its adoption had significantly improved the economic and agricultural facets.

Prospects of micro-irrigation in India (2016)

A strategy paper focusing on the role of micro-irrigation in Indian agriculture brought to light its pivotal role in propelling agricultural growth within India. Water technology can enhance productivity while conserving water and elevating micro-irrigation to a technological dais in Indian agriculture.

Irfan *et al*. (2014)- impact irrigation management on maize

Studied the impact of different irrigation systems on the production of maize and concluded that drip irrigation was more efficient under saline water. The recommendation from the study was to adopt drip irrigation in the marginal to hazardous groundwater quality for better crop production and water use efficiency.

Kumar *et al*. (2016) - Moradabad, U.P.

As per this study, the drip irrigation practice resulted in more brinjal yield and water use efficiency, whereas the optimal water use efficiency was noticed under 65% of irrigation.

Namara *et al*. (2005) - Maharashtra and Gujarat, India

Assessment of Adoption and Impact of Micro-level Irrigation Technologies led to the conclusion that the marginal productivity of water improved with micro-irrigation, resulting in the efficient utilization of water.

Paul *et al*. (2013) - Bhubaneswar, India

From the impact assessment of drip and surface irrigation on capsicum yield, it was evident that drip irrigation provided a significant yield advantage compared to surface irrigation. The net benefit/post sent was also considerably higher, thus showing the economic benefit of drip irrigation.

Wrachienb *et al*. (2014) - Maharashtra, India

This study evaluated the potential of micro-irrigation for people with low incomes and the rural community in India. The study showed that micro-irrigation increased the productivity of bananas, grapes and sugarcane. It further explained the economic benefit and the efficiency of resources using the system.

Bhamoriya and Mathew (2014) - Gujarat, India

This empirical study analyzed the impact of micro-water harvesting on different crops in India and concluded that the dripped crops yielded more vegetables of better quality than the others. The drip-irrigated farmers could also get a higher price for the yield due to sheer quality.

Chandrakanth *et al*. (2013) - Karnataka, India

Assessed the benefits of micro-irrigation for dryland crops in India and found that drip irrigation increased the net return per farm. The marginal productivity of water had gone up.

Chandran and Surendran (2016) - Kerala, India

Studying the factors that affect drip system adoption in humid tropical Kerala, they reported a positive effect of socio-economic characteristics on drip adoption. It was noticed that the yield response had increased from 13% to 47% in the case of different crops.

Panigrahi *et al*. (2010) - Odisha, India

In the study conducted about 'Water use and yield response of tomato under drip and furrow irrigation,' they found that drip irrigation could increase the yield of tomato by 15.4% and saving and saving of 17.9% more water compared to furrow irrigation.

Priyan and Panchal (2017) - India

In the paper 'Study on the beneficial impact of micro irrigation technology, India,' in Agro-Micro Irrigation Technologies and Gurukul System of Farming, Priyan and Panchal have found that there is an increase in yield and water use efficiency with a decline in the cost of water, fertilizer and weeding. This study helps identify and realize the economical components of the judicious use of water under micro-irrigation systems.

Tiwari *et al*. (2014) - Kharagpur, India

The study on the 'effect of drip irrigation and plastic mulch on Sapota yield and soil nutrient' conducted by Tiwari *et al*. (2014) found that there has been a positive influence on Sapota growth and yield. Significantly higher yields were obtained through plastic mulch irrigation than the traditional irrigation system.

Narayanamoorthy (2008) - Maharashtra, India

The paper 'Water saving technologies and transfer' focused on the linkages between drip irrigation and rainfed crop cultivation in Maharashtra. It was found that drip irrigation can save about 140 Kwh/acre of electricity

Table 1: State-wise review of studies on micro-irrigation conducted by different researchers.

Studies and sources	Method of Micro-irrigation	Study Area/ region	Water saving (%)	Yield increased/ Income (%)	Additional area under irrigation(%)	Cost saving (%)
Rahul Kapur *et al*., 2015	Sprinkler and drip	Maharashtra	50 to 90	42.4 to 52.7	31.9	30 to 45 and 30.4
Narayanamoorthy, 2008, 2005	Drip	Maharashtra	12 to 84 and 8-60	114		50
Wrachienb *et al,* 2014	Drip and Sprinkler	Maharashtra	37	19 to 29		
Bhaskar *et al*., 2005	Drip	Maharashtra	40 to 50	30 to 100		
Reddy *et al.,* 2017	Drip	Guntur District, AP			55 to 60	25 to 40
Paul *et al*., 2013	Drip	Bhubaneswar, Odisha		57	54	
Tiwari *et al*., 2014	Drip	Kharagpur, W.B.		21.05		
Kumar *et al*., 2016	Drip	Moradabad,Uttar Pradesh	35			
Chandrakanth *et al*., 2013	Drip	Karnataka		65		
Panigrahi *et al*., 2010	Drip	Odisha		15.4		17.9
Chandran and Surendran, 2016	Drip	Kerala		13 to 47		
Bhamoriya and Mathew, 2014	Drip	Gujarat		20 to 30		
Patel and Rank 2020; Dolhey *et al*., 2023	Drip	Gujarat	25.35	28.41		
National Mission on Micro MIS, Impact study for the Govt. of India, June 2014	Drip and Sprinkler	India	22.96 to 42.73	19.37 to 73.48	32.6 to 68.02	
Raina *et al.,* 2011, Himabindu *et al*., 2019	Drip	India	30 to 35			41.37
Priyan and Panchal, 2017	Drip and Sprinkler	India	50-90			
Global Agri. System and their Impact Evaluation Study, 2014	Drip and Sprinkler	India	20 to 40	20 to 25		
National Committee on Plasticulture Application in Horticulture (https://www.ncpahindia.com)	Drip and Sprinkler	India	25 to 40	30	30	40

compared to conventional flooding. The economic scenario exhibits positive effects regarding resource savings, cost of cultivation, crop yields and farm profitability.

Suresh Kumar and Palanisami (2010)

The economic analysis of crop growing under Texas irrigation revealed a high impact on resource saving, cost of cultivation, crop yields and farm profitability.

The efficacy of various micro-irrigation technologies in achieving water conservation, energy efficiency and input optimization and their impact on employment and income have been thoroughly investigated. This exploration encompasses an extensive literature review and an in-depth analysis of data. Table 1 offers a comprehensive overview of the advantages associated with micro-irrigation and comparison of different micro-irrigation methods as documented by researchers in previous studies.

Most of these investigations demonstrate noteworthy savings in water, energy and fertilizers, accompanied by increased yields, expanded crop areas and an overall reduction in production costs attributable to adopting micro-irrigation techniques. Nevertheless, it is essential to recognize that the magnitude of these benefits fluctuates based on various factors, including differences in methodology, farming systems, climatic conditions, socio-economic contexts and other pertinent variables. The National Committee on Plasticulture Applications in Horticulture (NCPAH) conducted extensive experimental studies and observed that different crops exhibit distinct input savings when subjected to micro-irrigation, specifically through drip and sprinkler systems. The findings presented in the following table encapsulate outcomes from diverse research studies carried out at experimental research stations across India. It is noteworthy, however, that the available information primarily stems from experimental studies and there is a lack of field survey-based investigations on this subject.

Maharashtra

In Maharashtra, an in-depth analysis was conducted by ICAR- National Institute of Agricultural Economics and Policy Research on Efficiency of Micro-Irrigation in economizing water use in India: Learning from potential and under-explored states in May 2019-study focusing on six major crops cultivated by both adopters and non-adopters of Micro-Irrigation Systems (MIS). The findings reveal substantial economic advantages for adopters, mainly cost savings and enhanced productivity. Comparing adopters to non-adopters, adopters exhibited significant savings in seed and planting material costs, ranging from 4.91% to 36.31%. Furthermore, adopting MIS resulted in noteworthy savings in Farm Yard Manure (FYM) costs, ranging from 2.94% to an astonishing 96.01%. Adopters also experienced substantial fertilizer cost savings, ranging from 12.98% to 52.09%, potentially attributed to the adoption of liquid fertigation practices, leading to reduced quantity requirements. The economic impact extended to savings in chemical and pesticide costs, with percentages varying from 5.08% to a substantial 50.0%, particularly notable in cotton cultivation. Water savings, a critical aspect, ranged from 16.43% to an impressive 85.81%. The adoption of MIS also translated into reduced labor and machine hours, with savings ranging from 8.35% to 51.15% across different crops.

When considering the overall cost savings, adopters experienced reductions ranging from 7.76% to 35.15% across various crops. Notably, the net returns for adopters demonstrated a substantial increase, varying from 20.95% to an impressive 58.69% across different crops, as highlighted in Table 2. These findings solidify the assertion that adopting MIS not only enhances net income but also significantly reduces input costs, showcasing the economic and agronomic benefits of micro-irrigation in the context of Maharashtra.

Table 2: Saving in inputs costs, increase in yield, income adoption of micro irrigation in. (Per cent)

Particulars	Name of crops					
	Cotton	Bajra	Maize	Onion	Soybean	Sugarcane
Seed/Planting material	-32.27	-9.21	19.65	-36.31	-4.91	-11.59
FYM	-2.94	-20.45	-	-10.85	-8.33	-96.01
Fertilizer	-15.04	-22.37	-16.41	-12.98	-36.10	-52.09
Chemical	-50.00	-	-	-5.08	-38.84	-43.66
Irrigation	-27.50	-42.14	-16.43	-85.81	-31.13	-28.33
Labour	-51.15	-12.94	-19.92	-8.25	-25.88	-10.05
Machine use	-35.81	-47.47	-12.67	-7.64	-35.61	-4.22
Total cost	-35.15	-31.31	-7.76	-12.74	-24.08	-17.10
Yields	18.64	17.37	15.56	12.54	8.69	10.01
Net income	35.26	58.69	39.35	20.95	25.88	25.74

Source: Report of ICAR- National Institute of Agricultural Economics and Policy Research on Efficiency of Micro-Irrigation in economizing water use in India: Learning from potential and under-explored states (May 2019).

Table 3: Sprinkler and drip irrigation sets and subsidy distributed in Maharashtra.

Year	Sprinkler irrigation sets		Drip irrigation sets		Subsidy
	No. of sets	Area (ha)	No. of sets	Area (ha)	(` Crore)
2019-20	77,279	46,538	1,21,979	1,05,190	505.44
2020-21	47,889	35,322	39,655	33,960	163.37
2021-22	1,01,899	66,277	1,11,980	185,534	532.88
2022-23 (Target)	90,482	65,943	1,52,866	1,22,754	666.66#

#anticipated.

Source: Commissionerate of Agriculture, Government of Maharashtra, Economic Survey of Maharashtra 2022-23.

Present status and prospectus of Rashtriya Krishi Vikas Yojana - Per Drop More Crop micro-irrigation scheme in Maharashtra

The 'Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) - Per Drop More Crop' micro-irrigation scheme, initiated in 2015-16, aims to maximize crop production with minimal water usage and enhance efficiency. Since 2022-23, this initiative has operated as part of the Rashtriya Krishi Vikas Yojana (RKVY). The subsidy criteria are 55% for small and marginal farmers and 45% for others, limited to a five-hectare area. As of 2020-21, the Maha DBT portal facilitates subsidy distribution. The micro-irrigation coverage reached approximately 8.86 lakh hectares by 2021-22. In the same year, a subsidy of ` 532.88 crore was disbursed to 2,12,964 eligible farmers. In 2022-23, until October, 4,48,351 applications were received, 3,50,674 farmers were selected *via* lottery and subsidy distribution to 83,611 farmers with installed micro-irrigation sets is in progress. Refer to Table 3 for details on sprinkler and drip irrigation sets and the corresponding subsidy distribution.

Conclusion

In conclusion, diverse studies underscore the extensive benefits of micro-irrigation, including increased crop yields, enhanced water use efficiency and economic gains, emphasizing its transformative potential in modern agriculture. However, formidable challenges, such as high implementation costs and socio-economic intricacies, must be addressed to ensure widespread adoption. Urgent action is needed through targeted policies and innovative strategies that mitigate existing challenges and create an environment conducive to micro-irrigation acceptance. Crucially, unlocking the full potential of micro-irrigation requires dynamic and adaptive approaches, encompassing strategic policies that address economic barriers, simplify technology and consider socio-economic nuances. Such efforts can surmount obstacles, ushering in sustainable agriculture marked by heightened productivity, resource efficiency and economic prosperity. In Maharashtra, the study on Micro-Irrigation Systems (MIS) revealed significant financial advantages for adopters, including substantial savings in seed, planting material, Farm Yard Manure and fertilizer costs. Adopters experienced remarkable reductions in chemical and pesticide expenses, water savings ranging from 16.43% to 85.81% and decreased labor and machine hours. The overall cost savings for adopters ranged from 7.76% to 35.15%, with net returns witnessing a noteworthy increase of 20.95% to 58.69%. This comprehensive analysis solidifies the argument that MIS adoption in Maharashtra boosts net income and markedly reduces input costs, establishing micro-irrigation as an economically and agronomically beneficial practice.

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Conflict of interest

We declare that we have no conflict of interest.

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