

Micro-irrigation development in India: challenges and strategies

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In the context of climate change, micro-irrigation (MI; drip and sprinkler systems) has the potential to address problems like water scarcity and emission of greenhouse gases from agriculture. The central and state governments promote MI through heavy subsidies, but without much consideration to supply-side factors like water harvesting, socio-economic factors, including affordability of upfront capital cost and agronomic factors like extant farming system. Despite heavy investments, MI coverage is less than 15% of the potential. This article contextualizes MI development in India and proposes alternative policies to achieve the twin objectives of water harvesting and its efficient usage. They include developing affordable systems, small farm orientation of technology, popularizing MI in canal commands, prioritization and water budgeting, harnessing circular economy in water usage, and developing institutional mechanisms. MI has the potential to serve both as an adaptation and mitigation strategy against climate change.

Keywords: Climate change, micro-irrigation, water harvesting, greenhouse gases, water-use efficiency.

As a demand-side management strategy, micro-irrigation (MI) has received considerable policy focus in India^{1,2}. Promotion of MI is critical to enhance water-use efficiency in the context of rampant extraction of groundwater for irrigation and high variability in rainfall due to climate change. By the year 2030, the demand for food in India is projected to be around 355 million tonnes (mt) for food-grains, 180 mt for vegetables, 182 mt for milk, 15 mt for meat, and 16 mt for fish, warranting an improvement of 50–100% over the current production³. The strategies to attain this are water-intensive. Further, increased production is to be achieved through reduced emission of greenhouse gases (GHGs) and using cleaner energy. Therefore, development strategies in agriculture need to be centred on regional water availability, water budgeting and its efficient use. This article contextualizes MI development in India, and identifies key strategies to place it as a policy variable for rapid and inclusive agricultural growth.

Structural change in the irrigation sector in India

The structure of irrigation in India has changed drastically^{4–6}. Over the years, the area underground-water based minor irrigation has increased sharply over major and medium dam-based irrigation projects. Between 1995–96 and 2010–11, the number of wells in use increased from 8.1 million to 11.4 million (Table 1).

The term ‘wells’ constitutes both dugwells and tube wells (shallow, medium and deep). Tube wells accounts for more than 90% of the total wells, and contribute to about three-quarter of the total well-irrigated area. Between 1995–96 and 2010–11, the number of tube wells increased from 6.0 million to 7.5 million. As on 2010–11, among the total wells in use, about 88% were with pump sets and about 45% of tube wells were electricity-operated.

Climate change and water-use efficiency

The annual average temperature in South Asia is projected to increase by 1.6°C (with a range 1.0°–2.3°C) under the climate-sensitive scenario, and 2.2°C (range 1.5°–3.1°C) under the carbon-intensive scenario by 2050, relative to 1981–2010 (ref. 7). Agriculture contributes around 20% of India’s net GHG emissions annually⁸. The direct use of diesel and indirect use of electricity in irrigation are major contributors towards this. Under the ‘business as usual’ scenario, the twin objectives of meeting irrigation water demand with reduced energy footprints cannot be materialized. Hence, the water and energy savings will have to come from improvements in water and energy efficiency. With every 1% improvement in irrigation efficiency, GHG emissions reduce by 2.1% (ref. 5).

Savings in water and fertilizer

The MI, viz. drip and sprinkler, helps targeted application of water to the root zone of the crop, drop by drop as in

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Table 1. Trend in holding size, wells, pump sets and energy sources, 1995–96 to 2010–11

Year	Total holding ('000)	Average holding size (ha)	No. of wells in use ('000s)			No. of wells not in use ('000s)	No. of tube wells ('000s)		
			With pump sets	Without pump sets	Total		Electricity-operated	Diesel-operated	Total
1995–96	115,580	1.41	6,710	1,401	8,111	3,159	2,989	3,059	6,048
2000–01	108,143	1.41	7,377	1,430	8,807	3,030	3,976	3,032	7,008
2005–05	100,849	1.31	7,167	980	8,147	2,801	4,421	3,121	7,542
2010–11	138,348	1.15	10,100	1,316	11,416	3,083	3,425	4,067	7,492

Source: Compiled from the National Agricultural Censuses, <https://agcensus.nic.in/>.

the drip system or a spray of tiny droplets on crops akin to rainfall as in the sprinkler system, thereby achieving higher water application efficiency and distribution uniformity. The drip system is suitable for orchard crops like fruits, vegetables and plantation crops, whereas the sprinkler system is more suitable for field crops. MI increases water-use efficiency to the extent of 50–90% (refs 9, 10).

In 2015–16, India applied about 27 mt of fertilizers on its farms. About 10–20 kg/ha of nitrogen nutrient applied is leached to reach the streams and other water bodies, including groundwater. With a potential savings in fertilizer application along with MI system of 25%, the savings in fertilizer usage and fertilizer subsidy are also significant. The associated benefits of savings in energy and fertilizer reduce cost of cultivation, leading to raised farm income^{11–13}. MI also has the potential to bridge the increasing gap between irrigation potential created (IPC) and irrigation potential used, which stands at 22% of IPC as on 2012 (ref. 6).

Water policy: subsidized electricity and groundwater extraction

Groundwater development in many states is unsustainable and has crossed 100%, where the annual groundwater usage is far beyond water recharges. Punjab tops the list with a groundwater development of 149%, followed by Rajasthan (140%; Figure 1). Heavy subsidy on electricity has favoured installation of deep tube wells, disregarding the hydrologic character of the locality^{14,15}. Highly subsidized power and water prices have reduced the marginal cost of electricity and water, leading to inefficient usage. The groundwater is applied to the field by flood irrigation method with efficiency less than 40% (ref. 15). The competitive installation and deepening of bore wells and field application through flooding have led to several social, economic and ecological repercussions¹⁶.

Micro-irrigation development in India: current status

MI in India is popularized with a subsidy component, by both the central and state governments. As on 2017, the

area covered under MI is about 8.7 m ha, accounting for only about 13% of the potential. Maharashtra, Andhra Pradesh, Telangana, Karnataka and Gujarat together account for about 85% of total drip-irrigated area (Table 2)¹⁷. In case of sprinkler system, Rajasthan and Haryana top the list. Madhya Pradesh, Punjab and Haryana lag far behind compared to their potential. However, groundwater development in these states is more than 100%.

Micro-irrigation schemes

In 2006, Government of India (GoI) started a centrally sponsored scheme (CSS) for MI. In 2010, CSS was enhanced in scope and renamed as National Mission on Micro Irrigation (NMMI), which was subsequently brought under the ambit of the National Mission on Sustainable Agriculture. In 2015, NMMI was brought as a scheme under the Prime Minister's Krishi Sinchayee Yojana (PMKSY). The scheme envisages providing end-to-end solution to irrigation supply chain. The MI development was enhanced through budgetary supports. Union Budget 2017 announced allocation of Rs 7377 crores towards PMKSY. This constitutes an increase of about 42% over the revised estimates for the fiscal year 2016–17. About 46% of this is set aside for the 'per drop more crop' component, which mainly focuses on the development of MI. The government has also proposed to create a MI fund with an initial corpus of Rs 5000 crores, to be mobilized by NABARD through market borrowings. Over and above the subsidy provided by the central government, the states add their share, taking the subsidy component to more than 80% of the capital costs.

Potential strategies for popularizing micro-irrigation

Focusing on vulnerable areas and affordable systems

Prioritization of locations to popularize MI, taking into consideration location-specific demand–supply scenario is warranted. The Central Ground Water Board, New Delhi classifies districts/talukas as safe, semi-critical, critical and over-exploited, depending on groundwater

Table 2. Spread of micro-irrigation structures across states in India as on 2016

State	Area ('000 ha)	Share to all-India (%)	Share to the state (%)	
			Drip	Sprinkler
Andhra Pradesh	1323.21	15.34	71.99	28.01
Bihar	107.92	1.25	9.04	90.96
Chhattisgarh	271.15	3.14	6.67	93.33
Gujarat	1068.81	12.39	50.01	49.99
Haryana	576.83	6.69	4.27	95.73
Himachal Pradesh	7.82	0.09	54.77	45.23
Jharkhand	20.75	0.24	52.20	47.80
Karnataka	953.35	11.05	51.08	48.92
Kerala	30.32	0.35	75.46	24.54
Madhya Pradesh	430.66	4.99	52.12	47.88
Maharashtra	1309.67	15.18	70.59	29.41
Odisha	104.84	1.22	18.49	81.51
Punjab	47.09	0.55	73.65	26.35
Rajasthan	1752.67	20.32	11.62	88.38
Sikkim	9.09	0.11	66.52	33.48
Tamil Nadu	363.36	4.21	90.38	9.62
Telangana	94.97	1.10	79.82	20.18
Uttar Pradesh	42.66	0.49	39.40	60.60
Uttarakhand	1.01	0.01	68.77	31.23
West Bengal	51.18	0.59	1.18	98.82
All India	8626.78	100.00	45.44	54.56

Source: ref. 17.

Table 3. Trend in the status of blocks/mandals/taluks according to groundwater development, 1995–2013 (%)

Category	Definition	1995	2004	2009	2013
Safe (0–70%)	Areas which have groundwater potential for development	92	73	72	69
Semi-critical (70–90%)	Areas where cautious groundwater development is recommended	4	9	10	10
Critical (90–100%)	Areas which need intensive monitoring and evaluation for groundwater development	1	4	4	4
Over-exploited (>100%)	Areas where future groundwater development is linked with water conservation	3	14	14	16

Source: Central Groundwater Board, <http://cgwb.gov.in>.

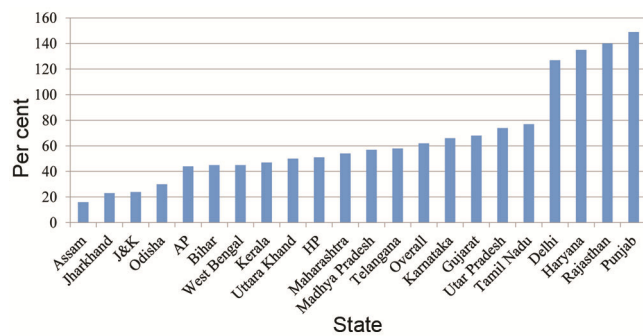


Figure 1. Stage of groundwater development across major states in India in 2013. Source: Central Groundwater Board, New Delhi, <http://cgwb.gov.in>.

development. The over-exploited districts increased from 3% in 1995 to 16% in 2013, and semi-critical and critical areas together from 5% to 14% (Table 3). Thus MI needs to focus on areas where unsustainable water extraction is rampant.

The current schemes, which follow direct transfer of subsidy to the producer firms of MI systems, fail to

incentivize technology upgradation and cost reduction by instilling competition among producer firms. The technology has to take into account the dominance of small farms (less than 2 ha) in Indian agriculture and has to reduce the unit cost with add-on technology features so as to hasten the adoption. The experience from Karnataka is a pointer to the importance of reducing the unit cost to popularize the technology¹⁸.

Popularizing micro-irrigation in canal commands

Conjunctive use of surface water and groundwater is found to have complementary effect on water productivity and achieving water savings. MI is largely developed in minor irrigation schemes (area irrigated <2000 ha). Recent experiences from large irrigation projects also suggest the possibility of integrating MI in canal commands.

The canal commands generally follow flood irrigation system relying on gravity flow. The operational responsibility of dams is with government departments with less

involvement of beneficiary farmers. Some of the resultant mismatch can be overcome by collecting water in individual or collectively operated water storage structures at the time of release which later can be successfully applied through MI at the proper time. The system is operational in some districts of Gujarat, Karnataka and Rajasthan. Upscaling this technology would require redesigning of irrigation and crop plans in identified areas. Expansion of MI to paddy and sugarcane in canal commands would release much pressure on water demand.

Groundwater being a common property resource, individual farmers try to maximize its extraction. Area expansion of water-intensive crops and consequent over-extraction of water jeopardize water conservation objectives. The situation needs appropriate policy targeting limiting water-intensive crops in water-constrained areas. This could be achieved by popularizing MI in canal commands. Basin-wise water budgeting and agricultural plans would help towards this. The extension system needs to consider the issues of water management more emphatically¹⁹.

Role of renewable energy sources

The Ministry of Water Resources and Ganga Rejuvenation, GoI, conducts a census on minor irrigation. Currently, preliminary data on the 5th minor irrigation survey is in public domain. It indicates that the major source of power is electricity (71%), followed by diesel (24.8%; Table 4). Between the fourth and fifth minor irrigation census, the number of electricity-operated irrigation systems has increased while those with diesel, manual labour/animal power and 'other sources' has reduced. The share of renewable sources like windmill and solar constitutes only about 0.1%. Solar power-aided pump sets along with MI systems can further reduce the energy requirement and carbon footprints.

Technology development and service provisions

Irrigation technology is fast changing world over. Sensor-aided controllers and automated irrigation systems that can regulate application of water and nutrients are gaining popularity. In view of enhanced saving of water, the policy needs to target add-on features, including precision water management systems. MI is an integral component of precision agriculture technology which has been slowly but steadily gaining popularity, especially for high-value crops. Integration of GIS, GPS and hyper-spectral imaging with precise application of water and fertilizers through the MI system creates a much higher value proposition in the field of high-tech agriculture.

One major constraint faced in MI is the damage that may occur to the pipes and distributaries. Post-

installation services like timely and proper maintenance of the drip systems, including filters need to be ensured²⁰. Periodic servicing of MI systems by vendors, and encouraging private enterprises/custom-hiring centres is an option.

Circular economy solutions and linking with micro-irrigation

Circular economy is a model of production and consumption which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible²¹. Circular economy solutions target both the demand- and supply-side management measures in the water sector, for which MI can serve as a useful tool.

In India, out of the estimated sewage generation of 40–60 billion l/day in urban areas, only 20–30% is treated. This is in contrast with some technologically advanced countries like Germany and Israel (close to 100%), the United States (75%), and South Africa (60%)²². Treated wastewater reuse in Indian agriculture is constrained by policy gaps and ambiguity in tolerance thresholds of toxic chemicals and/or biological organisms. Though the National Water Policy (2012) encourages wastewater reuse to offset the impacts of freshwater extraction, the only standard or policy relevant to governing the application of wastewater in agriculture is the inadequate Central Pollution Control Board standards governing the application of treated agricultural fields²³. Lack of such standards affects both farmers and consumers alike. Wastewater irrigation through wastewater irrigation co-operatives exists in some districts of Gujarat²⁴. The three key factors identified to drive the spread of wastewater irrigation in Gujarat are reliability of water supply, rapid urbanization and profitability of using nutrient-loaded treated water in irrigation. Creation of more distributed infrastructure for wastewater treatment at block levels, establishment of quality and safety benchmarks for treated wastewater for irrigation, awareness building and scientific monitoring of nutrient load by a state-level independent regulator are key to exploring circularity solutions in agricultural water use. Such an arrangement at a large scale needs initiation of pilots at least in major water-constrained districts. Linking MI supports with wastewater recycling initiatives could help attain the objectives of water recycling and its efficient usage.

Financial innovations

The top-down approach of MI development is fraught with several financial constraints. Further, the minor irrigation distribution in India is inequitable and favours relatively large farmers⁴, which transgresses to the sprinkler and drip irrigation as well. Consequently, much

Table 4. Change in major sources of power for minor irrigation in India between the fourth and fifth minor irrigation census

MI Census	Electricity	Diesel	Windmill	Solar	Manual/animal	Others	Total
In numbers ('000)							
Fourth	11,448.4	6,474.5	27.9	5.8	777.5	1,671.6	20,405.6
Fifth	14,729.5	5,147.8	29.9	16.1	281.7	557.0	20,762.1
Percentage to total							
Fourth	56.1	31.7	0.1	0.0	3.8	8.2	100
Fifth	70.9	24.8	0.1	0.1	1.4	2.7	100

Source: Minor irrigation census, Government of India; <http://mowr.gov.in/schemes-projects-programmes/schemes/irrigation-census>.

of the subsidy is appropriated by relatively richer farmers. One approach to address larger financial constraints in MI popularization is to follow innovative financial products like hybrid annuity model, which has several advantages over the traditional public–private partnership (PPP) model. Examples of substitution of water-guzzling crops with drip/sprinkler-friendly crops, and pursuing models that offer PPP opportunities (e.g. Ramthal Irrigation project, Karnataka) at a large scale are emerging²⁵.

Linking micro-irrigation with water harvesting and conservation initiatives

The subsidies in MI can be linked with water harvesting initiatives. Rainwater harvesting can be implemented as a viable alternative to conventional water-supply schemes²⁶, as noted below.

Run-off interception and recharge: Typically, infrastructure assets required for this intervention depend on the hydro-geomorphology of the watershed and the user characteristics. In arid drylands of India, this offers a low-cost, soft-technology option often adapted by indigenous knowledge, yet producing an optimal return on investments made.

Force infiltration and recharge: This can provide significant gains in increasing resilience of aquifers if coupled with rational groundwater planning and management, coupled with MI. Bhungroo, a water management system that injects and stores excess rainfall underground and lifts it out for use during dry spells, is a rural innovation that has yielded significant gains in water harvesting. The massive underground reservoir can hold as much as 40 million litres of rainwater. It harvests water for about 10 days per year and can supply for as long as seven months²⁷.

Linkage of MI with such initiatives in the long term would address supply-side constraints as well.

Enabling institutions and policies for water security

Managing water resources confronts the issues of managing common property resources. Effective policy-making and institutional governance in water sector become practical when stakeholders with competing interests and demands jointly identify priorities and solve the problems consultatively. Multi-stakeholder/sectoral platforms (MSPs) have produced success stories in several sectors such as renewable energy and agriculture.

MSP models for governance and policy making in agriculture²⁸ and water management²⁹ have proven success stories from the developing world. MI has to be considered as an integral part of the technology solution considered in the MSP initiative.

Conclusion and implications

Aided by policy support, groundwater extraction has reached unsustainable proportion in India. MI helps in attaining greater water-use efficiency, thereby reducing the pressure on groundwater sources with reduced GHG emissions. MI has the potential to function both as demand- and supply-side management tool. However, only about 15% of potential areas could be brought under MI, warranting a course correction.

MI development needs to be seen as an integral component of the overall agricultural policy, rather than a water conservation strategy. There is a need to develop water budgeting for highly localized agricultural units like watersheds, taking into consideration the demand and supply of water, and integrate MI in the crop plans. The command area development programmes need to factor in possibilities of MI development. The targeted geographical locations are to be prioritized, towards which the current stage of groundwater development could function as an indicator.

MI development strategies need to technologically address the concerns of small farms in terms of scale economies, capital constraints and post-installation service requirements. The concept of 'affordable systems' is

a key element. Ensuring competition among various companies can help in devising irrigation systems with desirable attributes suitable for small farms at lower costs. Water recharge and recycling need to be considered as an integral part of the overall water resource development strategy and linked with the financial schemes promoting MI. Also, MI in canal commands can be promoted through viable PPPs and innovative financial schemes, incentivizing water conservation and recycling. Over a period of time, the subsidy schemes can be reformatted to include incentives to water conservation and water saving. In the context of climate change and water stress, MI programmes could be a worthwhile adaptation and mitigation strategy.

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