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Potential area of micro-irrigation and its outreach across Indian states

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ABSTRACT

Indian agriculture is predominantly dependent on groundwater and consumes nearly 89% of its total groundwater draft. With recurrence of drought and faster depletion of groundwater resources in recent past, micro-irrigation technology has emerged to play crucial role in managing irrigation water demand and sustaining food security. The policy makers, recognising gravity of water scarcity across the Indian states, have focussed water policy pivotal to micro-irrigation. So, present study aims to estimate potential area across Indian states that are suitable for adoption of micro-irrigation. For estimation, sources of irrigation and crop suitability for micro-irrigation primarily under drip and sprinkler irrigation are considered across the states for year 2018–19. Based on different combinations of irrigation sources, estimate shows that country endows an area of 72–78 million ha on which micro-irrigation can be adopted. At country level, micro-irrigation penetration to our estimates ranges from 14.71–15.81% in recent years. Further, location coefficient reveals that concentration of micro-irrigation has improved over the years, however noticeable variation exists across the states. The states with dedicated agencies to improve micro-irrigation adoption like Andhra Pradesh and Gujarat, show higher penetration. However, the state like Punjab that faces water scarcity has low penetration of micro-irrigation. Therefore, there is need to have state-specific schemes to scale up micro-irrigation area for better trade-off between environmental sustainability and food security.

Keywords: India, Micro-irrigation, Outreach, Potential, Water

Groundwater has emerged as a predominant source of fresh water to fulfil increasing water demand of various sector of economy (Matthew *et al.* 2009, Singh *et al.* 2019, Jia *et al.* 2020). Over the years, the unrestricted extraction of groundwater without accounting its availability in aquifer, resulted into stern depletion of water level in several parts of the world (Chaudhuri and Ale 2014, Machiwal and Jha 2014, Patle *et al.* 2016, Steward and Allen 2016, Singh and Kasana 2017). India endowed with world's largest area under irrigation and primarily dependent on groundwater (Shah 2009). Indian agriculture sector alone consumes 89% of total groundwater draft as irrigation (CGWB 2019). The increasing dependence on groundwater resulted into faster depletion of groundwater resources in the country and more serious in north-western states – Punjab, Haryana, Rajasthan and Delhi (Matthew *et al.* 2009, Kishore *et al.* 2020).

In the context of over exploitation of groundwater causing water scarcity, more efficient irrigation method like micro-irrigation could be a suitable demand management measure (Amarasinghe 2007b). Properly designed and managed drip and sprinkler irrigation system have irrigation efficiency about 90% and 70% respectively, contrast to surface irrigation method with 40% (INCID 1994, Dhawan 2002, Saleth 2009). Overall, micro-irrigation shows superiority over other traditional irrigation methods in term of water-use efficiency, energy saving, yield increase and water productivity (Narayanamoorthy and Deshpande 2005, Kumar and Palanisami 2010, Chandrakanth *et al.* 2013, Kishore 2019, Chand *et al.* 2020). Management of irrigation water demand with micro-irrigation will be pivotal in reducing irrigation water demand and holding back faster depletion of groundwater resources. In year 2015, government bundled all ongoing irrigation schemes as *Pradhan Mantri Krishi Sinchayee Yojna* (PMKSY) in which micro-irrigation is an integral component. With this backdrop, this study is an attempt to estimate potential area for micro-irrigation across Indian states for scaling up micro-irrigation area.

MATERIALS AND METHODS

Present study is based on secondary data collected from various published sources of the government for year 2018–19 across Indian states. In the study, primarily 22 states considered that cover nearly 97.4% of the country's gross cropped area. In the country, government gives subsidies up to 90% for micro-irrigation installation. For installing micro-irrigation, farmers need to have any source

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of irrigation more preferably groundwater or tank. However, in present time some states like Gujarat, Rajasthan and Punjab have diverted canal water to doggies (farm pond) constructed along distributaries of canals and lift water for micro-irrigation. Drawing insight from National Committee on Plasticulture Applications in Horticulture and PMKSY, authors have categorised crops suitable for drip and sprinkler irrigation and presented in Table 1.

In short run, gross irrigated area considered as core potential for micro-irrigation adoption as these area have at least one source of irrigation. In long run, un-irrigated area may be suitable for potential estimate (distant potential). However, independence and reliability of irrigation source play major role in adoption and utilization of micro-irrigation. Farmers who have access to sufficient water resource at their own or access to canal water may not go for immediate adoption of micro-irrigation. So, two indices constructed for each state based on different combination of irrigation sources. These indices are as follow:

Irrigation Index 1 (II-1): Consider proportion of area irrigated by groundwater, tank and 30% of canal irrigated area.

Irrigation Index 2 (II-2): Consider proportion of area irrigated by groundwater, tank and 50% of canal irrigated area.

Based on these irrigation indices, potential area estimated under:

Scenario 1: Potential area estimated based on II-1

Scenario 2: Potential area estimated based on II-2

Outreach of micro-irrigation

Location coefficient estimated to comprehend concentration of micro-irrigation area across states. This helps to analyse the development pattern and regional disparity of micro-irrigation.

The location coefficient is calculated as:

$$L = \frac{M_J/M}{G_J/G}$$

where, M_j, area under micro-irrigation in the j^{th} state; M, area under micro-irrigation at the national level; G_j, area under minor irrigation in the j^{th} state; G, area under minor irrigation at the national level.

Table 1 Crop categorised under drip and sprinkler irrigation system

Irrigation method	Crops
Drip irrigation	Paddy*, Arhar, Sugarcane, Condiments and Spices, Fruits, Sunflower, Cotton, Tobacco, Coconut.
Sprinkler irrigation	Paddy*,Wheat, Bajra, Maize, Ragi, Jowar, other cereals and millets, Gram, Other pulses, Vegetables, Sesamum, Rapeseed and mustard, Groundnut, linseed, Soybean, Other oilseed, Fodder crops.

*Paddy area equally distributed among drip and sprinkler irrigation.

The higher coefficient value depicts the higher concentration of micro-irrigation (Ramasamy *et al.* 2005, Suresh *et al.* 2018). The entire exercise was carried out with utmost care so that estimation bias remain slow.

RESULTS AND DISCUSSION

Irrigation indices: Accounting various sources of irrigation in each state, two irrigation indices constructed assigning different proportion of canal irrigated area. Groundwater and tank irrigated area remained constant in both indices but canal irrigated area varied. The index value is higher for the states which have higher proportion under irrigation (Supplementry Table 1).

Potential estimate of micro-irrigation: Based on indices constructed, potential area for micro-irrigation estimated and categorised under sprinkler and drip irrigation system with crop suitability. Total irrigated area has been termed as ultimate potential area on which micro-irrigation can be adopted in short run. The estimate of potential area for micro-irrigation came out to be about 72 and 78 million ha with index 1 and index 2 respectively (Table 2). In scenario 1, sprinkler irrigation potential estimated to be 51.01 million ha which is $2/3^{rd}$ of total potential area estimated and rest is contributed by drip irrigation. Of the total potential estimated under scenario 1, Uttar Pradesh shares largest potential area (25%) followed by Rajasthan (12%) and Madhya Pradesh (10%). In scenario 2, absolute potential area has increased by 7.44% compared to scenario 1 potential estimate with inclusion of addition 20% of canal irrigated area in irrigation index. Estimate of potential area for sprinkler irrigation by TFMI, 2004, is exactly same (42.5 million ha) as of INCID, 1998. However, present estimate shows nearly 20-29% higher value compared to earlier estimate due to increase in irrigated area over the years. Narayanmoorthy (2006) assumed that the area which could be brought under sprinkler irrigation can also be considered under drip irrigation and vice versa except cereals and our estimate under scenario 1 is almost same following different methods. Potential estimate by Raman (2010) has considered only those crop area for which subsidise were given for installation of micro-irrigation system under National Mission on Micro-irrigation for potential estimate and resulted into under estimation.

Realization of micro-irrigation coverage area

Scenario 1: In sprinkler irrigation, Karnataka state could be able to cover its 72% of estimated potential area, which is highest among other Indian states followed by Chhattisgarh and Andhra Pradesh. Rajasthan which contribute largest area (nearly 27%) of sprinkler irrigation at country level have covered 23% of its estimated potential. Andhra Pradesh which contributes nearly $1/4^{th}$ of total drip irrigated area in country, have covered about 93% of it estimated potential area. Farmers in Andhra Pradesh uses drip irrigation very intensively even for vegetable and maize cultivation contrast to other states (PMKSY 2020). Overall, Andhra Pradesh achieved nearly $2/3^{rd}$ of estimated potential area which is highest compared to other states. This may be due to

Table 2 Micro-irrigation potential area across states (in million ha)

State	Ultimate irrigation potential			Scenario* 1			Scenario# 2		
	Sprinkler	Drip	Total	Sprinkler	Drip	Total	Sprinkler	Drip	Total
Andhra Pradesh	1.72	1.95	3.67	1.23	1.39	2.62	1.35	1.53	2.88
Assam	0.25	0.16	0.41	0.08	0.05	0.13	0.09	0.06	0.15
Bihar	3.92	1.36	5.29	2.92	1.01	3.93	3.16	1.10	4.26
Chhattisgarh	1.02	0.78	1.80	0.53	0.40	0.93	0.65	0.50	1.15
Goa	0.02	0.01	0.04	0.02	0.01	0.03	0.02	0.01	0.03
Gujarat	3.35	2.70	6.05	2.84	2.28	5.12	2.96	2.38	5.34
Himachal Pradesh	4.46	1.37	5.83	3.17	0.97	4.15	3.54	1.09	4.63
Haryana	0.16	0.05	0.21	0.04	0.01	0.05	0.04	0.01	0.05
Jammu & Kashmir	0.33	0.15	0.48	0.11	0.05	0.15	0.16	0.07	0.24
Jharkhand	0.18	0.05	0.23	0.13	0.04	0.17	0.13	0.04	0.17
Karnataka	1.86	1.97	3.83	1.19	1.27	2.46	1.32	1.40	2.72
Kerala	0.13	0.34	0.47	0.07	0.19	0.27	0.08	0.21	0.29
Madhya Pradesh	8.83	1.26	10.08	6.56	0.93	7.49	6.85	0.97	7.83
Maharashtra	2.36	1.90	4.26	1.81	1.46	3.27	1.97	1.59	3.55
Odisha	0.74	0.67	1.41	0.33	0.29	0.62	0.45	0.40	0.85
Punjab	5.77	1.97	7.75	4.67	1.60	6.27	4.98	1.70	6.69
Rajasthan	8.98	1.51	10.49	7.24	1.22	8.46	7.69	1.29	8.99
Tamil Nadu	1.53	1.74	3.27	1.27	1.44	2.71	1.35	1.53	2.87
Telangana	1.31	1.27	2.57	1.16	1.12	2.28	1.19	1.16	2.35
Uttar Pradesh	15.52	5.00	20.52	13.35	4.30	17.65	13.92	4.49	18.41
Uttarakhand	0.34	0.20	0.54	0.26	0.15	0.41	0.28	0.16	0.44
West Bengal	3.75	1.73	5.49	2.05	0.95	3.00	2.54	1.17	3.71
Total	66.53	28.15	94.68	51.01	21.16	72.17	54.71	22.86	77.58

*Calculated based on index 1, #-calculated based on index 2. *Source:* Author's calculation.

collective effort of government in and special purpose vehicle namely Andhra Pradesh Micro-Irrigation Project (APMIP) which was created in year 2003. With scenario 1, at country level, 15.81% of estimated potential area has been achieved under micro-irrigation (Table 3).

Scenario 2: Total estimated potential increased from 72.17–77.58 million ha due to addition of higher proportion of canal irrigated area (Table 3). So, estimate of Potential 2, may show lower penetration as more area has come under potential estimate for each state. Overall, highest penetration of micro-irrigation has been made in Andhra Pradesh followed by Karnataka and Maharashtra. On basis of this estimate, 14.71% of estimated area of India has been covered under micro-irrigation. The share of micro-irrigation area to earlier estimated potential area varied from 11.1-19.9% in sprinkler irrigation and 19.8–45.8% in drip irrigation (INCID 1998, TFMI 2004, Narayanmoorthy 2006, Raman 2010). However, this study with well-defined methods provides narrow range of 110.07–11.88 % for sprinkler and 23.42–25.31% for drip irrigation.

Outreach of micro-irrigation across states: Data (Supplementry Table 2) shows estimate of location coefficient representing regional disparity in adoption of micro-irrigation compared to minor irrigation development. Location coefficient for Andhra Pradesh indicates that concentration of micro-irrigation has increased rapidly over the years due to scarcity of groundwater and dedicated implementing agency like APMIP since year 2003. In recent years, area under micro-irrigation has intensified in the other states like Karnataka, Gujarat and Chhattisgarh. However, coverage of micro-irrigation in the states with over-exploited groundwater such as Punjab, Haryana etc., is still low and need specific policy supporting adoption of micro-irrigation.

With initiation of PMKSY, additional area of 4.42 million ha brought under micro-irrigation. However, there exists immense variation across states. Estimate of micro-irrigation potential area ranges between 72.17–78.58 million ha and only, 14.71–15.81% of the estimated area is covered under micro-irrigation. States like Andhra Pradesh, Karnataka and Maharashtra able to cover more than 50% of its estimated potential area. On the other extreme, one

Table 3 Penetration of micro-irrigation compared to estimated potential

	Actual area*covered under			Per cent to Scenario 1			Per cent to Scenario 2		
	Sprinkler	Drip	Total	Sprinkler	Drip	Total	Sprinkler	Drip	Total
Andhra Pradesh	489.56	1295.66	1785.22	39.82	93.03	68.08	36.21	84.59	61.91
Assam	2.45	0.37	2.82	3.03	0.70	2.10	2.63	0.61	1.82
Bihar	105.00	10.50	115.50	3.60	1.04	2.94	3.32	0.96	2.71
Chhattisgarh	291.52	24.75	316.27	55.42	6.13	34.01	44.91	4.96	27.56
Goa	1.13	1.19	2.32	5.94	9.79	7.44	5.63	9.29	7.06
Gujarat	698.69	723.22	1421.91	24.63	31.68	27.78	23.61	30.37	26.63
Himachal Pradesh	572.62	32.76	605.38	18.05	3.36	14.60	16.18	3.01	13.08
Haryana	4.32	5.39	9.71	11.60	50.41	20.25	11.25	48.87	19.63
Jammu & Kashmir	0.06	0.02	0.08	0.05	0.05	0.05	0.03	0.03	0.03
Jharkhand	15.76	20.63	36.39	12.05	58.61	21.92	11.95	58.13	21.74
Karnataka	863.32	658.17	1521.49	72.27	51.96	61.81	65.32	46.96	55.87
Kerala	8.68	23.61	32.29	11.84	12.23	12.12	11.03	11.39	11.29
Madhya Pradesh	242.73	313.89	556.62	3.70	33.66	7.43	3.54	32.21	7.11
Maharashtra	505.37	1199.96	1705.33	27.95	82.19	52.18	25.72	75.63	48.01
Odisha	97.94	24.79	122.73	30.00	8.43	19.78	22.00	6.19	14.51
Punjab	13.20	35.59	48.79	0.28	2.23	0.78	0.26	2.09	0.73
Rajasthan	1645.43	245.30	1890.73	22.72	20.17	22.36	21.39	18.99	21.04
Tamil Nadu	188.14	487.51	675.65	14.80	33.80	24.90	13.99	31.95	23.54
Telangana	70.57	191.72	262.29	6.10	17.06	11.50	5.93	16.59	11.18
Uttar Pradesh	128.53	25.58	154.11	0.96	0.59	0.87	0.92	0.57	0.84
Uttarakhand	5.04	7.08	12.12	1.96	4.68	2.97	1.83	4.38	2.77
West Bengal	65.72	0.96	66.69	3.21	0.10	2.22	2.59	0.08	1.80
Total	6057.82	5355.11	11412.93	11.88	25.31	15.81	11.07	23.42	14.71

*Thousand hectare. *Source*: GoI, 2019 and Author's calculation

third of states show less than 5% of estimated area covered with micro-irrigation. Location coefficients indicate uneven concentration of micro-irrigation across the states. So, there is utmost need to have dedicated schemes antithetical to state specific constraints similar to Andhra Pradesh Micro-irrigation Project and Gujarat Green Revolution Company.

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