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Role of Institutions and Policies in Diffusion of Micro-irrigation in Gujarat, Western India

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Abstract

The alarming water scarcity in the Gujarat state justifies the adoption of water efficient technologies like micro-irrigation. While the promotion of micro irrigation in Gujarat corresponds with the national mission on micro irrigation, an unequivocal dynamism was observed in the expansion of this in the state as compared to the other states. This dynamism can be attributed to the specific policies and institutional innovations that the state had vigorously adopted and followed in terms of provision of differential subsidies targeted towards the farmers segregated by their socio-economic status as well as the physical and economic water scarcity of the agro-ecological regions. In this regard, this paper examines the role of institutional innovations and subsidy policy interventions in the diffusion of micro-irrigation across the state in the recent years. While the first part makes a comprehensive review of the state policy and intervention for the promotion of micro irrigation in the last decade, the second part of this paper provides a detailed analysis of the trends in the status of adoption of micro irrigation under the various subsidy policy and institutional intervention regimes.

Keywords : Micro irrigation, Institutional innovations, Subsidy, Diffusion, Gujarat

JEL Classification : Q15, Q16, Q33, Q55, Q58

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Role of Institutions and Policies in Diffusion of Micro-irrigation in Gujarat, Western India

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1. Introduction

The state of Gujarat in western India, consisting of seven agro-climatic zones, is mostly covered by arid and semi-arid regions. While the state receives rainfall in a range of minimum 18 days (north-west arid region) to maximum 63 days (southern hills) in a year, almost 90% of the total rainfall occurs during the monsoon season (Varshneya, *et al.*, 2009; Mehta, 2013). High variability in temperature and rainfall is observed across the agro-climatic regions in the state (Ray, *et al.*, 2009; Hiremath and Shiyani, 2012; Mehta, 2013). As a result, the state has been experiencing frequent droughts over the years (Kishore, 2013). Hiremath and Shiyani (2013), for instance, report that the state had 12 drought years between 1978 and 2008 – i.e., one drought year at least once in every three years (Cenacchi, 2014).

Despite the drought conditions along with looming water scarcity across regions, farmers had continued with intensive irrigation practices overtime. For example, the state had achieved an overall irrigation ratio (irrigated area as % of the gross cropped area) of 40% by 2011-12, while it was hardly 7% in the early 1960s (Government of Gujarat, hereafter, GoG, 2008, 2013). Given the high inequality in the distribution of surface water across the state[1], around 80-85% of the total area was irrigated through groundwater sources (Shah, 2009; Kishore, 2013; Viswanathan and Pathak, 2014). Since groundwater is a 'common pool resource' with unregulated withdrawal as well as absence of marginal pricing for water,

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[1] Almost 70% of the freshwater resources are concentrated in the south and central regions, while 75% of the agricultural lands are spread across North, Saurashtra and Kutch regions (Viswanathan and Pathak, 2014).

over-extraction and inefficient allocation are quite widely observed in the state (Kishore, 2013), thus reflecting Hardin's (1968) paradox of 'tragedy of commons'. As of 2011, the stage of groundwater development (SGWD)[2] in the state was around 67% against 41% in 2004, with four districts falling in over-exploited (critical) category and five districts grouped under grey/ semi-critical category (Bahinipati and Viswanathan, 2016). Over the past several years, various studies have pointed about depletion of groundwater in many parts of Western India, particularly in Gujarat (Kumar, 2005; Narula *et al.*, 2011). The impending water crisis along with the emerging challenges of adverse environmental and climatic uncertainties underscores the imperatives for adopting the water saving technologies, while also maintaining high levels of farm production. Micro-irrigation (MI) is one of the interventions widely promoted by the state government in the recent years as part of the various water and energy supply and demand management measures[3] undertaken.

MI, consisting of drip and sprinkler irrigation, is considered to be pillars of 'sustainable intensification' of farming (Fishman *et al.*, 2014). This is highly acceptable in regions experiencing water scarcity and overexploitation of groundwater (Caswell and Zilberman, 1983; Palanisami, *et al.*, 2011). Empirical evidences around the world suggest that it saves water up to 40% to 80% and enhances water use efficiency[4] (Saleth and Amarasinghe, 2010; Palanisami *et al.,* 2011). Apart from this, a large number of other benefits are also reported: reduced tillage requirement, energy use, labour cost, reduction in cost of well deepening and incidence of well failures, and increase in crop yields and fertilizer use efficiency (Palanisami *et al.*, 2002; Narayanamoorthy, 2001, 2004, 2005; Verma *et al.*, 2004; Kumar *et al.*, 2004; Kumar, 2007, Kumar and Palanisami, 2011, Kumar and van Dam, 2013; Fishman *et al.*, 2014; Viswanathan and Bahinipati, 2015; Bahinipati and Viswanathan, 2016).

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[2] It is the ratio of annual groundwater draft and net annual groundwater availability in percentage.

[3] The other measures are: Sardar Sarovar project, river lining and inter-basin transfer of water, Sardar Patel participatory water conservation scheme and the Jyotigram Yojana (see Kishore, 2013).

[4] It is the ratio of water used in plant metabolism to water lost by the plant through transpiration.

Given the positive externalities of adopting MI, it has been promoted by the Government of India (GoI) ever since the early 1980s[5] (see Bhamoriya and Mathew, 2014). However, a significant trend in adoption was not achieved. For instance, only around 9% of the total potential area was brought under MI as of 2010 (Palanisami *et al.*, 2011), which had increased to 14% in 2013 (Palanisami, 2015). Based on the recommendation of the task force on micro-irrigation set up in 2004, the GoI has launched a centrally sponsored scheme on MI in 2006, and this was further revised in 2010 with the announcement of the 'national mission on micro-irrigation (NMMI)' (Pullabhotla *et al.*, 2012). In particular, the task force recommended subsidizing farmers' capital cost and also suggested to provide greater flexibility to states in terms of designing institutions and subsidy disbursement (Pullabhotla *et al.*, 2012) policies.

In Gujarat, the state government had set up a special purpose vehicle (SPV), called the Gujarat Green Revolution Company limited (GGRC) in 2004-05, which acts as a nodal agency to promote MI in the state. In addition, the state government has adopted a differential subsidy policy such that amount of financial subsidy differs with respect to social groups (SC/ST), geographical location and marginal landholdings.

In this backdrop, this paper examines the role of institutional innovations and subsidy policy interventions in the diffusion of MI across the state in the recent years. It has larger policy implications as it investigates the effectiveness of NMMI's recommendations and the resultant state interventions in enhancing adoption of MI in the state.

Rest of the paper is organized as follows. In section two, we present an overview of the policy and institutional interventions for promotion of MI in Gujarat. While section three attempts a detailed analysis of adoption and diffusion of MI in the state, section four concludes the paper with key findings and some policy recommendations.

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[5] The GoI introduced a central scheme during 1982-83 (i.e., sixth plan) for MI under Ministry of water resources (minor irrigation division). Under this, the GoI provides subsidy of 50% to farmers with the matching contribution from the state government. Out of the total subsidy amount, 75% was allocated for small and marginal farmers, and the rest (25%) for other group of farmers. Since it was not well-received in the seventh plan, the GoI modified the scheme, ie., the subsidy amount limited to 50% of total cost or INR 15,000/ha whichever is lower (Narayanamoorthy, 2006).

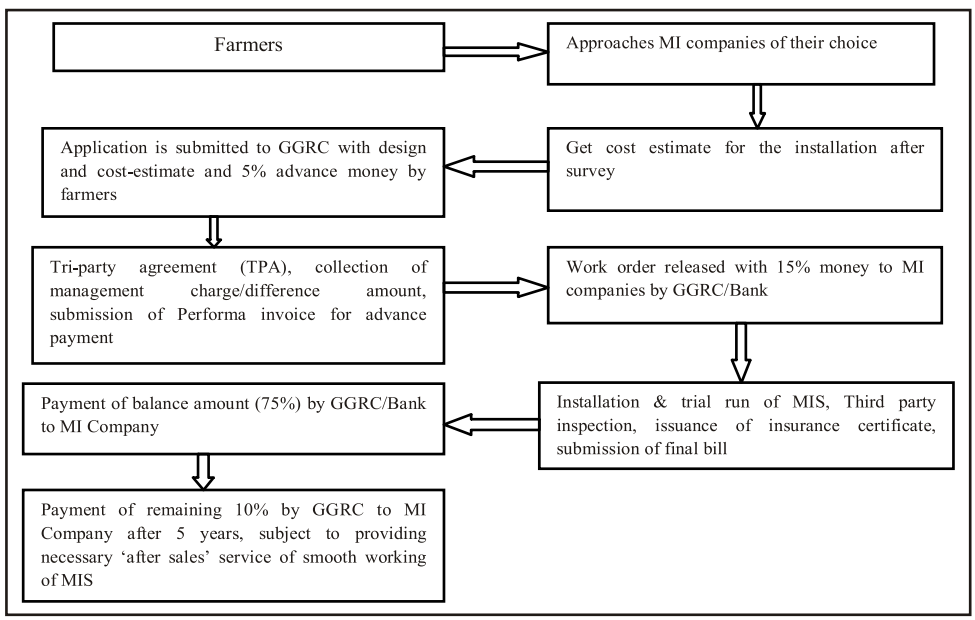
2. Micro-irrigation (MI): Institutional innovations and subsidy policy

As noted, the adoption of MI has been promoted by the GoI as part of the water demand management programme, especially in the water-starved states, such as Gujarat, Rajasthan, Maharashtra and Andhra Pradesh, etc. The government has set up a three-tier system at the national, state and district levels for the effective implementation of MI. Three committees are constituted at the national level to look into different tasks, *viz.*, National Committee on Plasticulture Application in Horticulture (NCPAH), executive committee on MI scheme and the technical support group (TSG). The NCPAH is the central body responsible for enhancing adoption of MI across India. While the executive committee looks into overall activities of diffusion of MI, the TSG committee, consisting of experts from different disciplines, provides guidance in the technical matters (GoI, 2014).

At the state level, state micro-irrigation committee (SMIC) was constituted under either the agriculture or horticulture department. Some states also established special purpose vehicle to enhance adoption of MI. The main duty of this committee is to conduct baseline and feasibility study and ensure smooth allocation of funds across the districts (GoI, 2014). Under SMIC, district micro-irrigation committee (DMIC) is formed in each district. Like the SMIC, the activities of DMIC includes reviewing district action plan, mobilising credit requirement of the prospective MI adopters, monitoring and reviewing the physical and financial progress of the MI system, and reviewing the submission of utilization certificate by the implementing agency (GoI, 2014).However, the modalities for promoting MI scheme are not the same across the states (Bassi, 2013). While states like Gujarat and Andhra Pradesh have their own SPV to promote MI (e.g., GGRC in case of Gujarat and APMIP – Andhra Pradesh micro-irrigation project, in Andhra Pradesh), either the state agriculture or horticulture department is responsible for implementing the scheme in other states (Bhamoriya and Mathew, 2014). Further, the subsidy scheme also varies across the states with regard to social groups, landholdings and geographical location (IRAP, 2012). In the following, we provide a brief review of the institutional intervention and policies for the promotion of MI in Gujarat.

In Gujarat, a SPV, i.e., the GGRC was formed in 2004-05 by the state government to promote diffusion and adoption of MI in the state. GGRC is a joint initiative of the Gujarat State Fertilizers and Chemicals Ltd, Gujarat Narmada Valley Fertilizers Company Ltd and the Gujarat Agro-industries Corporation Ltd. Figure 1 shows the processes of implementing MI scheme. As per the GGRC norms, farmers have to approach first to a recognized MI installation company, and after that, the respective company does a survey at the farm and estimates the total cost of installing the system. Also, the MI installation company takes the administrative responsibility and generates awareness - this reduces transaction cost to both government and consumer (Pullabhotla *et al*., 2012). Along with the survey record and cost estimates, the farmer makes an application to the GGRC, with the payment of remaining cost (i.e., beneficiary share) excluding the eligible subsidy amount. After verification of the documents, the GGRC places a work order to the concerned MI Company with releasing 15% of the total cost. There is third party verification after the installation of MI and after that, 75% of the total cost is released. The remaining 10% is paid after five years – this is to make sure that the Company provides the necessary 'after installation' service for smooth working of the system (Bassi, 2013).

Figure 1: Process of Implementation of MIS under GGRC



Source: Pullabhotla *et al*. (2012); Bassi (2013).

Instead of implementing Pigouvian tax to control over-use of common-pool resources, the governments, mostly in the developing nations including India, find it easy to provide subsidy for adoption of resource efficient technologies, especially for water and energy, in order to reduce pressure on these resources (Fishman *et al.*, 2014). Both the national and state governments provide subsidy on capital cost, which varies from Rs. 19,700 to Rs. 1,27,700 per ha depending on the crops and the specific devices and gadgets installed[6]. It is reported that on an average, the cost of MI system installation incurred by the beneficiaries ranged between Rs. 54,457 and Rs. 72,086/ha in drip system and Rs. 20,481 to Rs. 28,171/ha in sprinkler depending on the cropping patterns, crop spacing, etc. (GoI, 2014). Figure 2 outlines the various subsidy programmes adopted by the state government. All the farmers, irrespective of social group status, landholding, crops and geographical location, are entitled to get subsidy of 50% of capital cost of MI or Rs. 60,000 per ha, whichever is lower[7]; of which, 40% is provided by the national government, and the state government bears the remaining 10%. Moreover, the farmers in the 54 notified dark zone[8] talukas (defined as per GoG norms[9]) get additional 10% subsidy for any crops since April 2012, i.e., 60% of capital cost or Rs. 60,000 per ha, whichever is lower (Figure 2).

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[6] The rate of subsidy provided by the national government (under the NMMI) is fixed uniformly for different categories of farmers with a limit of 5 hectares. However, the rate of subsidy provided under the state schemes range from 50 to 80% of the total capital costs in case of general farmers and 50 to 100% of capital costs in case of small and marginal and tribal farmers (GoI, 2014).

[7] Earlier the limit was Rs. 50,000 per ha (see Government Resolution No. PRCH-102005-497-N dated 09.05.2005), and based on Government Resolution (GR) No. TAP/122008/79/B of GoG taken on 10/7/2008, this was enhanced to Rs. 60,000 per ha.

[8] Region where there is an over-extraction of groundwater with the extent of groundwater reaching critical levels.

[9] As per GR No. GWR-2003-14.J1 (Narmada, Water Resources, Water Supply and Kalpsar Department) dated 16/12/2003, 57 talukas of the state were notified as dark zone talukas. As of now, there are only 54 talukas; because, two talukas mentioned in this GR such as Bhildi and Panthawada were no more named as taluka (based on personal communication with department officials), and Vagdod taluka of Patan district was merged in Patan taluka (Census 2011).

To promote adoption of MI in dark-zone talukas, the government has withdrawn the restriction of electricity connection[10] for agriculture since 2012 – it was made mandatory that the farmer adopt MI in order to get new electricity connection[11]. Given their poor socio-economic status, the tribal farmers in the 43 tribal talukas are entitled to get a subsidy of 75% of capital cost of installing MI or Rs. 90,000 per ha, whichever is lower since 2008[12].

From January 2015, the GoG announced that all the SC (Schedule Caste) and ST (Schedule Tribe) farmers in the state are eligible to avail 75% of capital cost of MI or Rs. 90,000/ ha, whichever is lower[13]. Though various studies have found that credit constraint as one of the major determinants of MI adoption (Namara *et al.*, 2007; Palanisami *et al.*, 2011), there were no separate financial incentives for small and marginal farmers. This has been a major reason for the lower adoption of MI amongst the small and marginal farmers in Gujarat in particular. Hence, an additional subsidy was announced since March 2015 for small and marginal farmers. But, still the subsidy is different between dark-zone and non dark-zone talukas[14]. For instance, the small and marginal farmers in the non-dark zone talukas are entitled to get subsidy of 60% of installation cost of MI or Rs. 70,000, whichever is lower. Whereas, the farmers in the dark-zone talukas are entitled for a subsidy of 70% of total capital cost of installing MI or Rs. 70,000, whichever is lower (see Figure 2).

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[10] As per the GR dated 19/9/2001, the ground water levels were very low in certain areas, and therefore, the GoG had decided not to permit water extraction by tube wells in the interest of geo-hydrology of the regions and the public at large(http://deshgujarat.com/2012/02/28/gujarat-govt-to-give-power-connection-to-57-talukas-under-dark-zone/ (accessed on 12th May, 2015).

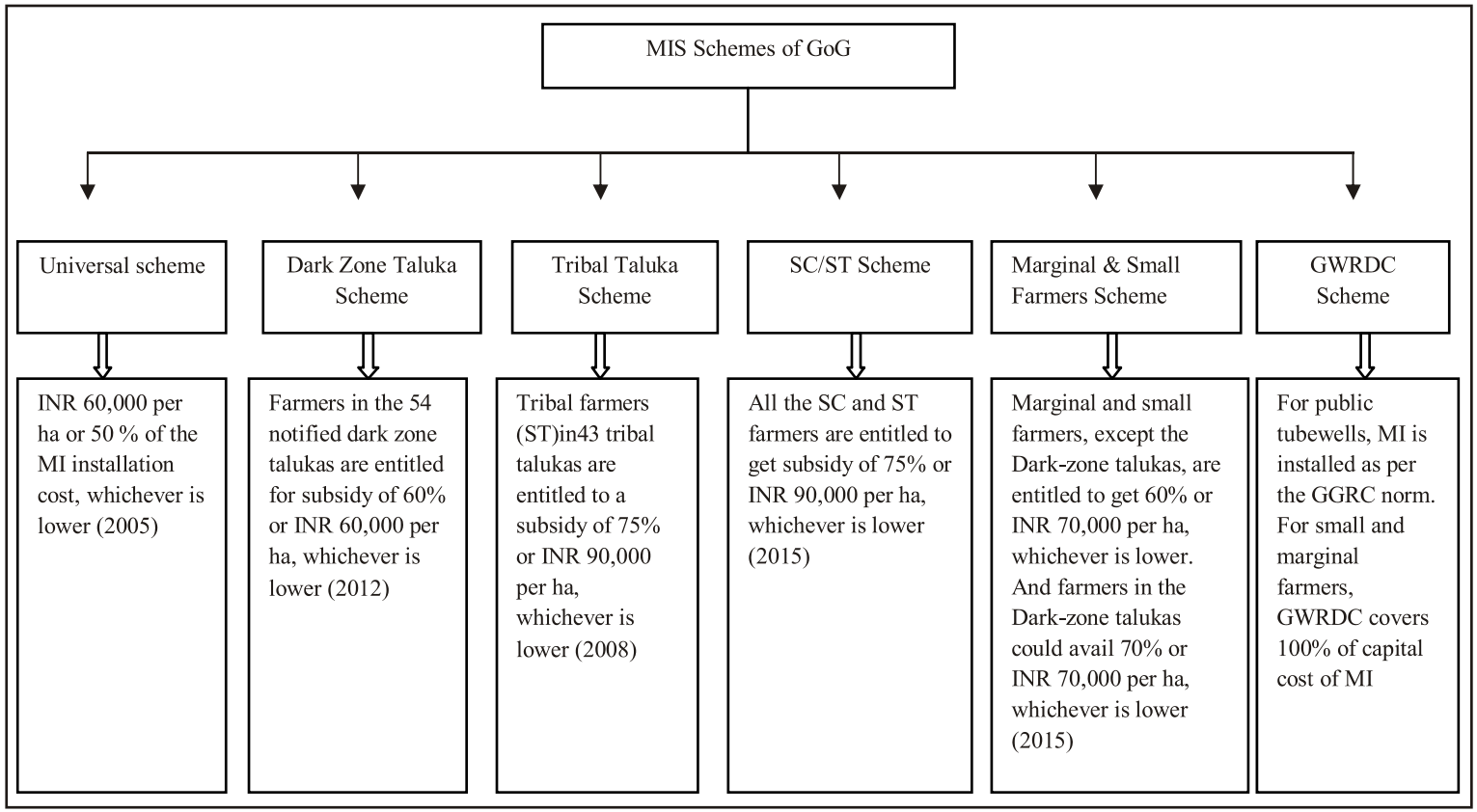
[11] See GR No: PRCH-102005-497(38) dated 3/4/2012.

[12] See GR No: VKY-2007-345-DSeg date 6/10/2008.

[13] See GR No: PRCH/102005/497(38)/Part-2/N dated 3/1/2015.

[14] See GR No: PRCH/102005/497(38)/Part-4/N dated 19/3/2015.

Figure 2: Details of subsidy provided by Government of Gujarat and GGRC



Note: Parenthetic figures indicate that the year in which the subsidy policy has been implemented.
Source: Authors' figure based on various government orders (GOs) of GoG

In addition, the Gujarat Water Resource Development Corporation (GWRDC) also promotes installation of MI on the public tubewells owned by them, mostly in the north Gujarat districts of Banaskantha, Gandhinagar, Mehsana, Patan and Sabarkantha. Under this scheme, small and marginal farmers were entitled to avail 75% of total capital cost or Rs. 90,000, whichever is lower (Viswanathan and Bahinipati, 2015), and currently, it is reported that the GoG subsidizes 100% of cost of capital of PINS (pressurized irrigation network system) and MI installation on public tubewells (GWRDC, personal communication).Further, the GoG provides additional support for promoting MI scheme in the state. For instance, Gujarat UrjaVikas Nigam Limited (GUVNL) provides electricity connection on priority basis to the farmers adopting MI. To enhance adoption of MI in the command areas of surface irrigation schemes, the government supports for installation of PINS in the canal commands of Sardar Sarovar Project (SSP) – the entire cost of PINS installation is reported to be borne by the Sardar Sarovar Narmada Nigam Ltd. (SSNNL) and the capital cost of MI shared by both the government and the beneficiary farmers as per the GGRC norms (see Figure 2). In the following sections, we examine the status and trends in adoption of the different subsidy programmes for promoting MI across regions in the state under various institutional arrangements.

3. Trends and patterns of diffusion and adoption of MI Sin Gujarat

3.1. Micro-irrigation adoption: overall scenario

It is reported that about 4.94 million ha area was covered under MI in India as of 2010; of which, 1.9 million ha was under drip irrigation (i.e., 38% of the total area) and 3 million ha under sprinkler irrigation (i.e., 62%; see Table 1). Among the states, Maharashtra and Rajasthan occupied the first and second positions respectively, with a coverage of 0.9 million ha, each accounting for 18% of the total area under MI (see Table 1 and Figure 3).

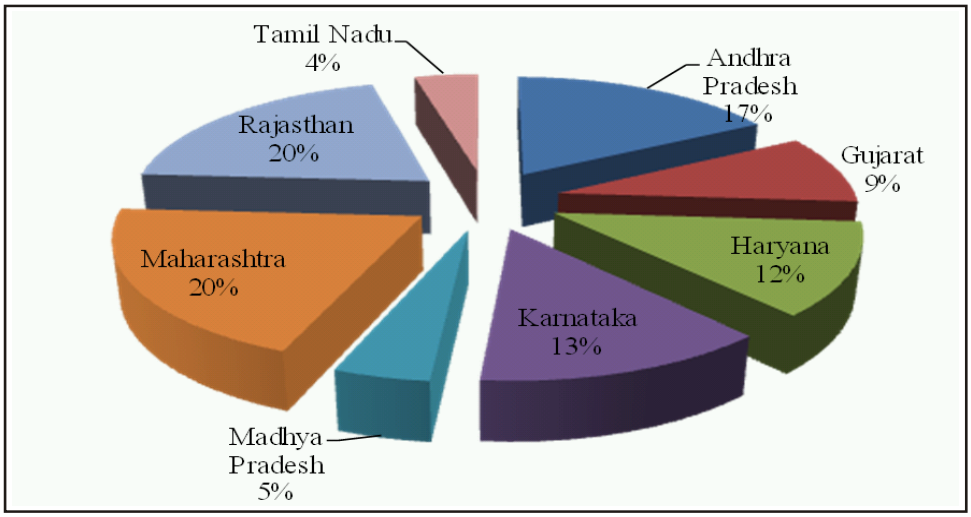
Table 1: Area under Micro Irrigation in Major States in India, 2010

Name of State	Drip Irrigation ('000 ha)	(%) share	Sprinkler Irrigation ('000 ha)	(%) share	Total Micro-Irrigation ('000 ha)	% of total area under MIS
Andhra Pradesh	505.21	66.29	256.91	33.71	762.12 (3)	15.42
Chhattisgarh	6.36	6.23	95.74	93.77	102.10 (10)	2.07
Gujarat	226.77	55.66	180.67	44.34	407.45 (6)	8.24
Haryana	11.35	2.08	533.74	97.92	545.09 (5)	11.03
Karnataka	209.47	35.20	385.58	64.80	595.05 (4)	12.04
Madhya Pradesh	51.71	26.53	143.23	73.47	194.95 (7)	3.94
Maharashtra	604.44	67.17	295.38	32.83	899.82 (1)	18.21
Rajasthan	30.05	3.35	866.59	96.65	896.64 (2)	18.14
Tamil Nadu	153.44	84.65	27.83	15.35	181.27 (8)	3.67
West Bengal	0.25	0.16	150.20	99.84	150.44 (9)	3.04
India	1897.28	38.39	3044.94	61.61	4942.22	-

Note: The figures in the parentheses indicate rank of the respective state.
Source: Sankaranarayanan *et al.* (2011)

The total area reported under the MI in Gujarat was 0.41 million ha and the state occupies sixth position in India. The area irrigated under drip systems was the highest, i.e., 0.23 million ha accounting for 56% of the total area under MI, which is much above the national average (38%) and similar to the patterns in the states, viz., Tamil Nadu, Maharashtra and Andhra Pradesh. In terms of the total reported area under MI as proportion of the potential area, it is observed that Gujarat has a lower share achieved so far, i.e., around 9% of the total potential area (Palanisami *et al.*, 2011); which is notably lower as compared to other major states. As of 2014-15, Gujarat state roughly covered around 20% of the total net sown area. This is despite the state having taken various initiatives in terms of designing institutions and several ongoing schemes for promotion of MI within the state. Moreover, it should be noted that GGRC model performs better in the context of promoting MI in the state as compared to the various models adopted by the Indian states (Palanisami, 2015).

Figure 3: Share (%) of major states in area under MIS (2010)



Source: Table 1.

Based on the discussion in the foregoing and some literature (Caswell and Zilberman, 1983; Palanisami, *et al.*, 2011), we propose a hypothesis that there could be a higher probability of adopting MI in a region where water is a scarce resource and/or a high dependency on groundwater for irrigation. Since state's agro-ecological conditions satisfy both, an increasing trend was found with respect to the number of farmers adopting MI and the area under MI[15] (Table 2 and Figure 4). The figures report the year wise adoption scenario[16]. For instance, 12.96 thousand farmers had adopted MI by the year 2006-07, and this number increased more than 10 times in the recent years, i.e., 140.1 thousand and 123.78 thousand farmers in 2013-14 and 2014-15, respectively. Likewise, 25.7 thousand ha land was under MI during 2006-07, which had increased by around 9 times to 224.95 thousand ha during 2013-14 and 200.55 thousand ha during 2014-15. Indeed, both the number of MI adopted farmers and the corresponding area had significantly increased after 2009-10 (Figure 4).

[15] The information presented in this study were collected from GGRC and pertains to the period from 2006-07 to 2014-15. Some farmers could have adopted MI before GGRC intervened and some may have adopted without support of GGRC (e.g., farmers under the GWRDC scheme) – such information is not included in the analysis in this section.

[16] Appendix 1 and 2 reports district-wise adoption of MI and area under MI in Gujarat.

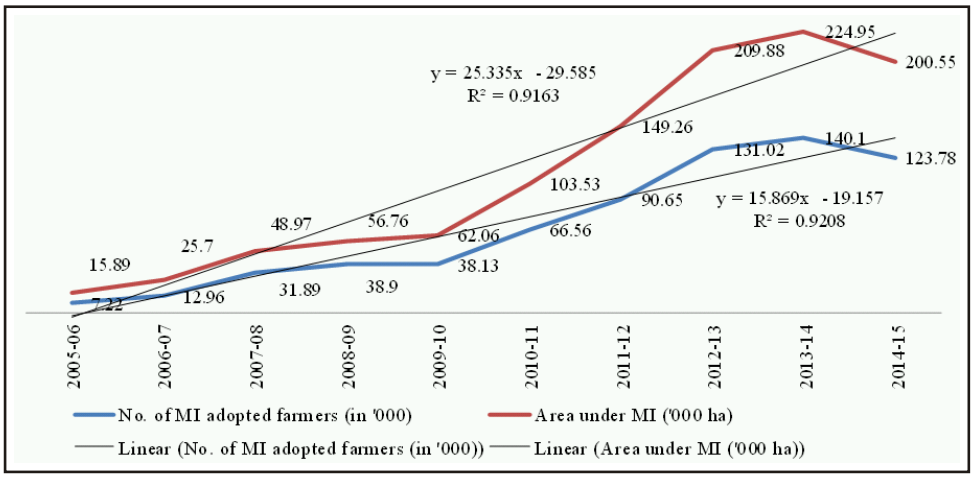
Table 2: Year-wise trends in the adoption of Micro-Irrigation in Gujarat (2005-06 to 2014-15)

Year	Total		Achievement under Tribal Scheme		Crop group-wise area coverage under MIS (in '000 ha)		Category of farmers (in '000) covered under Micro Irrigation System				Grant from GoG & GoI under MIS (Rs. in million)
	No. of Farmers adopted MI (in '000)	Area under MI ('000 ha)	No. of Farmers adopted MI (in '000)	Area under MI ('000 ha)	Agri-culture Crops	Horti-culture	Marginal	Small	Medium	Large	
2005-06	7.22	15.89	-	-	10.49	5.40	1.04	3.38	1.86	0.93	230
2006-07	12.96	25.70	-	-	19.60	7.63	1.56	7.86	3.09	1.29	1110
2007-08	31.89	48.97	1.99	3.31	36.67	13.59	1.39	7.56	13.94	9.61	1100
2008-09	38.90	56.76	2.53	3.74	42.10	15.63	2.51	12.88	22.92	1.13	1610
2009-10	38.13	62.06	9.94	14.14	56.68	14.14	2.90	12.81	26.49	1.33	1390
2010-11	66.56	103.53	25.97	33.41	91.32	11.17	4.32	19.13	39.99	2.16	2560
2011-12	90.65	149.26	24.12	34.62	137.29	13.19	6.91	27.47	54.36	2.65	4300
2012-13	131.02	209.88	32.19	42.12	188.72	16.48	10.98	35.44	77.58	4.25	5820
2013-14	140.10	224.95	20.97	28.21	202.00	23.26	15.11	39.42	81.64	4.04	6670
2014-15	123.78	200.55	27.64	38.71	170.99	29.56	13.34	33.09	73.09	4.26	5310
Total (2005-15)	681.21 (14.38)	1097.55 (11.00)	145.35	198.26	-	-	60.06 (3.44)	199.04 (14.42)	394.96 (25.68)	31.65 (43.96)	30100

Note: The figures in the parentheses indicate the percentage figure out of the total famers and area in Gujarat.

Source: Authors' table based on data collected from GGRC.

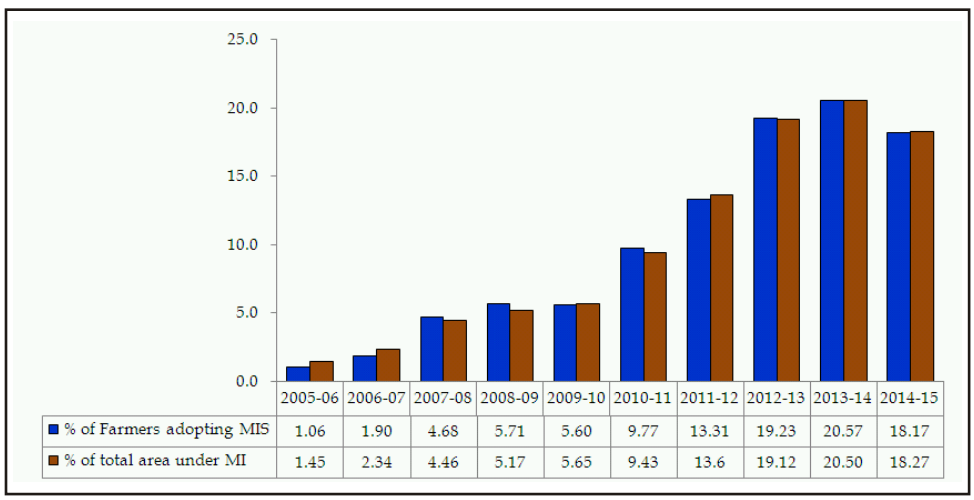
Figure 4: Share (%) of major states in area under MIS (2010)



Source: Table 2.

From Figure 5, it may be seen that around 81% of the farmers (and the area) have adopted MI between 2010-11 and 2014-15. This reveals that the MI technology was widely adopted in Gujarat within a shorter span of less than five years.

Figure 5: Share (%) of major states in area under MIS (2010)



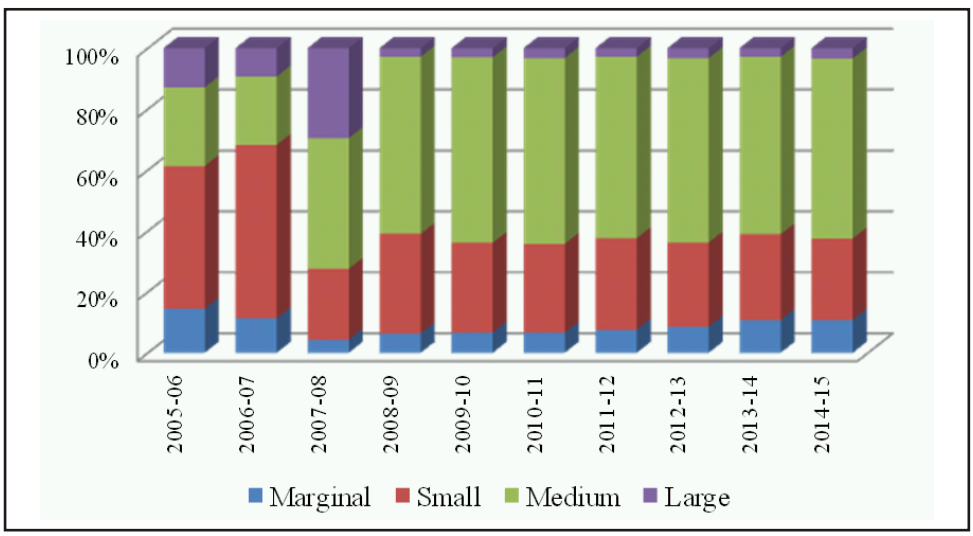
	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
% of Farmers adopting MIS	1.06	1.90	4.68	5.71	5.60	9.77	13.31	19.23	20.57	18.17
% of total area under MI	1.45	2.34	4.46	5.17	5.65	9.43	13.6	19.12	20.50	18.27

Source: Table 2.

3.1.1. MI adoption: size class-wise pattern

When we examine the adoption pattern across land size classes, it is found that, currently, medium farmers (2-10 ha) are the dominant adopters of MI in Gujarat, who accounted for 60% of the total number of farmers adopted MI during 2014-15 (Figure 6). The combined share of small (1-2 ha) and marginal (<1 ha) farmers was 37% during the same period. It is also important to note that in the initial years of launching of the MI scheme, the small and marginal farmers were the largest adopters, whose combined share was 61% during 2005-06, which had increased to 68% in the next year (2006-07).

Figure 6: Year-wise percentage of farmers and area under MI by Land size Classes, 2005-06 to 2014-15

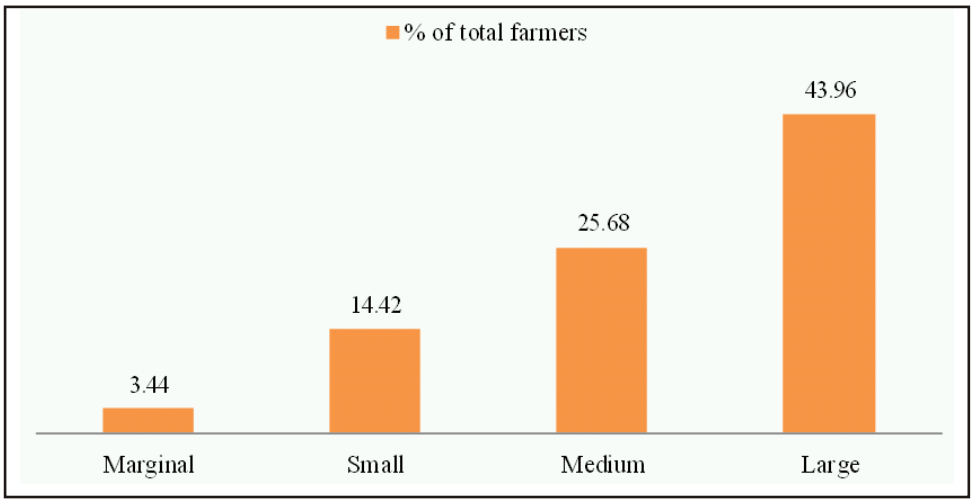


Source: Table 2

The later years saw an increasing trend in MI adoption by the medium farmers with the share of large farmers remaining stable at about 3% since 2008-09. From Figure 7, it is found that around 44% of the total large farmers and 26% of the total medium farmers have adopted MI; it is very low in the case of marginal and small farmers, i.e., 3% and 14% respectively[17]. This reveals that the MI is mostly adopted by medium and large farmers, while 66% of the total farmers are small and marginal. Overall scenario suggests that there is still a potential for increasing MI adoption particularly among the small and marginal farmers. This also raises a question needing further probing as to why a large percentage of small and marginal farmers

do not adopt MI. In fact, the state government, as outlined above, has recently initiated a separate subsidy policy for small and marginal farmers (see Figure 2) and hopefully, this will motivate these farmers to adopt MI in the near future.

Figure 7: Percentage of total farmers by land size classes (2005-06 to 2014-15)



Note: The figures are percentage of farm households out of the total number of marginal, small, medium and farm households respectively, as per the 2011 Census'.

Source: Table 2

3.1.2. Micro-Irrigation Adoption across Agro-Climatic Regions

The agro-climatic region wise status of MI adoption in the state is presented in Tables 3 and 4, respectively. It is observed that both the indicators (i.e., total number of MI adopted farmers and total area under MI) have seen an increasing trend over the years across agro-climatic regions.

For instance, the CAGR (compounded annual growth rate) of number of MI adopted farmers across regions was 34.7% (see Table 3), and it was 31% in case of area under MI between 2006-07 and 2013-14 (Table 4). This, in other words, signifies that the proactive state policy of providing subsidy in

[17] This comparison is based on the census 2011 data on operational holdings by size class. Accordingly, the total number of marginal, small, medium and large farm households were 1.75, 1.38, 1.54 and 0.07 million respectively. Based on these figures, the respective shares of farmers adopting MI (Table 2) were 3.44, 14.42, 25.68 and 43.96% respectively as shown in Figure 7.

the range of 50-75% would have motivated a large number of farmers to adopt MI over the years, in view of the anticipated economic, physical and environmental benefits of MI.

Table 3: Agro-climatic zone wise number of farmers adopting MIS in Gujarat, 2006-07 to 2013-14

Agro-climatic Region	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	Total	CAGR (%)
North-West Arid	0.59 (4.5)	0.75 (2.4)	0.76 (1.9)	0.81 (2.1)	1.26 (1.9)	0.80 (0.9)	4.84 (3.7)	5.82 (4.2)	15.62 (2.8)	33.27
North Gujarat	2.43 (18.8)	6.6 (20.7)	6.35 (16.3)	13.89 (36.4)	21.46 (32.3)	25.90 (28.6)	44.22 (33.7)	47.65 (34.0)	168.51 (30.6)	45.04
Middle Gujarat	1.05 (8.1)	1.62 (5.1)	2.15 (5.5)	3.32 (8.7)	7.83 (11.8)	15.58 (17.2)	17.08 (13.0)	13.39 (9.5)	62.02 (11.3)	37.55
North Saurashtra	2.73 (21.1)	9.95 (31.2)	18.78 (48.3)	12.22 (32.1)	13.67 (20.5)	27.67 (30.5)	30.96 (23.6)	37.52 (26.8)	153.50 (27.9)	38.75
South Gujarat	1.69 (13.0)	2.11 (6.6)	2.13 (5.5)	1.81 (4.7)	10.62 (15.9)	7.29 (8.0)	10.94 (8.3)	8.00 (5.7)	44.60 (8.1)	21.47
Southern Hills	0.86 (6.6)	0.94 (2.9)	1.17 (3.0)	0 (0)	4.78 (7.2)	3.62 (3.9)	5.53 (4.2)	3.65 (2.6)	20.55 (3.7)	19.75
South Saurashtra	3.61 (27.9)	9.91 (31.1)	7.56 (19.4)	6.06 (15.9)	6.93 (10.4)	9.80 (10.8)	17.46 (13.3)	24.08 (17.2)	85.42 (15.5)	26.75
Gujarat	12.96	31.89	38.90	38.13	66.56	90.65	131.02	140.10	550.21	34.66

Note: The reported figures are in '000; Figures in parentheses indicate percentage; CAGR – Compound Annual Growth Rate.

Source: Adopted from Bahinipati and Viswanathan (2016).

Table 4: Agro-climatic zone wise area under MIS in Gujarat, 2006-07 to 2013-14

Agro-climatic Region	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	Total	CAGR (%)
North-West Arid	2.11 (8.2)	2.46 (5.0)	2.30 (4.1)	2.40 (3.9)	3.50 (3.4)	2.19 (1.5)	9.68 (4.6)	12.06 (5.4)	36.70 (4.2)	24.37
North Gujarat	5.98 (23.3)	12.78 (26.1)	13.08 (23.0)	24.38 (39.3)	34.08 (32.9)	48.64 (32.6)	75.92 (36.2)	78.68 (34.9)	293.53 (33.3)	38.02
Middle Gujarat	2.27 (8.8)	3.00 (6.1)	3.67 (6.5)	6.04 (9.7)	13.74 (13.3)	24.88 (16.7)	23.55 (11.2)	17.52 (7.8)	94.68 (10.7)	29.09
North Saurashtra	4.62 (17.9)	13.01 (26.6)	22.06 (38.9)	17.16 (27.7)	21.81 (21.1)	43.41 (29.1)	52.21 (24.9)	63.98 (28.4)	238.26 (27.0)	38.91
South Gujarat	3.92 (15.3)	3.49 (7.1)	3.54 (6.2)	3.04 (4.9)	13.73 (13.3)	10.55 (7.1)	15.55 (7.4)	12.27 (5.5)	66.09 (7.5)	15.32
Southern Hills	1.56 (6.1)	1.59 (3.3)	1.81 (3.9)	0 (0)	6.36 (6.1)	5.05 (3.4)	6.62 (3.2)	4.35 (1.9)	27.34 (3.1)	13.64
South Saurashtra	5.25 (20.4)	12.63 (25.8)	10.31 (18.2)	9.04 (14.6)	10.32 (9.9)	14.53 (9.7)	26.34 (12.6)	36.09 (16.1)	124.52 (14.1)	27.26
Gujarat	25.70	48.97	56.76	62.06	103.53	149.26	209.88	224.95	881.11	31.15

Note: The reported figures are in '000 ha; Figures in parentheses indicate percentage; CAGR – Compound Annual Growth Rate.

Source: Adopted from Bahinipati and Viswanathan (2016).

Further disaggregation across the agro-climatic regions reveals that a majority of farmers adopted MI in the three agro-climatic regions, namely, north Gujarat, north Saurashtra and south Saurashtra, as these regions are reportedly experiencing severe water scarcity and high levels of groundwater extraction. While the north Gujarat reported as critical and over-exploited (SGWD> 85%), the other two regions (e.g., north Saurashtra and south Saurashtra) are coming under dark category (SGWD is in between 65-85%) [see GoI, 2014]. These three regions together cover around 74% of the total MI adopted farmers and 75% of the total area under MI in the state. Among them, north Gujarat occupies the first position in terms of number of farmers adopting MI (i.e., 168.51 thousand farmers, i.e., around 31% of total farmers) and total area under MI (i.e., 293.53 thousand ha, i.e., around 33% of total area) in the state. This reveals that the emerging hydrological scenario also act as a major determinant in the adoption of MI in the state.

3.1.3. Micro-Irrigation Adoption in Dark-zone and Tribal Talukas

It has been noted that the subsidy amount varies with respect to socio-economic group and geographical location in Gujarat under the new policy frame (see Figure 2). In this sub-section, we examine the possible impact of extra subsidy provided to dark-zone and tribal talukas on the diffusion and adoption of MI. Table 5 presents the year-wise number of farmers adopting MI and area under MI by dark-zone and tribal talukas in the Gujarat state; following this, Figures 8 and 9 show year-wise trends in number of farmers and area covered under MI in the dark-zone and tribal talukas, respectively.

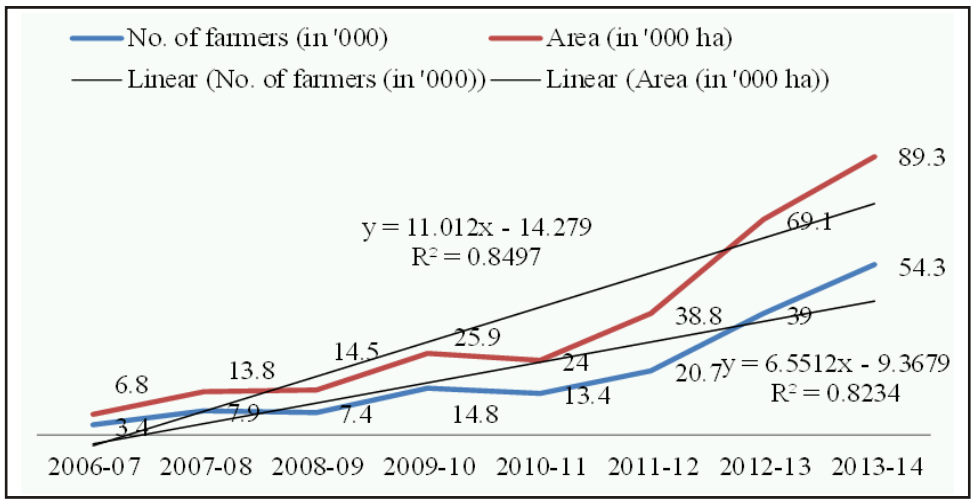
Table 5: Trends in adoption of MI in the dark-zone and tribal talukas

Year	Dark-Zone[a]				Tribal Talukas			
	No. of Farmers adopted MI		Total area under MI		No. of Farmers adopted MI		Total area under MI	
	No. (in '000)	%	in '000 ha	%	No. (in '000)	%	in '000 ha	%
2006-07	3.4	2.1	6.8	2.4	1.9	1.6	4.22	2.6
2007-08	7.9	4.9	13.8	4.9	3.1	2.6	4.84	2.9
2008-09	7.4	4.6	14.5	5.1	3.8	3.2	6.00	3.6
2009-10	14.8	9.2	25.9	9.2	6.9	5.8	9.67	5.9
2010-11	13.4	8.3	24	8.5	28.3	23.9	36.91	22.4
2011-12	20.7	12.9	38.8	13.7	24.9	21.0	36.00	21.9
2012-13	39.0	24.2	69.1	24.5	26.9	22.7	35.87	21.8
2013-14	54.3	33.7	89.3	31.6	22.8	19.2	31.02	18.9
Total (2006-14)	160.9	100.0	282.2	100.0	118.6	100.0	164.53	100.0

Note: a- the figures reported excludes tribal talukas

Source: Authors' compilation based on data collected from GGRC.

Figure 8: Year-wise farmers and area under MI in the Dark-zone talukas, 2006-07 to 2013-14



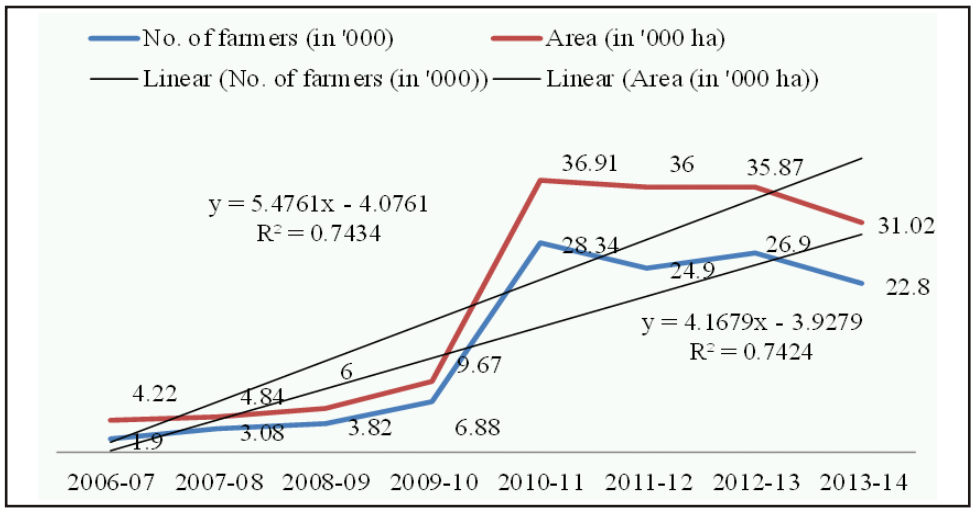
Source: Table 5.

As noted, the state government announced extra 10% subsidy since 2012 in the case of dark-zone talukas, and therefore, an increasing trend was observed in the case of farmers and area under MI (see Figure 8). Certainly, this sharp increase in adoption of MI could have happened due to the extra subsidy given to the farmers in the dark zone talukas that also coincided

with the lifting of the ban on water extraction and the release of agricultural power connections. Moreover, in order to identify the specific impact of the treatment (additional subsidy), one need to apply various methods of impact evaluation (e.g., difference-in-difference, regression discontinuity design approach, etc.) – this is future area of research. In the meantime, Fishman *et al.* (2014) find an evidence of additional subsidies enhancing the adoption of MI in Gujarat state, i.e., drip irrigation by 32%, the area installed with drip by 30% and the probability of having at least one purchase by 11%. In fact, there is no such study so far to our knowledge, which mainly focused on the dark-zone talukas.

The state government has provided additional subsidy to the tribal farmers in the tribal talukas since 2008. An increasing adoption trend was also observed in the case of number of tribal farmers adopting MI until 2012-13 as evident from Figure 9. For instance, around 1.99 thousand tribal farmers had adopted MI in 2007-08 with an area of 3.31 thousand ha, and this number and area had increased to 32.19 thousand farmers and 42.12 thousand ha respectively, by 2012-13 (Table 5). However, a declining trend was observed in the last two years as compared to the previous three years. The reported adoption of MI during the latest two years was 20.97 thousand farmers and 27.64 thousand farmers, respectively. This may be explained in terms of the point that by 2014-15, all potential farmers with access to groundwater irrigation sources would have adopted the MIS and further adoption would call for development of new groundwater sources on which MIS could be installed. Nevertheless, this point needs further empirical validation.

Figure 9: Year-wise trends in number of farmers and area under MI in Tribal talukas, 2006-07 to 2013-14



Source: Table 5

In the case of tribal talukas, it may be seen that there was a sudden rise in the number of farmers and area under MI in the 2010-11 as compared to 2009-10. For instance, around 3.82 thousand farmers adopted MI in the year 2008-09 with 6 thousand ha area, and this was increased to 6.88 thousand farmers (with 9.67 thousand ha area) in 2009-10 and 28.34 thousand farmers (with 36.91 thousand ha area) in 2010-11. After that, these figures remained static in case of area and a decline in case of number of farmers adopting MIS. It may be surmised that the increase in the number of farmers adopting MI in the tribal talukas certainly reflects on the immediate response towards the new policy of incremental subsidy for MIS in the tribal talukas.

On the whole, the major reasons for the increased adoption in the dark zone and tribal talukas could be the increasing awareness about the benefits of MI along with the subsidy policy of the state, providing higher rate of subsidies to farmers in the tribal and dark-zone talukas as well as the suitability of the system for various agricultural crops, etc. As a cumulative outcome, the total amount of subsidy provided by the government had increased by more than six fold over the 10 year period from Rs. 1110 million during 2006-07 to Rs. 6710 million during 2013-14 and Rs. 5310 million in 2014-15 (Table 2). In contrast to the existing findings that MI is suitable mostly for horticultural and high valued commercial crops, for majority of Indian states (Palanisami *et al.*, 2011), we find that a large percentage of MI adopted area in Gujarat is under agricultural crops (see

Table 2). This contrast may be explained in terms of the prevalence of different state-sponsored subsidy schemes for promotion of MI in Gujarat, unlike other states.

4. Concluding Remarks

This paper makes a comprehensive review of the state policy and intervention for the promotion of micro irrigation systems in Gujarat during the last decade. While the promotion of MI in Gujarat corresponds with the NMMI, an unequivocal dynamism was observed in the expansion of MI in the state as compared to other states. This dynamism in the promotion of the MI can be attributed to the specific policies and interventions that the state had vigorously adopted and followed in terms of provision of differential subsidies targeted towards the farmers segregated by their socio-economic status as well as the physical and economic water scarcity of the agro-ecological regions. In this regard, the paper provides a detailed analysis of the trends in the status of adoption of micro irrigation systems in Gujarat under the various subsidy policy and institutional innovations. By and large, the analysis reveals that the rate of adoption of the MI has been quite significant across farm size classes, agro-climatic regions, water stressed (dark zone) talukas as well as tribal talukas. However, it is important to note that the initial responses towards adoption of the MI as evinced by the farmers and regions may have been exceptionally influenced by the specific subsidy policies and institutional interventions. While the initial enthusiasm in the adoption of a frontier water saving technology as MI is quite contextual and commendable, it needs to be further explored that: 'how far the MI technological interventions make a significant and sustainable impact on the agrarian performance of the regional economies and the rejuvenation of the heavily depleted groundwater aquifers in the state'.

Further, though the adoption of MI had been significant, the aggregate level of adoption in the state is still low in terms of total farmers and coverage of area under MI, i.e., only around 14% of the total farmers have undertaken MI with 11% of the total potential area between 2005 and 2015. This indicates that the diffusion of MI is still low across the state, even though the state has launched institutional interventions and differential subsidy policies to enhance the adoption rate. It may be quite interesting to find out 'why a large number of farmers are still not adopting such water saving technologies while there are favourable policies and differential subsidy programmes'?

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Appendix 1: District wise number of farmers adopting MIS in Gujarat, 2006-07 to 2013-14

District	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	Total
Ahmedabad	0.05	0.13	0.29	0.42	0.32	1.06	1.62	2.39	6.27 (21)
Amreli	0.47	2.65	4.54	2.60	2.81	6.47	5.34	7.86	32.73 (6)
Anand	0.21	0.21	0.19	0.22	0.24	0.38	0.36	0.43	2.23 (26)
Banas Kantha	0.97	3.84	3.59	6.52	10.66	13.80	24.41	25.40	89.18 (1)
Bharuch	0.71	0.74	0.66	0.76	0.91	1.15	1.96	2.49	9.37 (16)
Bhavnagar	0.47	2.63	3.45	2.71	4.91	6.86	9.08	8.36	38.47 (5)
Dahod	0.01	0.02	0.16	0.50	1.85	3.43	5.68	3.28	14.93 (12)
Gandhinagar	0.14	0.20	0.14	0.17	0.40	0.50	1.36	1.71	4.62 (24)
Jamnagar	0.54	1.64	3.99	2.59	1.33	4.24	3.15	5.61	23.08 (8)
Junagadh	3.23	7.72	6.04	5.23	6.14	8.73	15.76	21.77	74.6 (2)
Kheda	0.17	0.22	0.18	0.28	0.36	0.65	1.32	2.55	5.73 (22)
Kutchh	0.59	0.75	0.76	0.81	1.26	1.73	4.84	5.82	16.55 (10)
Mehasana	0.20	0.28	0.35	0.38	0.59	0.89	2.56	4.71	9.96 (15)
Narmada	0.19	0.50	0.64	1.06	3.05	1.63	1.96	1.83	10.85 (13)
Navsari	0.63	0.66	0.47	0.00	1.67	1.58	2.01	1.58	8.6 (18)
Panch Mahals	0.03	0.11	0.20	0.61	1.26	2.98	2.09	1.09	8.36 (20)
Patan	0.09	0.21	0.16	0.38	0.32	0.48	1.87	2.20	5.72 (23)
Porbandar	0.39	2.19	1.52	0.83	0.80	1.07	1.70	2.31	10.81 (14)
Rajkot	0.82	2.28	5.81	3.14	2.70	7.31	7.00	11.33	40.4 (4)
Sabarkantha	0.98	1.95	1.83	6.03	9.17	8.23	12.40	11.25	51.83 (3)
Surat	0.49	0.61	0.55	0.00	1.42	1.65	2.00	2.00	8.72 (17)
Surendranagar	0.44	0.75	0.99	1.18	1.91	2.79	6.39	4.36	18.82 (9)
Tapi	0.29	0.26	0.29	0.00	5.24	2.87	5.03	1.68	15.66 (11)
The Dangs	0.001	0.002	0.08	0.00	1.29	0.39	1.25	0.51	3.52 (25)
Vadodara	0.63	1.07	1.42	1.72	4.12	8.13	7.62	6.05	30.77 (7)
Valsad	0.23	0.27	0.63	0.00	1.82	1.66	2.28	1.55	8.44 (19)
Gujarat	12.96	31.89	38.90	38.13	66.56	90.65	131.02	140.10	550.21

Note: The reported figures are in '000; Figures in parentheses indicate rank.

Source: Authors' compilation based on data collected from GGRC.

Appendix 2: District wise area under MIS in Gujarat, 2006-07 to 2013-14

District	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	Total
Ahmedabad	0.16	0.33	0.79	1.47	1.04	3.13	3.91	4.95	15.80 (15)
Amreli	0.65	3.10	5.05	3.46	4.06	9.84	8.93	13.74	48.83 (6)
Anand	0.39	0.31	0.29	0.27	0.28	0.48	0.38	0.47	2.87 (26)
Banas Kantha	1.99	7.07	7.54	11.70	17.34	26.50	43.26	44.68	160.07 (1)
Bharuch	1.86	1.35	1.26	1.48	1.71	2.01	3.07	3.85	16.60 (14)
Bhavnagar	0.63	3.05	3.53	3.46	7.15	10.27	13.73	12.64	54.46 (5)
Dahod	0.03	0.07	0.23	0.85	3.29	5.72	7.56	4.36	22.12 (11)
Gandhinagar	0.43	0.44	0.29	0.31	0.60	1.06	1.95	2.44	7.52 (24)
Jamnagar	0.87	2.20	4.80	3.66	2.32	6.80	5.51	10.52	36.67 (10)
Junagadh	4.63	9.65	7.77	7.58	8.93	12.75	23.23	31.45	105.99 (2)
Kheda	0.51	0.54	0.48	0.64	0.95	1.36	2.06	3.26	9.80 (23)
Kutchh	2.11	2.46	2.30	2.40	3.50	4.32	9.68	12.06	38.83 (9)
Mehasana	0.51	0.51	0.56	0.70	0.99	1.45	3.28	5.44	13.45 (18)
Narmada	0.32	0.66	0.85	1.56	3.56	2.08	2.69	2.60	14.30 (17)
Navsari	1.06	1.03	0.69	0.00	2.44	2.30	2.70	2.13	12.35 (21)
Panch Mahals	0.06	0.16	0.31	1.04	1.98	5.11	2.96	1.59	13.20 (20)
Patan	0.24	0.56	0.48	0.99	0.77	0.76	4.85	4.74	13.37 (19)
Porbandar	0.61	2.98	2.55	1.46	1.39	1.79	3.11	4.64	18.53 (13)
Rajkot	1.19	2.88	6.46	3.99	3.83	10.54	10.80	17.85	57.55 (4)
Sabarkantha	2.66	3.86	3.41	9.21	13.33	13.61	18.67	16.44	81.20 (3)
Surat	1.09	1.06	0.93	0.00	2.14	2.60	3.36	3.25	14.43 (16)
Surendranagar	1.28	1.77	2.21	2.60	4.44	5.96	13.26	9.23	40.75 (8)
Tapi	0.65	0.42	0.50	0.00	6.32	3.86	6.42	2.57	20.75 (12)
The Dangs	0.001	0.001	0.10	0.00	1.30	0.40	1.25	0.52	3.57 (25)
Vadodara	1.29	1.92	2.37	3.23	7.23	12.22	10.59	7.84	46.69 (7)
Valsad	0.51	0.56	1.02	0.00	2.62	2.35	2.67	1.70	11.42 (22)
Gujarat	25.70	48.97	56.76	62.06	103.53	149.26	209.88	224.95	881.11

Note: The reported figures are in '000 ha; Figures in parentheses indicate rank.

Source: Authors' compilation based on data collected from GGRC.

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