Policy Paper 36

Potential, Adoption and Impact of Micro Irrigation in Indian Agriculture

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Foreword

ICAR-NIAP regularly undertakes research on policy and institutional issues related to water management in agriculture. This study on micro irrigation is of special interest because of its impact on water use in agriculture. The study examines adoption of micro irrigation in six states, namely Punjab, Maharashtra, Gujarat, Andhra Pradesh, Uttar Pradesh and Rajasthan, which have varied agro-ecologies and water management structures.

The evidences point out that farmers are keen to adopt drip irrigation, primarily to cope with the scarcity in at least one of three factors of production, namely water, power, and labour. The results indicate that micro irrigation has a positive impact on improving crop productivity and addressed the scarcity of water, power, and labour. The study clearly establishes micro irrigation is a worthy technology for improving water use efficiency and realizing other associated benefits.

The study explores the adoption of micro irrigation, farmers' management, and role of other stakeholders. The different phases of micro irrigation, including purchase of the equipment, installation, subsidy approval, and disbursements, are very important. The post-adoption phase is important as it helps maximize the benefits from the system. While the initial adoption phase is substantially influenced by friends, family and local networks, the post-adoption phase is dominated by the action of the dealers, company sale persons for after-sale service. The report makes a ground for redesigning micro irrigation implementation strategies for higher water productivity in a sustainable manner. I hope the findings will be useful for researchers and other readers.

Suresh Pal
Director

Acknowledgements

Micro irrigation technology has occupied a predominant place in recent policy discourse on addressing water management issues in India. The paper has analyzed potential, adoption pattern, impact and institutional arrangements for disseminating micro irrigation technology in the country. The study is conducted in six potential and progressive states in terms of adoption of micro irrigation technology. We acknowledge the financial grant received from NITI Aayog and ICAR for conducting the study. We express our gratitude to Dr Suresh Pal, Director, ICAR-NIAP for continuous motivation, guidance and support for publishing this paper. Our sincere thanks are due to Dr P. S. Birthal, ICAR National Professor, anonymous referees, Dr Raka Saxena and other members of the Publication Committee for their valuable suggestions for improving the manuscript. We acknowledge contribution of officials of the state governments for providing required information and project staff particularly Mr Praveen Kumar and Mr Arun Kumar for collecting farmers' response. We are obliged to the sample farmers' for their active participation and cooperation in conducting the survey.

Authors

Acronyms and Abbreviations

APMIP	Andhra Pradesh Micro Irrigation Project
BCM	Billion Cubic Meter
BCR	Benefit -Cost Ratio
CEO	Chief Executive Officer
CGWB	Central Ground Water Board
CSS	Centrally Sponsored Scheme
DAC& FW	Department of Agriculture Cooperation & Farmers Welfare
DACNET	Department of Agriculture Cooperation (India)
DDA	Deputy Director Agriculture
DIM	Drip Irrigation Method
DIP	District Irrigation Plan
DLIC	District-Level Implementation Committee
DM	District Magistrate
GGRC	Gujarat Green Revolution Company
GRACE	Gravity Recovery and Climate Experiment
ICAR	Indian Council of Agricultural Research
ICT	Information and Communication Technology
IDWG	Inter-Departmental Working Group
JDA	Joint Director Agriculture
KVK	Krishi Vigyan Kendra
MIS	Micro Irrigation Scheme
MoA	Ministry of Agriculture
NASA	The National Aeronautics and Space Administration
NCPAH	National Committee on Plasticulture Applications in Horticulture

NEC	National Executive Committee
NGO	Non-Governmental Organization
NMMI	National Mission on Micro irrigation
NMSA	National Mission for Sustainable Agriculture
NSC	National Steering Committee
OFWM	On-Farm Water Management
DRDA	District Rural Development Agency
PIA	Programme Implementing Agency
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
PPI	People's Participation Index
SCMIP	Solar-Powered Community Micro irrigation Project
SLSC	State-Level Sanctioning Committee
SWC	Soil and Water Conservation
VIIDP	Vidarbha Intensive Irrigation Development Programme

Executive Summary

Amidst rising water scarcity, micro irrigation technology as a tool to improve water use efficiency and farmers' welfare has occupied a prominent place in policy discourse in India. This study examines the spread and adoption of micro irrigation in six progressive and potential states of Andhra Pradesh, Gujarat, Maharashtra, Rajasthan, Punjab and Uttar Pradesh. The specific objectives of the study are: (1) examine institutional arrangements and government schemes to promote adoption of micro irrigation technology, (2) study efficacy of direct benefit transfer (DBT) in existing schemes on micro irrigation, (3) estimate potential area under micro irrigation technology and analyze its adoption pattern across the states, and (4) assess impact of micro irrigation technology in terms of savings in water, farm inputs, increase in farm income, employment generation, etc.

The study has used both secondary and primary data (farm level) to examine potential, adoption and impact of micro irrigation technology. The time-series data was compiled from various published sources for estimating potential area under micro irrigation and analyzing its adoption pattern across the states. The primary data was collected from randomly selected 1,566 farm households (adopters and non-adopters of micro irrigation) from selected study states during the year 2017-18 using pre-tested survey schedule. Appropriate analytical techniques like descriptive statistics, logit model, two-stage Heckman procedure and fixed effects regression models have been used to analyze data.

Field-level observations revealed differences in operational procedures and modalities in implementing micro irrigation scheme across the states, leading to a wide variation in their effectiveness. However, for selection of beneficiaries and disbursement of subsidy, the states follow common guidelines suggested by the central government. The implementation of the micro irrigation scheme in Andhra Pradesh, Gujarat and Maharashtra was found to be relatively effective in terms of simplified operational procedures, fairness in subsidy disbursement, transparency, farmers' satisfaction and clarity in subsidy disbursement than in the potential states of Punjab and Uttar Pradesh. Andhra Pradesh and Gujarat states have established a dedicated department/agency for implementation of micro irrigation scheme (MIS), whereas Maharashtra, Punjab, Rajasthan and Uttar

Pradesh are implementing the scheme through agriculture-horticulture, and soil and water conservation departments. The study revealed that frequent transfer of personnel engaged in MIS adversely affects progress of the scheme, particularly in Punjab and Maharashtra. This necessitates establishment of a dedicated department/agency for promotion of MIS. There exists an ample scope of improving the administrative procedures for effective implementation of MIS in Punjab on the lines of Andhra Pradesh Micro Irrigation Project (APMIP) and or Gujarat Green Revolution Company (GGRC). Use of information and communication technology (ICT) was effectively being utilized by Andhra Pradesh, Maharashtra and Gujarat in expanding coverage under micro irrigation, which can be replicated in other states with suitable modification(s).

In India, total area under micro irrigation increased considerably from 2.24 million hectare (Mha) in 2005-06 to 11.41 Mha in 2018-19. Sprinkler and drip irrigation system constituted 53.1% and 46.9 % share in total area in 2018-19, respectively. Presently, five states, namely Andhra Pradesh, Gujarat, Karnataka, Maharashtra and Rajasthan, contribute three-fourth of the total area covered under micro irrigation. State-wise potential area that can be brought under drip and sprinkler irrigation systems was estimated under two scenarios: Under the Scenario 1, potential area has been estimated using proportion of area irrigated by groundwater (tubewell + other well), tank, and 30% of canal irrigated area. The potential area under the Scenario 2 has been arrived at by adding 50% of canal irrigated area to the Scenario 1 estimates. The potential area, which could be brought under micro irrigation systems (drip and sprinkler) is estimated as 72.17 Mha and 77.58 Mha under scenario 1 and scenario 2, respectively. Among the states, Uttar Pradesh constitutes the largest share (25%), followed by Rajasthan (12%) and Madhya Pradesh (10%) in estimated potential area under micro irrigation. Interestingly, Uttar Pradesh, having the highest potential under micro irrigation (17.65 Mha), has realized the least (0.6%) level of coverage under micro irrigation. Similarly, in potential state like Punjab, where groundwater is overexploited, the realization level is abysmally low (0.78%). Thus, serious efforts are needed to promote micro irrigation in high potential but under-utilized states. The results revealed only 14.7 to 15.8 % realization of the potential area under sprinkler and drip irrigation system till the year 2018-19. The extent of realization was relatively higher for drip than the sprinkler system.

The present level of land ceiling for the micro irrigation subsidy is five hectares. Medium and large farmers constituting about 15% of total farmers operate more than 55% of total land holdings in the country. A conditional relaxation on the land ceiling for availing subsidy can be taken as a measure to expand coverage under micro irrigation. Post-installation services of micro irrigation system and training to the adopter farmers must be critically monitored to ensure maximum benefit from MIS. This will also instill confidence among farmers for its adoption.

Inadequate finance to farmers for margin money towards installing micro irrigation was found to be a major challenge among the sample farmers across the study states. Inadequate credit facilities were also linked with lack of trained human resources and poor infrastructure for training to farmers. The extent of participation of adopter farmers in installation of micro irrigation at their field was lower than expected. This needs to be improved by engaging farmers right from the planning stage of the scheme to the post-installation services stage. Micro irrigation is generally perceived as capital-intensive technology and its acceptance among farmers needs constant persuasion. Emphasis needs to be given on creating awareness about micro irrigation scheme focusing its positive effects to motivate and encourage the farmers to adopt it. Though in the states of Andhra Pradesh, Maharashtra and Gujarat MIS is progressing well, there was a lack of information among farmers on the spatial and temporal variation in soil moisture, optimal fraction of soil to be wetted, location-and crop-specific irrigation and fertigation scheduling, low cost water-soluble fertilizers availability, and other agro-chemicals. In the states like Punjab with over-exploited groundwater resources, emphasis must be given on promoting water efficient technologies through conducive policy decisions and technological interventions.

Since January 2013, the approach of Direct Benefit Transfer (DBT) has been initiated in various welfare schemes in the country for accurate targeting and faster flow of funds to beneficiaries. A case study on DBT linked agro-inputs in Uttar Pradesh has revealed an equitable participation by the farmers in DBT registration process to avail benefits across the regions. Selection of farmers and disbursement of subsidy was transparent and quick. Key factors that influence registration under DBT scheme include farming experience, education level, possession of smart phone, banking facilities and ownership of diesel engine. It was noted that farmers who followed micro irrigation were relatively more educated and possessed large land holdings. The farmers adopting micro irrigation technology in wheat crop saved water by 15% and improved yield by 21% as compared to the farmers using flood irrigation. Technical efficiency in crop cultivation was also found to be higher among adopters of micro irrigation technology.

The adopters of micro irrigation realized a higher level of productivity and income as compared to non-adopters. The adopters incurred relatively less cost on inputs as compared to non-adopters. In Gujarat, total cost savings varied between 4.15 and 30.39% and 17.63 to 52.01% higher net return was realized by the adopters in the selected crops. In Andhra Pradesh, savings in cost of selected crops varied between 4.59 and 24.60% for adopters, whereas net return increased from 12.28 to 43.02%. In Maharashtra, total cost saved in different crops varied from 7.76 to 35.15%, and gains in net return varied from 20.95 to 58.69% across selected crops. Input cost saving and output enhancement due to micro irrigation was observed in Gujarat and Punjab too. It could be noted that MIS not only reduced water demand but also saved other inputs used as well. Application of sprinkler system by farmers in Rajasthan revealed increase in area under cultivation across crops including returns as compared to non-adopters. Results show that increase in cropped area varied from 5.6% in wheat to 111.5% in gram, while increase in yield varied from 23% in gwar (Cluster beans) to 45% in bajra during kharif season, and in rabi crops, increase in yield was highest for gram (97.3%), followed by wheat (19.4%).

Field level observations revealed that micro irrigation has created opportunities of employment and income generation, and attracted rural youths towards agriculture in Chittoor district of Andhra Pradesh. The reverse migration was also noticed in some areas of Andhra Pradesh and Punjab due to improved agriculture productivity, better price of produce and employment opportunities. Shining example of DBT and GPS-based location of installed micro irrigation need to be replicated in other states as well. Special purpose vehicles such as GGRC and APMIP can be created in states with lesser penetration of micro irrigation. In the guidelines of micro irrigation scheme, states such as Punjab, where micro irrigation coverage is less (0.78%), should be shifted from category "A" to category "B" or "C" so that more financial assistance could be allocated. Further, in Punjab, assured availability of water source is a necessary condition for farmers being eligible in getting benefits under micro irrigation scheme. Such conditions may be relaxed and farmers with shared water sources may also be made eligible for such benefits. Liquid chemicals and fertilizers should be made available in local markets to make use of by the farmers. Financial accessibility in terms of credit may be made easy for MI farmers. Capacity building programme should be an integral part of starting and expanding micro irrigation schemes. The awareness and mass contact programmes should be a continuous process so that more farmers can be brought in the ambit of micro irrigation. A system of R&D may be developed at central or the state research organization level to advise about drip or sprinkler system. Region-specific demonstrations of micro irrigation system may be developed for successful execution of this scheme. To realize long-term benefits of micro irrigation, a continuous process of monitoring and impact evaluation studies should be an integral part of implementation programme.

1 Introduction

Water is fundamental for sustaining a quality life, as well as economic and social development of human society. The Earth's hydrosphere contains a huge amount of water, but 97.5% of total water is saline and remaining 2.5% is fresh water. Out of total available fresh water, 68.7% is in the form of ice and permanent snow cover in polar and high mountainous regions and 29.9% is present as groundwater. The rest 0.3% is available in lakes, rivers and 0.9% in soil moisture, swamp water and permafrost atmosphere (GoI, 2015). India is blessed with vast network of 20 river basins with utilizable water resources of 1123 billion cubic meter (BCM) including both surface and groundwater. There is a large spatial and seasonal variation in the endowment of water resources (Srivastava *et al.,* 2012).

With the rising population, the per capita availability of water in India has declined from 5178 m^3/year in 1951 to 1441 m^3/year in 2015, which is lower than the water-stressed norm of 1700 m^3/year. About 60% of Indian population have per capita water availability close to or lower than the water scarcity threshold of 1000 m^3/year. By the year 2050, India's population is projected to reach 1.64 billion and consequently, the per capita water availability will further decline to 1139 m^3/year. On the demand side, the gross water requirement for all users in India was 813 BCM in 2010 and is expected to grow up to 1447 BCM in 2050 (CWC, 2010). Due to rising inter-sectoral competition, the share of agriculture in total water use is expected to decline to 74% in 2050 from its present level of 85% (GoI, 2015). These estimates clearly suggest that agriculture has to produce more food from less water to feed the burgeoning population with changing food habits. This implies the need for adoption of efficient irrigation methods to make agriculture sustainable in the long-run.

In India, agriculture is the predominant user of water resources. Irrigation has played a catalytic role in agricultural growth and development of the country due to its positive, direct and indirect impacts. With the massive financial investment by the governments and the farmers, net irrigated area in the country increased from 20.85 million hectare (Mha) in 1950-51 to 68.38 Mha in 2014-15 (DES, 2019). Although India is a world leader in irrigation infrastructure, still half of the total cropped area (51%) remains rainfed and depends on monsoon rainfall. Further, many studies have flagged sustainability and equity concerns in irrigation development in the country (Selvarajan and Roy, 2004; Narayanamoorthy, 2011; Srivastava *et al.*, 2014). It has been observed that positive impact of irrigation development could not be achieved equally across different geographical regions, and unsustainable water resource development in north-western region co-exists with its under-utilization in eastern region of the country (Srivastava *et al.*, 2014).

A structural shift in the sources for irrigation has also been observed during the course of irrigation development. While the area under both surface and groundwater sources has increased, the share of surface water sources has declined from 41% in 1970-71 to 23% in 2015-16. On the other hand, the share of groundwater in net irrigated area increased from 38% to 62% during the same period. The over-dependence on groundwater sources has raised several sustainability issues and its socio-economic and ecological manifestations in many pockets of the country (Janakaranjan and Moneach, 2006; Shah, 2007; Kumar *et al.*, 2013). Low level of water use efficiency (WUE) in agriculture is another serious challenge for sustainable development of water resources. At present the WUE in Indian agriculture is estimated between 35% and 40% for canal irrigation and about 60% for groundwater irrigation. The main reasons attributed to this is the dominant use of conventional flood method of irrigation, causing huge conveyance losses due to poor irrigation supply system.

Amidst rising demand for water, inter-sectoral competition, declining per capita availability and depleting water resources, several demand-side management and supply-side augmentation measures have often suggested for holistic management of water resources (Rosegrant, 1997; Kumar, 2003; Briscoe and Malik, 2006). In this context, improving WUE in irrigation is accorded high priority. Under the National Water Mission, the Government aims to achieve at least 20% improvement in WUE from the existing level. It is estimated that with 10% increase in present level of WUE in irrigation projects, an additional 14 Mha area could be brought under micro irrigation from the existing irrigation capacities which would involve a very modest investment as compared to the investment that would be required for creating equivalent potential through new schemes (Swaminathan, 2006). Concerted efforts are being made to promote the use of drip and sprinkler irrigation technologies for enhancing WUE in agriculture and save water resources.

There are two lines of arguments regarding the water-saving potential of micro irrigation technologies. The first line of argument is that the adoption of micro irrigation technologies results in net water savings thereby eases the prevailing water-scarcity problems. The water saving is attained through substantial reduction in losses due to evaporation and inefficient field conveyance and distribution systems. This is the declared motive of the government to embark on the promotion of these technologies. However, the farmers' rationale for adopting these technologies may be different from the policy objectives of the government. Farmers may give more weightage to the other attributes of micro irrigation technologies such as improvement in yield, reduction in labor requirement, improvement in output quality, etc. in their adoption decisions. The second line of thought is that even though micro irrigation technologies can result in water savings at the plot or field level, it may not translate into net water savings at aggregation level such as the watershed or the basin (Molden *et al*., 2001; Narayanmoorthy *et al*., 1997). According to this line of thought, the net water savings could be only modest if the phenomenon of return flows, much of which goes to recharge the underground water source, is considered as useful. Thus, the adoption of micro irrigation technologies may not automatically lead to water saving at the basin level, unless enabling institutional and economic policy instruments are put in place that allow the equitable distribution or allocation of the saved water.

In the backdrop of this observation, the paper analyzes institutional arrangements, potential, adoption, and impact of micro irrigation in selected study states, in order to gain insights for upscaling this technology. The specific objectives of the study are: (1) examine institutional arrangements and government schemes to promote adoption of micro irrigation technology, (2) study efficacy of direct benefit transfer (DBT) in existing schemes on micro irrigation, (3) estimate potential area under micro irrigation technology and analyze its adoption pattern across the states, and (4) assess impact of micro irrigation technology in terms of savings in water, farm inputs, increase in farm income, employment generation, etc. The study has used both secondary and farm-level data to examine different aspects of micro irrigation in study states of Andhra Pradesh, Gujarat, Maharashtra, Rajasthan, Punjab and Uttar Pradesh.

The paper is organized into five Chapters. Chapter 2 provides a comparative analysis of the government scheme, and operational and administrative procedures followed in extending government support for spreading micro irrigation technology at farmers' field. Chapter 3 estimates potential area which can be brought under micro irrigation and examines spread of micro irrigation technology across the states. Factors affecting adoption and constraints faced by farmers in adoption of micro irrigation are also discussed. Chapter 4 provides empirical evidences on impact of micro irrigation in terms of savings in water and farm inputs, and increase in farm income, employment generation, etc. The conclusions and policy implications are discussed in Chapter 5.

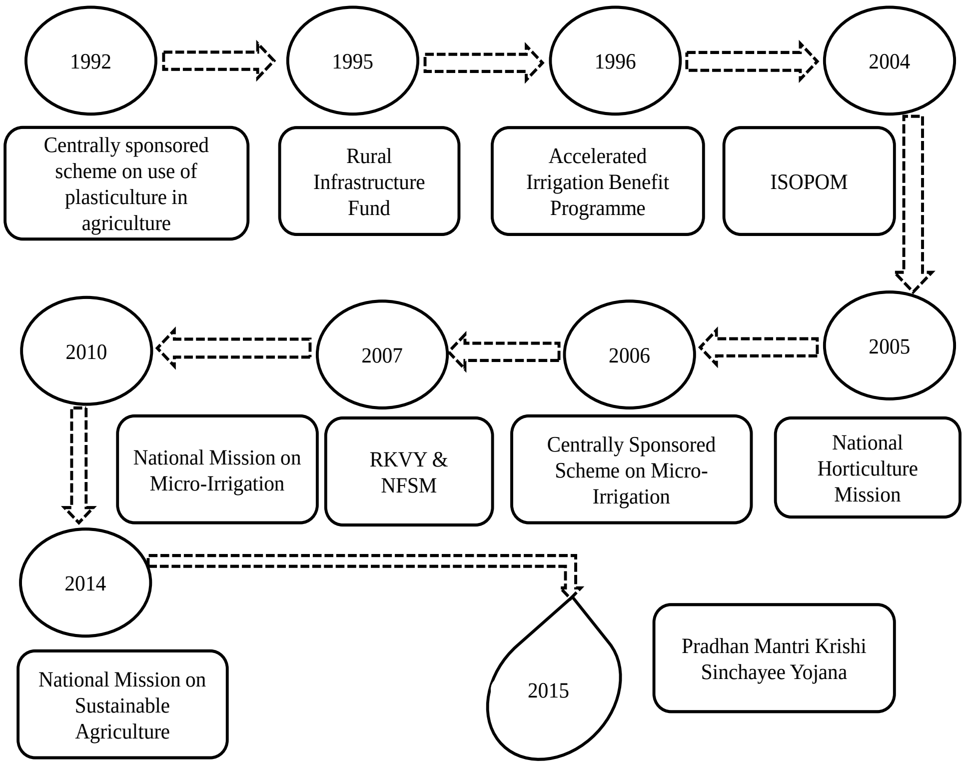
2 Operational and Administrative Procedures for MI Scheme

2.1. The Evolution of Micro Irrigation Scheme in India

The journey of micro irrigation (MI) in India was started in 1981 when the National Committee on Plasticulture in Agriculture (NCPA) approved the use of plastics in agriculture on a pilot basis. The NCPA, in its four successive report (1982, 1983, 1984, and 1985), emphasized upon promoting use of plastics for drip irrigation, mulching and green houses to boost horticulture production. Based on the recommendations of NCPA, the Government of India launched a centrally-sponsored scheme on the use of plastics in agriculture in 1992. Under the scheme, farmers were eligible for financial assistance or subsidy for installing MI system depending on land size, cost and economic condition of farmers. Besides installing drip system, the Government also extended subsidy for drip demonstration farms. To accelerate spread of MI technologies, the Government created the Rural Infrastructure Development Fund (RIDF) under the purview of National Bank for Agriculture and Rural Development (NABARD) in 1995-96 with an initial corpus of Rs. 2000 crore. A total of 36 eligible activities including micro, major and medium irrigation projects were provided the financial assistance through RIDF. In 1996-97, Accelerated Irrigation Benefit Programme (AIBP) was launched for giving financial assistance to states with an objective of expediting completion of ongoing irrigation projects. The Extension, Renovation and Modernization (ERM) of irrigation projects, with the provision of implementation of MI in at least 10% of command area, were given priority in extending financial support. Similarly, in the centrally-sponsored Integrated Scheme of Oilseeds, Pulses, Oil Palm and Maize (ISOPOM) launched in 2004 in 14 major oilseeds growing states, financial assistance was provided for creating efficient irrigation infrastructure through distribution of sprinkler sets or drip system. All types of farmers, including small and marginal categories, were eligible to participate in this scheme. The launching of National Horticulture Mission (NHM) in 2005 strengthened the MI activities and accelerated its spread on a large scale. The mission aimed at creation of water sources, protected cultivation, and precision farming, which promote MI technology. With broad objectives for the holistic growth of horticulture sector, NHM was restructured into a Mission for Integrated Development of Horticulture (MIDH) in 2014-15. In MIDH, adoption of MI is being fostered through the activities of protected cultivation and creation of water sources.

Having realized the potential benefits of MI technology in conserving water resources and sustaining crop yield, the Government of India launched a dedicated scheme named Centrally-Sponsored Scheme (CSS) on MI on January 20, 2006. The main objective of the scheme was to enhance WUE in agriculture sector by encouraging farmers to adopt appropriate technological interventions like drip and sprinkler irrigation. At the time of launch, about 2.24 Mha area was covered under MI. In the flagship scheme, Rashtriya Krishi Vikas Yojana (2007), MI was included as one of the components for ensuring an aggregate growth rate of 4% in agriculture and allied sector. To bring all states, including north eastern and Himalayan states, under the ambit of MI scheme, the Government upgraded the CSS on MI into National Mission on Micro irrigation (NMMI) in June 2010 and further to National Mission on Sustainable Agriculture (NMSA) in April 2014 and implemented On Farm Water Management (OFWM) programme from year 2014-15. The objective of the scheme was to create additional irrigation facilities through installing MI structures at the command of the farmers. From the year 2015-16, the Government has subsumed all existing schemes of irrigation into Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). The main motive of PMKSY is to provide water to every field (*har khet ko pani*), improve on-farm water use efficiency, enhance adoption of precision irrigation and water-saving technologies (*per drop more crop*). The scheme also aims to augment recharge of aquifers and introduce sustainable water conservation practices by reusing treated water for peri-urban agriculture and attract greater private investment. An outlay of Rs. 50,000 crore over a period of five years (2015-16 to 2019-20) was allocated for PMKSY. The scheme provides a comprehensive and holistic view of the entire 'water cycle' and proper water budgeting is done for all sectors namely, household, agriculture and industries. Presently, 11.4 Mha area has been brought under MI, 53.1% of which is covered under sprinkler system (6.06 Mha) and 46.9% under drip system (5.35 Mha) (MoA&FW, 2019). A timeline of development of schemes promoting MI in the country is presented in Figure 1.

Figure 1. Evolution of micro irrigation scheme in India



Source: Prepared by authors

2.2. Architecture of PMKSY

A Mission Directorate has been established in the Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India, for implementing PMKSY in mission mode. The mission is responsible for overall coordination and outcome-focused monitoring of all components of PMKSY for achieving its target. Micro irrigation is an integral component of the PMKSY (*per drop more crop*) to amplify WUE at farm level. This component (*per drop more crop*) is being implemented by the Ministry of Agriculture and Farmers' Welfare (MoAFW), Government of India. Table 1 presents the committees and their responsibilities to implement the PMKSY at various levels. District irrigation plan (DIP) provides a holistic irrigation development perspective of the district, outlining medium-to long-term development plans integrating three components viz. water sources, distribution network, and water use applications.

Table 1. Committees involved in implementation of PMKSY

Committee		Chairperson and Member	Work
National level	National Steering Committee (NSC)	PM as Chairperson and Union Ministers from concerned ministries and Vice Chairman, NITI Aayog as members	To provide general policy strategic directions for programme implementation and overall supervision addressing national priorities, etc.
National level	National Executive Committee (NEC)	Vice Chairman, NITI Aayog as Chairperson and Secretaries of concerned ministries/ departments and Chief Secretaries of selected States as members	To oversee programme implementation, allocation of resources, inter-ministerial coordination, monitoring & performance assessment, addressing administrative issues
State level	State Level Sanctioning Committee (SLSC)	Chief Secretary of the State as Chairperson	To sanction projects and activities as recommended by Inter-Departmental Working Group
State level	Inter Departmental Working Group (IDWG)	Agriculture Production Commissioner/ Development Commissioner as Chairperson and Secretaries of line departments as members.	Recommend project and activities to SLSC
District level	District Level Implementation Committee (DLIC)	District Magistrate Collector / CEO of Zila Parishad/ PD DRDA as Chairperson, and JD/ DD of line departments and progressive farmers, representative of MI industry, and leading NGO as members	To oversee PMKSY implementation and inter-departmental coordination.

Source: GoI (2017a)

The DIP identifies gap in the existing irrigation plan after assessing available resources, which could be added from ongoing schemes. So, DIP is considered as foundation for planning and implementation of all components of PMKSY. All communications between the MoAFW and State Governments are made through the nodal department. The state agriculture department may be the nodal department for implementation of PMKSY (Table 1). The main motive of PMKSY is to ensure efficient delivery and use of water at every farm for enhancing agricultural production and productivity. However, a state government is free to identify the nodal department based on the established institutional set up and mandate of the department.

Assistance Pattern for Micro Irrigation

The subsidy scheme of MI (borne by the Centre and the states) aims to encourage farmers to adopt innovative irrigation system on a large scale with faster speed. However, with a view to broadening the scope and coverage of MI, many states have supplemented the specific subsidy structure with funds from their own resources and prioritized its allocation towards specific regions and beneficiary groups. For instance, while the SC/ST and general categories of farmers in Andhra Pradesh were provided subsidy up to 100% and 90%, respectively, all categories of farmers in Bihar were offered subsidies of 50%, irrespective of their landholdings on micro irrigation methods[1] (Table 2). Further, subsidy on drip irrigation is significantly higher than sprinkler irrigation in Andhra Pradesh which implies that the state is encouraging drip system over the sprinkler irrigation. In Gujarat, subsidy on MIS was higher for dark zone than non-dark zone, while Rajasthan provides higher subsidy to DPAP/DDP area as compared to their counterparts. Also, Maharashtra is offering higher subsidy to farmers of Vidarbha region than other regions.

The unit-cost of drip irrigation system varies with plant spacing and location of water resources. The Central Government issues guidelines on the cost structure for installing MI system with different plant spacing. As per the guideline, subsidy is given to farmers under various categories. Small and marginal beneficiary farmers installing MI systems receive 55% and other beneficiary farmers receive 45% as subsidy on total cost. Subsidy amount is shared by the Centre and State Government in the ratio of 60:40 for all states, except North Eastern and Himalayan states, wherein the ratio is 90:10. The Central Government grants total fund to the Union Territories. In the present scheme, subsidy is limited to five ha per beneficiary for installation of MI system.

Based on MI coverage, states are classified into following three categories:

Category A states: States with comparatively better penetration of drip technology have been brought under category "A". These include Andhra Pradesh, Delhi, Gujarat, Goa, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, and Telangana.

[1] In Bihar state, the assistance is limited to 50%, irrespective of irrigation method (drip or sprinkler) and farm category and size (accessed at http://www.horticulture.bih.nic.in/Norms/Micro_Irrigation_scheme/ on 22 May 2019).

Category B states: All the states except covered under the category "A" and those falling in the Himalayan belt come under category "B". These include Bihar, Chhattisgarh, Jharkhand, Odisha, Uttar Pradesh, West Bengal and Union Territories. Considering lesser availability of companies and after sale service, the unit cost of MI is considered 15% higher for these states.

Category C states: States with very low penetration of drip technology due to poor infrastructure and difficult terrain have been grouped under "C". These states include north eastern and hilly regions, namely, Assam,

Table 2. Subsidy structure in selected states as on March 2018

State	Type of beneficiary		Subsidy (%) Drip	Sprinkler
Andhra Pradesh	SC/ST farmers in small and marginal category		100	50
	Small and marginal farmers in other category		90	50
	Medium farmers of Rayalseema and Prakasam districts		90	50
	Medium farmers of coastal districts		70	50
	Other farmers		50	50
Gujarat	SC/ ST farmers*	Dark zone area	90	90
		Non Dark zone area	85	85
	General farmers**(small and marginal)	Dark zone area	80	80
		Non Dark zone area	70	70
	General farmers*** (above 2 ha)	Dark zone area	70	70
		Non Dark zone area	70	70
Maharashtra	Small and marginal farmers of Vidarbha region		75	75
	Small and marginal farmers		60	60
	Other farmers		50	50
Punjab	SC/ST farmers under small and marginal category		90	90
	Other farmers		70	70
Rajasthan	DPAP/DDP	Small and marginal farmers	60	60
		Other framers	45	45
	Non DPAP/ DDP	Small and marginal farmers	45	45
		Other framers	35	35
Uttar Pradesh		Small and marginal farmers	90	90
		Other framers	80	80

Note: * indicates subsidy rates of MIS or Rs. 1,00,000/- per ha, whichever is less; ** indicates subsidy rates of MIS or Rs. 80,000/- per ha, whichever is less; *** indicates subsidy rates of MIS or Rs.70,000/- per ha, whichever is less.

Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Sikkim, Jammu & Kashmir, Himachal Pradesh and Uttarakhand. The unit cost for installing MI is considered 25% higher for these states due to undulated terrain.

Pre-Installation Activities

The implementing agency identified by the state government advertises scheme at block and village levels through its existing networks. At the district level, it appoints a nodal officer who is responsible for coordination with scheme implementation. It disseminates the suppliers list and unit price approved by SLSC to the farmers.

At least one district level seminar/ workshop is conducted for creating awareness about MIS. The implementing agency will compile and scrutinize the application submitted by the farmers and forward the same to the company's or manufacturer's local office as indicated by the farmers. The beneficiary share may be deposited with manufacturer or their representative or the state nodal agency as per the practice to be adopted by the state with the approval of SLSC. The beneficiary is free to purchase MI equipment from any manufacturer from the approved list of registered manufacturers. The manufacturers need to follow certain processes indicated in Table 3.

Table 3. Processes to be followed by the material supplying firms

Approval
Assessment of the crop water requirement and design the system accordingly
Prepare cost estimate and submit it to the implementing agency duly indicating the time frame for installation
The implementing agency will approve the estimate, issue work order and ensure installation
Installation
Quality components with BIS marking are installed at farmer's field
The installed system should match the water requirement of the crop earlier estimated
Necessary orientation and training given to the beneficiary farmers for system maintenance and irrigating the crop
Proper warranty and a user's manual for running and maintenance of system are provided to farmers
A certificate towards successful installation/commissioning of system is obtained from the beneficiary

Source: GoI (2017a)

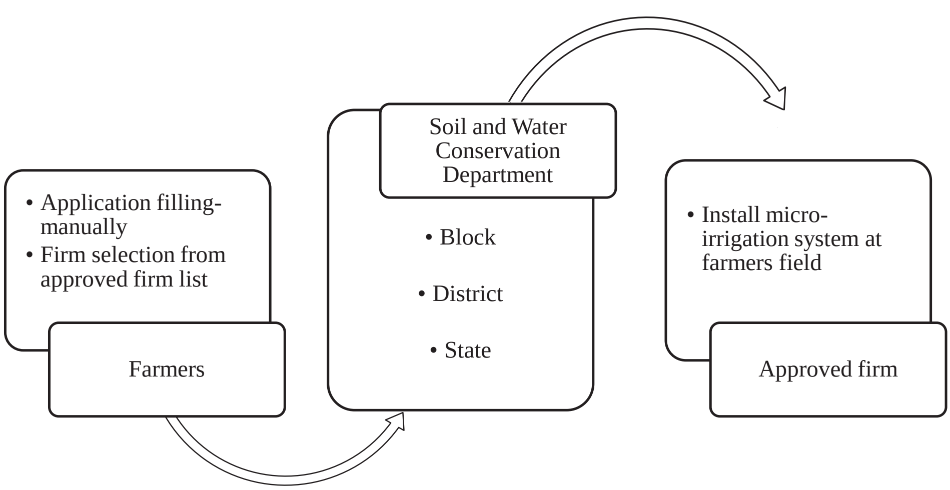
Post Installation Disbursement of Subsidy

The manufacturer will install the MI system as per the agreement with the state nodal agency and the procedure for payment is decided by the SLSC. After physical verification of MI system with satisfactory certificate from beneficiary, the implementing agency will disburse recommended subsidy amount to the beneficiary bank account electronically. In case the amount is placed with the manufacturers or companies or financial institutions on behalf of the beneficiary, the consent of beneficiary is required and the transaction details are conveyed to him or her over SMS immediately and subsequently in writing.

2.3. Operational and Administrative Procedures for MIS

Punjab: Drip and sprinkler irrigation systems were introduced in the state under CCS during the year 1992-93. In Punjab, the Soil and Water Conservation Department is the nodal department for implementing the centrally-sponsored scheme of MI which also assists the state, central government farms, state agriculture universities, ICAR, progressive farmers and NGOs for demonstration of plots. The operational procedure for micro irrigation implementation adopted by Punjab is shown in Figure 2.

Figure 2. Flow diagram on procedures adopted by Punjab



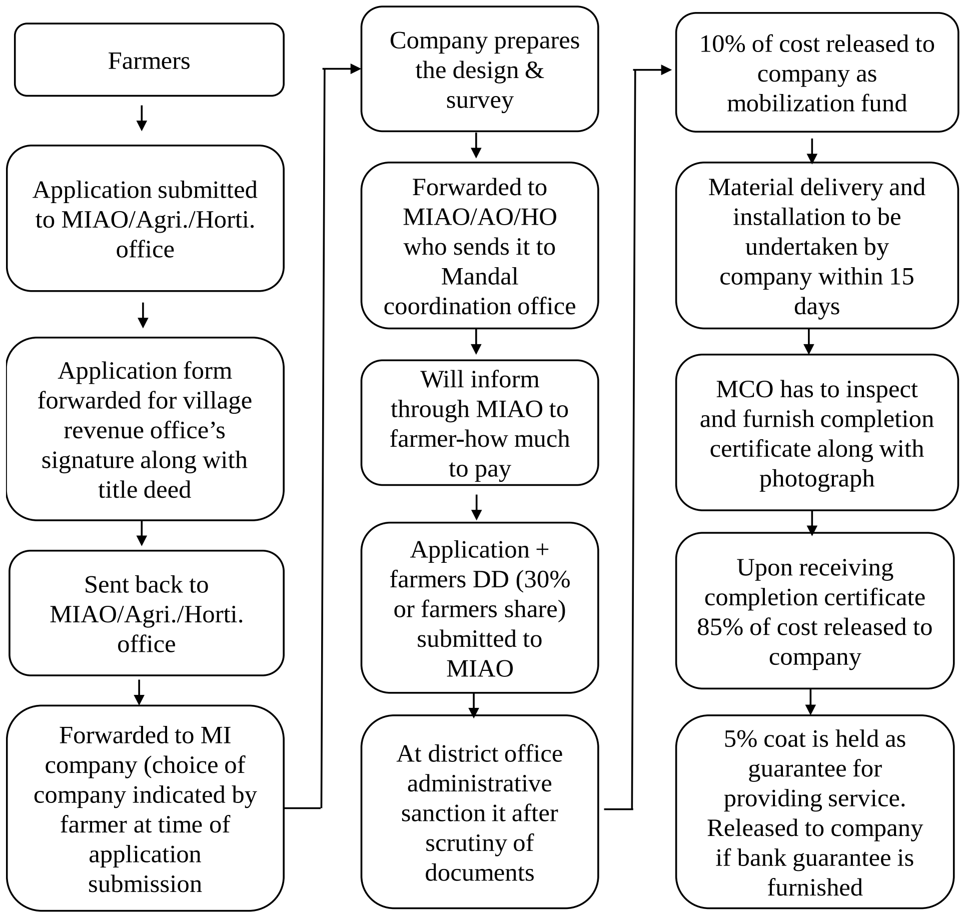
Source: Prepared by the Authors

The land ceiling for subsidy is five ha per beneficiary. Despite having a vast potential, coverage of micro irrigation in Punjab has not reached the desired level. Only 48,281 ha area has been covered under MI till 2018, which is about 0.78% of the net sown area of the state (DES, 2019). The state is facing a serious problem of depletion of groundwater resources and conservation of irrigation water is of utmost importance. Recently, a World Bank sponsored pilot scheme on solar powered micro irrigation has been implemented in Punjab to provide the irrigation to undulating terrain of Hoshiarpur district. Under this scheme small and marginal farmers who had limited irrigation facilities, were given priority for providing micro irrigation for agriculture cultivation. This project is known as Solar-Powered Community Micro Irrigation Project (SCMIP) and is performing well in Punjab.

Andhra Pradesh: In Andhra Pradesh, the micro irrigation technology is promoted under the scheme "Andhra Pradesh Micro irrigation Project (APMIP)" which is unique and the first comprehensive project implemented in November 2003. The project aims at improving the economic condition of farmers through conserving water, bringing additional area under cultivation with the available water, enhancing crop productivity and quality, facilitating judicious use of groundwater, saving power consumption, and reduce cultivation cost. APMIP is being implemented with assistance from Central Government, State Government, and contribution from the beneficiary farmers. The Government of Andhra Pradesh has set a goal to cover the entire potential area under MI in all 13 districts of State by the year 2022. On Farm Water Management (OFWM) is one of the four components of the National Mission for Sustainable Agriculture, which focuses primarily on enhancing WUE by promoting efficient on farm water management technologies and equipment. The entire process of filling and processing of application is online and app-based. This has helped farmers in checking the application status and subsidy amount without visiting the government office. The operational procedures adopted in Andhra Pradesh is presented in Figure 3.

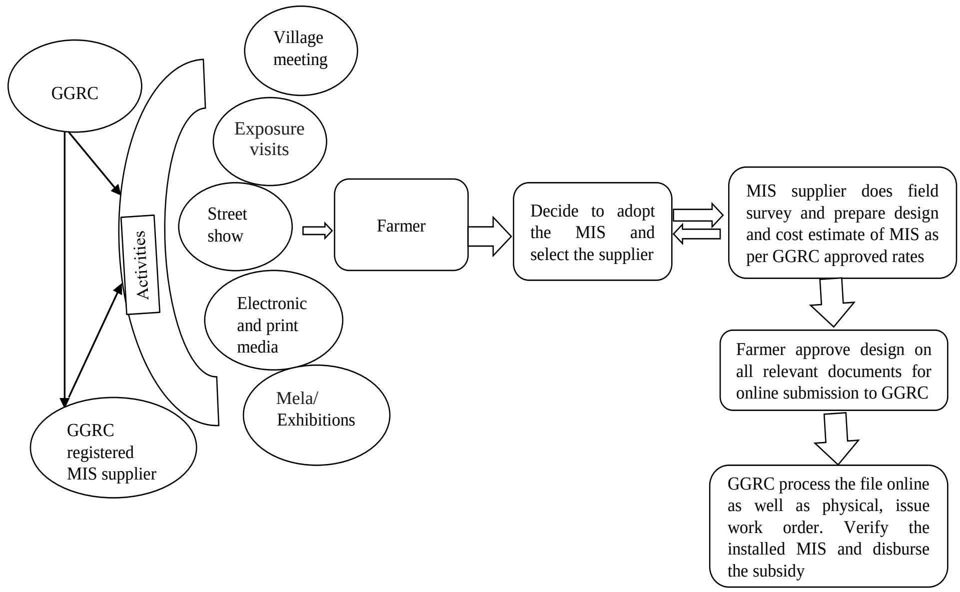
Gujarat: The Government of Gujarat established Gujarat Green Revolution Company Ltd. (GGRC) in May 2005 and made it the nodal agency for implementing all types of MI projects in the state. The government also introduced a unique scheme for promoting adoption

Figure 3. Operational procedures under APMIP in Andhra Pradesh



of MI in which the farmers get 70-90% subsidy without any land ceiling. The scheme has been welcomed by farmers, and has accelerated the rate of adoption of MI. The operational procedures adopted by the Gujarat is presented in Figure 4. The system of allocating funds and transfer of payment is very transparent. The different media and platforms are used to motivate and create awareness among the farmers. The GGRC takes the responsibility to conduct various programmes. Farmers who decide to install the MI, select the firm for supplying the material. The selected firm conducts the field survey of the particular farm and prepare design, which is approved by the farmer. Full application process is completed online. Finally works are executed and subsidy is disbursed. The modalities adopted by GGRC seem to be systematic.

Figure 4. Operational procedures adopted by GGRC



Maharashtra: The Government of Maharashtra is implementing this scheme through Department of Agriculture. The government provides capital subsidy of 50% to 60% for installation of drip and sprinkler systems. For Vidarbha region, a special programme called Vidarbha Intensive Irrigation Development Programme (VIIDP) is being implemented since 2012-13. The programme is operational under modified guidelines wherein financial assistance of 75% is provisioned for small and marginal farmers in eight districts of Vidarbha region. The procedure followed to avail the benefits under the scheme is presented in Figure 5.

Comparative Analysis of Operational Procedures Adopted by Selected states

The comparative analysis of operational and administrative procedures adopted by selected states is presented in Table 4. It was observed that study states followed different modalities in execution of MI scheme. In few states, additional amount of money was added with subsidy provided by the central government, to make the total subsidy up to 70% to 90%. States such as Andhra Pradesh and Gujarat have established the dedicated department/agency for implementation of MIS, whereas Maharashtra, Punjab, Rajasthan and Uttar Pradesh are implementing the scheme with their agriculture/horticulture, and soil and

Figure 5. Activities undertaken by beneficiary farmers in accessing MIS

1. Farmers
2. Approach to MI company of their choice
3. Get cost estimate for the installation after survey
4. Application is submitted to GGRC with design and cost estimation and 5% advance money
5. Tri-party agreement, collection of management charges/difference amount, submission of proforma, invoice for advance payment
6. Work order released with 25% money to MI companies by GGRC/bank
7. Installation & trial run of MIS, third party inspection, issuance of insurance certificate, submission of final bill
8. Payment of balance amount (75%) by GGRC/bank to MI companies

Source: GGRC (2016)

water conservation departments. The online submission of application and a mobile app help government functionaries and farmers to monitor the progress of scheme and status of their application. However, manual submission of application is also being practiced in Punjab. As per the guideline of MIS of Centre, states are categorized in A, B and C categories, based on area coverage under drip system. It was found that despite very low penetration (0.78%) under micro irrigation, Punjab is classified in A category. The state has huge potential and efforts are needed to accelerate the process of promoting water-saving technologies. The state can create a separate department for promotion of MI. The model adopted by Andhra Pradesh and Gujarat can be replicated in other states so that adoption of MI technology spread at a faster pace. The review of operational procedures in study states indicate that in Punjab, WUE can be improved substantially by adopting MIS on the lines of states like Andhra Pradesh and Gujarat. The capacity building programs may help in improving local technical expertise of rural youth in management of MI system. Strong policy on punishment to the defaulter firms is needed in the country.

Table 4. Comparison of operational and administrative procedures

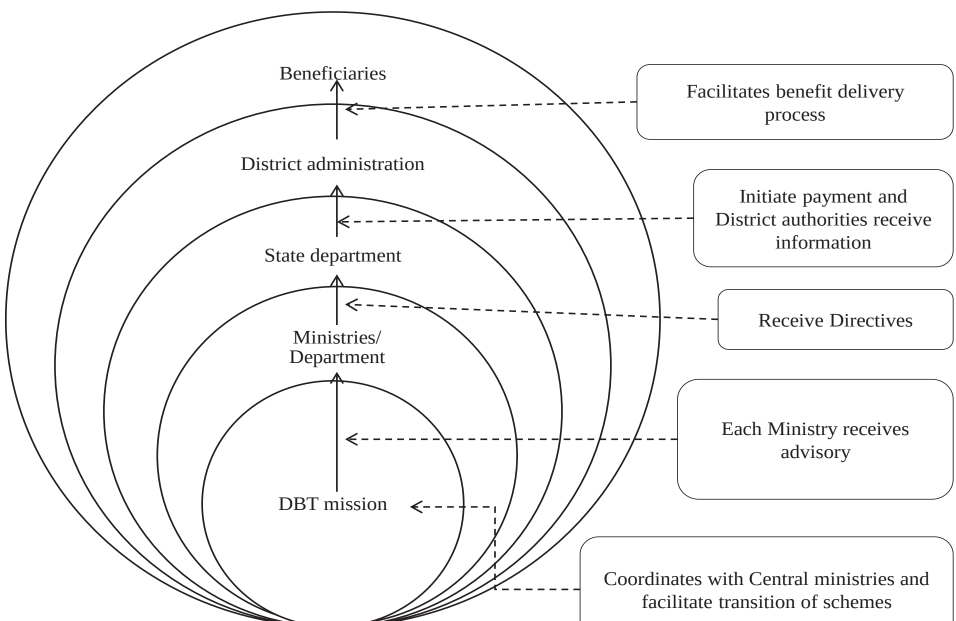
Particulars	Andhra Pradesh	Gujarat	Maharashtra	Punjab	Rajasthan	Uttar Pradesh
Mode of application	Online	Online	Online	Manual	Online	Online
Dedicated Department for MIS implementation	APMIP	GGRC	Horticulture Department	No	Horticulture Department	Agriculture & Horticulture Department
Subsidy limit (%)	50-100	70-90	65-90	70-90	60-70	80-90
Land ceiling (ha)	5*	No limit	5	5	5	5
Selection of beneficiary	Own/ sharing of irrigation in close relation	Own irrigation source	Own irrigation source	Own irrigation source	Own irrigation source	Own irrigation source
Financial help for creation of irrigation source	No	No	No	Yes	No	No
Selection of MI installing agency	Approved with department	Approved with department	Approved with department	Approved with department	Approved with department	Approved with department
Action against default firm	Fine and debar from list	Debar from list	Debar from list	Debar from list	Debar from list	Debar from list
Post-installation service period (Yrs)	3	5	3	3	3	3
Provision for margin money	Banks linked with the farmer	Farmer responsibility	Farmers responsibility	No	Farmer responsibility	Farmer responsibility
Mode of subsidy disbursement	DBT	DBT	DBT	Physical	DBT	DBT
Training and exposure for farmers	Training organized & exposure visit	Training organized & exposure visit	Limited, awareness camps held	Limited	Limited, awareness camps held	Limited, awareness camps held
Training for staff	Yes	Yes	Yes	Yes (limited)	Yes	Yes
Training for youth	Yes	No	Yes	No	No	No
Administrative system strength	Strong	Strong	Strong	Weak	Moderate	Moderate
Implementation efficiency of MIS	Fast	Fast	Medium	Slow	Medium	Medium
Satisfaction level of beneficiary	Highly satisfied	Moderately satisfied	Satisfied	Neutral	Satisfied	Satisfied

Source: Authors' compilation
Note: *After 7 years, beneficiaries can again apply for availing subsidy for reinstalling MI

2.4. Approach of Direct Benefit Transfer: A Case Study of Uttar Pradesh

To ensure accurate targeting of beneficiaries and faster flow of information or fund, Direct Benefit Transfer (DBT) scheme was launched by the Government of India in 2013. A nodal point was created in the Planning Commission (now NITI Aayog) to implement the scheme. To strengthen the DBT scheme further, it is now placed in the Cabinet Secretariat under Secretary (Co-ordination) from September, 2015. The present structure of Centre-State participation in DBT initiative is depicted in Figure 6.

Figure 6. Direct benefit transfer initiatives at Centre and state level



Source: GoI (2017b)

The DBT initiative has made a significant progress in the country since its implementation. During 2013-14 and 2018-19, the number of schemes covered under this initiative increased from 27 to 439 and 346 crore beneficiaries received government subsidy of Rs 6.87 lakh crore. DBT has led to saving of about Rs. 1.21 lakh crore till February, 2019 in which PAHAL[2] scheme (Pratyaksh Hanstantarit Labh) contributed 47% (GoI, 2019). In October 2016, DBT in fertilizer was implemented in 17 districts in the country on a pilot basis to plug the incidence of pilferage and protect the interest of farmers (Department of Fertilizer, 2019). More recently, the central government has announced *PM Kisan Samman Nidhi*

[2] PAHAL is Direct Benefit Transfer Scheme for LPG (DBTL), India

Yojana under which Rs. 6,000 is transferred to a farmer's bank account in three equal instalments in a year. Uttar Pradesh, with a population of more than 200 million, is a leading example in DBT implementation for agricultural inputs since 2014-15. The operational procedures followed in DBT scheme in Uttar Pradesh are discussed in following section.

Procedure followed in Direct Benefit Transfer scheme: Like in other states, agricultural input subsidies in Uttar Pradesh were usually disbursed to the input dealers, who in-turn provide subsidized inputs to the farmers. The DBT initiative in selected schemes is intended to have accurate targeting and transparency in distribution of farm inputs. Step-wise process followed in the selection and disbursement of benefits to farmers is given below:

Step 1: Registration-The first and foremost requirement of availing the government subsidy under DBT scheme by an eligible farmer is to register him or her on the online portal of state agriculture department. It is done by farmer themselves or with help of dealer at *Jan Suvidha Kendra* or at agriculture office. For registration, they require a voter's ID or Aadhar card, detail of passbook and land records. After registration, a unique ID number is generated, which along with all three documents, are required to be submitted to agriculture office within 7 days of online registration. This unique ID number is needed each time to avail benefit under different government agricultural schemes.

Step 2: Application for scheme- After unique ID number is generated, farmers can apply to avail benefits. There are a number of government schemes for seeds, farm implements, micro irrigation, plant protection chemicals, soil reclamation, etc. for which farmers can apply according to their need and as per eligibility. It is to be noted that farmers are eligible to avail benefits for seeds, farm machinery (human operated) and farm machinery (power operated) schemes only after 2, 3 and 10 years of availing benefit under these schemes, respectively.

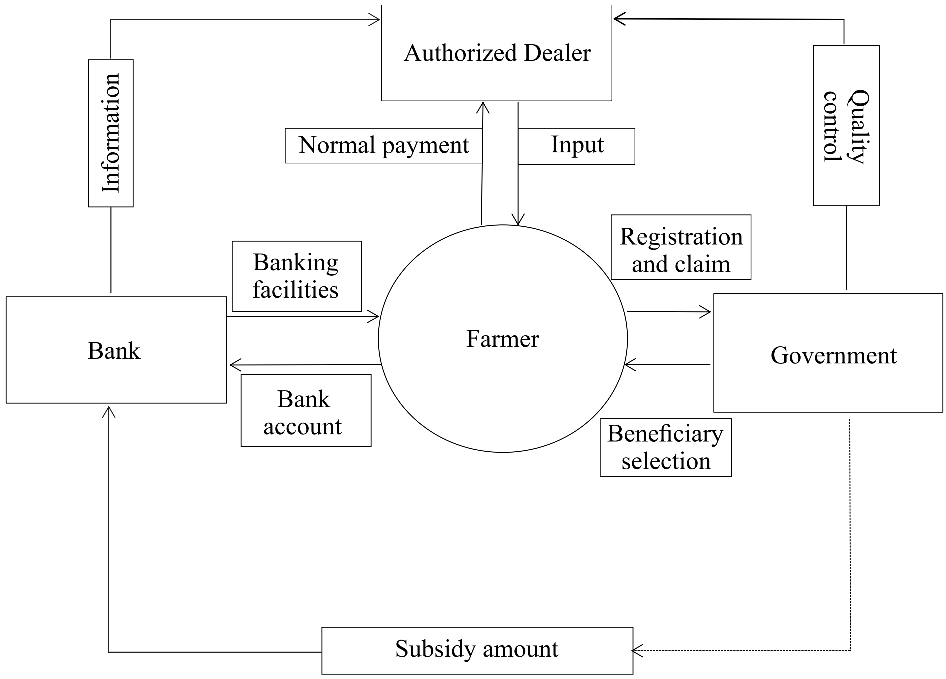
Step 3: Selection of beneficiaries- The selection of beneficiaries is done on the principle of "*first come first serve*". The state government, under various schemes, provides grant to districts for disbursement among farmers. The district officials divide this grant among its blocks mostly in equal proportions. Once the name of farmer comes in the selected list of beneficiaries, a message is sent on his/her mobile number. The message is also communicated through traditional means such as a dealer or a gram sahayak. Farmers are given nearly 10 days to inform his or her consent for availing benefits. If the farmer does not reply during this period, then other farmers in the list are selected automatically for the benefits.

Step 4: Document submission- The selected farmers need to submit certain documents to Kisan Shahayak or directly to the agriculture office. The required documents are (a) Voter's ID or Aadhar card – for identification (b) *Khasara khatauni* – to verify land records (c) First page of the bank passbook – bank account details (d) Agricultural department form (e) Gram panchayat letter – for proof of residence and good character (f) Non-judicial bond of Rs.10 notary paper – stating that machinery will not be sold to other (in case of farm machinery scheme). After verification of all documents, the Kisan Shahayak will write comments for approval and documents are forwarded to the district office.

Step 5: Distribution-The assigned official in the district agriculture office will verify documents and enquire the authorized dealers in the district for required quantity and quality demanded by the applicant. If the required quantity is available with dealers, then a date is fixed on which the official, the dealer and the beneficiary will meet. The official will check quality and if the farmer is satisfied with quality then bill is prepared by the dealer for further processing. In case the farmer is not satisfied with the quality of product being distributed, then another authorized dealer is contacted. Farmers are given farm input or machinery once the total amount is paid. Sometime, total billing amount is too high for farmers. In that case, the farmer should at least provide their own share of total cost and the remaining amount is conditioned to (a) if the farmer is known and reliable, then input provided with assurance to pay after receiving DBT amount, and (b) if the farmer is unknown/ unreliable, then a blank cheque is taken by dealer with future date of payment.

Step 6: Direct benefit transfer-The purchase bill provided by the dealers are attached with the farmers' documents and uploaded online. If the DBT amount is more than Rs. 25000, physical verification is done by higher official in-charge within four working days of uploading the bill. After physical verification, the DBT amount is credited to beneficiary account within 15 days. The dealer keeps a track of this process and once the amount is credited in the farmer's account, the dealer approaches the farmers to make due payment, in case of deferred payment. If the dealer has a blank cheque, then he/she deposits it to bank and draws money from the farmer's account (Figure 7).

Figure 7. Flow chart of procedures followed under DBT

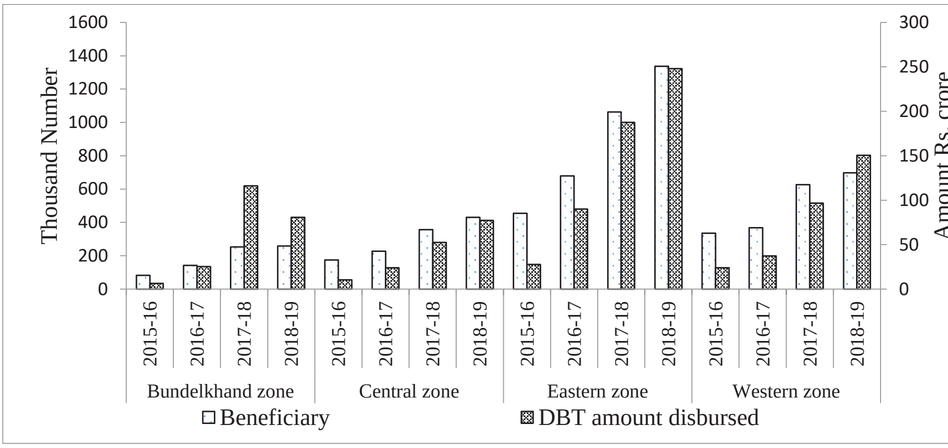


Source: Prepared by authors

Status of Beneficiaries under DBT in Uttar Pradesh

Nearly three crore farmers (cumulative) have registered to avail subsidy for agricultural inputs in Uttar Pradesh during 2014-15 to 2018-19 out of them 74.85 lakh farmers have availed subsidy amount of Rs.1255 crore. Figure 8 shows increasing trend in number of beneficiaries and amount disbursed across zones. The subsidy disbursed through DBT stands at Rs.1677 per beneficiary since the initiation of this approach. Among zones, eastern zone has received the highest subsidy followed western and Bundelkhand zones. Further subsidy on seeds constituted the highest share (45%) followed by subsidy on farm machinery and implements (30%), and farm machinery bank and custom hiring centre received equal share (5%, each) for year 2015-16 to 2018-19.

Figure 8. Number of beneficiaries and amount disbursed under DBT in Uttar Pradesh



Source: Authors' estimate

2.5. Perception of Adopters on Operational Procedures and Subsidy Support

The perception of beneficiary farmers who adopted MI was assessed by asking open-ended questions and their responses are summarized in Figure 9. The farmers' perception on the behaviour of departmental staff and agencies involved in processing and disbursing the subsidy varied across the states. The per cent of the respondents perceiving 'very good' behavior of the staff varied from 17.5% in Punjab to 44.6% in Andhra Pradesh. In Andhra Pradesh, Gujarat and Maharashtra, agencies behaved fairly well with the beneficiaries which might have contributed to the better adoption of MI in these states.

Farmers' perception on the clarity in subsidy and operational procedures is presented in Figure 10. Clarity about the process of support was higher in Andhra Pradesh (52%), Gujarat (51%) and Maharashtra (49%), whereas it was very low in Punjab (8.45%). In each state, there were few beneficiaries who did not clearly understood the procedures and mechanisms of getting subsidy and the share of such beneficiaries in total respondents was the highest in Punjab (64%).

The transparency in process of subsidy distribution is also an important issue, and the perception of farmers on this aspect is presented in Figure 11. The evidences show that about two-third of adopters of Andhra Pradesh (68%) felt that subsidy support was transparent, followed by Gujarat (52%), Maharashtra (46%) whereas it was low in Punjab (8%). About 19% of the sample adopters in Punjab, 10% in Gujarat, 9% in Maharashtra

Figure 9. Farmers' perception on officials behavior involved in granting subsidy

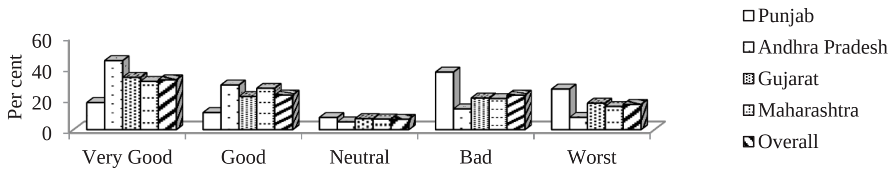


Figure 10. Farmers' perception on clarity of procedures to avail subsidy

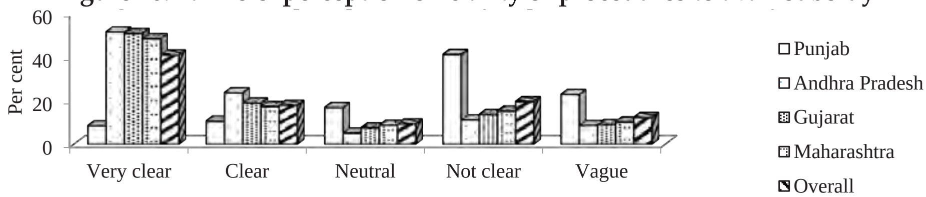


Figure 11. Farmers' perception on transparency in subsidy support

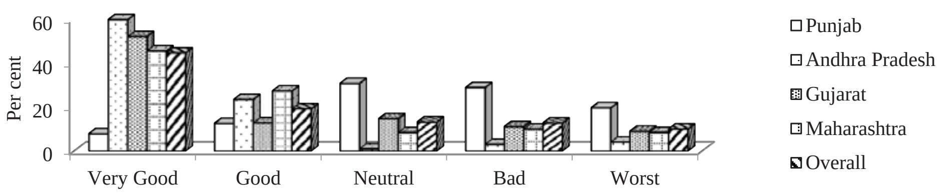
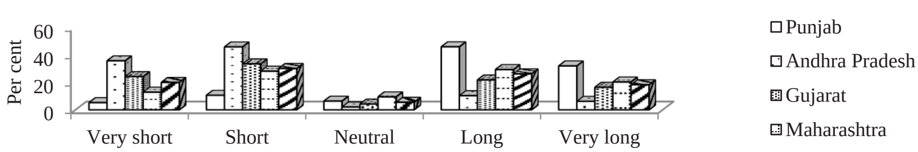


Figure 12. Farmers' perception on time taken in availing subsidy



Source: Authors calculation

and 7% in Andhra Pradesh perceived worst level of transparency in the subsidy disbursal procedure. This implies a need to improve transparency in the procedure upto the satisfaction of the intended beneficiaries. The disbursement of subsidy should be transferred at the earliest possible time. The perception of adopters on the time taken to get subsidy has been analyzed and evidence showed that in Andhra Pradesh, Gujarat and Maharashtra duration was very short for majority of beneficiaries, whereas in Punjab only a smaller number of beneficiaries (16%) indicated the same (Figure 12).

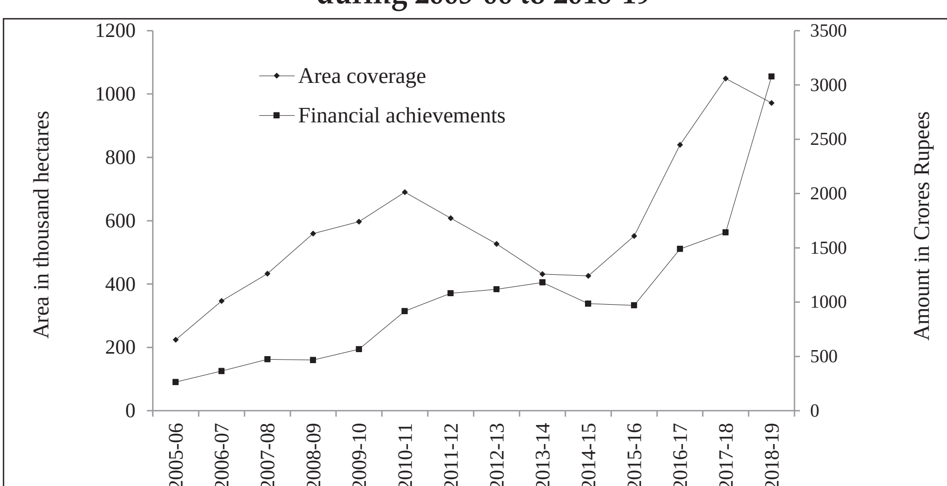
3 Adoption of Micro Irrigation in India

One of the key objectives of this study was to estimate potential area under micro irrigation and analyze its adoption pattern in selected states of India. This chapter presents evidence on trends in public spending and area under micro irrigation at all India level, and inter-state variation in its adoption. Subsequently, factors determining adoption of MI are discussed at states and farm levels and constraints in adoption are identified.

3.1. Trends in Public Spending and Area under Micro Irrigation

At the time of launch of Central Sector Scheme on MI in 2005-06, the area covered under micro irrigation was 2.24 Mha. The public investment and area covered with micro irrigation has shown a consistent increase, except in few year (Figure 13). The public spending witnessed over 10 times increase between 2005-06 and 2018-19. Consequently, coverage under MI increased from 2.24 Mha in 2005-06 to 11.41 Mha in 2018-19. Of the total coverage (11.41 Mha), sprinkler system constituted 53.1% share and remaining 46.9% of area was covered under the drip system in 2018-19.

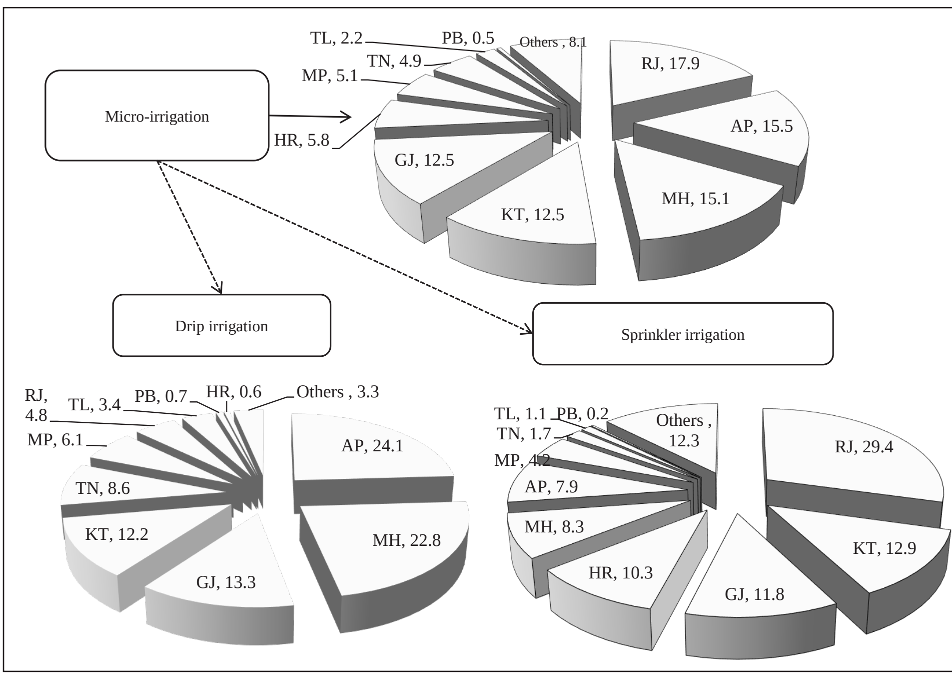
Figure 13. Trend in public spending and area under micro irrigation during 2005-06 to 2018-19



Source: DES (2019)

The target of 10 Mha was fixed under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) for a period of 5 years (2015-16 to 2019-20), however, county achieved only 4.78 Mha. Presently, five states, namely Andhra Pradesh, Gujarat, Karnataka, Maharashtra and Rajasthan contribute three-fourth of the total area covered under MI. Distribution of MI coverage across the states is presented in Figure 14. Andhra Pradesh and Maharashtra are the top contributing states in area under drip irrigation, while Rajasthan and Karnataka are the leading states in terms of area under Sprinkler irrigation.

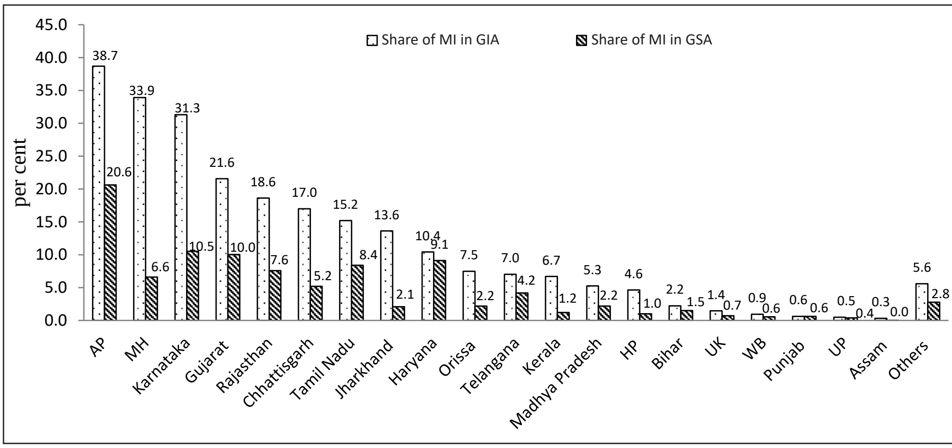
Figure 14. Distribution of micro irrigation coverage across states in the year 2018-19



Source: DES (2019)

The share of area under micro irrigation in gross irrigated area/ gross sown area in the state gives an idea about of level of adoption of the technology. Presently, 11.8% of gross irrigated area (96.75 Mha) in the country is covered under micro irrigation. The coverage of micro irrigation varies significantly across the states (Figure 15). Among the states, Andhra Pradesh, Maharashtra and Karnataka are the leading states wherein 38.7 %, 33.9% and 31.3% of the gross irrigated area was covered under micro irrigation in the year of 2018-19, respectively.

Figure 15. Penetration of micro irrigation across states in the year 2018-19



Source: Authors' estimate, GIA = Gross irrigated area, GSA = Gross sown area

3.2. Estimation of Potential Area for Micro Irrigation

Several scholars and agencies have estimated potential area which could be brought under micro irrigation. There exists large variation in the existing estimates on the potential area. Table 5 presents potential area under micro irrigation estimated by existing studies and compares with the estimates of the present study. Existing estimates on potential area under sprinkler irrigation varies from 30.5 Mha to 51.1 Mha, while potential area under drip irrigation ranges from 11.7 Mha to 27.0 Mha. Wide variation in these estimates are due to differences in the methodology and assumptions followed in these studies.

Estimate of potential area for sprinkler irrigation by Task force on Micro Irrigation (TFMI, 2004) is exactly same as of Indian National Committee on Irrigation and Drainage (INCID, 1998), however methodology for its estimation is not available in the public domain. Narayanmoorthy (2006) has estimated crop-wise and state-wise potential area for micro irrigation by considering irrigated area as core potential for MI. The potential was estimated separately for drip and sprinkler irrigation. The authors assumed that the area which could be brought under sprinkler irrigation can also be considered under drip irrigation and vice versa, except cereals. The study by Raman (2010) on estimation of state-wise potential area for micro irrigation, considered irrigated area and crop-wise suitability for different micro irrigation system (except paddy in canal irrigation system). However, estimate is much lower than other estimates as author has considered only those crops for which subsidies were given for installation under National Mission on Micro irrigation during estimation year. Based on insight drawn from these estimates, the present study has attempted to estimate micro irrigation potential of the country using recent database available.

Table 5. Crop-wise estimates of potential area of micro irrigation in India

(Area in Mha)

Estimate by	INCID (1998)	GoI (2004)		Narayanamoorthy (2006)		Raman* (2010)		Scenario[1]		Scenario[1]	
Crops	**Spr.**	**Spr.**	**Drip**	**Spr.**	**Drip**	**Spr.**	**Drip**	**Spr.**	**Drip**	**Spr.**	**Drip**
Cereals	27.6	27.6		27.7				36.0	9.3	38.5	10.2
Pulses	4.2	7.6		2.6	2.6			3.4	0.1	3.6	0.1
Oilseeds	1.1	1.1	3.8	5.8	5.8			5.6		6.0	
Cotton	2.6	1.8	7.0	3.0	3.0				3.2		3.3
Fruits and vegetables	2.5	2.4	7.5	3.4	3.4			3.0	1.7	3.4	1.8
Spice and condiments	1.2	1.0	1.4	1.4	1.4				2.1		2.2
Flowers, medicinal and aromatic plants		1.0							0.2		0.2
Sugarcane	3.3		4.3	4.2	4.2				3.9		4.3
Coconut, plantation crops, oil palm			3.0						0.6		0.7
Others				2.9	0.4			3.1		3.3	
Total	42.5	42.5	27.0	51.1	20. 9	30.5	11.7	51.0	21.2	54.8	22.8
Share of actual area in potential (%)	14.3	14.3	19.8	11.8	25.6	19.9	45.8	11.9	25.3	11.1	23.5

Note: Scenario[1] and Scenario[2] estimated in present study. Spr.-Sprinkler, * estimates are note available by crops

The share of actual area (for the year 2018-19) in potential area under micro irrigation estimated under different studies varied from 11.1-19.9% in sprinkler irrigation and 19.8-45.8% in drip irrigation (Table 5). This shows inconsistency among the existing estimates. Table 6 presents state-wise potential area under MI estimated by past studies including present one. The assessment of micro irrigation potential area given by Narayanmoorthy and Raman have categorised Uttar Pradesh as highest potential state contributing nearly 1/4th of their total estimate. Present study has also arrived at similar estimate under which Uttar Pradesh contributes 24.45% of potential area followed by Rajasthan (11.92%) and Punjab (8.69%).

Table 6. State-wise estimates on micro irrigation potential in India

(Area in Mha)

State	Narayanmoorthy (2006)			Raman (2010)			Present study		
	Spr.	Drip	Total	Spr.	Drip	Total	Spr.	drip	Total
Andhra Pradesh	1.95	1.68	3.63	0.39	0.73	1.12	1.23	1.39	2.62
Assam	00	00	0.01				0.08	0.05	0.13
Bihar	3.83	0.42	4.25	1.71	0.14	1.85	2.92	1.01	3.93
Chhattisgarh				0.19	0.02	0.21	0.53	0.40	0.93
Goa				00	0.01	0.01	0.02	0.01	0.03
Gujarat	3.16	2.27	5.42	1.68	1.60	3.28	2.84	2.28	5.12
Haryana	4.15	1.17	5.32	1.99	0.40	2.39	3.17	0.97	4.15
Himachal Pradesh	0.13	0.03	0.15	0.10	0.01	0.12	0.04	0.01	0.05
Jammu & Kashmir	0.23	0.08	0.31				0.11	0.05	0.15
Jharkhand				0.11	0.04	0.16	0.13	0.04	0.17
Karnataka	2.18	1.5	3.69	0.70	0.75	1.44	1.19	1.27	2.46
Kerala	0.27	0.23	0.51	0.04	0.18	0.21	0.07	0.19	0.27
Madhya Pradesh	4.11	1.62	5.73	5.02	1.38	6.39	6.56	0.93	7.49
Maharashtra	3.25	1.97	5.22	1.60	1.12	2.71	1.81	1.46	3.27
Nagaland				0.04	0.01	0.05			
Odisha	0.45	0.41	0.86	0.06	0.16	0.22	0.33	0.29	0.62
Punjab	5.37	1.15	6.52	2.82	0.56	3.38	4.67	1.60	6.27
Rajasthan	5.92	2.7	8.63	4.93	0.73	5.66	7.24	1.22	8.46
Tamil Nadu	1.50	1.35	2.85	0.16	0.54	0.70	1.27	1.44	2.71
Telangana							1.16	1.12	2.28
Uttar Pradesh	13.95	3.98	17.93	8.58	2.21	10.79	13.35	4.30	17.65
Uttarakhand							0.26	0.15	0.41
West Bengal	0.67	0.33	1.01	0.28	0.95	1.23	2.05	0.95	3.00
Others				0.19	0.13	0.32			
Total	51.13	20.89	72.02	30.58	11.66	42.24	51.01	21.16	72.17

Source: Authors' compilation and estimate

Methodological Approach for Estimating Potential Area under Micro Irrigation

The present study has reviewed the methodological differences and standardized the methodology for estimating the potential area under MI. The methodological procedure used to estimate potential area has been discussed below:

National Committee on Plasticulture Applications in Horticulture (NCPAH) has classified crops that are suitable for drip and sprinkler irrigation systems. Further, crop-wise area coverage under MI across states is available on PMKSY website. Drawing insight from these data, crops suitable for drip and sprinkler irrigation have been identified (Table 7).

Table 7. Crops suitable under drip and sprinkler irrigation systems

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 & mustard, Groundnut, Linseed, Soybean, Other oilseeds, Fodder crops.

Source: NCPAH (2014)

Note: *- Area under paddy has been equally put under both type of irrigations based on studies and PMKSY

In short run, gross irrigated area is considered as core potential under MI as this area has assured source of irrigation. However, in long run, unirrigated area could also be included in potential area estimate (distant potential) once irrigation facility on these areas are developed. However, independence and reliability of irrigation source play a major role in adoption and utilization of MI. Farmers who have access to sufficient groundwater resources or canal water may not opt MI immediately. So, it cannot be said that MI will be installed on all irrigated area in India. Hence, there is a need to have data on crop-wise area irrigated by different irrigation sources to estimate potential area under MI. So, two indices were constructed for each state based on different combination of irrigated area with different sources of irrigation as follows:

Irrigation Index 1- Proportion of area irrigated by groundwater, tank, and 30% of canal irrigated area.

Irrigation Index 2- Proportion of area irrigated by groundwater, tank, and 50% of canal irrigated area.

For estimating potential area under MI, gross irrigated area under different crops was compiled for major states for the triennium ending (TE) 2015-16. As data on gross irrigated area under fruits and vegetables was not available separately, gross irrigated area of fruits and vegetables was bifurcated, based on their share in gross sown area. Based on the indices prepared, potential area estimated under scenario 1 and scenario 2 are given below:

Scenario 1: Potential area estimated based on index I

Scenario 2: Potential area estimated based on index II

Indices were constructed based on area irrigated by different sources of irrigation. Groundwater and tank irrigated area remained constant in both indices but canal irrigated area varied. Therefore, states with higher proportion of area irrigated with canal will have high index value. The scores of both indices are presented in Table 8.

Table 8. Irrigation indices for estimation of potential area under micro irrigation

States	Index 1	Index 2
Andhra Pradesh (AP)	0.714	0.785
Assam (AS)	0.329	0.378
Bihar (BR)	0.744	0.806
Chhattisgarh (CG)	0.518	0.639
Goa (GA)	0.816	0.861
Gujarat (GJ)	0.846	0.882
Haryana (HR)	0.712	0.794
Himachal Pradesh (HP)	0.231	0.239
Jammu & Kashmir (J&K)	0.318	0.494
Jharkhand (JH)	0.717	0.723
Karnataka (KT)	0.643	0.712
Kerala (KL)	0.562	0.604
Madhya Pradesh (MP)	0.743	0.776
Maharashtra (MH)	0.767	0.834
Odisha (OD)	0.440	0.600
Punjab (PB)	0.809	0.864
Rajasthan (RJ)	0.807	0.857
Tamil Nadu (TN)	0.830	0.878
Telangana (TL)	0.886	0.912
Uttar Pradesh (UP)	0.860	0.897
Uttarakhand (UK)	0.754	0.806
West Bengal (WB)	0.546	0.676

Source: Authors' estimate

The total irrigated area has been termed as "ultimate potential" because irrigation sources are essential for adopting MI. This area can only be brought under MI in the short-run. In the long-run, these estimates will change with the change in gross irrigated area which has grown at compound annual growth rate of 1.84% during the period 2001-2014. Potential area for MI has been estimated as 72.17 Mha and 77.58 Mha under scenario I and scenario II, respectively (Table 9). In scenario 1, more than 2/3rd of total potential area is constituted by sprinkler irrigation (51.01 Mha) and the remaining area can be irrigated with drip irrigation. Among states, Uttar Pradesh shares largest potential area (25%), followed by Rajasthan (12%) and Madhya Pradesh (10%). These states constitute the largest share in total potential area under scenario 2 as well.

Table 9. Micro irrigation potential across Indian states

(Area in Mha)

States	Ultimate Irrigation Potential			Scenario[1*]			Scenario[2#]		
	Sprinkler	Drip	Total	Sprinkler	Drip	Total	Sprinkler	Drip	Total
AP	1.72	1.95	3.67	1.23	1.39	2.62	1.35	1.53	2.88
AS	0.25	0.16	0.41	0.08	0.05	0.13	0.09	0.06	0.15
BR	3.92	1.36	5.29	2.92	1.01	3.93	3.16	1.10	4.26
CG	1.02	0.78	1.80	0.53	0.40	0.93	0.65	0.50	1.15
GA	0.02	0.01	0.04	0.02	0.01	0.03	0.02	0.01	0.03
GJ	3.35	2.70	6.05	2.84	2.28	5.12	2.96	2.38	5.34
HP	4.46	1.37	5.83	3.17	0.97	4.15	3.54	1.09	4.63
HR	0.16	0.05	0.21	0.04	0.01	0.05	0.04	0.01	0.05
J&K	0.33	0.15	0.48	0.11	0.05	0.15	0.16	0.07	0.24
JH	0.18	0.05	0.23	0.13	0.04	0.17	0.13	0.04	0.17
KT	1.86	1.97	3.83	1.19	1.27	2.46	1.32	1.40	2.72
KL	0.13	0.34	0.47	0.07	0.19	0.27	0.08	0.21	0.29
MP	8.83	1.26	10.08	6.56	0.93	7.49	6.85	0.97	7.83
MH	2.36	1.90	4.26	1.81	1.46	3.27	1.97	1.59	3.55
OD	0.74	0.67	1.41	0.33	0.29	0.62	0.45	0.40	0.85
PB	5.77	1.97	7.75	4.67	1.60	6.27	4.98	1.70	6.69
RJ	8.98	1.51	10.49	7.24	1.22	8.46	7.69	1.29	8.99
TN	1.53	1.74	3.27	1.27	1.44	2.71	1.35	1.53	2.87
TL	1.31	1.27	2.57	1.16	1.12	2.28	1.19	1.16	2.35
UP	15.52	5.00	20.52	13.35	4.30	17.65	13.92	4.49	18.41
UK	0.34	0.20	0.54	0.26	0.15	0.41	0.28	0.16	0.44
WB	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

Source: Authors' estimate
Note: *-calculated based on index 1 #-calculated based on index 2

3.3. Extent of Realization of Micro Irrigation Potential

The extent of realization of micro irrigation potential was examined by estimating the share of actual area under MI in estimated potential in both the scenarios. In scenario 1, only 15.8% of the total potential under MI in the country was actually realized by the year 2018 (Table 10). The extent of realization was relatively higher for drip irrigation system (25.3%) as compared to sprinkler system (11.9%). Spread of MI and realization of potential varied significantly across the states. Among the states, Andhra Pradesh achieved highest level of realization, followed by Karnataka and Maharashtra. Comparatively better progress in Andhra Pradesh might be due to the government's dedicated efforts to achieve the objective and creation of Special Purpose Vehicle (SPV) in 2003. It is noted that Uttar Pradesh, which has the highest potential under MI (17.65 Mha), has the least (0.9%) level of realization. Similarly, in high potential state of Punjab, where groundwater is over-exploited, the level of realization is low (0.78%). Thus, serious efforts are needed to promote MI technology, particularly in high potential and under-exploited states. In scenario 2 where relatively higher proportion of canal irrigated area is used for estimating potential, the value of the estimate increases from 72.17 Mha to 77.58 Mha. Due to higher value of potential area, the level of realization reduces to 14.71% at country level in scenario 2. Among the states, Andhra Pradesh, Karnataka and Maharashtra remain the most progressive states in terms of MI coverage (Table 10).

3.4. Concentration of Micro irrigation in Different States (Location Coefficient)

Location coefficient has been estimated to analyze concentration of MI area in different states. This has been targeted to examine development pattern and regional disparity of MI as all states are growing at different rate.

The location coefficient is calculated as:

$$L = \frac{\mathrm{Mj/M}}{\mathrm{Gj/G}}$$

Where,

Mj = area under micro irrigation in the j^{th} state

M = area under micro irrigation at the national level

Gj = area under minor irrigation in the j^{th} state

G = area under minor irrigation at the national level

Table 10. Penetration of micro irrigation compared to estimated potential

	Actual area			Per cent to Scenario 1			Per cent to Scenario 2		
	Sprinkler	Drip	Total	Sprinkler	Drip	Total	Sprinkler	Drip	Total
AP	489.56	1295.66	1785.22	39.82	93.03	68.08	36.21	84.59	61.91
AS	2.45	0.37	2.82	3.03	0.70	2.10	2.63	0.61	1.82
BR	105.00	10.50	115.50	3.60	1.04	2.94	3.32	0.96	2.71
CG	291.52	24.75	316.27	55.42	6.13	34.01	44.91	4.96	27.56
GA	1.13	1.19	2.32	5.94	9.79	7.44	5.63	9.29	7.06
GJ	698.69	723.22	1421.91	24.63	31.68	27.78	23.61	30.37	26.63
HP	572.62	32.76	605.38	18.05	3.36	14.60	16.18	3.01	13.08
HR	4.32	5.39	9.71	11.60	50.41	20.25	11.25	48.87	19.63
J&K	0.06	0.02	0.08	0.05	0.05	0.05	0.03	0.03	0.03
JH	15.76	20.63	36.39	12.05	58.61	21.92	11.95	58.13	21.74
KT	863.32	658.17	1521.49	72.27	51.96	61.81	65.32	46.96	55.87
KL	8.68	23.61	32.29	11.84	12.23	12.12	11.03	11.39	11.29
MP	242.73	313.89	556.62	3.70	33.66	7.43	3.54	32.21	7.11
MH	505.37	1199.96	1705.33	27.95	82.19	52.18	25.72	75.63	48.01
OD	97.94	24.79	122.73	30.00	8.43	19.78	22.00	6.19	14.51
PB	13.20	35.59	48.79	0.28	2.23	0.78	0.26	2.09	0.73
RJ	1645.43	245.30	1890.73	22.72	20.17	22.36	21.39	18.99	21.04
TN	188.14	487.51	675.65	14.80	33.80	24.90	13.99	31.95	23.54
TL	70.57	191.72	262.29	6.10	17.06	11.50	5.93	16.59	11.18
UP	128.53	25.58	154.11	0.96	0.59	0.87	0.92	0.57	0.84
UK	5.04	7.08	12.12	1.96	4.68	2.97	1.83	4.38	2.77
WB	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

Source: Authors' estimate

The higher value of coefficient depicts higher concentration of MI (Ramasamy *et al.*, 2005; Suresh *et al.*, 2018). The value of coefficient represents concentration of MI with respect to groundwater. These coefficients have been calculated based on potential utilized under groundwater irrigation development at three points of time. Coefficient for Andhra Pradesh shows that concentration of MI has increased rapidly from 0.3 in 2006-07 to 6.39 in 2018-19. States such as Rajasthan have shown that area under MI has not been in accordance with its groundwater development. In other states, MI has spread at a slower pace as compared to spread of groundwater development (Table 11).

Table 11. Location coefficient across states at different points

States	2006-07	2014-15	2018-19#
Andhra Pradesh	**0.30**	**1.62**	**6.39**
Bihar	0.08	0.04	0.19
Chhattisgarh	0.73	1.38	2.31
Goa	4.85	3.67	4.16
Gujarat	**0.25**	**0.25**	**1.99**
Haryana	0.00	1.52	1.01
Himachal Pradesh	0.08	0.03	1.12
Jharkhand	0.02	0.04	1.07
Karnataka	1.85	1.51	2.97
Kerala	1.18	0.58	3.95
Madhya Pradesh	1.47	0.91	0.48
Maharashtra	**0.65**	**0.62**	**1.74**
Odisha	0.02	0.04	2.38
Punjab	**0.00**	**0.00**	**0.04**
Rajasthan	**8.02**	**5.98**	**1.61**
Tamil Nadu	0.26	0.68	0.86
Telangana		0.20	0.70
Uttarakhand	0.01	0.00	0.00
Uttar Pradesh	**0.06**	**0.04**	**1.56**
West Bengal	0.18	0.01	0.18

Source: Authors' estimate

Note: #- potential area taken from 5th minor irrigation census and actual area from Agricultural Statistics at a Glance, 2018.

3.5 Determinants of Adoption of Micro Irrigation

Micro irrigation technologies are perceived as system of increasing WUE and providing water to every field. Besides, this system of irrigation offers significant economic and environmental benefits. Despite having concerted support of the government and institutions, the pace of adoption of MI system is slow. This section discusses the relative importance of key factors that determine the adoption of MI technology based on the results of the fixed effects regression model. The dependent variable was 'area under MI', and explanatory variables included groundwater availability, canal irrigated area, labour availability, subsidy provision, power availability in agriculture, pump-set services to net sown area, and area under horticultural crops (particularly fruits and vegetables). Based on the Hausman Test (p-value significant at 5% level), fixed effect model was selected over random effect and linear models.

Tubewell irrigation has emerged as key factor in the adoption of MI technologies. Assured irrigation facilities like tubewell motivate farmers to invest in capital intensive irrigation system. If groundwater facilities are utilized using micro irrigation technologies, the WUE would improve substantially over traditional method of irrigation (35-40%). Improvement in WUE not only increases cropped area during next cropping seasons, but also enhances yield of crops and product quality. Availability of pump sets (both electric and diesel) was also found to be positively associated with the adoption of MI technology.

The average electricity consumption in agriculture was 0.97 kWh/ha in the country in 2017-18. Reduction in electricity use is reported from adoption of MI system by few studies (Gorain et al., 2018; Narayanamoorthy, 2004). The savings in electricity consumption and its assured availability encourage farmers for moving towards mechanization of farm activities. The labour availability per ha of net sown area was 0.74 day. As MI technologies are labour intensive, its adoption will create employment opportunities. Declining groundwater depth at a faster rate than its natural replenishment, particularly in north western India, is pressing hard the policy makers and farmers to promote MI technologies. Imbalance in demand-supply scenario of water due to increasing pressure from all sectors of economy is also pressing hard to adopt MI. The average groundwater depth was 10 meter in 2017-18. The high-value crops like fruits and vegetables require less water than water-intensive crops like sugarcane and paddy. Growing of fruits and vegetables using MI increases average productivity of these crops by about 42.3% and 52.8%, respectively, mainly because of spacing and judicious use of water and other inputs, etc. (GoI, 2015). The overall benefits accrued from the MI system are reflected in the income enhancement of the farmers. Studies have reported increase in farmer's income in the range of 20% to 68% with an average increase of 48.5% (GoI, 2015).

The relationship between adoption of MI and its determinatns such as groundwater availability, canal irrigated area, groundwater depth, labour availability, fruits and vegetables area, pumpset services to cultivated area, electricity use in agriculture and subsidy provision was analyzed by fitting panel data regression. The regression estimates for adoption of MI technologies are presented in Table 12. The explanatory variabes jointly explained 35.2% of variations in the adoption of MI technologies. The estimated F value (18.4915) was found to be significant. Further, all explanatory variables except canal irrigated area and area under fruits and vegetables were found to be significant.

Table 12. Determinants of adoption of micro irrigation at state level

Variables	Coefficient	t-value	p-value
Dependent Variable: Area under micro irrigation			
Independent Variables:			
Groundwater availability (tubewell irrigated area, ha)	0.605	3.704	0.000
Labour availability	1.124	3.65	0.000
Ground water depth (mt)	-1.078	-3.054	0.002
Subsidy (after 2005 = 1, otherwise = 0)	0.244	1.908	0.057
Electricity use in agriculture (kWh per ha)	0.279	1.792	0.074
Pumpset serving net sown area (ha)	0.902	4.745	0.000
Canal area (ha)	-0.153	-1.262	0.208
Fruit and vegetable area (predicted) ha	0.016	0.152	0.880
Number of observations	294		
F (8, 272)	18.4915		
Prob > F	0.0000		
R-square	0.35228		

Source: Authors' estimates

As expected, the groundwater availability was positively and significantly associated with the area under MI. It could be inferred that assured irrigation water prompts farmer to adopt capital-intensive irrigation technology to increase its efficiency by irrigating more area with existing water. Past studies have also noted the role of assured water sources in adoption of MITs (Afrakhetch *et al.,* 2015). Policy makers are also convinced that adoption of MI is effective in increasing area under irrigation and make use of precious water resources judiciously. Pumpset accessability among farmers was also found to be signficianly and positively associated with the adoption of MI technologies.

Declining groundwater depth was found to be an important determinant of adoption of MI technology. To check the fast deplting groundwater, meeting the increased water demand of other sectors and saving water for future geneferation, the government is strongly promoting adoption of MI by giving priority to the regions with declining groundwater depth.

The regression coefficient for electricity use in agriculture was positive and significant. It implies that assured electricity encourages farmers to adopt MI technologies. This might be due to assured availabilty of power (electricity), as its use in agriculture reduces the energy cost with increased meachanization, reduces production cost and assures sustainable farm production.

The main vehicle of government policies to promote MI systems are product subsidies which range from 50% to 90%. Provision of the government subsidy has been instrumental in promoting adoption of MI technologies. The regression coefficient for government subsidy was positively associated with the area under MI technology. It could be concluded that adoption of MI in major states increased with provision of subsidy for installation of MI technologies. This could be due to the fact that financial support provided by the government reduced the cost of installation that motivated the farmers to go for installating capital-intensive irrigation infrastructure, which otherwise was difficult for individual farmers.

Labour intensity was positively and significantly related with the adoption of MI. As the adoption of MI technologies requires more labour due to more frequencey of irrigation over traditioal method of irrigation. Also, adoption of this technology could be seen as creating more employment opportunities in both primary and secondary sectors owing to higher production including better produce quality. The regression coefficients for canal irrigated area and fruits & vegetables area had expected sign but were non-significant.

3.6. Determinants of Farm-level Adoption of Micro Irrigation

The factors affecting adoption of MI at farm level have been identified using farm households' data collated through farm survey in Punjab, Andhra Pradesh, Gujarat and Maharashtra (Table 12). The key factors affecting adoption of MI were identified using logit regression analysis. The procedure of logit analysis is given below:

The logit model uses a logistic cumulative distribution function to estimate the linear determinants of the logit (Li) or the logged odds and has the following form:

$$Li(Y) = ln\left[\frac{P_i}{1 - P_i}\right] = \beta_0 + \beta_k X$$

where, (Pi /1- Pi) is the odds expressing the conditional mean or probability of an occurrence of the event relative to the likelihood of a non-occurrence given X; β_0 is the constant term or intercept, β_k is a vector of regression coefficients to be estimated and X is a set of independent variables determining the probability of the event. The model in terms of Y would then be written as:

$$Y_i = \alpha + \sum_{k=1}^{K} \beta_k X_k + \varepsilon$$

where Yi is a binary dependent variable; and Yi equals 1 when a farm household adopted MI system and 0 otherwise, α is the constant term and β_k are regression coefficients of k independent variables to be estimated and ε is the error term. The important thing is to find β that produces the logits and the conditional mean of Y given X values that have the greatest likelihood of producing the observed data.

Empirical model specification

The logit model of adoption of MI (Yi) has been specified as a function of all independent variables as follows:

$$Y_i = f(X_i) + u$$

where, dependent variable (Yi) is adoption of MI and independent variables (Xi) are age (years), family size (number), working labour (number), schooling (years), mobile use (years), caste (Gen or OBC = 1 Otherwise = 0), soil health card (Yes = 1 No = 0), income from food grain (Rs.), income from horticulture (Rs.), total expenditure per month (Rs.), crop insurance (Yes=1 No=0), water table depth (in feet), tube well ownerships (Yes=1 No=0), source of energy to extract water, irrigated area (ha), rainfed area (ha).The estimated coefficients of the parameters with marginal effect are summarized in Table 13. Logistic regression functions have been fitted separately for each state and for pooled data (all states together).

The results of the regression revealed that family size, mobile use, possession of soil health card, availing benefits of crop insurance schemes and possession of tubewell positively affect the adoption of MI. Possession of irrigation source is one of the essential eligibility criteria to avail benefits under PMKSY. Farmers with own tubewell have better access to water supply which increases probability of MI adoption. Farmers who are aware about ongoing schemes like crop insurance schemes and soil health card showed more interest in the MI scheme. Possession of rainfed area is negatively affecting the adoption of MI, though MI is adopted primarily for water saving and to bring un-irrigated area under irrigation with saved water. In Punjab, increase in water table had positive association with adoption of MI. This may lead to a positive effect in future in checking groundwater depletion.

Table 13. Factors affecting adoption of micro irrigation at farm household level

Variables	Punjab		Andhra Pradesh		Gujarat		Maharashtra	
	Coef.	Marginal Effect	Coef.	Marginal Effect	Coef.	Marginal Effect	Coef.	Marginal Effect
Dependent variable: Adoption of MIS (yes=1; no=0)								
Independent variables:								
Family size (no)	-0.137	-0.034	0.205	0.051	-0.009	-0.002	-0.011	-0.002
Family labour available (no)	0.133	0.033	-0.263	-0.065	-0.893	-0.211	-0.621	-0.142
Schooling (years)	0.067	0.017	0.155***	0.038***	-0.115	-0.027	0.001	0.001
Mobile use (years)	0.003	0.001	0.238***	0.059***	0.835***	0.198**	-0.065	-0.015
Caste (Gen+OBC=1 Otherwise=0)	-0.001	0.000	1.152*	0.256**	-2.907	-0.565	1.087	0.215
Soil health card (Yes=1 No=0)	3.502***	0.568***	0.297	0.074	7.095**	0.809***	1.961**	0.453**
Crop insurance (Yes=1 No=0)	1.265***	0.306***	0.643	0.158	8.049***	0.962***	6.03	0.892***
Water table depth (in feet)	0.010***	0.003***	0.005***	0.001***	-0.003	-0.001	0.01***	0.001
Tube well ownership (Yes=1 No=0)	3.366***	0.631***	3.073***	0.592***	3.373	0.520*	2.968***	0.442***
Irrigated area (ha)	0.031	0.008	0.073	0.018	0.646***	0.153**	0.229**	0.052**
Rain-fed area (ha)	-0.627	-0.154	0.611	0.151	-3.6	-0.852	2.52	0.577
Energy (Diesel=1 otherwise=0)	1.671***	0.388***	-1.226*	-0.295**	-1.483	-0.353	-0.522	-0.125
Constant	-2.750**		-9.249***		-10.58		-3.730*	
Number of observation	183		204		220		220	
LR $chi^2(12)$	103.9		151.79		279.59		229.97	
Prob > chi^2	0.000		0.000		0		0	
Pseudo R^2	0.4095		0.5368		0.9167		0.75	
Log likelihood	-74.895		-65.497		-12.696		-37.279	

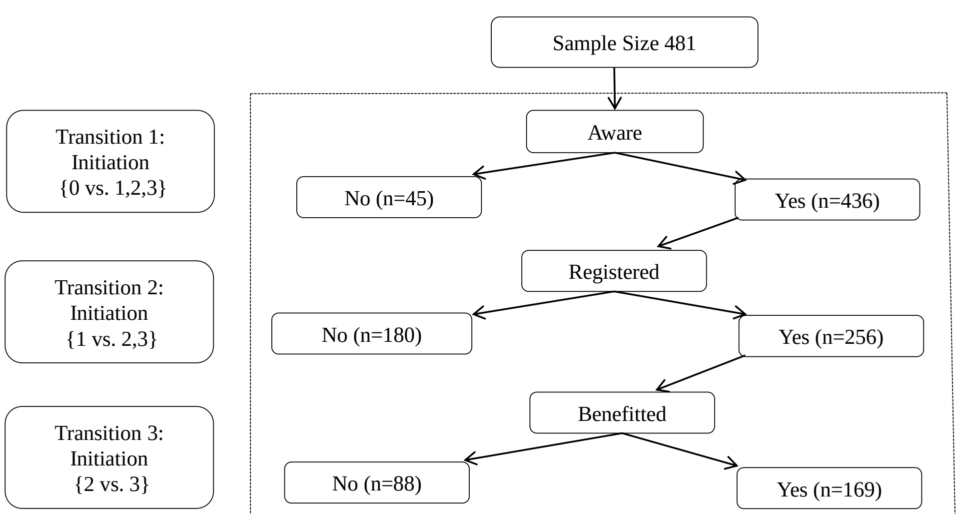
Source: Authors' estimate
Note: ***, ** and * denote significance at 1%, 5% and 10% level, respectively.

Farmers who possess diesel engine had a higher probability to adopt MI. Free electricity connection may be a discouraging factor for farmers to adopt MI as they can draft groundwater with nominal cost or free of cost. In Andhra Pradesh, education played a significant and positive role in adoption of MI besides other factors. The probability of adoption of MI was higher among general and or OBC category, despite higher rate of subsidy for disadvantaged groups (SC/ST). In Gujarat, years of mobile use, possession of soil health card, crop insurance and irrigated area positively affected adoption of MI. In Maharashtra, irrigated area is nearly 18% of cropped area and nearly 4% of it is under sugarcane cultivation. So, in the context of water scarcity, irrigated area had positive affect on adoption of MI besides depth of water table.

3.7. Determinants of Participation in DBT in Uttar Pradesh

Participation in DBT is a step-wise process i.e. whether farmers are aware about DBT or not, if they are aware then whether they have registered for it or not, and if they have registered, then whether they received benefit or not. Sequential logit model was used to find out determinants of participation in the DBT process. This analysis quantifies the effect of explanatory variables on the odds of passing a specified number of transitions. This method compares the factors affecting farmer participation in DBT process at different stages. The dependent variables were noted in accordance with the sequence of decision. The transition steps involved in sequential logit model is depicted in Figure 16.

Figure 16. Transition steps for sequential logit model



Source: Prepared by authors

The variables considered in the sequential logit model have been given in Table 14 with its odds ratio for its transitions from lower to higher stage. The first step is to find determinants of awareness of DBT schemes among the surveyed sample households against those who are not aware. Farming experience and ownership of electric pump significantly influenced awareness level. This may be due to increase in farming experience that have developed linkage with other progressive farmers and government officials. When compared between registered and non-registered farmers among aware farmers, except being member of social organization and possession of kisan credit card, other variables played a significant role in DBT registration. In registration of DBT, possession of smart mobile phone was found to be associated with higher odds for registration. Other variables like farming experience, year of schooling, possessing tube well, electric and diesel pumps were associated with the higher odds of registration. Among benefitted and not benefitted categories, being the member of any social organization like gram panchayat, self-help group, co-operative, etc. have played a positive and significant role in availing benefits under DBT. Other variables like year of schooling, ownership of electric and diesel pumps are also associated with the higher odd of getting benefits.

Table 14. Factors affecting participation of households in DBT

Sequential logit model (Odd Ratio)	Aware vs not aware		Registered vs not registered		Benefitted vs not benefitted	
	Odds Ratio	Std. Err.	Odds Ratio	Std. Err.	Odds Ratio	Std. Err.
Farming experience (years)	1.02*	0.01	1.02***	0.01	1.01	0.01
Schooling (years)	1.05	0.04	1.12***	0.03	1.06*	0.03
Possession of smart mobile (yes=1, no=0)	1.98	0.94	1.99***	0.53	1.35	0.46
Member of social organization (yes=1, no=0)	2.64	1.98	1.64	0.56	3.04**	1.45
Possession of KCC (yes=1, no=0)	1.25	0.43	1.29	0.31	1.10	0.36
Caste (Gen + OBC=1,others=0)	1.30	0.68	0.42**	0.16	1.19	0.56
Banking facilities (SCB =1, others = 0)	1.25	0.42	0.55***	0.12	0.83	0.24
Possession of tube well (yes =1, no = 0)	0.68	0.29	1.60*	0.43	0.63	0.25
Possession of electric pump (yes =1no = 0)	7.25*	7.50	1.59	0.51	1.94*	0.77
Possession of diesel pump (yes =1 no = 0)	1.57	0.59	2.09***	0.53	2.06**	0.74
Cons	1.48	1.19	0.24**	0.15	0.47	0.37

Source: Authors' estimate
Note: *, ** and *** denote significance at 10, 5 and 1% level, respectively; KCC= Kisan credit card; OBC-Other Backward Caste; SCB-Scheduled Commercial Bank

3.8. Determinants of Adoption of Sprinkler Irrigation

Average yield, water productivity, and technical efficiency for wheat growers using sprinklers were compared with their counterparts following flood method of irrigation in Uttar Pradesh. While this is useful to demonstrate efficiency gains from sprinkler irrigation, a simple comparison of means is a biased measure of gains because adoption of sprinkler involves a selection process. Farmers may self-select to adopt sprinkler irrigation, or they may be selected as beneficiaries of DBT scheme. Hence, it is likely that population of adopters differs from that of non-adopters.

To take this into account, we adopt treatment effects models from the programme evaluation literature (two-stage Heckman procedure). In a regression framework, the treatment effects model is given by:

$$R_i = a + bC_i + c'X_i + \varepsilon_i$$

Where, R_i is an outcome variable (yield, water productivity, technical efficiency) for farmer i, C_i is a dummy variable taking value 1 for a farmer who has adopted sprinkler method of irrigation and otherwise 0. X_i is a vector of control variables, and ε_i is zero mean random variable.

An ordinary least squares estimate from above equation is likely to be biased if ε_i contains within it random unobservable factors such as ability that are not uniformly distributed within the population of adopter and non-adopters. In such a case, error term is likely to be correlated with C_i. Thus, for instance, if adopters are more productive than non-adopters because of unobserved ability, then a simple comparison of the means as well the OLS estimates would yield an overestimate of the true measure of gains from adoption. Hence, we apply two-stage Heckman procedure to correct the bias from the endogeneity of right-hand side variables.

Consider the following adoption equation:

$$C_i = \alpha_i Z_i + u_i$$

Where, C_i is a binary variable (1 for adopters and 0 for non-adopters), Z_i is a vector of variables that matters for adoption, Variables in Z_i will overlap with variables in X_i. Identification requires that there be at least one variable in Z_i that is not in X_i. If this condition is met, the predicted value, $\hat{c}$ can be used as instrument for C_i in earlier regression equation. This would yield a consistent estimate of b provided the instruments are uncorrelated with the error term. Table 15 presents estimates of probit model.

Table 15. Determinants of adoption of sprinkler irrigation

Variables	Coefficient	Std. Err.	Marginal effect	Std. Err
Dependent variable: Adoption of sprinkler (yes=1; no=0)				
Independent variables:				
Ln landholding size (acre)	0.617***	0.145	0.162***	0.036
Ln farming experience (years)	-0.261	0.185	-0.068	0.048
Ln schooling (years)	0.074	0.049	0.019	0.013
Member of social organisation (yes=1, no=0)	0.477**	0.233	0.125**	0.060
Possess a Kisan Credit Card (yes=1, no=0)	0.134	0.194	0.035	0.051
Caste (SC/ST and OBC=1, others =0)	0.185	0.266	0.048	0.070
Own tube-well (yes=1, no=0)	0.501*	0.288	0.131*	0.075
Own electric pump (yes=1, no=0)	0.851***	0.254	0.223***	0.064
Own diesel engine (yes=1, no=0)	-0.109	0.208	-0.029	0.054
Constant	-2.192***	0.804		
Number of observations		403		
LR chi^2		65.84		
Prob>chi^2		0.0082		

Source: Authors' estimate

Note: *, ** and *** denote significance at 10, 5 and 1% level, respectively.

Key factors that influence adoption of sprinkler irrigation are landholding size, ownership of tube well and electric pump, and households' association with any social organization. The probability of adoption of sprinkler irrigation is higher for larger farmers, and those who own their own tube wells and electric engines for pumping groundwater for irrigation. Interestingly, a household's association with social organization increases chances of adoption of sprinkler irrigation perhaps due to their better awareness about benefits of sprinkler irrigation and flow of information on government schemes.

Efficiency Gains from Sprinkler Irrigation

The estimates of effect of sprinkler irrigation on crop yield, technical efficiency and water productivity after accounting for selection bias is presented in Table 16.

Table 16. Effects of sprinkler irrigation on crop yield, technical efficiency and water productivity

Particulars	Yield	Technical efficiency (TE)	Water productivity
Ln seed (kg/acre)	-0.231*** (0.059)	-	-
Ln fertilizer (kg/acre)	0.006 (0.06)	-	-
Ln labour use (mandays/acre)	0.040** (0.019)	-	-
Ln machine use (hour/acre)	0.175*** (0.039)	-	-
Ln irrigation (hour/acre)	0.152*** (0.036)	-	-0.609*** (0.089)
Sprinkler irrigation=1, otherwise=0	0.207*** (0.024)	19.252*** (2.322)	0.238*** (0.059)
Ln farming experience (years)	0.008 (0.02)	0.573 (2.024)	-0.016 (0.05)
Ln family size (no)	-	-0.1 (0.379)	-
Ln schooling (years)	-	1.116** (0.545)	0.023* (0.014)
Caste (SC/ST, OBC=1, otherwise=0)	-	-	-0.204*** (0.069)
Ownership of tube-well (yes=1, otherwise=0)	-	9.301*** (3.102)	0.003 (0.079)
Ownership of electric pump (yes=1, otherwise=0)	-	2.623 (3.021)	0.282*** (0.077)
Access to extension support (yes=1, otherwise=0)	-	4.910** (2.024)	-
District dummy (Jhansi=1, otherwise=0)	0.053*** (0.021)	3.328* (2.008)	0.288*** (0.05)
Inverse Mills Ratio (IMR)	-0.034* (0.02)	1.489 (2.368)	-0.058 (0.061)
Constant	2.419*** (0.408)	52.351*** (8.692)	1.942*** (0.432)
Number of observations	403	403	403
Prob > F	0.000	0.000	0.000
R-squared	0.331	0.232	0.296

Source: Authors' estimate

Note: Figure in parentheses are standard errors; *, ** and *** denote significance at 10, 5 and 1% level, respectively.

Inverse Mills Ratio is significant only in case of crop yield. The sign of dummy for sprinkler irrigation is positive and highly significant, suggesting that application of sprinkler irrigation contributes towards improving yield. The other variables that have a positive and significant effect on crop yield are: irrigation hours, labour use, and machine use. However, yield is negatively associated with seed rate, as farmers were fund to apply almost double the quantity of the recommended rate. Technical efficiency was calculated using stochastic frontier production function. The key variables which influence efficiency of farm, are method of irrigation applied, educational status of farmers and access to extension support. Use of sprinkler irrigation has positive and significant effect on technical efficiency. Access to better education led to higher efficiency by influencing decision making in input use.

Water productivity was calculated based on total quantity of water used in entire cropping season. The key variables that influence water productivity are irrigation hours, irrigation type, electric pump ownership, years of schooling and social class of farmers. Farmers with sprinkler irrigation have positive and significant impact on water productivity.

3.9. Constraints in Adoption of Micro Irrigation

The sample farm households of study states of Punjab, Andhra Pradesh, Gujarat and Maharashtra felt that the process of getting MI is lengthy. This can be smoothened through administrative reforms in the line departments involved in promotion of MI in study states. However, response was not uniform across the states. Where farmers and line departments had better understanding and cooperation, process of MI access was simple (Table 17). In some areas of Punjab, adopters reported favouritism based on the caste, association with the political party, and status in the society. A small number of respondents in each state also informed about prevalence of nepotism. During post-installation period, farmers faced several constraints like clogging of laterals and pipes. Although concerned line departments had clear instructions of maintenance by installing firms, still a large number of farmers faced problems of clogging and chocking of laterals.

In Andhra Pradesh, Gujarat and Maharashtra, programme implementing agency (PIA) and firms organized a series of training programs for farmers and field level staff on maintenance. In Punjab, availability of post-installation service was perceived to be poor as compared to other states. The damage to MI by own or wild animals was noticed in all the states. Farmers have reported that once laterals are damaged, it is very difficult to replace or to get serviced due to remote location of the fields.

In the state of Maharashtra and Gujarat, there were incidences of theft of MI system. Difficulties in maintenance and unreliable energy source were other constraints faced by the respondents. For scaling up of the MI, these constraints need to be addressed on priority.

Table 17. Constraints related to administrative procedures faced by adopters

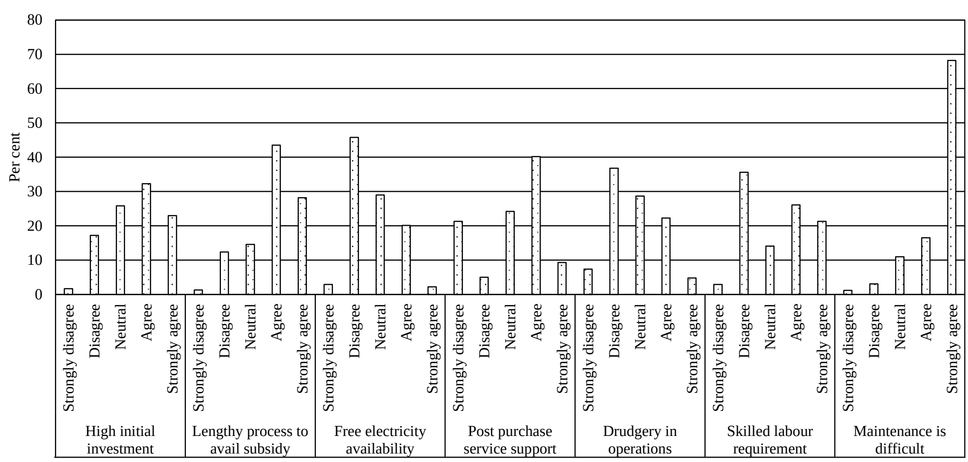
Particulars	Punjab (n=91)	Andhra Pradesh (n=103)	Gujarat (n=105)	Maharashtra (n=110)
In process of getting MI				
Very lengthy	23	19	27	19
Lengthy	9	14	10	16
Neutral	5	1	3	2
Good	13	17	19	23
Very good	41	52	46	50
Favouritism				
Very much prevalent	18	15	21	19
Prevalent	13	11	13	17
Neutral	9	18	7	4
No Favoritism	28	39	40	45
Not at all Favoritism	23	20	24	25
Post installation service is available				
Yes	49	94	86	78
After installation problem Faced by farmers				
No problem	13	45	72	25
Clogging	49	63	43	86
Animal damage	37	45	27	67
Unreliable energy supply	48	78	66	47
Difficult in repair and maintenance	78	36	94	81
Problem of theft	23	12	17	24

Source: Authors' estimate

3.10. Reasons for Non-Adoption of Micro Irrigation

The information from the non-adopters was analyzed and is summarized in Figure18. The non-adopters of micro irrigation were asked open-ended questions like whether micro irrigation involved high initial cost and their perceptions were gauged on Likert-type-scale. About 55 % non-adopters (both strongly agree and agree) perceived that MI required high initial investment. Only 19% of the sample farmers indicated that it was not highly capital-intensive. On the time required for getting MI, more than 71% farmers said that process is very lengthy. It was also examined whether free energy availability hampers the adoption of MI. The responses revealed that the free sources of energy discourage the adoption of MI as it fails to incentivize farmers to save energy and water by adopting efficient technologies. Thus, they do not come forward to install MI on their fields. The farmers' response on the issues of drudgery involved in the MI operations and handling indicated that it involved some drudgery as more than 44% farmers agreed with this. The question like whether skilled person needed for working with MI, farmers said that MI needs the skilled persons to operate the system responded by 47% farmers (Figure 17).

Figure 17. Reasons for non-adoption of micro irrigation



Source: Authors' estimate

About 85% farmers (both strongly agree and agree) informed they feel maintenance of MI is difficult. Further, farmers have pointed out that during farm operations, they face the problem of damage and break down and delay in getting the service in time. Thus, it can be inferred from the above discussions that farmers were hesitant to install MI due to several operational and maintenance related problems. The associated problems/constraints with MI need to be addressed through policy intervention, creating awareness by conducting the exposure programs for the farmers so that they may understand the benefits of MI.

3.11. Challenges in Implementation of Micro Irrigation Scheme

Lack of dedicated team and IT backed operations: Tracking of installation of the MI system, from initiation of work order to installation and payment is a challenging task and this has emerged as a major source of inefficiencies in the system. In most states, PIA staff is deputed from line departments to execute the MIS for a time-bound period. The inconsistency in the posting hampers the execution of the projects.

Delay in release of guidelines/government orders: It has been experience of the key informants at the ground level that government order and direction reaches to them very late. This has hampered the speed of work related to this scheme. Therefore, to avoid these bottlenecks at the official level, works need to be faster.

Lack of easy financing mechanisms for farmers: Farmers face major challenge in finding financing options for micro irrigation products for depositing the margin money. In case they find a financing source, high collateral security is demanded by the lender. Adequate credit facilities to the farmers, trained human resources, and infrastructure for training of farmers are other major constraints affecting its adoption.

Inadequate promotional and information efforts: Micro irrigation is generally perceived as technology intensive; hence, its acceptance by farmers needs much persuasion. The survey revealed lack of information on temporal and spatial variation in soil moisture, optimal fraction of soil to be wetted, location specific and crop-specific irrigation and fertigation scheduling and lack of availability of low-cost water-soluble fertilizers and other agrochemicals at farmer level. Lack of information limits scaling up of the MI technology.

Poor integration with farm irrigation system: Micro irrigation technology was found to be viewed as isolated technology which poorly integrates with the existing farm irrigation management systems.

Free energy sources: At several places, farmers are allowed to run their water pumps using free and subsidized energy resulting in over-exploitation of groundwater. Farmers do not have incentives to adopt water saving technology and thus are hesitant to invest in it. Thus, there are many challenges in MI adoption and these challenges can be overcome through reforms in institutional capacity and creating required infrastructure.

4 Impact of Micro Irrigation

This chapter presents farm-level impact from adoption of MI technology. The farm level data on inputs use, cost and return from the crop cultivation by both adopters and non-adopters in Punjab, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan, and Uttar Pradesh was collected in the year 2018-19. The impact has been analyzed in terms of difference in input use, cost and returns between adopters and non-adopters.

4.1. Evidences from Previous Studies

A review of previous studies on the impact of MI technology in terms of water saving, energy and input saving, employment and income enhancement is summarized in Table 18.

The analysis has revealed significant savings in water, energy, and fertilizer, and increase in cropped area and yield resulted from adoption of MI, thereby overall reduction in production cost. However, the extent of benefits varied depending upon underlying factors such as differences in MIS components, farming system, climatic conditions, socio-economic settings, etc. It is to be noted that most of the studies are based on experiments at research farms, and impact studies based on field survey are limited in numbers.

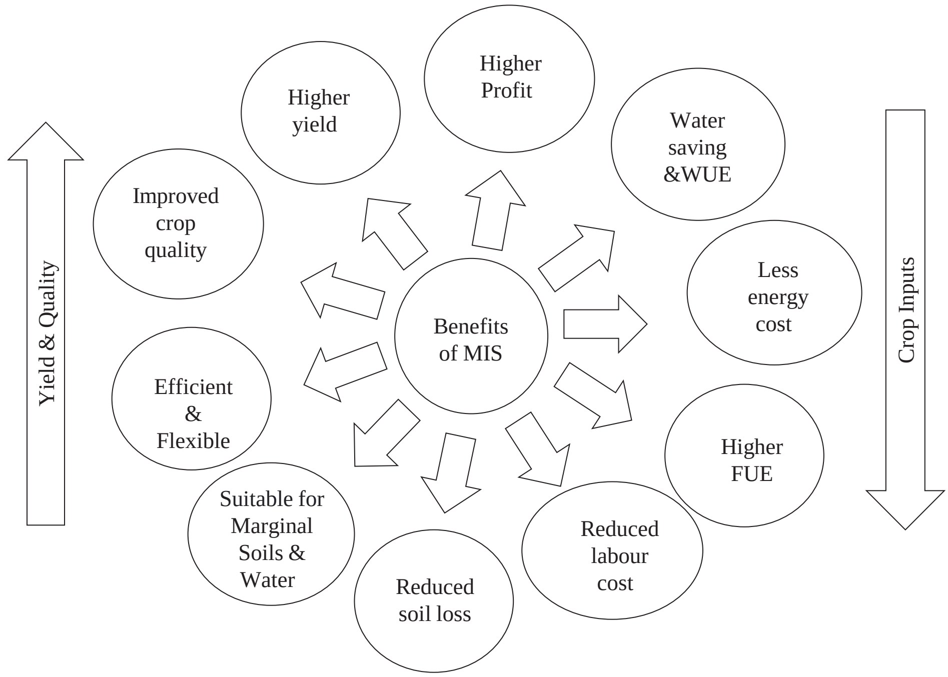
Ten key benefits of MI identified from past studies are presented in Figure 18. These benefits are classified into two categories: (1) input saving, and (2) yield increasing/quality enhancing. Water saving and water use efficiency, reduction in labour use, reduced soil loss, and reduction in energy cost are some of the benefits noted under input saving category. The benefits like higher yield, improved quality resulting to higher farm profit are classified under returns from MI technologies.

Table 18. Review of past studies on impact of micro irrigation in India

Studies	Study Area/ region	Water saving	Energy saving	Fertilizer saving	Cost saving	Additional area under irrigation	Yield/ income increase
Kapur *et al*. 2015	Maharashtra	50-90	30.5	28.5	30-45	31.9	42.4-52.7
Raina *et al*. 2011	Himachal Pradesh	30-35			41.37		
Narayanamoorthi, 2003, 2005, 2006, 2008, 2018	Maharashtra, India	12-84 & 8-60			50		114
Reddy *et al*., 2017	Guntur, AP				25-40	55-60	
Wrachienb *et al*. 2014	Maharashtra	37					19-29
Paul *et al*. 2013	Bhubaneswar, Odisha					54	57
Biswas *et al*. 2015	Gazipur, Bangladesh	50					25-27
Kumar *et al*. 2016	Moradabad, Uttar Pradesh	35					
Bhaskar *et al*. 2005	Maharashtra	40-50					30-100
Tiwari *et al*. 2014	Kharagpur, India						21.05
Chandrakanth *et al*, 2013	Karnataka						65
Priyan and Panchal, 2017	India	50-90	30.5	28.5			
Panigrahi *et al*, 2010	Odisha				17.9		15.4
Chandran and Surendran, 2016	Kerala						13-47
Bhamoriya and Mathew, 2014	Gujarat			20			20-30
NCPAH, 2014	India	25-40	30-40	20	40	30	30
Jha *et al*. 2017	Punjab	40-42					9.13
Vanitha and Mohandass, 2014	Tamil Nadu	50		100			19.05
Rao, et al. 2017	MP		40				11.03
Present study	Punjab, Andhra Pradesh, Gujarat, Maharashtra	17-50	6-36	25-40	11-36		12-43

Source: Authors' compilation

Figure 18. Benefits of micro irrigation



Source: Prepared by authors

4.2. Benefits of Micro Irrigation based on Field Survey in the Study States

This section discusses the benefits realized by the farm households adopting MI technologies. The benefits were estimated using farm-level data on cost of cultivation collected through farm survey from both adopter and non-adopter farmers. For the analysis, crops were selected based on their dominance in the cropping pattern of the selected states. Cost estimation includes both variable and fixed costs.

Punjab: Four crops namely cotton, kinnow, maize and wheat based on suitability for MI and data availability were selected for estimating benefits in Punjab. The cost of cultivation for each crop (derived from input price and output price realized at farm gate) was taken from the sample farmers for detailed analysis. The inputs used and output produced from adopters using MIS were compared with non-adopters and evidence showed reduction in cost on seed and planting materials, which varied from 2.25% in cotton to 46.87% in wheat crop. Cost savings on use of Farm Yard Manure (FYM) in the selected crops varied from 3.17% to 9.78%. Saving in FYM cost for adopters might be because of less quantity required in line sowing as compared to non-adopters. The savings in chemical fertilizers varied from 12.89% to 37.51%, while in plant protection, chemicals used for pest and disease management, the saving varied from 17.71 to 48.23% among selected crops in the state (Table 19). This might be due to application of fertilizers in liquid form using MI technology in right dosage and at right time, which saved the cost of fertilizers. Non-adopters applied fertilizer and chemicals in traditional way (i.e. granule form) which require large quantity resulting to high cost of cultivation. The cost saving on human labour and machine hours used varied from 5.14% to 9.83% and 31.72% to 17.79%, respectively. The saving in total cost of cultivation varied from 1.33% to 18.06% and net return increased in the range of 32.27% to 54.10% in Punjab.

Among crops, higher increase in net return was observed in maize cultivation followed by Kinnow. The saving of inputs and increase in income has also been reported by different researchers (Kapur *et al.,* 2015; Raina *et al.,* 2011; Narayanamoorthi, 2003, 2005,2006, 2008, 2018; Reddy *et al.,* 2017; Wrachienb *et al.,* 2014; Paul *et al.,* 2013; Biswas *et al.,* 2015; Kumar *et al.,* 2016; Bhaskar *et al.,* 2005; Quevenco, 2015; Tiwari *et al.,* 2014; Chandrakanth *et al.,* 2013; Jha *et al.,* 2017; Vanitha and Mohandass, 2014; Rao *et al.,* 2017; Chand *et al.,* 2019).

Andhra Pradesh: Five crops viz. brinjal, sugarcane, coconut, papaya and tomato grown at adopted farms were selected for the analysis. Savings in cost of planting materials varied from about 8.0% in sugarcane to 89% in brinjal, while in crops like coconut, papaya and tomato, seed cost was marginally higher on adopted farms as compared to their counterparts. This might be because of adopted farmers applied quality planting material. The saving in cost of FYM varied between 7.42% and 30.40%. However, FYM cost was higher for papaya on adopted farms. This may be due to high quantity of FYM used in papaya crop by the adopters. The savings in cost on chemical fertilizers varied from 12.6% to 68.76% in the selected crops grown by the adopter farmers in Andhra Pradesh. Similarly, savings in cost on chemicals and pesticides varied from 1% to 22.62% in selected crops. Water is very crucial and scarce resource in the study area. Results have shown that saving in cost of irrigation water varied from 16.07% to 51.19% in the crops grown on adopted farms. The cost saving in labour use varied from 22.78% to 29.41% in selected crops, except tomato. The saving in total cost varied from 4.59% to 24.60% on adopted farmers, while net returns increased from 12.28% to 43.02%. This clearly indicates improved profitability due to adoption of MI system in Andhra Pradesh (Table 19).

Table 19. Impact on input cost, yield and income in Punjab and Andhra Pradesh, 2018

(per cent)

Particulars	Punjab				Andhra Pradesh				
	Cotton	Kinnow	Maize	Wheat	Brinjal	Coconut	Papaya	Tomato	Sugarcane
Seed/ Planting material	-2.25	13.48	-29.76	-46.87	-89.40	4.43	34.87	3.90	-8.14
FYM	-5.46	-3.17	-9.78	3.67	-16.10	-7.42	6.53	-7.65	-30.40
Fertilizer	-12.89	-18.50	-20.73	-37.51	-68.76	-13.60	-38.12	-26.38	-21.66
Chemical	-48.23	-17.71	22.11	-45.30	-22.62	-6.25	-12.48	-8.89	-0.92
Irrigation	-14.77	-60.24	-35.21	-32.00	-34.63	-29.62	-51.19	-16.07	-43.59
Labour	-5.14	-12.35	-31.72	-13.77	-22.78	-26.16	-26.56	3.81	-29.41
Machine use	4.69	-17.29	-14.13	-9.83	9.08	-5.08	-5.35	1.40	-25.35
Total cost	-1.33	-8.14	-13.07	-18.06	-13.63	-8.52	-5.31	-4.59	-24.60
Yield	11.62	10.76	8.17	12.96	10.54	20.17	10.51	22.27	6.82
Net income	32.27	34.40	54.10	35.14	32.40	42.03	12.28	43.02	21.32

Source: Authors' estimate
Note: Total cost includes the variable and fixed cost

Gujarat: Savings in input cost, and increase in yield and returns analyzed for five selected crops namely cotton, groundnut, potato, soybean and bajra for Gujarat. Savings in cost of seed and planting materials ranged from 4.32% to 59.76% on adopted farms as compared to non-adopted farms. The reduction in FYM cost varied from 13.73% to 57.94%, while savings in cost of fertilizers on adopter farmers varied from 45.45% to 63.89%. It might be due to liquid fertigation used on adopted farms, which helped in reducing quantity and thereby cost saving. Similarly, chemical and pesticide cost saving varied from 33.68% to 90.29%. The saving in irrigation water varied from 12.60% to 88.62%. There was a saving in labour use and machine hours on adopters to the extent of 8.31% to 48.65% across different selected crops. Total cost saved in different crops varied from 4.15% to 30.39% and net return was higher for adopters to the extent of 17.63% to 52.01% (Table 20). Thus, it is clear that adoption of MI technology reduces input cost and increase net income. These finding are in conformity with the past studies on micro irrigation (Vanitha and Mohandass, 2014).

Maharashtra: The six major crops namely cotton, bajra, maize, onion, soybean and sugarcane grown by adopter farmers in Maharashtra were considered for analysis on cost saving and increase in yield and return. It was noticed that savings on seed and planting material on adopted farms varied from 4.91% to 36.31% as compared to non-adopters. The cost on FYM saved to the extent of 2.94% to 96.01%, while savings on fertilizers varied from 12.98% to 52.09%. Similarly, savings in chemical and pesticide cost varied from 5.08% to 50.0%. The saving in water cost varied from 16.43% to 85.81% in different crops. The savings in labour and machine hours used by adopters varied from 8.35% to 51.15%. The reduction in total cost in different crops varied from 7.76% to 35.15%, while increase in net return on adopted farms varied from 20.95% to 58.69% across crops (Table 20).

Table 20. Impact on input cost, yield and income in Gujarat and Maharashtra, 2018

(Per cent)

Particulars	Gujarat					Maharashtra					
	Cotton	Groundnut	Potato	Soybean	Bajra	Cotton	Bajra	Maize	Onion	Soybean	Sugarcane
Seed/ planting material	-6.67	8.76	-4.32	-21.28	-59.79	-32.27	-9.21	19.65	-36.31	-4.91	-11.59
FYM	-13.73	-57.94	-29.21	-22.53	-	-2.94	-20.45	-	-10.85	-8.33	-96.01
Fertilizer	-53.91	-49.76	-56.38	-63.89	-45.45	-15.04	-22.37	-16.41	-12.98	-36.10	-52.09
Chemical	-57.72	-34.54	-33.20	-90.29	-33.68	-50.00	-	-	-5.08	-38.84	-43.66
Irrigation	-12.60	-88.62	-37.21	-27.48	-39.46	-27.50	-42.14	-16.43	-85.81	-31.13	-28.33
Labour	-21.48	-36.03	-21.33	-48.65	-34.66	-51.15	-12.94	-19.92	-8.25	-25.88	-10.05
Machine use	-8.31	-20.84	-10.64	-20.25	-9.88	-35.81	-47.47	-12.67	-7.64	-35.61	-4.22
Total cost	-26.65	-30.39	-10.35	-29.59	-4.15	-35.15	-31.31	-7.76	-12.74	-24.08	-17.10
Yield	21.72	10.00	18.49	13.09	4.82	18.64	17.37	15.56	12.54	8.69	10.01
Net income	42.80	17.63	37.86	52.01	41.64	35.26	58.69	39.35	20.95	25.88	25.74

Source: Authors' estimate

4.3. Input Use Pattern and Output of Wheat under Flood and Sprinkler Irrigation System in Uttar Pradesh

Table 21 presents result of the survey conducted in Jhansi and Mahoba districts of Uttar Pradesh in the year 2018-19 to examine difference in input use pattern and output of wheat using sprinkler and flood irrigation (traditional) systems. Irrigation hours for sprinkler irrigation were found to be significantly lower than flood irrigation method. This led to a significant reduction in diesel use and thus irrigation cost for the farmers adopting sprinkler irrigation. No significant difference was found in the use of seed and fertilizer between sprinkler and flood irrigation. Labour use in sprinkler irrigation was significantly lower than in flood method.

No significant difference was found in machine hours used for field preparation, harvesting and threshing. However, total cost of cultivation for wheat crop under sprinkler irrigation was significantly lower than the flood method. Wheat crop yield was significantly higher in case of sprinkler irrigation in comparison to flood irrigation. The groundwater draft using sprinkler system was than that in traditional method of irrigation. Water productivity (kg/m^3) in sprinkler system was significantly higher than flood system.

Table 21. Average input and output in wheat cultivation using flood and sprinkler irrigation

Particulars	Jhansi		Mahoba		Uttar Pradesh	
	Flood (165)	Sprinkler (59)	Flood (148)	Sprinkler (37)	Flood (313)	Sprinkler (96)
Irrigation (hrs/acre)	54.28	48.81**	53.43	53.11	53.88	50.47**
Diesel (litrs/acre)	73.83	65.25**	71.76	70.79	72.85	67.39**
Irrigation cost (Rs/acre)	4447	3859*	4623	4523	4530	4115**
Engine power (BHP)	7.42	6.97	6.96	7.26*	7.20	7.08
Fertilizer (Kg/acre)	96.57	96.73	90.61	92.05	93.76	94.93
Fertilizer cost (Rs/acre)	1832	1998	2298	2011	2052	2003
Seed (Kg/acre)	73.50	73.68	81.19	78.62	77.13	75.58
Labour (mandays/acre)	13.48	12.37	11.97	10.08**	12.77	11.49**
Labour cost (Rs/acre)	3364	3070	2986	2524*	3185	2860**
Machine (hrs/acre)	5.17	5.15	4.86	4.78	5.02	5.01
Machine cost (Rs/acre)	3607	3637	3388	3268	3503	3494
Total cost (Rs/acre)	14563	13975	14623	13577**	14591	13822**
Yield (quintal/acre)	12.12	14.13***	10.72	14.09***	11.46	14.12***
Gross income (Rs/acre)	21022	24524***	18604	24451***	19879	24495***
Net income (Rs/acre)	6460	10549***	3981	10874***	5288	10674***
Groundwater use (m^3)	2199	1846**	2782	2596	2475	2135**
Water productivity (kg/m^3)	0.68	0.88***	0.51	0.72**	0.60	0.82***
Water table now#	60.03	58.64	48.11	54.27	54.39	56.96
Water table 10 years back#	32.01	34.48	26.86	30.76	29.57	33.03*

Source: Authors' estimate
Note: *, ** and *** denote significance at 10%, 5% and 1% level, respectively; #-feet

4.4. Effect of Micro Irrigation on Youths' Attraction towards Agriculture

The issue of youths returning in agriculture was analyzed using data received from sample farms of selected study states viz., Andhra Pradesh, Gujarat, Maharashtra and Punjab. The evidences show that youths engaged in farming using MI had higher qualification and professional degrees. A large percentage of youths shifted to agriculture were from science background (34%), followed by engineering (28%), humanities & management (23%) and other disciplines (14%). The reasons stated by youths to returning to agriculture included jobs in hands less remunerative, jobs not as per qualification, parental lands remain fallow and long distance posting from native (Table 22). Returning of youths in agriculture implies that farming is becoming remunerative and less risky with advent of improved technology and improved infrastructure facilities like development of MI, power, mechanization and others.

Table 22. Change in youths' interest towards agriculture due to better returns

Education type	Reasons for returning to agriculture (%)				
	Current job less remunerative	Job is not as per qualification	Distance from native	Parental lands remain fallow due to no caretaker	Overall
Engineering	13.89 (3)	35.25 (6)	24.87 (4)	25.99 (5)	100(18)
Science	28.60 (6)	31.52 (7)	25.24 (6)	14.64 (3)	100(22)
Arts and Management	32.81 (5)	28.63 (4)	34.12 (5)	4.44 (1)	100(15)
Others	27.70 (3)	32.45 (3)	25.45 (2)	14.40 (1)	100(9)

Source: Authors' estimate
Note: Figures in parentheses indicate the number of respondents

4.5. Micro Irrigation Impact on Income and Employment Opportunities

The development of MI in an area provides employment and income generation opportunities both within and outside the farms. To quantify the perceptions of farmers on scope of opportunities developed from the creation of MI, we have used Likert-type-scale of five-point (Very high=5, High=4, Neutral=3, Less scope=2, No scope =1). It was noted that unemployed youths improved their skill about different aspects of MI through training organized by PIA, NGO and MIS firms. After acquiring skill, youths were getting jobs in their locality with agencies supplying MI systems as well as engaged in minor repairs works (Table 23). Score value three for a particular activity indicates higher scope for the activity in the area. The evidences show that activities like getting jobs with MI supplying firms, self-esteem in society and marketing of farm produce received higher score. Similarly, supply of seeds, fertilizer and service related to MIS also had good scope in the area. The value of standard deviation above one (1) indicates the higher variation in the opinion of the respondents. It was informed by farmers of Andhra Pradesh that these youths come for the service of MIS at the earliest because they reside in the locally. These youths also expressed their happiness on account of getting decent work opportunity at their native areas. The survey findings from Hoshiarpur district of Punjab revealed that out-migration of small and marginal farmers reduced to a large extent after introduction of MI. These insights were received from both sample farmers and staff of project implementing agency the Solar Powered Community Micro irrigation Project (SCMIP). The similar insights were also found from Chittoor district of Andhra Pradesh and Ahmednagar district of Maharashtra.

Table 23. Income and employment opportunities change due to micro irrigation

(Likert scores)

Type of activities	Extent of improvement				
	Andhra Pradesh	Gujarat	Maharashtra	Punjab	Overall
Direct cultivation work	4.8 (1.53*)	4.1 (1.04*)	4.3 (1.12*)	3.8 (1.25*)	4.2 (1.16*)
Marketing of farm Produce	4.7 (1.09*)	4.7 (0.89)	4.7 (0.78)	4.7 (1.02)	4.7 (0.86)
Supply of seed and Planting material	4.6 (1.54*)	3.6 (1.04*)	3.8 (1.28*)	3.9 (1.34*)	3.7 (1.21*)
Supply of fertilizer and chemicals	4.7 (089)	4.1 (1.20*)	4.3 (1.04*)	3.8 (1.12*)	3.9 (1.22*)
Service to MIS	4.9 (1.32*)	3.9 (0.89	3.7 (0.98)	3.9 (0.65)	3.6 (0.83)
Skill improvement	4.5 (1.14*)	3.5 (1.01*)	4.6 (1.12*)	3.7 (0.99)	3.9 (1.01*)
Self-esteem in the society	3.5 (0.85)	4.3 (1.02*)	3.8 (0.87)	4.6 (0.92)	4.4 (0.45)

Source: Authors' estimate

Note: Very high=5, High=4, Neutral=3, Less scope=2, No scope =1 and Figures in parentheses are Standard Deviation (SD), * indicate the SD more than one.

4.6. Micro Irrigation Impact on Out-Migration of Small and Marginal Farmers

The response of farmers from Hoshiarpur district of Punjab revealed that out-migration of farmers (especially of small and marginal farmers) due to rising water scarcity reduced to a large extent after adoption of micro irrigation. Such perceptions were reported by farmers and project staff executing the Solar Powered Community Micro irrigation Project (SCMIP). Similar perceptions were also reported by the sample farms and project staff from Chittoor district of Andhra Pradesh and Ahmednagar district of Maharashtra.

4.7. Micro irrigation Impact on Area Augmentation

The farmers' response about several benefits from adoption of MI were recorded and summarized. Data show that adoption of MI brought additional area under cultivation, varying from 4% in Punjab to 50-200% in Andhra Pradesh (Table 24). A large proportion of additional area carried out under cultivation was also reported from Gujarat and Maharashtra. The main reason for large area brought in under cultivation in states of Andhra Pradesh, Gujarat and Maharashtra could be higher coverage of area under MI. Due to insufficient water farmer used to keep some lands fallow, but after adoption of MI they could extend area under cultivation using saved water. This has resulted in increased cropping intensity and enhanced the income of the farmers. Therefore, MIS has created the opportunity of increasing agriculture production and income of the farmers

Table 24. Farmers' perception on benefits of micro irrigation

Particulars	Punjab	Andhra Pradesh	Gujarat	Maharashtra
Additional areas brought under Cultivation	Very less (4.5%)	Very high (50-200%)	High (12-45%)	High (13-47%)
Fallow land put under cultivation	Yes	Yes, double cropping	Yes	Yes
Increased cropping intensity (%)	Yes, limited extent	43% (from 132 to 175%)	58% (from 130 to 188%)	18% (from 135 to 153%)
Received higher productivity and better price	Yes, quality horticulture produce fetched better price	Yes, productivity of horticulture and other crops improved	Yes, productivity of horticulture, pulses and oilseed improved	Yes, productivity of sugarcane, grapes and other crops improved

Source: Authors' estimate

4.8. Impact of Sprinkler Irrigation in Rajasthan

Water is the most critical input in agriculture. The improved irrigation water availability has a bearing on cropped area, yield and returns from crops grown. This section discusses the farm level impacts of sprinkler irrigation on major crops in Rajasthan by analyzing the data collected from 259 sample farmers from Bikaner and Sikar districts in 2017-18. Analysis showed notable change in yield of major crops grown on the sample farms using sprinkler irrigation. Farmers having sprinkler irrigation grew cash crops like groundnut and gram (Table 25). The increase in cropped area for *rabi* crops varied from 5.6% in wheat to 111.5% in gram as compared to non-adopter farms. The large area increase in gram is attributed to assured irrigation which is critical for crop growth and good harvest. Notwithstanding cultivation of gram requires less water as compared to other *rabi* season crops of wheat and mustard.

During *kharif* season, the cropped area across crops declined marginally on adopter farms over non-adopter farms (varied 1% in *gwar* to 8% in moth). Adopter farms introduced groundnut as new crop which requires frequent irrigation at regular interval. Adopter farmers also grew high value crops like fenugreek (*methi*) and *Isabgol* for better returns, though on very small area. Though the area sown across crops and seasons did not change much (except for gram in *rabi* season), adopter farmers obtained higher yields than their counterparts. In *kharif* season, the increase in yield varied from 23% in gwar to 45% in bajra. The large increase in yield of *bajra* and moong is attributed to assured irrigation, as these crops require less water and facility of critical irrigation in stress condition makes difference in crop growth and yield. In *rabi* crops, yield increase was highest for chickpea (97.3%), followed by wheat (19.4%).

Table 25. Change in cropped area and yield of crops after adoption of sprinkler irrigation

Crop	Average cropped area (ha)		Difference	Average yield (q/ha)		Difference
	Adopter	Non-adopter		Adopter	Non-adopter	
Kharif crop						
Groundnut	2.96	-		30.32	-	
Gwar	1.93	1.95	-0.02 (-1.02)	19.20	15.56	3.64 (23.39)
Moth	1.51	1.65	-0.14 (-8.48)	11.18	11.13	0.05 (0.45)
Bajra	1.07	1.12	-0.05 (-4.46)	21.34	14.73	6.61 (44.87)
Moong	1.12	1.16	-0.04 (-3.45)	14.21	11.17	3.04 (27.22)
Rabi crop						
Wheat	1.32	1.25	0.07 (5.60)	42.47	35.56	6.91 (19.43)
Rapeseed & mustard	1.81	2.26	-0.45 (-19.91)	25.26	25.12	0.14 (0.56)
Gram	2.39	1.13	1.26 (111.50)	22.41	11.36	11.05 (97.27)

Source: Computed from field survey, 2017-18
Note: Figures within the parentheses show percentage difference.

Perceived Impacts

An assessment of social and economic benefits of MI is presented here based on the perceptions of farmers witnessing visible changes that emerged from adoption of sprinkler irrigation in the study area (Table 26). The farmers who adopted sprinkler irrigation reported that they strongly agree to the perceived changes in water saving (73.7%), labour saving and proper land utilization (51.3%, each) and equal distribution of water in field (50%). Farmers also strongly perceived visible changes in risk reduction (40.8%), higher yield (36%) and early fruiting & quality produce (33%, each). Apart from these, a large percentage of farmers agreed on perceived changes of less insect-pests (59.2%), less diseases (54%), reduction in labour use (44.7%) and risk reduction and higher yield (42%, each). Data also revealed that between 25% and 35% farmers were not sure for perceived visible decline in diseases, insects and early fruiting.

Table 26. Farmers' perception on effect of micro irrigation in Rajasthan

(per cent)

Particulars	Strongly agree	Agree	Cannot say
Water saving	73.7	23.7	2.6
Labour saving	51.3	44.7	3.9
High yield	36.0	42.7	21.3
Reduced risk	40.8	42.1	17.1
Quality produce	33.3	32.0	34.7
Less diseases	9.2	53.9	36.8
Less insects	15.8	59.2	25.0
Less weeds	26.3	38.2	35.5
Early fruiting	32.9	40.8	26.3
Less soil erosion	27.6	43.4	28.9
Proper land utilization	51.3	34.2	14.5
Proper water supply in field	50.0	34.2	15.8

Source: Authors' estimation Impact on Cost and Returns from Crops

The impact of sprinkler irrigation on costs and returns of major crops (both *kharif* and *rabi*) grown on sample farms is provided in Table 27. In bajra, the cost of cultivation per ha increased by 38%, from Rs. 25,594.2 to Rs. 35,257.1, while gross return increased by 40% from Rs. 30,030.8 to Rs. 41,976.6 per ha, and net returns by over 51%, from Rs. 4,436.6 to Rs. 6,719.5 per ha on an average adopted farm over non-adopted farm. Similarly, increase in cost A2 for moth was 29% and gross return about 31% resulting to over 33% increase in net return. The increase in gross returns from both bajra and moth crops were statistically significant. This implies that providing irrigation using sprinkler at critical growth stages helps in raising returns (Table 27).

In other crops too, study showed increase in cost A2, along with increase in gross and net returns by higher percentage as compared to the cost.

Table 27. Average costs and returns of major crops with adoption of sprinkler irrigation

(Rs./ha)

Particulars	Cost A2+FL	Gross value of output	Net return
Kharif crop			
Groundnut			
Adopter	60595.4	140667.3	79987.8
Non-adopter	-	-	-
Difference	-	-	-
Gwar			
Adopter	40425.3	84199.9	36820.9
Non-adopter	33255.5	64375.3	31119.8
Difference	7169.8 (21.6)	12870.9 (20.0)	5701.1 (18.3)
Bajra			
Adopter	35257.1	41976.6	6719.5
Non-adopter	25594.2	30030.8	4436.6
Difference	9662.9 (37.8)	11945.8*** (39.8)	2282.9 (51.4)
Moth			
Adopter	40017.6	62069.5	22001.8
Non-adopter	30966.2	47450.4	16484.2
Difference	9051.4 (29.2)	14619.1 (30.8)***	5517.6 (33.5)
Rabi crop			
Wheat			
Adopter	63135.0	105822.9	42687.8
Non-adopter	55745.0	90970.0	35225.0
Difference	7390.0 (13.2)	14852.9 (16.3)	7462.8 (21.2)
Rapeseed & mustard			
Adopter	53949.0	115823.9	61874.9
Non-adopter	50680.6	103805.6	53125.0
Difference	3268.4 (6.4)	12018.3 (11.6)	8749.9 (16.5)
Chickpea			
Adopter	55415.9	101429.1	46013.2
Non-adopter	43237.3	81226.7	37989.3
Difference	12178.6 (28.2)	22202.4 (24.9)	8023.9 (21.1)

Source: Field survey, 2017-18; *** significant at <1%.
Note: Figures within the parentheses show percentage difference.

Major *rabi* crops like wheat and rapeseed and mustard (R&M) became profitable using irrigation through sprinkler at critical stages of growth and development of crops. In wheat, the cost A2 increased by 13.2%, while gross and net returns increased by 16% and 21%, respectively. Similarly, for R&M, cost grew by 6%, while gross and net returns rise by 11% and 16%, respectively. However, increase in returns from wheat and R&M were statistically insignificant. Study evinced that growing of groundnut (*kharif*) with assured irrigation provided highest net return among crops. To better understand the role of irrigation with respect to increase in irrigated area, farm income and profitability, average difference in irrigated area, total cost, and net return of adopters was compared with non-adopters. Independent sample t-test was used to test the significant difference in the mean of the outcome variables (irrigated area, total cost, and net return). The results showed a significant difference among adopters and non-adopters.

Though the difference is observed among adopters and non-adopters, we cannot attribute it as a result of adoption of sprinkler irrigation. The average treatment effect of the treated (ATET), which can be attributed as the impact on the outcome variable estimated using RA method. ATET shows the difference in the mean value of the outcome variables. Use of sprinkler irrigation provided increase in area under irrigation by 53%, and net return derived from the adoption of the technology was Rs. 17421.5/ ha. The analysis shows that irrigation could help in improving income of farm households adopted sprinkler irrigation over non-adopters.

5 Conclusions and Policy Implications

The main purpose of promoting MI technology (drip and sprinkler) by the governments and other stakeholders is to increase WUE, thereby bringing more area under irrigation (*water to every field*) and increase water productivity (*per drop more crop*). With the launch of Central Sector Scheme on MI in 2005-06, there has been a substantial increase in area under micro irrigation. Presently, 11.4 Mha area is covered under MI (comprising 6.06 Mha under sprinkler and 5.35 Mha under drip) in 2018-19. Both central and state governments are promoting this capital-intensive irrigation technology by providing subsidy, creating awareness, organizing fair & camps, and demonstrating benefits. States like Andhra Pradesh, Gujarat, Haryana, Karnataka, Maharashtra, Rajasthan, and Tamil Nadu are promoting the MI technology vigorously, while other states need to take serious efforts to achieve the potential. To promote the adoption of MI, central government have provided common guidelines over years with modifications, states have fine-tuned the guideline within its basic framework as per their priority and necessity.

The analysis of farmers' response on institutional arrangements and operational guidelines to promote MI revealed that administrative and operational procedures being followed in Andhra Pradesh, Gujarat, and Maharashtra states are effective and satisfactory in terms of clarity, transparency and disbursement of subsidy. The functioning of dedicated department promoting MI in Andhra Pradesh and Gujarat has been found to be satisfactory and is the main reason for speedy progress of MIS in these states. The routine operational procedures are not very effective in other study states. Hence, the models of Andhra Pradesh and Gujarat with other needed reforms can be proliferated in other parts of country for scaling up of MI. The provision of free electricity in agriculture should be discouraged to check over exploitation of groundwater. However, assured availability of electricity for promoting MIS is critical as it is cost effective and environment friendly as compared to diesel energy. The easy availability of loan to the farmers to cover the margin money for installing MI is critical. In case loan is not possible, a lump sum grant by the department may be given for time bound and refundable manner. For successful and widespread diversification of agriculture, installation of MI systems can be made an integral part of the agricultural development programs. The subsidy provided under National Mission on Micro Irrigation (NMMI) through central government is fixed uniformly for different categories of farmers with a ceiling of five hectare. This needs to be revisited as about 15% of large and medium farmers' hold more than 55.42% of operational landholdings in India.

There has been a considerable progress in area coverage under MI in India during past one and half-decades. The area coverage increased from 2.24 Mha in 2005-06 to 11.41 Mha in 2018-19. Of the total MI area, sprinkler system accounts for 53.1% share and the remaining (46.9%) area is covered by drip system. Presently, five states namely Andhra Pradesh, Gujarat, Karnataka, Maharashtra and Rajasthan, contribute three-fourth of the total area coverage under MI in India. State-wise potential area under drip and sprinkler irrigation was estimated under two scenarios. Scenario 1 included gross irrigated area under various crops by groundwater (tubewell +other well), tank and 30% of canal irrigated area. Scenario 2 adds 50% of canal area to estimate arrived under scenario 1. The potential area which can be brought under MI is estimated as 72.17 Mha and 77.58 Mha in scenarios 1 and 2, respectively. Under scenario 1, Uttar Pradesh has emerged as the state possessing largest potential area (25%), followed by Rajasthan (12%) and Madhya Pradesh (10%) which can be irrigated with micro irrigation. Though, Uttar Pradesh has the highest potential under MI (17.65 Mha), the state has created less than 1% of the potential so far. Similarly, in high potential state of Punjab, where groundwater is overexploited, the level of realization is very less (0.78%). Thus, sincere efforts are needed to promote MI technology in such high potential but under-exploited states. Overall, only 14.71% to 15.81% of the total micro irrigation potential in the country is actually realized by the year 2018. The extent of realization was relatively higher for drip irrigation as compared to sprinkler irrigation.

For accurate targeting of the beneficiaries and to check leakages of government subsidy, the DBT scheme was launched by the Government of India from January 2013. A case study on DBT linked distribution of subsidy for agro-inputs revealed equitable participation of farmers in registration process in Uttar Pradesh. Results show that factors like farming experience, education, possession of smart phone, banking facility, and ownership of diesel engine positively and significantly influence registration under DBT. Farmers using sprinkler irrigation in wheat crop, saved water by 15% and improved yield by 21% as compared to their counterparts using flood irrigation. Farmers using sprinkler also performed better on technical efficiency and water productivity.

The evidences show reduction in input cost and increase in productivity and income from adoption of micro irrigation in selected study states. The adopter farmers have saved cost on the seed and planting material to the extent of 2.25% to 89.40% as compared to non-adopters. The savings in cost on farm yard manure (FYM) varied from 3.17% to 57.94% in different crops whereas saving in cost from fertilizers on adopted farms ranged from 12.89% to 68.76%. It is from the fact that adopter farmers applied liquid fertilizers and this way less fertilizer required when it applied through MIS. Similarly, savings in cost on chemicals and pesticides use varied from -0.92% to 90.29% across different crops in different states. The savings in water ranged between 12.60% and 88.62% across crops grown by sample adopter households. There was a saving in labour use and machine hours used by adopters and it varied from 5.14% to 48.65% across crops selected for analysis. The total cost saved for crops in the study states varies from -1.33% to 35.15% and net return was higher on adopted farms to the extent of 12.28% to 54.10%. Thus, it is clear that adoption of micro irrigation technology helps in lowering input use thereby reduction in cost, which helped in improving income of farm households in the selected states. Based on these evidences, it can be concluded that adoption of MIS not only help in reducing the water demand but also saves both inputs quantity and cost used in agriculture production. Hence, the promotion of MI technology should be taken on priority basis to achieve higher production with less cost of cultivation. Application of sprinkler system by farmers in Rajasthan revealed increase in area under cultivation across crops and seasons including returns as compared to non-adopters. Results show that increase in cropped area varied from 5.6% in wheat to 111.5% in gram, while increase in yield varied from 23% in gwar to 45% in bajra during Kharif season, and in *Rabi* crops, increase in yield was highest for gram (97.3%), followed by wheat (19.4%).

Adoption of MI provides better employment and income generation opportunities to rural youths by attracting them towards agriculture and improving their skills through capacity building program. Study observed that because of delay in sanction and installation of MI system, fellow farmers approach to unauthorized firms for getting the micro irrigation system installed on their farms without intimating the nodal department. When the system fails due to sub-standard components, the farmers blame the department officials. To avoid such difficulty to farmers, a blanket ban on the unapproved firms should be enforced. The components like water storage tanks, electric motors and pump sets should be part of MI system for effective implementation of this scheme on larger scale. The evidences from Rajasthan revealed that sprinkler irrigation is financially viable and has potential to increase irrigated area with same amount of available water. The constraints in implementation and operational process of MI scheme need to be narrowed down. The post-installation maintenance of MI system after and training to the farmers should be ensured so that the system works regularly without interruption. The firms supplying the system must be made responsible for the maintenance and supply of spares at least for five years. Keeping above provisions in place will be able to ensure spread and adoption of MI systems in achieving the sustainable development goals. States like Punjab, where micro irrigation coverage is very poor, should be placed from "A" category to "B" or "C" category in the guidelines of MIS, it will help in allocation of sufficient financial resources. The land ceiling of five hectare should be revisited for extending the subsidy benefits. Further, in Punjab assured availability of water resources is a necessary requirement for the farmers for being eligible for the getting benefits under MIS. Such conditions may be relaxed and farmers with shared water resources may also be made eligible for such benefits. The farmers should make liquid chemicals and fertilizer available at local level in areas where MI has penetrated satisfactorily to encourage their use. Make finance accessibility in terms of easy credit for the farmers adopting micro irrigation. Capacity building program should be an integral part of MIS. The awareness and mass contact programs should be a continuous process, so that more farmers can be brought in ambit of MI. Some R&D system may be developed at the central or the state research organization to make recommendations about drip or sprinkler irrigation system. Region specific demonstration farms may be supported and organized for successful adoption of MI systems.

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