Improving Water Use Efficiency in India's Agriculture - The Performance and Impact of Micro Irrigation:

A Study of the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) - Per Drop More Crop (PDMC)

Vasant P. Gandhi
Nicky Johnson
Gurpreet Singh

विद्याविनियोगाद्विकासः
IIM AHMEDABAD

Centre for Management in Agriculture (CMA)
Indian Institute of Management, Ahmedabad (IIMA)

Supported by
Ministry of Agriculture and Farmers Welfare, Government of India

March 2021

Improving Water Use Efficiency in India's Agriculture - The Performance and Impact of Micro Irrigation:

A Study of the
Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)
- Per Drop More Crop (PDMC)

Vasant P. Gandhi

Nicky Johnson

Gurpreet Singh

Final Report

Centre for Management in Agriculture (CMA)
Indian Institute of Management Ahmedabad (IIMA)

Supported by Ministry of Agriculture and Farmers Welfare
Government of India

Preface

India's agriculture is facing acute water scarcity and a major reason for this is very low water use efficiency – only about 25 to 35 percent in conventional irrigation. It is of tremendous importance to improve the efficiency and in this context, the modern technology of micro irrigation (MI) which includes drip and sprinkler irrigation offers a very significant advantage. The Government of India has been promoting and supporting the adoption of micro irrigation by the farmers through various schemes over the years, including since 2015/16 particularly, the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) - Per Drop More Crop (PDMC) scheme, being implemented by the Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India. About Rs 7800 crores have been spent under the scheme towards this during 2015/16 to 2019/20.

The study has sought to examine the performance and impact of micro irrigation in terms of changes in the use of various inputs including water, power, fertilizers, pesticides and labour. It has sought to examine the enhancement of productivity, quality and other benefits in selected crops including water-intensive crops such as sugarcane and banana, and the impact on employment. It has sought to understand the adoption behavior including issues of subsidy & its distribution, water conservation, landholding, fragmentation, capital & maintenance cost, and state differences. It has sought to examine the overall impact on farmer incomes and the cost-benefit, as well identify issues/problems in the scheme benefit transfer and monitoring. The study was coordinated by the Centre for Management in Agriculture (CMA), Indian Institute of Management Ahmedabad (IIMA) and implemented through different Agro-Economic Research Centres (AERCs) covering a wide sample across the states including Maharashtra, Madhya Pradesh, Telangana, Uttar Pradesh, and Sikkim. The Centre for Management in Agriculture (CMA), Indian Institute of Management Ahmedabad (IIMA) is actively engaged in research and education on important current topics and challenges in the management of the food, agriculture, agribusiness and rural sectors of the Indian economy and the world.

The authors wish to convey their thanks to many including:

- AERC Allahabad/Prayagraj, for Uttar Pradesh: Prof. GC Tripathi, Prof SA Ansari, Mr. Hasib Ahmad, Dr. H.C. Malviya

- AERC Jabalpur, for Madhya Pradesh Dr. Hari Om Sharma, Dr. Deepak Rathi
- AERC Pune, for Maharashtra: Prof. Sangeeta Shroff, Dr. Varun Miglani, Mr. Prashant Warankar
- AERC Visakhapatnam AP, for Telangana: Dr. K. Rambabu, Dr. P. Ramu, Dr. M. Nageswara Rao, Dr. KV Giri Babu
- AERC Visva-Bharati WB, for Sikkim: Prof. BC Roy, Dr. Debajit Roy, Mr. Debanshu Majumder, Dr. R. K. Biswas
- Ministry of Agriculture & Farmers Welfare (MoA&FW), Natural Resource Management/ Rainfed Farming Systems (NRM/RFS) Division, Mr. Pankaj Tyagi, Mr Atish Chandra, Mr BVN Rao, Directorate of Economics & Statistics, Mr. PC Bodh.
- Centre for Management in Agriculture (CMA), Indian Institute of Management Ahmedabad (IIMA), Prof. Poornima Varma, Prof. Sukhpal Singh, CMA faculty, CMA staff, DTP-Paresh A.

We hope the study will be found useful by policymakers, administrators, service providers, researchers, and those seeking to bring innovation and change for enhancing the performance of the agriculture sector, the rural economy and the welfare of farmers.

Vasant P. Gandhi
Nicky Johnson
Gurpreet Singh
Centre for Management in Agriculture
Indian Institute of Management Ahmedabad

Table of Contents

List of Abbreviations

AERC	Agro-economic Research Centre
AIBP	Accelerated Irrigation Benefit Program
CAGR	Compounded Annual Growth Rate
CIIE	Centre for Innovation Incubation & Entrepreneurship
CMA	Centre for Management in Agriculture
CWC	Central Water Commission
DAC&FW	Department of Agriculture Cooperation & Farmers Welfare
DIA	District Agriculture Plans
DIP	District Irrigation Plan
FAO	Food and Agriculture Organisation
FYM	Farm Yard Manure
GIS	Geographic Information System
GoI	Government of India
ICID	International Commission on Irrigation & Drainage
IIMA	Indian Institute of Management-Ahmedabad
ISOPOM	Integrated Scheme of Oilseeds, Pulses, Oil-palm and Maize
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Scheme
MI	Micro Irrigation
MP	Madhya Pradesh
NMMI	National Mission on Micro Irrigation
NMSA	National Mission on Sustainable Agriculture
OFWM	On-Farm Water Management
PDMC	Per Drop More Crop
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
UP	Uttar Pradesh

List of Tables

List of Figures

Executive Summary

Introduction, Background and Study Objectives

The Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) with the very important component of Per Drop More Crop (PDMC) – Micro Irrigation, is being implemented by the Ministry of Agriculture & Farmers Welfare - Department of Agriculture, Cooperation and Farmers Welfare, Government of India, since 2015-16. India is increasingly facing acute water scarcity and the PDMC component focuses on improving water use efficiency at the farm level through promotion and support of Precision or Micro Irrigation (MI) which includes Drip and Sprinkler Irrigation. The main premise of the PDMC component is that the water use efficiency in India's agriculture is very low compared to global standards, and is reported to be as low as 25-35 percent, Vaidyanathan and Sivasubramaniyan (2004) – which indicates that 65 to 75 percent of the water is being wasted. This is substantially due to the widespread practice of conventional flood irrigation technique all over India.

MI techniques can bring numerous benefits including not only enhanced water use efficiency, but also increase in irrigated area with the given quantity of water, enhanced crop productivity/ yields, labour cost savings, electricity and energy savings through lesser pumping hours. Under the government schemes described above, most of the states are giving subsidies of often over 70 percent for the installation of MI system, and the states often compete with each other to increase the subsidy component. There is a great need to better understand MI implementation, including the adoption of MI across crops, farmers and regions, the costs and benefits, and the impact of the technology on farmers, resources and agriculture, which would be very important for improving the implementation and benefits from the schemes.

The crisis of water in India is widely talked about and needs little elaboration. India is a water-stressed country with an estimated availability of 1434m^3 per person per year. Groundwater withdrawal is increasing very rapidly in India, more rapidly than in USA and China, and is about 780 billion cubic meters annually (FAO, 2018). 54 percent of observed groundwater wells in India are reported to be overexploited and many states show even more exploitation, such

as Karnataka (80%), Maharashtra (75%), Uttar Pradesh (73%). About 60 percent of the India's districts fall in water-scarce category or suffering from poor water quality (CWC, 2019) (Niti Ayog, 2019).

The promotion of MI is extremely important in reducing the water footprint, and increase water use efficiency at the farm level, and this has led to the government schemes such as Per Drop More Crop (PDMC) under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). The mandate of PMKSY is to expand the irrigated area (Har Khet Ko Pani), and also increase water use efficiency (Per Drop More Crop) through promotion of water-saving technologies such as MI. Low-cost MI is often through innovation by the farmers and small farmer-focused R&D. It includes Pepsee (with light plastic pipes) drip, drum and bucket kits, micro-sprinklers, microtube. The commercialized MI is capital intensive and includes drip and sprinkler irrigation equipment commercially available through companies such as Jain Irrigation, Netafim, and others. The capital investment in the latter can be around Rs. 1.3 lakhs per hectare of installation varying land resource and type of crops (GoI, Guideline, 2018).

PMKSY (Per Drop More Crop-PDMC) focuses on micro level storage structures, efficient water conveyance & application, precision irrigation systems, topping up of input cost beyond MGNREGA permissible limits, secondary storage, water lifting devices, extension activities, coordination & management - being implemented by Department of Agriculture Cooperation & Farmers Welfare (DAC&FW). The main objectives of Per Drop More Crop (Micro Irrigation) are as follows:

- Increase the area under micro irrigation technologies to enhance water use efficiency in the country.
- Increase productivity of crops and income of farmers through precision water management.
- Promote micro irrigation technologies in water intensive/consuming crops like sugarcane, banana, cotton etc and give adequate focus to extend coverage of field crops under micro irrigation technologies.
- Make potential use of micro irrigation systems for promoting fertigation.
- Promote micro irrigation technologies in water-scarce, water-stressed and critical groundwater blocks/districts
- Link tube-well / river-lift irrigation projects with micro irrigation technologies for best use of energy both for lifting and pressurised irrigation as far as possible.

- Establish convergence and synergy with activities of on-going programmes and schemes, particularly with created water source for its potential use, integration of solar energy for pressurised irrigation etc.
- Promote, develop and disseminate micro irrigation technology for agriculture and horticulture development with modern scientific knowledge.
- Create employment opportunities for skilled and unskilled persons, especially unemployed youth for installation and maintenance of micro irrigation systems.

The main objective of the study are to analyse the various benefits of MI to the farmers including in input use, costs and returns. Specifically, the objectives were to examine the following:

(a) To examine the savings of various inputs such as water, fertilizers, power, pesticides and labour

(b) To examine the enhancement of productivity, quality and other benefits in selected agriculture/ horticulture crops including water-intensive crops such as sugarcane and banana, and if there is employment generation due to MI.

(c) To examine the adoption of MI including some of its determinants/ features such as need/ importance of subsidy, culture of water conservation, issues of fragmented land holdings, capital cost, maintenance cost and the distribution of subsidy across states.

(d) To study overall impact on farmer incomes and the cost-benefit in selected crops.

(e) To identify any issues/problems in the benefit transfer work flow and monitoring by the implementing agency.

The project is implemented as a coordinated study covering 5 selected states and involving respectively 5 Agro-Economic Research Centres (AERCs) under the Ministry of Agriculture & Farmers Welfare. It is coordinated by CMA, IIM Ahmedabad which is an Agro-Economic Research Unit under MoAFW. The states & locations are sampled for representation and diversity based on different criteria including extent of micro irrigation implementation/ adoption, diversity in region & agro-climate stress, diversity in cropping and willingness/ cooperation of the necessary AERCs. The state sample covering both high & low adoption states includes Maharashtra, Telangana, Uttar Pradesh, Madhya Pradesh, and Sikkim. The AERC's in Pune, Visakhapatnam, Allahabad, Jabalpur and Shantiniketan are involved for implementation of the study in the respective states under the research design and guidance of CMA-IIMA.

Micro Irrigation Development in India under the PMKSY-PDMC

Data from 2017-18 shows that Andhra Pradesh, Maharashtra and Karnataka received the highest amount of funds. Overall Rs. 3400 crores were spent at the national level for various interventions and Rs. 2500 crores on micro irrigation.The highest numbers of beneficiaries are in Andhra Pradesh, Gujarat and Telangana. The total numbers of beneficiaries are about 3.4 lakhs. Data shows that Karnataka, Andhra Pradesh and Gujarat show the highest area covered under MI. In last five years from 2015-2020, Karnataka shows highest percentage area of the total area brought under micro irrigation, followed by Gujarat and Andhra Pradesh. There is substantial variation across districts. Data shows that a total of 47 lakhs hectare has been brought under micro irrigation between 2015-2020 with an expenditure of Rs. 781,736 lakhs. The states of Karnataka, Andhra Pradesh, Gujarat, Tamil Nadu and Maharashtra have contributed highest to the physical achievement under PDMC scheme. Coverage is poor in eastern states and also in states such as Punjab, Haryana, and Uttar Pradesh. The coverage of micro irrigation is skewed towards a few western states while some important states with high water scarcity, are not well covered. Better implementation is required in eastern states and water-scarce states under the programme. The financial coverage is also skewed towards a few western states which were already doing well before the programme launch. Better focus is required on eastern and water-scarce states. In the sample states, the major crops covered under MI are vegetables, cotton, pulses, tomato, and sugarcane. Vegetables have the highest coverage in Madhya Pradesh, Telangana and Uttar Pradesh and Cotton has a high coverage in Maharashtra. The coverage in water-intensive crops such as sugarcane and banana is the highest in Maharashtra while area brought under micro irrigation in sugarcane in Uttar Pradesh very small.

Internationally, many countries recognized the merit of micro irrigation in since the 1980s, and many countries with poor water availability have developed micro irrigation to manage within the limited water. A well-known such country is Israel which is very poorly endowed in water. There, within the irrigated area, they have almost 100 percent adoption of micro irrigation. Relative to this, share under MI for India is low at 13.5 percent. In India Sikkim, Andhra Pradesh and Maharashtra are at the top, while UP, MP have among the least share under MI in India. Not all the area under irrigated area may have potential to be brought under MI in India, since all land and crops may not suited for MI.

Study Survey: Sampling and Sample Profile

To carry-out an in-depth examination of micro irrigation under the different objectives of the study, a substantial amount of primary data was collected through a sample survey of farmers. Five states across the country were selected

for the study, namely Uttar Pradesh, Madhya Pradesh, Maharashtra, Telangana and Sikkim. It was planned to sample and cover 120 farmers in each state including the 96 adopters and 24 non-adopters of micro irrigation. Thus, across five states 600 farmers were planned to be covered. A special questionnaire was developed to collect all the relevant information.

The actual/ final sample survey covered 500 MI adopters and 121 non-adopters, a total of 621 farmers across 95 villages, 10 districts and 5 states. The findings show that most of the farmer respondents are of 30 to 50 years in age, with very few younger farmers and many over 50 years age. Almost 50 percent of the adopters have at least a 10th standard education or more. However, a large percentage have less education, and 17 percent are illiterate. The findings on the source of water available for irrigation / micro irrigation show that the major source of water is tubewell followed by wells. Thus, groundwater is the major source of water for micro irrigation as indicated by almost 70 % of the farmers. Whereas 62 percent report sufficient water, 36 percent report scarcity though very few have acute scarcity. Most of the farmers have medium to heavy soil and not light soil, and most of the farms have a flat terrain.

Most of the farmers have started using micro irrigation in the recent years. 33% of the farmers have started using micro irrigation only in the last year whereas 16% have started using two years ago, and 25% have started using three years ago. Almost all the farmers who have adopted micro irrigation have availed of subsidy, that is 98% of the farmers. The adopters are spread across farm sizes, with 28 percent marginal farmers, 27 percent small, 41 percent medium and 4 percent large, with an overall average landholding is 2.74 hectares. Those with smaller land holding sizes have a larger percentage of land under micro irrigation. Within micro irrigation, about 60 percent is drip and 40 percent is sprinkler, except marginal farmers show somewhat more land under sprinkler than drip.

Cropping Pattern and its Change with Micro Irrigation

Among the most frequently reported crops grown under MI are wheat and cotton, but there is substantial variation across states. Wheat is mainly reported in UP and MP and sugarcane is reported in UP and Maharashtra. Chickpea is reported under micro irrigation in MP and Telangana and Cotton is reported under micro irrigation in MP, Maharashtra and Telangana. Chilli is reported under MI in UP and MP, and Soybean as reported in Telangana. Thus there is a large amount of diversity across states in the crops that are brought under micro irrigation. Whereas some crops such as wheat and soybean are irrigated through sprinkler irrigation others such as sugarcane, cotton and banana are irrigated through drip. In Sikkim the only crops micro irrigated are vegetable crops of cauliflower and broccoli.

Wheat is largely grown under sprinkler irrigation whereas sugarcane is largely under drip irrigation. Chickpea and cauliflower are under sprinkler irrigation whereas cotton is grown under drip irrigation. Similarly, banana and chilli are grown under drip irrigation where as peas and groundnut are largely grown under sprinkler irrigation. The horticulture crops of cauliflower broccoli and cabbage are grown through sprinkler irrigation whereas orange is grown under drip irrigation. Thus, the kind of micro irrigation varies substantially by crop. Fertigation through MI is very common in sugarcane, cotton, banana, chilli, ginger and a few vegetable crops, but not in others.

On the whole for most crops there is no impact on area due to micro irrigation but for some crops such as soybean, broccoli, chilli, ginger and banana a positive impact is indicated by a large number of respondents. By across crop average, 64 percent indicate no impact on area, and 34 percent indicate an increase in area, with about 2 percent showing a decrease in area perhaps due to shift to other crops. The positive impact on yield is widely indicated and confirmed across most of the crops. It is widely indicated in wheat, chickpea, soybean, cotton, sugarcane, chilli, banana and ginger. On an average across crops, 20 percent indicate no change in yields, whereas 55 percent indicate increase in yields, and 24 percent indicate large increase in yields.

Changes in Incomes, Inputs and Farm Economics with Micro Irrigation

Changes in the crop economics due to micro irrigation, including production, prices, revenue/ gross income, various inputs and costs, and the net profits, were examined by comparing the with MI vs without MI numbers reported by the farmers based on recall. Findings indicate that there is 6% increase in the sugar cane area as well as wheat area, but a substantial increase in the banana area of 87%. Overall the crop area increases by 30%. In production, there is a 35 to 40% increase in the production of sugarcane and wheat, and there is a substantial 216% increase reported in the production of bananas. Overall there is a production increase of 88% over all crops. The market price also shows some increase and this is 12% for sugarcane, 40% for banana and 5% for wheat with overall a 16% increase in the prices. The result of this is a large increase in the sales revenue of 56% for sugarcane, 387% for banana, and 43% for wheat, and overall for all crops the sales revenue increases by 161%. Thus, there is a substantial impact of micro irrigation on the sales revenue reported, coming from area, production and price increases.

With the shift to micro irrigation there is also an increase in the cost of inputs of seed, fertilizer, farm yard manure (FYM) and pesticides. The input costs increase

in the range of 9 to 19% in case of sugarcane, but the increase substantially in the range of 134 to 253% in the case of banana. In the case of wheat whereas the seed, fertilizer and FYM costs increased by 15 to 22% the pesticide cost reduces by 34%. Overall there is 122% increase in seed cost, 78 percent increase in fertilizer cost, 79% increase in FYM cost, and 72% increase in pesticide costs. The findings indicate that with micro irrigation, because of the improved and assured good cropping conditions, the farmers tend use more and better inputs resulting in higher input costs.

The reverse is the case for irrigation costs and the results indicate that overall the electricity cost reduces by 6%, the water charges reduce by 13%, and the hours of pumping reduce by 33%. There is some increase in the diesel cost, and the number of irrigations – perhaps because these are easily possible in micro irrigation. The largest reduction is seen in the case of sugarcane where the water charges reduce by 69% and the hours of pumping reduces by 53%.

Other costs and profits also change. Overall it indicates that there is a 53% increase in farm power and equipment cost followed by increase in labour mandays and labour cost. The marketing and other costs also increase leading overall to 93% increase in the total cost. However, because of the substantial increase in revenue, the profits show an increase by 359%. The profit increase is 153% in the case of sugarcane, 105% in the case of wheat, and substantial 3095% in the case of banana. It may be noted that because of historical costs without MI and a longer history of adoption in banana, the reported increase may be high in the case of banana.

Whereas the area of chickpeas and cauliflower increases by 21 and 30%, the area under cotton falls by 11% - this may be because of a shift to other crops. In the case of production there is a substantial increase of 36 to 95% in all these crops, with an overall increase of 88%. There is also a price increase ranging from 14 to 25%. The overall result is a revenue increase ranging from 55% to 145% across these crops. As indicated above, overall there is 166% increase in the revenue of all crops.

On the cost of inputs for chickpea, cauliflower and cotton, whereas the seed cost increases in every case in the range of 19 to 74%, the fertilizer cost increases in chickpea but falls in the case of cotton. The FYM cost reduces by 26% in the case of chickpea, but increases for cauliflower and cotton. The pesticide cost increases substantially by 129% in the case of chickpea, but falls by 4% in the case of cotton. This is very significant since cotton uses large quantities of pesticide. Overall as indicated above there is 122% increase in the seed cost, 78% increase in fertilizer cost, 79% increase in FYM cost and 72% increase in pesticide cost.

On irrigation cost, no changes is indicated in the case of cauliflower but changes are reported for chickpea and cotton. In the case of chickpea, the electricity cost and the diesel cost reduce, but the number of irrigations and the hours of pumping increase. In the case of cotton there is a reduction in the electricity cost, increase in the number of irrigation, but a substantial reduction of 52% in the hours of pumping.

On other costs and in profits for chickpea, cotton, and cauliflower, the results show that there is increase in the farm power cost in every crop ranging from 22 to 60%. The number of man days and labour cost also increases considerably ranging from 44% to 168%. The marketing cost reduces in case of chickpea but increases in the case of cauliflower. The total cost increase by 102% in case of chickpea, 50% in case of cauliflower, and 29% in case of cotton. However, the net profits increase in every case - by 182% in case of Chickpea, 230% in case of cotton, and 67% in case of cauliflower.

In the case of soybean, chilli and broccoli, there is an increase in area in every crop ranging from 30% to 71% - substantially higher than the overall. The production increases in case of Soybean this is very substantial at 166%, but also substantially in the case of broccoli by 46%, and in Chilli by 56%. The prices also increase due to quality by 25% in case of soybean, 14% in Chilli and 8% in broccoli. Overall there is considerable increase in the sales revenue, soya bean at 232%, followed by Chilli at 86%, and broccoli by 56%.

On input costs in broccoli, chilli and soybean, the results show that the seed cost increases in every case ranging from 69% to 105%, the fertiliser cost also increases in the case of soybean by 148%, and in the case of chilli by 48 percent. The farmyard manure cost also shows increase substantially in the case of soybean by 276%, and 66 to 75% in the other crops. The pesticide cost also shows considerable increase at 184 percent in the case of soybean and 65% in the case of chilly. The increases are higher than overall averages.

On irrigation cost with the adoption of micro irrigation, the electricity cost in the case of chilly reduces by 12%, and in soybean by 2%. The diesel cost reduces by 30% in the chilli but increases by 121% in case of soybean. No changes are reported in the case of water charges. The number of irrigations increase considerably in the case of chilly by 182% and in soybean by 17%. However, there is a considerable reduction in the hours of pumping, which reduces by 35% in the case of chilli, and 33% in the case of soya bean.

On other costs and profits, farm power and equipment costs show a fall overall, but shows increases, by 46% in broccoli, 144% in Chilli, and 98% in the case of Soybean. The mandays and labour costs show considerable increases particularly

in soybean at 206%, and 77% in case of chilli for labour cost. The total cost shows increases ranging from 168% for soybean to 53% in the case of broccoli. However, the net profit increases in every case ranging from 333% in soybean, 86% in Chilli and 63% in broccoli. Thus, micro irrigation has a substantial positive impact on the net profits across the crops. The figures for all the crops indicate an increase of 359% in the net profit.

Findings on the reduction in water use in terms of pumping hours observed in the different states indicate substantial reduction by 55 percent in Saharanpur district UP, 51 percent in Pune district Maharashtra, and 66 percent in Nalgonda district Telangana. Reduction in water use with micro irrigation crop-wise indicates that there is 51 percent reduction in wheat, 52 percent reduction in sugarcane and 52 percent in cotton. Thus, there is evidence of substantial reduction in water use due to micro irrigation.

Capital and Maintenance Cost of Micro Irrigation

Micro irrigation is a capital intensive proposition. Most users invest in micro irrigation through drip irrigation or sprinkler irrigation kits, and the average reported expenditure on drip irrigation kits comes to Rs 181820 of which Rs 65889 is paid and Rs 117374 is received as subsidy which amounts to 65% subsidy on an average. The average expenditure for sprinkler irrigation kits comes to Rs 47166 of which Rs 14511 is paid and Rs 33714 is received as subsidy, which amounts to a subsidy of 71%. Some users report other expenditures such as on filters, pipes, and pumps. Overall average total capital expenditure (including both drip and sprinkler) comes to Rs 176967 of which Rs 89792 is paid and Rs 81843 is received as subsidy, which amounts to a subsidy amount of 46%. Very few farmers report taking loans - 12 percent for drip irrigation kits, and 10 percent for pumps. Given that the average net profit increase per farmer with MI over without MI (assuming only one crop per year) is Rs 148852, and the reported average total investment in MI as Rs. 176967, the rate of return works out to 84 percent on total investment cost (payback in 1 year 2.3 months), and to 166 percent on investment cost to the farmer (after deducting subsidy) (payback in 7.2 months). This shows that the return to micro irrigation is extremely high, and the investment in micro irrigation is highly profitable both on a total cost basis as well as a cost to farmer basis.

The annual replacement/ maintenance costs of micro irrigation is reported to be Rs 2877 on an average, which amounts to only 1.6% of the initial capital cost.
In capital investment, Jain irrigation is reported by 21% and other companies are reported by 57% apart from Netafim and Shakti. On maintenance products, Jain irrigation reported by 43% followed by Netafim by 29% and Kastha by 10%.

The results indicate the presence of a large number of companies though Jain Irrigation is the most common.

Factors and Determinants Affecting Micro Irrigation Adoption

Adoption behavior is complex and a large number of different factors may play a role in the adoption of agricultural inputs and technology by the farmers. A framework conceptualized and reported in Gandhi (2014), Gandhi and Patel (2000) and Desai and Gandhi (1992), is used. It indicates that the adoption of technologies is determined by five groups of determinants or factors which includes the agronomic potential, the agro-economic potential, effective demand, aggregate supply and distribution. In agronomic potential, 94% of the respondents strongly agree/ agree that micro irrigation increases yield and output, and 98% agree that it saves water and reduces water use. These two major agronomic benefits appear to the major drivers for the adoption of micro irrigation. Besides, 57% report reduced fertilizer use, 43% report reduced pesticide use, 64% reduced weed problem, and 74% reduced labour use in some operations as drivers. The strongest agro-economic determinants are the subsidy that is available for micro irrigation reported by 92%, increase in profitability reported by 89%, and increase in output quality and price reported by 85%. The high capital cost of micro irrigation is an important negative factor indicated by about 50% of the respondents.

On conversion of potential into effective demand, 85% of the respondents indicate that information on micro irrigation is easily available, and 89% report that micro irrigation technology is easy to understand and operate. Therefore, these issues do not seem to come in the way of the adoption of micro irrigation. To an extent, ease of getting subsidy and the ease of getting finance are indicated as important factors/ barriers by a large number of respondents. Some also indicate that the availability and reliability of electricity supply as a problem and some report difficulty in getting sufficient water supply. On the factor of aggregate supply (of equipment), the reliability and quality of micro irrigation equipment available is found suitable/ not a problem by about 80% of the respondents, but with access and the number of companies supplying micro irrigation equipment, about 40 percent have some difficulty. On the issue of distribution, regarding number of micro irrigation dealers nearby, 52% do not have a problem but the remaining have some difficulty. 81% are happy with the kind of equipment supplied by the dealers, and 62% think that the prices are reasonable. On whether dealers arrange for subsidy/ credit, 64% indicate no problem but the rest find some difficulty. With respect to dealers providing after sales service, 47% have no problem, but the remaining have some difficulty. Thus, after sales service, the number of micro irrigation dealers and the arranging of subsidy/ credit by

dealers are some important factors which may be inhibiting the adoption of micro irrigation.

Advantages, Impact and Problems of Micro Irrigation

The biggest advantage seen by the farmer farmers is less water needed indicated by 93% of the farmers. This is followed by higher yield as indicated by 91% of the farmers, higher profits by 88%, and better quality of output by 87%. Micro irrigation also appears to reduce risk and uncertainty, indicated by 67% of the farmers, and lower labour need (in some operations) as indicated by 75%. Thus overall the major advantages of micro irrigation appear to be less water needed, higher yields, higher profits, and better quality. It also reduces risk and labor need.

On the impact of micro irrigation on different aspects and groups, the strongest impact is expressed in terms of water conservation indicated by 91% of the farmers, positive impact on the village as a whole indicated by 89%, and benefits to the environment indicated by 74%. The benefits to low land farmers maybe greater than to upland farmers. The opinion is divided between positive impact and no impact on women, upper caste, lower caste, labour/ poor and youth/ young farmers. Hardy any report negative impacts.

On the problems faced by farmers in the adoption and use of micro irrigation, no major problems are related to the technology. The most common problem indicated is damage by animals indicated by 57%, followed by lack of fencing indicated by 52%. The other problems indicated include water table going down fast by 45%, high cost of tube wells/ wells by 43%, and poor after sales service by 42%. Lack of government support, and difficulty in getting government support is not seen as a problem by a majority of the respondents. Lack of credit, land fragmentation, and poor marketing arrangements are seen as a problem by some but not by others. Thus, the major problems are damage by animals, lack of fencing, water table going down fast, and high cost of tube wells.

Overall Assessment of the Performance of Micro Irrigation

The overall performance of micro irrigation is seen as excellent to good by 90% of the farmers, and performance on improving water use efficiency is also excellent to good by 90% of farmers. The performance on reducing input cost is seen as excellent to good by 64%, on increasing incomes and profits as excellent to good by 77% of farmers. Thus, the responses indicate a high level of satisfaction with respect to the performance of micro irrigation, especially overall and in improving water use efficiency. On continuing with micro irrigation, 97% of the farmers indicate that they would continue with micro irrigation, and 86% indicate that they would like to expand the use of micro irrigation. These responses also

indicate a high level of satisfaction and willingness to continue and expand its use.

On the suggestions for increasing the adoption and improving the impact of micro irrigation, the common responses were more subsidy/ government assistance indicated by 90% of the farmers, followed by easier process for getting subsidy/ government assistance indicated by 89% of the farmers. 85% of the farmers also wish for lower price of micro irrigation equipment, and 82% for better micro irrigation technology and equipment. A few express the need for better marketing arrangements, improved water availability, and more loans and credit.

Non-Adoption of Micro Irrigation : Reasons & Profile

The sample of 121 non-adopters are from across five states, 10 districts, and 53 villages. All of them are found to have access to irrigation. There is hardly any difference in the age profile between adopters and non-adopters. However, the non-adopters have a somewhat higher percentage of illiterates, and a slightly lower percentage of those having education of 12 standard and above. The landholding profile indicates that the non-adopters frequently have smaller land holdings sizes compare to the adopters. The percentage of marginal farmers in the non-adopters is greater, and the percentage of medium and large farmers is smaller. Small farm size may be an issue in adoption. On water sources, it is found that a larger percentage of the adopters have tube wells and wells as compared to the non-adopters and some non-adopters do not have their own sources of water and buy water from others. Thus, water sources maybe an important issue with the non-adopters. On the water situation, fewer non-adopters report having sufficient water and a greater percentage indicate scarcity of water.

On cropping profile, a much larger percentage of non-adopters grow staple and field crops such as wheat, paddy, chickpea, soybean and cotton as compared to the adopters, and many non-adopters report growing paddy whereas no adopters report growing paddy. Adopters seem to stop growing paddy and shift to other crops, and large percentage grow commercial and horticultural crops such as sugarcane, orange, and vegetables crops such as cabbage, cauliflower, and beans. This indicates a large shift towards growing commercial crops rather than subsistence or field crops with MI adoption.

On the reasons for non-adoption of micro irrigation, the responses indicate no overwhelming reason but a variety of different reasons. The major reasons indicated are micro irrigation equipment is not available by 52%, high investment cost of micro irrigation 49 percent, and subsidy for micro irrigation not sufficient 41 percent. Some also indicate the higher operating cost of micro irrigation, and crop damage by animals. Some aspects that do not constitute reasons for non-

adoption (70-80 percent disagree), are micro irrigation is not profitable, no market for micro irrigation crops, micro irrigation not suitable to the crops grown, and micro irrigation not suitable for their land. Preference for traditional irrigation, inadequacy in water availability, and fragmentation of land holdings are also not indicated as major reasons. Thus, it appears that the higher investment cost of micro irrigation, micro irrigation equipment not available, and subsidy is not sufficient are the important reasons for the non-adoption of micro irrigation.

Conclusions and Recommendations

Conclusions

Micro irrigation which includes drip and sprinkler irrigation are being given substantial importance in India in the recent years to address the objective of improving the water use efficiency given increasing water scarcity, and for enhancing agricultural production and farmer incomes. Micro irrigation is being actively promoted by the government under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) - Per Drop More Crop (PDMC) scheme since 2015–16. The study has examined the performance of the scheme and its impact from the point of view of the agricultural economy, the farmers, and the government.

The study sampled 621 farmers across the five states, and these included 500 micro irrigation adopters and 121 micro irrigation non-adopters. The study covered 95 villages across 10 districts in the five states of Uttar Pradesh, Madhya Pradesh, Maharashtra, Telangana and Sikkim. Most of the adopters are of 30 to 50 years age and most of them have education of 10th and above, but 17% of the adopters are illiterate. The main source of water for micro irrigation is groundwater through tube wells and wells. Most of the adopters report having sufficient water but about 35% report scarcity. About 75% of the adopters have started using micro irrigation only in the last three years, with 35% only since last year. Almost all adopters have availed of the subsidy for micro irrigation under the scheme. In terms of land area the majority are small and marginal farmers though many are medium farmers. Thus, marginal and small farmers are not excluded. The average landholding is 2.74 ha. The adopters devote about 70% of the land to micro irrigation with the rest being in non-micro irrigation and about 6% without Irrigation.

The most commonly reported crops under micro irrigation for the adopter farmers are wheat, sugarcane, chickpea, cauliflower, cotton, broccoli, banana, chilli, and soybean. In the case of wheat, 96% of the area of the crop is put under sprinkler irrigation by the adopter farmers. For sugarcane 95% is put under drip irrigation, for chickpea 90% under sprinkler irrigation, for cauliflower 85% under sprinkler irrigation, for cotton 69% under drip irrigation, for broccoli 91% under

sprinkler irrigation for banana 94% under drip irrigation, for Chilli 78% under drip irrigation, and in soyabean 95% under sprinkler irrigation. Do the area and yield increase with micro irrigation? For area, on an average across crops, 64% indicate no change in area after micro irrigation, whereas 35% indicate increase in area, and 2% report decrease in area of a few crops. For yield, on an average across crops, 70% of the farmers adopting micro irrigation report an increase in the yield, whereas 20% report no change in the yield.

The study of the economics of the major crops covered in the study under micro irrigation indicates that on an average there is 22% increase in the area and 73% increase in the production. 16% higher prices are realised due to better quality of the produce, and overall on an average, the total sales revenue increases by a substantial 141%. The adoption of micro irrigation is also found to be accompanied by increase in costs. Cost of seed or planting material cost increases by 101% and the fertiliser cost increases by 64%. The expenditure on farmyard manure increases by 70%, and the pesticide cost increases by 53%. Thus, farmers tend to use more/ better of these inputs with micro irrigation. However, adoption of micro irrigation leads to reduction in irrigation costs. The electricity cost reduces by 11%, the water charges per reduced by 48%, and the hours of pumping reduce by 50%. Thus, there is a sizeable reduction in the use of water and the cost of water as indicated by the results of the study - amounting to its reduction to almost half. The farm power and equipment cost also reduces by 41%. On the other hand, there is increase in labour use and the total labor mandays increase by 44% and the labour cost by 18%. Marketing costs increase by 38% and other cost by 64%. Overall the study indicates that there is a 59% increase in the total cost of growing crops with micro irrigation. However, with the substantial increase in revenue as indicated above, the net profit made by the farmers increases by 310% on an average from Rs. 48080 to Rs. 196932 for sample farmers. The profit increases varies substantially by crops in the range of 105 to 3000 percent. The water pumping hours reduce by over 50 percent in Saharanpur Dist UP, Pune Dist Maharashtra, and Nalgonda Dist Telangana, and reduces by over 50 percent in wheat, sugarcane and cotton. Thus, micro irrigation reduces the water requirement to half in most areas and crops.

The average investment cost of drip irrigation kits is reported to be Rs 181820 and the average cost of sprinkler kits is reported to be Rs 47166. The subsidies on these on an average are found to be 65% in the case of drip and 71% in the case of sprinkler. The total investment on an average on micro irrigation is reported to be Rs 176967. Given the estimates of crop returns of the farmers reported above, the rate of return works out to 84% on total investment and 166% on investment cost to the farmer. The payback periods respectively work out to just 1 year 2 months, and 7 months. This indicates that the returns on investment in micro

irrigation are extremely high both on total investment cost basis as well as on cost to farmer basis.

The factors leading to/ affecting adoption of micro irrigation have been studied using a comprehensive framework of technology adoption in agriculture. The major agronomic drivers are found to be reduction in water use, and increase in the yield. The major agro-economic drivers are increase in profits, and subsidy on micro irrigation, apart from improvement in output quality/ price. The major effective demand drivers are found to be information on micro irrigation being easily available, and micro irrigation technology easy to use. The major aggregate supply driver is the quality and reliability of micro irrigation equipment. The distribution drivers are dealers providing good quality product that can be trusted. However, some difficulty is reported with respect to after sales service and the number of dealers nearby.

The major advantages of micro irrigation are reported to be higher yields, less water needed, better quality, and higher profits. Advantages such as reduction in risk, less labour needed and higher output price are also reported. Micro irrigation is widely reported to have a strong positive impact on water conservation and availability, the development of the village as a whole, and the environment. The impact on upland farmers is somewhat less than for lowland farmers, and tribals and youth/ young farmers do not appear to benefit much.

In the problems faced by the farmers in the adoption and use micro irrigation, technical issues and problems are not found to be important/ frequent. The major problems reported are damage by animals, and the lack of fencing to prevent this. Some of the other problems are water table going down fast, and high cost of tubewells. Some report poor after sales service. On the other hand, lack of government support, and difficulty in getting government support not reported as problems by most respondents.

In overall assessment, the overall performance of micro irrigation is reported to be good to excellent by 90% of the respondents, and similarly the performance on improving water use efficiency is reported to be good to excellent by 90% of the respondents. Performance on increasing profits and incomes is reported to be good to excellent by 77% of the respondents. 97% of the respondents indicate that they plan to continue to using micro irrigation, and 86% report that they will expand micro irrigation. These responses indicate that there is a very high level of satisfaction with the performance of micro irrigation. The suggestions for improving adoption and impact of micro irrigation include more subsidy assistance, easier process of getting subsidy, lower price of micro irrigation equipment, and better micro irrigation technology.

The non-adopters have the same age profile as adopters but have somewhat less education. They have smaller farm sizes with substantially more percentage of marginal farmers. A smaller percentage of non-adopters have tube wells and wells and many don't have their own source of water. A larger percentage report having scarcity of water. In the cropping pattern, a larger percentage non-adopters grow staple and field crops such as wheat, rice and chickpea, whereas adopters report more commercial crops such as sugarcane, orange and vegetable crops and no paddy. No overwhelming reasons are indicated for not adopting micro irrigation but many report micro irrigation equipment not available, high investment cost, and subsidy not sufficient.

The results of the study clearly indicates that micro irrigation technology is highly beneficial in saving water/ reducing water use, and it substantially increases yields, profits and incomes of the farmer. It provides an extremely high return on the investment, both with subsidy (166%) and on total investment cost (84%). The results show that the PMKSY-PDMC scheme helps significantly in promoting the adoption of this very potent and useful technology, which brings substantial water savings and large increase in profits and incomes of the farmers. 90 percent of adopter farmers consider the performance of micro irrigation technology to be excellent or good, and almost all wish to continue using the technology and expand its use.

Recommendations

- The PMKSY-PDMC scheme shows very good performance and impact on improving water use efficiency, water conservation, boosting farmer incomes, and increasing employment. It is strongly recommended that the scheme should be continued.
- There is a strong demand and need for expanding the coverage of the scheme in terms of the number of beneficiaries covered. There no major problems reported with the current mode of implementation through state government and private service providers, though a few suggestions are made below.
- There is a strong request for increasing the subsidy component/ percentage. However, the present level of subsidy is invoking a strong demand from the farmers and has a high rate of return with subsidy as well on total investment.
- There is a great need to focus on low MI adoption states, particularly the eastern region.
- Training programs should be regularly organized for micro irrigation to provide good up-to-date technical guidance to the users, and for its popularization, and can be taken up through training institutes and agricultural universities. These will help the farmers to learn the correct and best use of the technology and solve problems.

- Damage by animals which is a serious problem. A component of support can be added for this in the scheme such as for fencing to help protect the investment in micro irrigation and enhance its sustainability.
- Many non-adopters report water scarcity and lack of water sources such as tube wells. Assisting them to access credit for creating these assets may be considered where groundwater availability is good.
- Need for improving the marketing arrangements for micro irrigation crops is frequently expressed in some states, and this may be addressed.
- In some states, institutions such as sugar cooperatives assist the farmers in obtaining the subsidy and implementing the investment in micro irrigation. Wherever possible, such institutions should be involved to facilitate implementation.
- The extent of subsidy could be varied inversely with land holding size in 2 to 3 slabs/ levels. Since the rate of return is very high, this may not affect adoption, promote use by marginal and small farmers and cover more with the same budget.
- In hilly terrains/ states such as Sikkim, are eminently suited for micro irrigation and other irrigation is not possible. Special focus should be there in such areas.
- There is a need to improve aftersales service, and entrepreneurial or skill building training can be imparted to village artisans/ mechanics/ input outlets or to educated youth in villages and rural towns.
- Rather than having separate scheme implementing bodies, it may be better to have one window/ body for the promotion of micro irrigation in each state.
- In some states, Special Purpose Vehicles (SPV) such as the Gujarat Green Revolution Company, have very effectively facilitated focused scheme implementation for micro irrigation. These could be used in other states such as eastern states which need a boost from the low adoption of micro irrigation.
- Special focus and priority may be given in the scheme to micro irrigation implementation in high water using crops such a sugarcane and banana.
- Given the large boost in profitability that micro irrigation gives, the technology can be promoted not just as a water saving technology but as a substantial yield, profit and income boosting technology. It will always give water saving as an additional benefit. This may attract wider interest and following.

CHAPTER 01

Introduction, Background and Study Objectives

Introduction

The Ministry of Agriculture & Farmers Welfare - Department of Agriculture, Cooperation and Farmers Welfare, Government of India is implementing the important Per Drop More Crop (PDMC) component of the scheme Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) since 2015-16. The Per Drop More Crop (PDMC) component focuses on improving water use efficiency at the farm level through promotion and support of Precision or Micro Irrigation (MI) which includes Drip and Sprinkler Irrigation.

The main premise of the PDMC component is that the water use efficiency in India's agriculture is very low compared to global standards, and is reported to be as low as 25-35 percent (max 40-45 percent), Vaidyanathan and Sivasubramaniyan (2004) – which indicates that 65 to 75 percent of the water is wasted. This is substantially due to the widespread practice of conventional flood irrigation technique all over India. Micro irrigation (MI) techniques, including drip and sprinkler irrigation started being introduced in India as important water saving technologies primarily from the 2000's. The Government of India Department of Agriculture & Cooperation, Ministry of Agriculture launched the Centrally Sponsored Scheme on Micro Irrigation in January 2006. In June 2010, this was up-scaled to the National Mission on Micro Irrigation (NMMI), and continued till the year 2013-14. From 1st April, 2014, NMMI was subsumed under National Mission on Sustainable Agriculture (NMSA), and implemented as On-Farm Water Management (OFWM) in the financial year 2014-15, and from April 1 2015, the Micro Irrigation component of OFWM was subsumed under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY).

MI techniques can bring numerous benefits including not only enhanced water use efficiency, but also increase in irrigated area with the given quantity of water, enhanced crop productivity/ yields, labour cost savings, electricity and energy savings through lesser pumping hours. Under the government schemes described above, most of the states are giving subsidies of often over 70 percent for the installation of MI system, and the states often compete with each other to increase the subsidy component. However, it has been found that higher subsidy

rates do not necessarily lead to more MI area coverage. The highest increase in area under MI is often achieved by states which offer subsidy in the range of 50-75 percent e.g. Maharashtra, Chhattisgarh, Gujarat and Odisha. Though AP increased subsidy from 70 to 90 percent in 2011-12, the additional area under MI showed a decline as compared to the previous years. An Impact Evaluation Study conducted by Global Agri System (June 2014) found that Maharashtra, without having the highest subsidy, showed the greatest increase in irrigated area under MI system. Thus, there is a great need to understand better MI implementation, including the adoption of MI across crops, farmers and regions, the costs and benefits, and the impact of the technology on farmers, resources and agriculture. This would be very important for improving the implementation of the schemes.

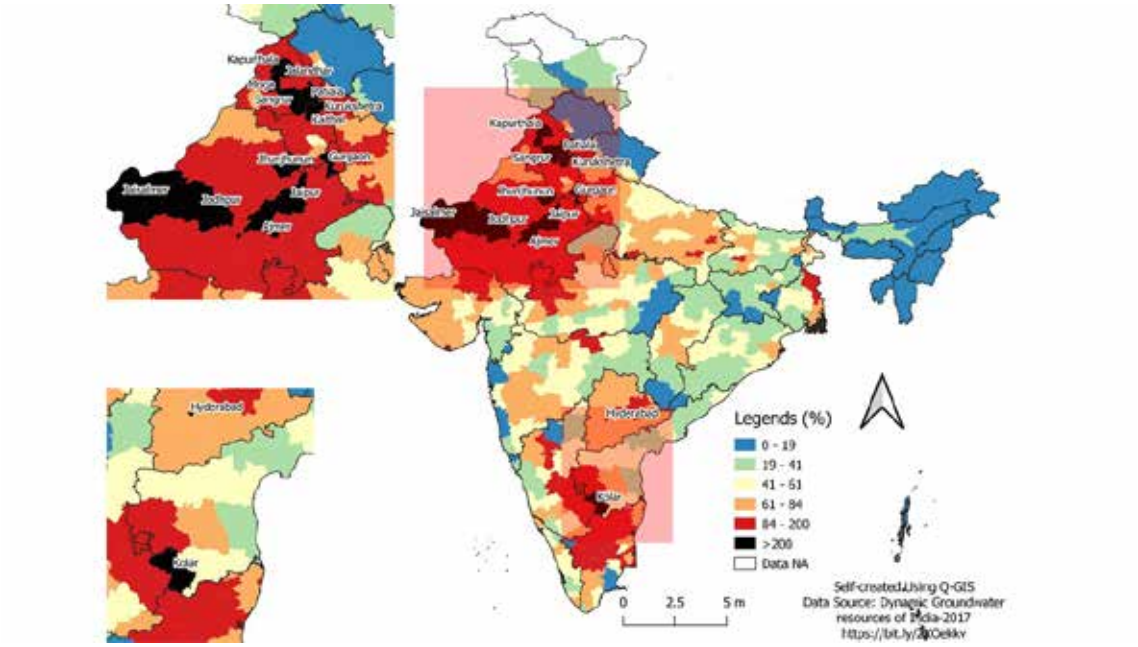
Background of Water Situation

Water is an essential requirement for survival of life on the planet Earth. Despite being abundantly available overall, only about 1 percent of water is fresh water and even less is potable/ usable. Water scarcity affects more than 40 percent people in the world, and it is projected that by 2025, two-thirds of the world population could be living under water-stressed conditions, with climate change further magnifying the problem (FAO 2015; Bates, Kundzewicz, & Wu, 2008). The crisis of water in India is widely talked about and needs little elaboration. India is a water-stressed[1] country with an estimated availability of 1434m^3 per person per year. Groundwater withdrawal is increasing very rapidly in India, more rapidly than in USA and China, and is about 780 billion cubic meters annually (FAO, 2018). Fifty-four percent of observed groundwater wells in India are reported to be overexploited and many states showing even more exploitation, such as Karnataka (80%), Maharashtra (75%), Uttar Pradesh (73%). About 60 percent of the India's districts fall in water-scarce[2] category or suffering from poor water quality (CWC, 2019) (Niti Ayog, 2019). Figure 1.1 below shows the groundwater extraction situation district-wise. It shows that states such as Punjab, Haryana, Rajasthan, Tamilnadu are widely facing severe groundwater situation. Some districts of Punjab, Haryana, and Rajasthan have acute depletion rate (marked as black) as they have more than 200 percentage water extraction rates compared to replenishment.

1 Falkenmark Index - measures water availability per capita per year. Water stressed < 1700m3 Water scarce <1000m3 (Falkenmark, 1989)

2 Based on water use and availability ratio (WUAR). If WUAR is > 40 % = Water Scarce (Alcamo & Henrichs, 2002)

Figure 1.1: District-wise Groundwater Extraction Situation



Source: Created by Authors, Data Source: Dynamic Groundwater resources of India- 2017

Agriculture's share in groundwater extraction is estimated to be 90 percent, and groundwater provides over 78 percent of the total irrigation potential (CWC, 2019). Apart from other reasons, the situation is often aggravated by misplaced incentives such as electricity subsidy and low water pricing which encourage growing of water-intensive crops including sugarcane, rice, wheat and banana, leading to excessive groundwater use (Kumar & Singh, 2001). It is estimated that the production of 1 kg of rice requires 2497 liters of water, 1 kg shirt cotton production requires 10,000 liter water, and 1 kg of sugar production requires 1782 liters of water (Mekonnen & Hoekstra, 2011).

Water management has two sides – supply-side and demand-side management and both require policy response. Demand-side management may include policies such as subsidies for water-saving technologies such as MI, incentives for shift to low water consuming crops, and reduction of electricity subsidies. Since flood irrigation is very inefficient since a huge amount of water is lost through leaching, surface runoff, evaporation, and weeds (Fereres et al., 2011). The promotion of MI is extremely important in reducing the water footprint, and increase water use efficiency at the farm level, and this has led to the government schemes such as Per Drop More Crop (PDMC) under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). The mandate of PMKSY is to expand the irrigated area (Har Khet Ko Pani), and also increase water use efficiency (Per Drop More Crop) through promotion of water-saving technologies such as MI.

Several technologies are included in micro irrigation, and they are often categorized based on both technology and socio-economics - low-cost micro irrigation technologies, and the high cost commercialized technologies (Namara, Upadhyay, & Nagar, 2007). Low-cost MI is often through innovation by the farmers and small farmer-focused R&D. It includes Pepsee (with light plastic pipes) drip, drum and bucket kits, micro-sprinklers, microtube. The commercialized MI is capital intensive and includes drip and sprinkler irrigation equipment commercially available through companies such as Jain Irrigation, Netafim, and others. The capital investment in the latter can be around Rs. 1.3 lakhs per hectare of installation varying land resource and type of crops (GoI, Guideline, 2018).

Sprinkler refers to a technology that sprinkles water over the plants across the field. Drip irrigation, on the other hand, is through pipes and tube ending with micro-tubes with pores/ drippers near the roots zone of plants which deliver the water drop by drop. The capital costs of two technologies differ and drip irrigation is usually more capital intensive as compared to the sprinkler irrigation. The investment in drip irrigation may be 2 to 2.5 times or more depending on the crops and the spacing between plants. Drip irrigation is typically used in stable and longer duration crops such as cotton, sugarcane, banana, and pomegranate. Sprinkler irrigation is often used in shorter duration crops such as groundnut, rice, pulses and pearl millet (Kumar, 2016).

Background of Government Schemes on Micro Irrigation

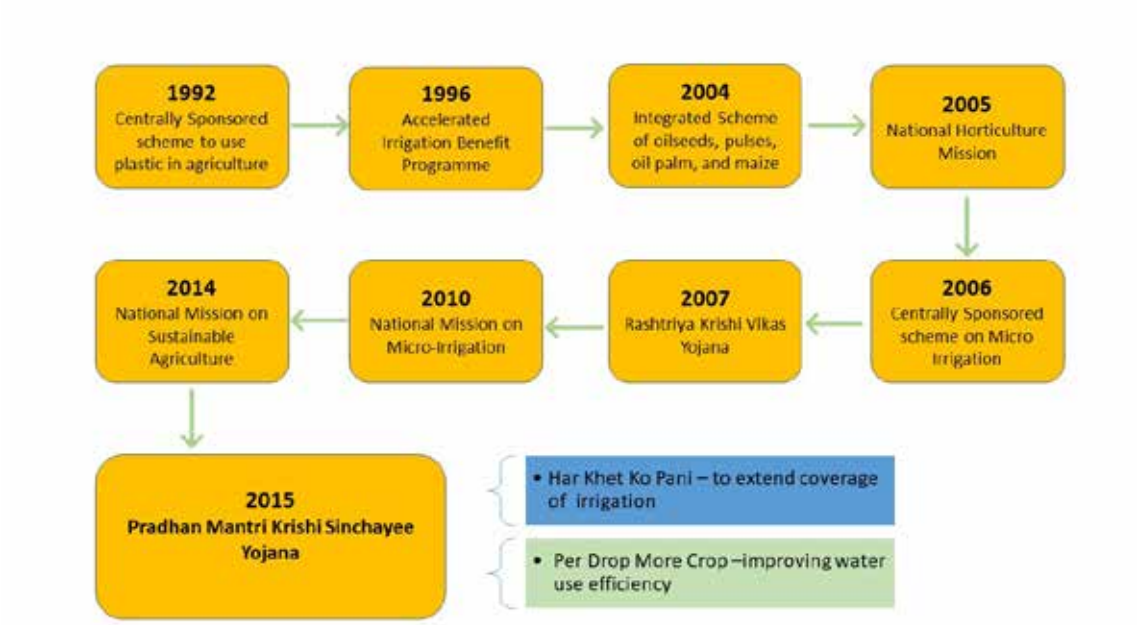
The Government of India has been making substantial efforts towards the expansion of irrigation since independence. The inclusion of micro irrigation had its early beginning soon after the introduction of plastics in agriculture. A centrally sponsored scheme in 1992 started promoting the use of plastics in agriculture such as in mulching materials, poly-houses, and micro irrigation. The centrally sponsored scheme Accelerated Irrigation Benefit Program (AIBP) launched in 1996-97 also promoted the use of micro irrigation in on-going irrigation projects through the state governments for increasing the area under irrigation. It provided loans and financial assistance to state governments in projects including major/ medium irrigation projects, their extensions, renovations, and modernization, and surface minor irrigation schemes, and lift-irrigation schemes. Experiments and extension for micro irrigation were also done for promoting adoption of micro irrigation in the Integrated Scheme of Oilseeds, Pulses, Oil-palm and Maize (ISOPOM) (which was renamed so in 2004). The scheme was mandated to increase the productivity of oil-seeds, pulses, oil palm, and maize, to reduce the import dependence. Micro irrigation area also increased. Micro irrigation in India really got a strong push after the Task Force Report on Micro irrigation in 2004 which paved way for a centrally sponsored scheme on micro irrigation in 2006. National Horticulture Mission launched in 2005-06 also had a small component

of "precision farming" which provided financial support to farmers for micro irrigation. Though it was limited to horticulture crops such as coconut, banana, orchard plants, it was the first of its kind with a targeted approach for increasing are micro irrigation due to its merit of saving water in orchard tree crops.

The Centrally Sponsored Scheme on Micro Irrigation was launched by the Department of Agriculture & Cooperation, Ministry of Agriculture in January 2006 which was first of its kind to have clear focus on promoting micro irrigation in Indian agriculture, to encourage the farmers to use it for conservation water and improving yield. Other schemes such as Rashtriya Krishi Vikas Yojana launched in 2007 also had provisions for financial support for micro irrigation promotion. In June 2010, the centrally sponsored scheme was renamed/upscaled to National Mission on Micro Irrigation (NMMI), which continued till the year 2013-14. From 1st April, 2014, NMMI was subsumed under National Mission on Sustainable Agriculture (NMSA) and implemented as On-Farm Water Management (OFWM) during the financial year 2014- 15. From 1st April 2015, Micro Irrigation component of OFWM has been subsumed under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY).

The Ministry of Agriculture & Farmers Welfare - Department of Agriculture, Cooperation and Farmers Welfare is implementing the Per Drop More Crop component of the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), which is operational from 2015-16 in the country. The PMKSY scheme was launched with two mandates of, "Har Khet Ki Pani" – to extend the coverage of irrigation, and "Per Drop More Crop" – to improve water use efficiency. The Per Drop More Crop component focuses mainly on improving water use efficiency at farm level through Precision/ Micro Irrigation (MI) (Drip and Sprinkler Irrigation). The timeline of the evolution of the government scheme on micro irrigation is shown in Figure 1.2.

Figure 1.2: Evolution of Micro Irrigation Schemes towards Pradhan Mantri Krishi Sinchayee Yojana



Source: Adopted and modified from Singh & Singh, 2018

Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)

As stated in his address by the Hon'ble President of India to the Joint Session of the Parliament of the 16th Lok Sabha, "Each drop of water is precious. My government is committed to giving high priority to water security. It will complete the long pending irrigation projects on priority and launch the 'Pradhan Mantri Krishi Sinchayee Yojana' with the motto of 'Har Khet Ko Paani'. There is a need for seriously considering all options including linking of rivers, where feasible for ensuring optimal use of our water resources to prevent the recurrence of flood and drought. By harnessing rainwater through 'Jal Sanchay' and 'Jal Sinchan', we will nurture water conservation and groundwater recharge. Micro irrigation will be popularized to ensure "Per Drop More Crop".

The major objective of PMKSY is to enhance/achieve:

- convergence of investments in irrigation at the field level
- expand cultivable area under assured irrigation
- improve on-farm water use efficiency to reduce wastage of water
- enhance the adoption of precision-irrigation and other water saving technologies (More Crop Per Drop)
- enhance recharge of aquifers
- introduce sustainable water conservation practices

- feasibility reusing of treated municipal wastewater for peri-urban agriculture
- attract greater private investment in precision irrigation systems

PMKSY has been conceived as an amalgamation of several ongoing schemes viz.

- Accelerated Irrigation Benefit Programme (AIBP) of the Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR,RD&GR)
- Integrated Watershed Management Programme (IWMP) of Department of Land Resources (DoLR)
- On Farm Water Management (OFWM) of Department of Agriculture and Cooperation (DAC)

The scheme is implemented by different Ministries: Rural Development, Water Resources and Agriculture & Farmer Welfare.

- Ministry of Rural Development is to mainly undertake rainwater conservation, construction of farm pond, water harvesting structures, small check dams and contour bunding etc.
- Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWR, RD &GR) is to undertake various measures for creation of assured irrigation source, construction of diversion canals, field channels, water diversion/lift irrigation, including development of water distribution systems.
- Ministry of Agriculture & Farmers Welfare is to promote efficient water conveyance and precision water application devices like drips, sprinklers, pivots, rain-guns in the farm "(Jal Sinchan)", construction of micro irrigation structures to supplement source creation activities, extension activities for the promotion of scientific moisture conservation and agronomic measures.

The programme architecture of PMKSY is to adopt a 'decentralized state level planning and projectised execution' structure that will allow States to draw up their own irrigation development plans based on District Irrigation Plan (DIP) and State Irrigation Plan (SIP). It will be operative as a convergence platform for all water sector activities including drinking water & sanitation, MGNREGA, and the application of science & technology, through a comprehensive plan. State Level Sanctioning Committee (SLSC) chaired by the Chief Secretary of the State will be vested with the authority to oversee the implementation and the sanctioning of projects.

Overall, the programme is supervised and monitored by an Inter-Ministerial National Steering Committee (NSC), constituted under the Chairmanship of Prime Minister with Union Ministers from concerned Ministries. A National

Executive Committee (NEC) is constituted under the Chairmanship of Vice-Chairman NITI Aayog, to oversee programme implementation, allocation of resources, inter-ministerial coordination, monitoring & performance assessment, and addressing administrative issues.

Per Drop More Crop-PDMC (Component of PMKSY)

PMKSY (Per Drop More Crop-PDMC) focuses on micro-level storage structures, efficient water conveyance & application, precision irrigation systems, topping up of input cost beyond MGNREGA permissible limits, secondary storage, water lifting devices, extension activities, coordination & management - being implemented by Department of Agriculture Cooperation & Farmers Welfare (DAC&FW).

Programme Architecture

Per Drop More Crops (Micro Irrigation) adopts the institutional setup and architecture of overall PMKSY framework as given in the Operational Guidelines of PMKSY. The broad institutional structure as per PMKSY guideline are:

a) National Steering Committee (NSC) under the Chairmanship of Hon'ble Prime Minister with 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.

b) National Executive Committee (NEC) under the Chairmanship of Vice-chairman, Niti Aayog with 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, and addressing administrative issues.

c) PMKSY Mission Directorate has been established in the Ministry of Water Resources, River Development and Ganga Rejuvenation for mission mode implementation of 99 major and medium irrigation projects. The Mission is also responsible for overall coordination and outcome-focused monitoring of all components of PMKSY for achieving its target.

d) State Level Sanctioning Committee (SLSC) under the Chairmanship of Chief Secretary of the State to sanction projects and activities as recommended by IDWG.

e) Inter Departmental Working Group (IDWG) under the Chairmanship of Agriculture Production Commissioner/ Development Commissioner with Secretaries of line departments as members. States, if they feel, may take the advice /input of MI manufacturers by inviting representative from manufacturers/ Micro Irrigation Industries as special invitees.

f) District Level Implementation Committee (DLIC) under the Chairmanship of Collector/District Magistrate / CEO of Zila Parishad/ PD DRDA, Joint Director/Deputy director of line departments in the district and progressive farmers, representative of MI industry, and leading NGO as members to oversee PMKSY implementation and inter-departmental coordination.

Nodal Department

Since the final outcome of PMKSY is to ensure access to efficient delivery and application of water at every farm thereby enhancing agricultural production & productivity, State Agriculture Department generally is the Nodal Department for implementation of PMKSY (Per Drop More Crop). However, State Government is free to identify the nodal department based on the established institutional set up and mandate of the department. All communication between Ministry of Agriculture (MoA) and State Government is through the nodal department. States are free to identify dedicated implementing agencies/departments for implementation of Per Drop More Crop (Micro Irrigation). If two departments are assigned for implementation, one department is be designated as the nodal department.

District and State Irrigation Plans (DIPs& SIPs)

District Irrigation Plans (DIPs) are the cornerstone for planning and implementation of different components of PMKSY which identify gaps in irrigation infrastructure after taking into consideration the District Agriculture Plans (DAPs) vis-à-vis irrigation infrastructure currently available and resources that would be added from ongoing schemes, both State and Central. DIPs present 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. The annual action plans for Per Drop More Crop (Micro Irrigation) are drawn from DIPs and implemented in conjunction with the water sources created under PMKSY in cluster mode for holistic development as far as possible.

Objectives of Per Drop More Crop-PDMC (Micro Irrigation)

The main objectives of Per Drop More Crop (Micro Irrigation) are as follows:

- Increase the area under micro irrigation technologies to enhance water use efficiency in the country.
- Increase productivity of crops and income of farmers through precision water management.
- Promote micro irrigation technologies in water intensive/consuming crops like sugarcane, banana, cotton etc and give adequate focus to extend coverage of field crops under micro irrigation technologies.

- Make potential use of micro irrigation systems for promoting fertigation.
- Promote micro irrigation technologies in water-scarce, water-stressed and critical groundwater blocks/districts
- Link tube-well / river-lift irrigation projects with micro irrigation technologies for best use of energy both for lifting and pressurised irrigation as far as possible.
- Establish convergence and synergy with activities of on-going programmes and schemes, particularly with a created water source for its potential use, integration of solar energy for pressurised irrigation etc.
- Promote, develop and disseminate micro irrigation technology for agriculture and horticulture development with modern scientific knowledge.
- Create employment opportunities for skilled and unskilled persons, especially unemployed youth for installation and maintenance of micro irrigation systems.

Review of Literature

The role of micro irrigation in improving irrigation efficiency has been studied all over the world. One of the first studies of micro irrigation commissioned in 1981 in California found that the irrigation efficiency of traditional irrigation is about 60 percent, sprinkler irrigation is about 85 percent, and drip irrigation is 95 percent (Caswell & Zilberman,1985). Another study, Jackson et al. (2010) found that a shift from flood to the MI in two different regions of Australia - New South Wales and South Australia, the water application quantity across various crops and farmers reduced from 10 to 66 percent indicating better water use efficiency. The energy demand as compared to flood irrigation increases for surface water source (by 163%) but reduces for groundwater source (12-44%) (Jackson et al.,2010). A meta-analysis study on water use efficiency on wheat and cotton crops have shown a significant advantage of MI over flood irrigation method. The study covers regression analysis of 101 cases and empirical studies from 9 countries for wheat and six countries for cotton, between 1986-2012. The study shows that MI reduces water use in wheat and cotton by 23 % and 39 %, respectively. MI also increases the yield by 37 % and 21 % respectively for wheat and cotton (Fan, Wang & Nan, 2018).

For the India context, many studies find a positive effect of MI in increasing input efficiencies as well as resource savings in water, labour, fertilizer, electricity (Narayanamoorthy, 2004; Rai & Mauria, 2006; Kumar & Palanisami, 2010; Jackson et al., 2010; Palanisami et al. 2011; Bhamoriya & Mathew, 2014; Kumar, 2016; Dar, Brar, & Singh, 2017). The farm enhancement comes in three ways; production enhancement; improving technical efficiency of inputs; and reducing the cost of

production (Kumar, 2016). The water efficiency enhancement ranges from 20 to 80 percent depending on the crop, technology and soil. Narayanamoorthy (2004) finds that the water savings as compared to flood irrigation in vegetable crops were 12 to 84 percent, fruit crops 45 to 81 percent, and field crops 40 to 65 percent. Labour saving for various crops in comparison to traditional flood irrigation ranges from 40 to 60 percent for sprinkler, and up to 50 percent for drip irrigation (Rai & Mauria, 2006)

The impact on farm return would be related to the quantity produced, the price of produce (also reflecting quality), and the cost involved in the production. Narayanmoorthy, (2004) finds that as compared to flood irrigation, there is an increase in yields in vegetables ranging from 2 to 47 percent, fruit crops 23 to179 percent, and field crops 12 to 66 percent. In another study, additional net returns due to sprinkler irrigation over furrow irrigation were found to be Rs. 19,649 per hectare in groundnut and Rs. 14,718 per hectare in maize, an additional net return of about 34 percent (Rai and Mauria, 2006). Some studies have calculated the investment pay-back period of MI and found it to about 18 months in the case of sugarcane (Rai and Mauria, 2006) and about 15 months in some other crops (CIIE, 2013) indicating the good viability and quick payback of the investment.

The Table 1.1 below shows the summary of findings of other important studies on MI, on the impact and the determinant in various crops and states.

Table 1. 1: Summary of all the reports and studies done earlier on MI

Particulars	Study 1	Study 2	Study 3	Study 4
Name of report	Impact Survey	Study of Micro irrigation in Karnataka-Drip and Sprinkler Irrigation	Adoption and Impacts of Micro irrigation technologies	Accelerating growth of Indian Agriculture: Micro irrigation an efficient solution
Commissioned by	GGRC	Government of Karnataka	IWMI-Colombo	Government of India
Conducted by	CIIE, IIM-Ahmedabad	Centre for Budget and Policy Studies	IWMI-India	Grant Thornton
Reference Year	2012-13	2013-14	2005	2016
Sample Size	5500	800	Secondary Data	Secondary Data
Area of Study	Gujarat	Karnataka	Gujarat, Maharashtra	-
Major Crops Studied	Banana, Castor, Cotton, Groundnut, Sugarcane, Vegetables	Groundnut, Sugarcane, Maize, Cotton	-	-
Reported Water Saving %	20-55%	30-40%	Improves substantially	50-90%

Particulars	Study 1	Study 2	Study 3	Study 4
Name of report	Impact Survey	Study of Micro irrigation in Karnataka-Drip and Sprinkler Irrigation	Adoption and Impacts of Micro irrigation technologies	Accelerating growth of Indian Agriculture: Micro irrigation an efficient solution
Reported Water Use Efficiency %	-	63-188%	-	-
Reported Labor Saved %	35-48%	up to 50% or 21-42 labor days per hectares	-	-
Reported Fertilizer Saved %	up to 25 %			28%
Reported Energy Saved	-	-	saving 706lakh KW from 2005-2011	30%
Reported Breakeven	1.8 years without subsidy, 1.5 years with subsidy	-	-	-
Reported Cost-Benefit Ratio	01:17	-	-	-
Reported Returns to the farmers	-	-	-	42%
Reported Productivity Increment (Range for crops)	25-30%	22-52%	-	42-53%
Reported Major Bottlenecks to adoption	Non-availability of spare parts, lack of skilled maintenance workers, poor after-sale services, damage by rodents and animals	Clogging of MI emitters, poor product quality, high installments, hassles in loans and subsidy, lack of technical support	Access to groundwater, cropping pattern, education, financial capability, social class/caste	-

Source: Compiled by the Authors

(Raman 2010) assessed the potential for micro irrigation (MI) - drip and sprinkler irrigation in India through secondary data. He estimated that the potential area which can be brought under MI was 43 million ha, and out of this only 3.87 million ha (9 percent) was currently irrigated under MI, thereby indicating a huge scope for increasing the coverage. (Narayanamoorthy et al. 2016) examined the impact of drip irrigation in vegetable crops and found that through drip irrigation, farmers could reduce the use of water, and substantially increase profits as compared to conventional flood irrigation. They also found that the investment made by farmers was economically viable. However, despite this they found that the adoption rate of drip irrigation was very low. They indicate that this may be mainly due to poor awareness and small landholdings.

The study by Namara et al. (2007) focused on three aspects of micro irrigation (MI): (1) productivity and economic gain, (2) Determinants of MI adoption, and (3) impact on poverty. Through economic analysis they find that adoption of MI has resulted in significant productivity and economic gain over the traditional surface irrigation method. They find that the yield response is better in standard drip systems when compared with the low-cost drip systems, indicating that the low-cost micro irrigation technologies may not be considered but a stepping stone to standard MI systems, which are technically robust with better benefits. They find that the awareness, access to MI systems, access to groundwater, cropping pattern and level of education were the most important determinants of MI adoption. With respect to poverty reduction they find that merely reducing the cost of system through subsidy was not sufficient for increasing adoption by the poor. It was very important in addition to build awareness about how to use the MI system, improve access/ availability of MI, and provide guidance regarding the right crops to grow under MI. The adoption rate and benefits of MI among poor farmers was found to be low.

Palanisami et al. (2011) examined the actual area covered compared under MI to the potential area, to understand the adoption of MI, and also the costs and returns for farm groups. They infer that MI is relatively "capital intensive" and suited for large farms. As a result, the adoption was poor. The main factors explaining poor adoption were high cost, complexity of the technology and socio-economic issues such as a lack of access to credit, fragmented landholdings, and local crop pattern. Their key suggestions included interventions to reduce the capital cost of the system, provision of technical support for operation after installation, relaxation of farm size limitation in providing subsidies, and the establishment of a single state level agency for implementing the programme.

Bhamoriya & Mathew (2014) examine the use of drip irrigation technology on resource conservation and sustainability of agriculture. The findings shows, that drip irrigation can be an important coping mechanisms to protect the farmer and agriculture from problems such as shortage of water, power and labour. Both adopters and non-adopters indicate that the technology is beneficial for improving water use efficiency. A positive impact on water table was also observed by many farmers. It was also reported that "saved water" is frequently used for expanding the area under irrigation. Malik et al. (2018) finds that the commonly cited reason in India for the low adoption of MI technology is the "high upfront capital costs". Despite subsidies of 70% or more provided by the central and state governments, the adoption rate is quite low. The implementation of micro irrigation in Madhya Pradesh was studied to understand why the subsidies were not meeting impact expectations, They found some problems with the subsidy system as currently operated, including increasing investment costs, reducing benefits, certification

procedures/ problems, delayed subsidy payments, equipment quality and performance issues.

Study Objectives

The Per Drop More Crop component of PMKSY mainly focuses on water use efficiency at farm level through Precision/ Micro Irrigation (MI) (Drip and Sprinkler Irrigation). The main objective of the study would be to analyse the various benefits of MI to the farmers including in input use, costs and returns. Specifically, the objectives would be to examine the following:

(a) To examine the savings of various inputs such as water, fertilizers, power, pesticides and labour

(b) To examine the enhancement of productivity, quality and other benefits in selected agriculture/ horticulture crops including water-intensive crops such as sugarcane and banana, and if there is employment generation due to MI.

(c) To examine the adoption of MI including some of its determinants/ features such as need/ importance of subsidy, culture of water conservation, issues of fragmented land holdings, capital cost, maintenance cost and the distribution of subsidy across states.

(d) To study overall impact on farmer incomes and the cost-benefit in selected crops.

(e) To identify any issues/problems in the benefit transfer work flow and monitoring by the implementing agency.

Methodology

The project is implemented as a coordinated study covering 5 selected states and involving respectively 5 Agro-Economic Research Centres (AERCs) under the Ministry of Agriculture & Farmers Welfare. It is coordinated by CMA, IIM Ahmedabad which is an Agro-Economic Research Unit under MoAFW. The states & locations are sampled for representation and diversity based on different criteria including extent of micro irrigation implementation/ adoption, diversity in region & agro-climate stress, diversity in cropping and willingness/ cooperation of the necessary AERCs. The state sample covering both high & low adoption states includes Maharashtra, Telangana, Uttar Pradesh, Madhya Pradesh, and Sikkim. The AERC's in Pune, Visakhapatnam, Allahabad, Jabalpur and Shantiniketan are involved for implementation of the study in the respective states under the research design and guidance of CMA-IIMA.

The study involved preliminary field visits, study of literature, and collection of secondary data and information available. This includes the study/ development of relevant theory and conceptual frameworks. This is followed by the design

of the survey instrument/ questionnaire based on the background and the study objectives. The questionnaire and sample design were discussed in a workshop at CMA-IIMA which included the participating AERCs, few experts, and implementing agency representatives, and then finalized after field testing. The survey was then implemented by the respective AERC/Us with guidance of CMA.

The data collected was scrutinized, and then entered into computers by the AERCs in formats provided by CMA, and then was compiled at the level of CMA. Each participating AERC/U studied and analyzed the data of the respective states on their own, and CMA compiled and analyzed the combined data. Detailed tabular and statistical analysis as well econometric analysis was carried out to obtain findings on different objectives and relevant questions. Conclusions and policy implications were then drawn.

CHAPTER 02

Micro Irrigation Development in India under the PMKSY-PDMC

This chapter examines the available secondary data collected from government and other sources to provide a profile of the PMKSY-PDMC implementation and the outcomes.

Profile of Micro Irrigation Expenditure and Development under PMKSY-PDMC Scheme

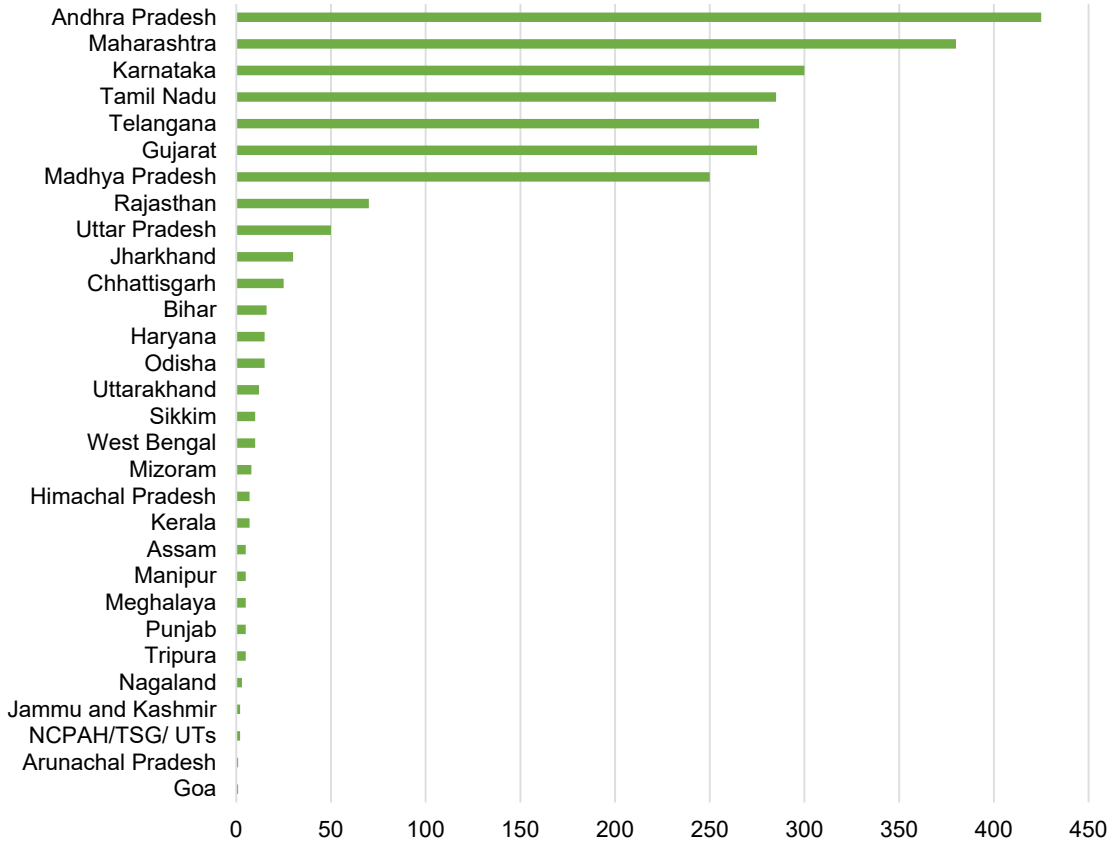
Table 2.1 and Figure 2.1 show the state-wise distribution of PMKSY-PDMC funds in 2017-18. It shows that Andhra Pradesh, Maharashtra and Karnataka received the highest amount of funds. Overall Rs. 3400 crores were spent at the national level for various interventions and Rs. 2500 crores on micro irrigation.

Table 2. 1: Selected State-wise Allocation of Funds under Per Drop More Crop Component of PMKSY in India (2017-2018) (Rs. in Crore)

States	Micro Irrigation (MI)	Other Interventions (OI)	Total
Andhra Pradesh	425	60	485
Arunachal Pradesh	1	5	6
Assam	5	30	35
Bihar	16	25	41
Chhattisgarh	25	40	65
Goa	1	1	2
Gujarat	275	50	325
Haryana	15	5	20
Himachal Pradesh	7	23	30
Jammu and Kashmir	2	10	12
Jharkhand	30	37	67
Karnataka	300	85	385
Kerala	7	15	22
Madhya Pradesh	250	40	290
Maharashtra	380	95	475
Manipur	5	6	11
Meghalaya	5	6	11
Mizoram	8	10	18
Nagaland	3	10	13
Odisha	15	36	51
Punjab	5	5	10
Rajasthan	70	98	168
Sikkim	10	5	15
Tamil Nadu	285	50	335
Telangana	276	50	326
Tripura	5	5	10
Uttar Pradesh	50	50	100
Uttarakhand	12	20	32
West Bengal	10	25	35
NCPAH/TSG/UTs	2	3	5
India	2500	900	3400

Source: India, Pradhan Mantri Krishi Sinchayee Yojana, 2019

Figure 2. 1: Selected State-wise Allocation of Funds under Per Drop More Crop (2017-2018)



Source: India, Pradhan Mantri Krishi Sinchayee Yojana, 2019

Table 2 and Figure 2 show the distribution of the number of beneficiaries across states. It shows that the highest numbers of beneficiaries are in Andhra Pradesh, Gujarat and Telangana. The total numbers of beneficiaries are about 3.4 lakhs.

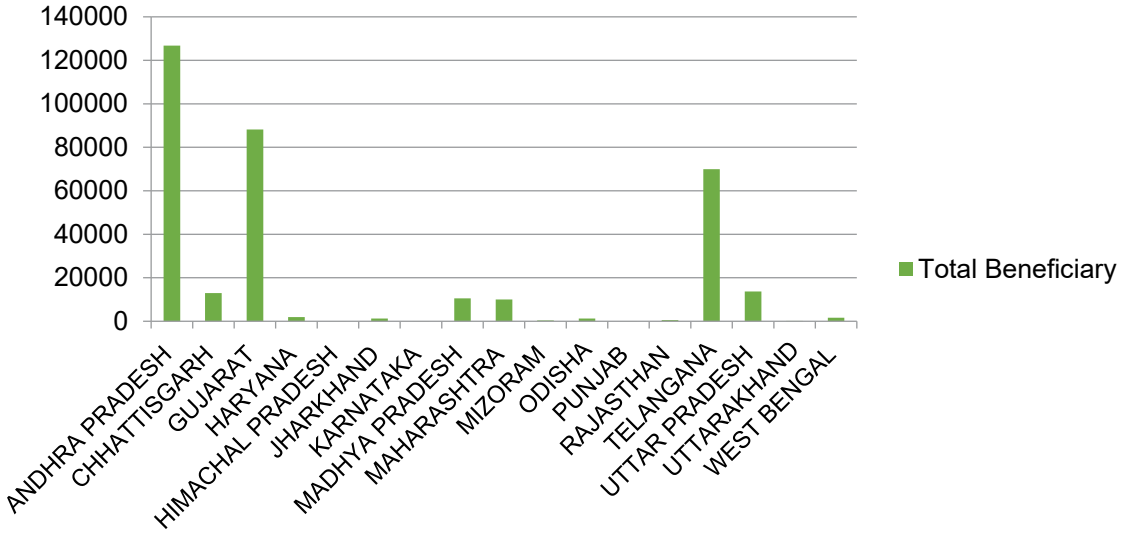
Table 2. 2: State-wise Beneficiary Count (2017-18)

State	Total No. of Beneficiaries (MI)	State	Total No. of Beneficiaries (MI)
Andhra Pradesh	126760	Mizoram	372
Chhattisgarh	12977	Odisha	1284
Gujarat	88216	Punjab	2
Haryana	1909	Rajasthan	511
Himachal Pradesh	12	Telangana	69911
Jharkhand	1267	Uttar Pradesh	13734
Karnataka	1	Uttarakhand	127
Madhya Pradesh	10548	West Bengal	1647
Maharashtra	9999	Total	339277

Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019.

It may be noted that the beneficiary count apparently deviates from the area and funding data. But it is exactly as reported in this data source.

Figure 2. 2: State-wise Beneficiary Count Report (2017-18)



Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019.

Table 2.3 and Figure 2.3 show the area covered under MI – state-wise. It shows that Karnataka, Andhra Pradesh and Gujarat show the highest area covered under MI.

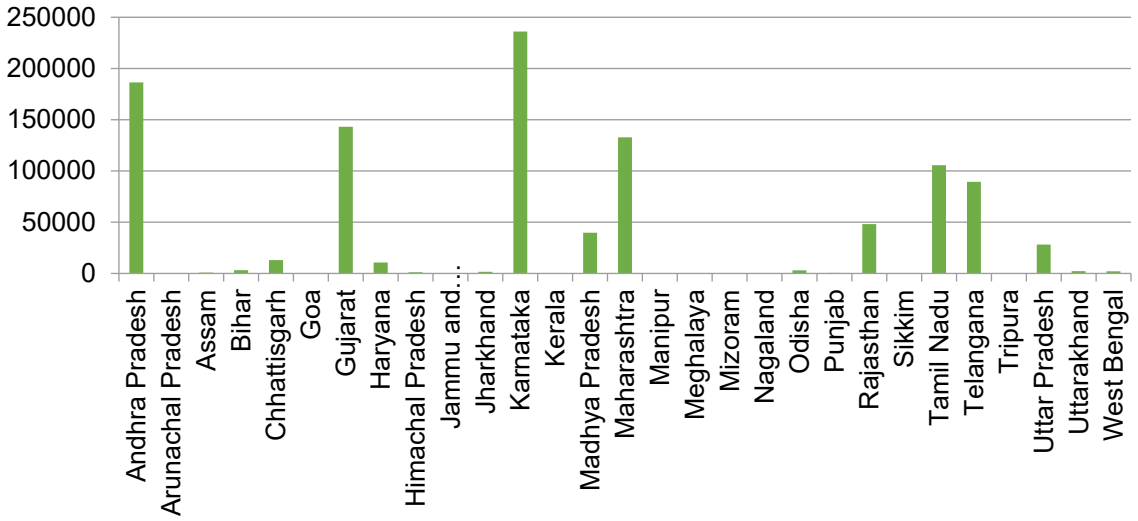
Table 2. 3: Selected State-wise Area Covered under Micro Irrigation (Drip and Sprinkler) in India 2017-18 (ha)

States	2017-18
Andhra Pradesh	186441
Arunachal Pradesh	0
Assam	782
Bihar	3143
Chhattisgarh	13087
Goa	236
Gujarat	143134
Haryana	10751
Himachal Pradesh	1197
Jammu and Kashmir	0
Jharkhand	1544
Karnataka	236107
Kerala	358
Madhya Pradesh	39761
Maharashtra	132829

States	2017-18
Manipur	0
Meghalaya	0
Mizoram	0
Nagaland	0
Odisha	3036
Punjab	600
Rajasthan	48205
Sikkim	0
Tamil Nadu	105695
Telangana	89474
Tripura	0
Uttar Pradesh	28235
Uttarakhand	2182
West Bengal	2137
India	1048934

Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019

Figure 2. 3:Selected State-wise Area Covered under Micro Irrigation (Drip and Sprinkler) in India 2017-18

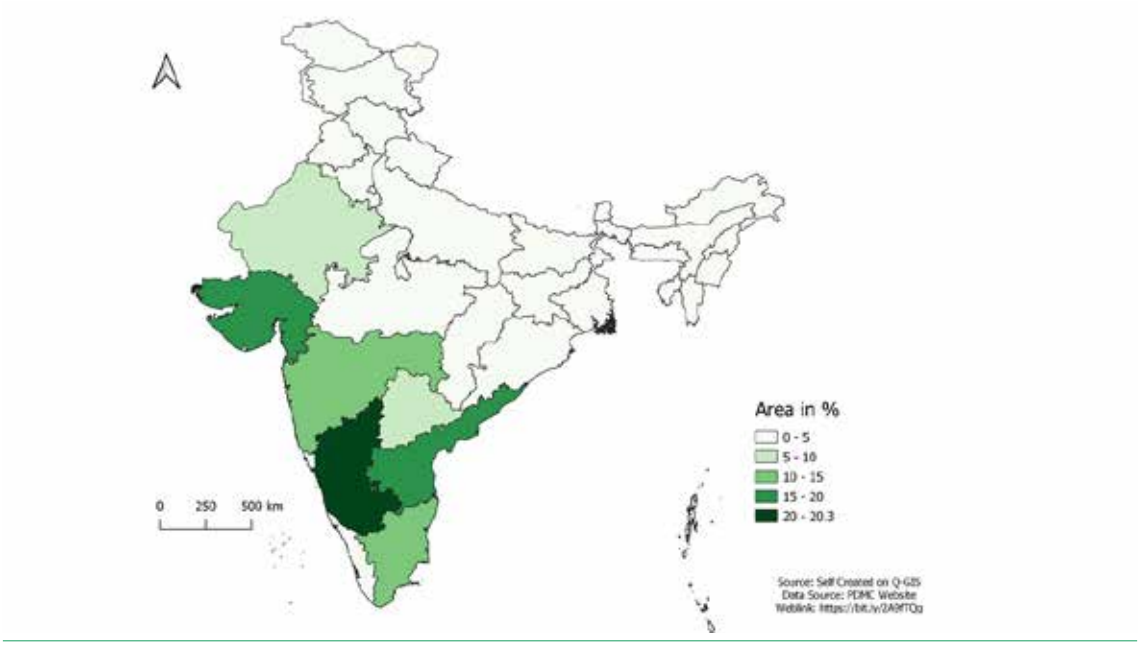


Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019

Profile of Micro Irrigation Development and Support under PMKSY-PDMC over the last five years

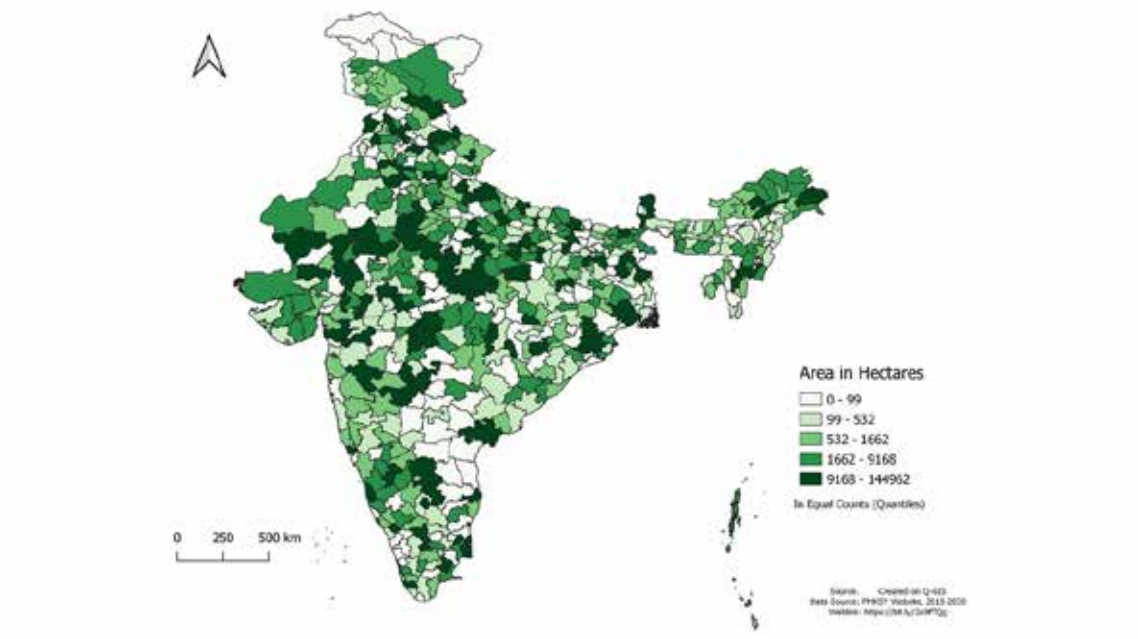
This section uses data from PMKSY website and represents it on GIS Maps. This is shown in Figure 2.5 below. The coverage expansion of micro irrigation shows increased coverage in states of Karnataka, Andhra Pradesh, Gujarat, Rajasthan and Maharashtra. In last five years from 2015-2020, Karnataka shows highest percentage area of the total area brought under micro irrigation, followed by Gujarat and Andhra Pradesh. The map on the right shows absolute area coverage in different districts of India. It shows that in the districts of Rajasthan, Madhya Pradesh, Karnataka higher absolute area has been brought under MI coverage as compared to other districts, but there is substantial variation across districts.

Figure 2. 4: State-wise percent share of area brought under Micro irrigation during 2015-2020



Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019, Created by Authors

Figure 2. 5: District-wise area coverage under PDMC from 2015-2020



Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019, Created by Authors

The Table 2.3 below shows the physical and financial coverage as reported on the PMKSY website. The Table shows that a total of 47 lakhs hectare has been brought under micro irrigation between 2015-2020 with an expenditure of Rs. 781,736 lakhs.

Table 2. 4: Financial Outlays and Physical Achievement under PDMC, 2015-2020

Years	Expenditure (in Rs lakhs)			Physical Coverage (in ha)		
	Drip	Sprinkler	Total	Drip	Sprinkler	Total
2015-16	83,708	13,208	96,916	346,936	204,650	551,586
2016-17	121,992	26,892	148,884	487,391	352,573	839,964
2017-18	129,797	34,466	164,263	541,468	507,473	1,048,941
2018-19	135,884	42,151	178,035	575,500	582,994	1,158,494
2019-20	151,449	42,189	193,638	596,091	524,653	1,120,744
Grand Total	6,22,829	1,58,906	781,736	25,47,386	21,72,343	4,719,729

Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019

The Table 2.5 gives the state-wise breakup of the expenditure and physical coverage of micro irrigation by drip, sprinkler and total for the last five years of the scheme. The Table shows that states of Karnataka, Andhra Pradesh, Gujarat, Tamil Nadu and Maharashtra have contributed highest to the physical achievement under PDMC scheme. Coverage is poor in eastern states and also in states such as Punjab, Haryana, and Uttar Pradesh, even though groundwater is depleting there. It is important to accentuate the efforts of extending the water-saving technologies in the states which have higher level of increased water scarcity. The visual representation of the physical and financial coverage can also be seen in the map in Figure 2.4. It is evident from the visualization that the coverage of micro irrigation is skewed towards a few western states while some important states with high water scarcity, are not well covered. Better implementation is required in eastern states and water-scarce states under the programme. The financial coverage is also skewed towards a few western states which were already doing well before the programme launch. Better focus is required on eastern and water-scarce states.

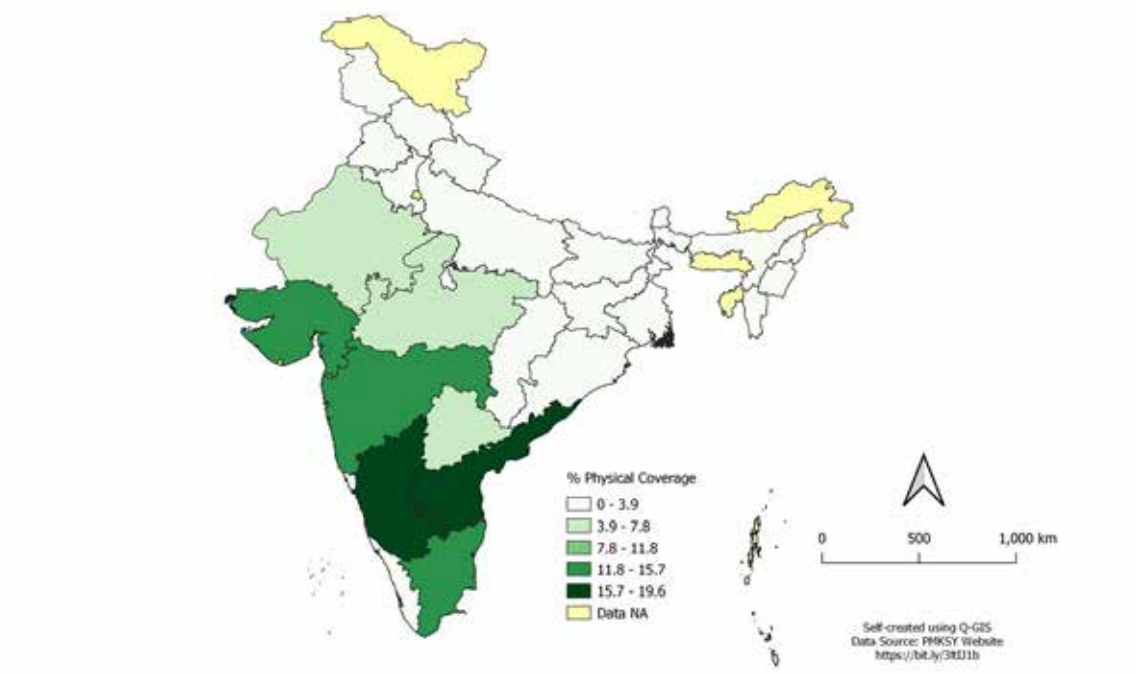
Table 2. 5: Percent share of states in physical achievement and budgetary expenditures over 2015-2020 (sorted by MI physical achievement)

States	Drip % of Physical Achievement	Drip % of Budgetary expenditures	Sprinkler % of Physical Achievement	Sprinkler % of Budgetary expenditures	MI % of Physical Achievement	MI % of Budgetary expenditures
Karnataka	11.5	12.0	29.1	25.7	19.6	14.8
Andhra Pradesh	21.7	21.2	8.8	6.8	15.8	18.3
Gujarat	15.3	15.4	14.3	9.4	14.8	14.2
Tamil Nadu	15.3	10.6	10.2	11.4	13.0	10.7
Maharashtra	16.1	13.2	8.0	11.0	12.4	12.7
Rajasthan	3.7	4.1	7.9	7.1	5.6	4.7
Telangana	6.7	7.3	3.0	2.9	5.0	6.4
Madhya Pradesh	5.9	6.8	2.4	2.7	4.3	5.9

States	Drip % of Physical Achievement	Drip % of Budgetary expenditures	Sprinkler % of Physical Achievement	Sprinkler % of Budgetary expenditures	MI % of Physical Achievement	MI % of Budgetary expenditures
Uttar Pradesh	0.7	0.9	7.2	7.4	3.7	2.2
Chhattisgarh	0.5	0.6	3.5	4.4	1.8	1.4
Haryana	0.4	0.5	1.9	3.3	1.1	1.0
Odisha	0.2	0.2	1.1	1.1	0.6	0.4
Jharkhand	0.7	1.2	0.1	0.5	0.5	1.1
Uttarakhand	0.4	0.4	0.3	1.3	0.4	0.6
West Bengal	0.0	0.0	0.7	0.3	0.3	0.1
Bihar	0.1	0.4	0.4	0.9	0.3	0.5
Assam	0.1	0.0	0.4	0.1	0.2	0.0
Himachal Pradesh	0.2	0.2	0.1	0.9	0.1	0.4
Punjab	0.2	0.1	0.1	0.1	0.1	0.1
Kerala	0.1	4.6	0.1	0.1	0.1	3.7
Manipur	0.0	0.0	0.2	1.3	0.1	0.3
Sikkim	0.0	0.1	0.1	1.2	0.1	0.3
Nagaland	0.1	0.1	0.0	0.1	0.1	0.1
Grand Total	100.00	100.00	100.00	100.00	100.00	100.00

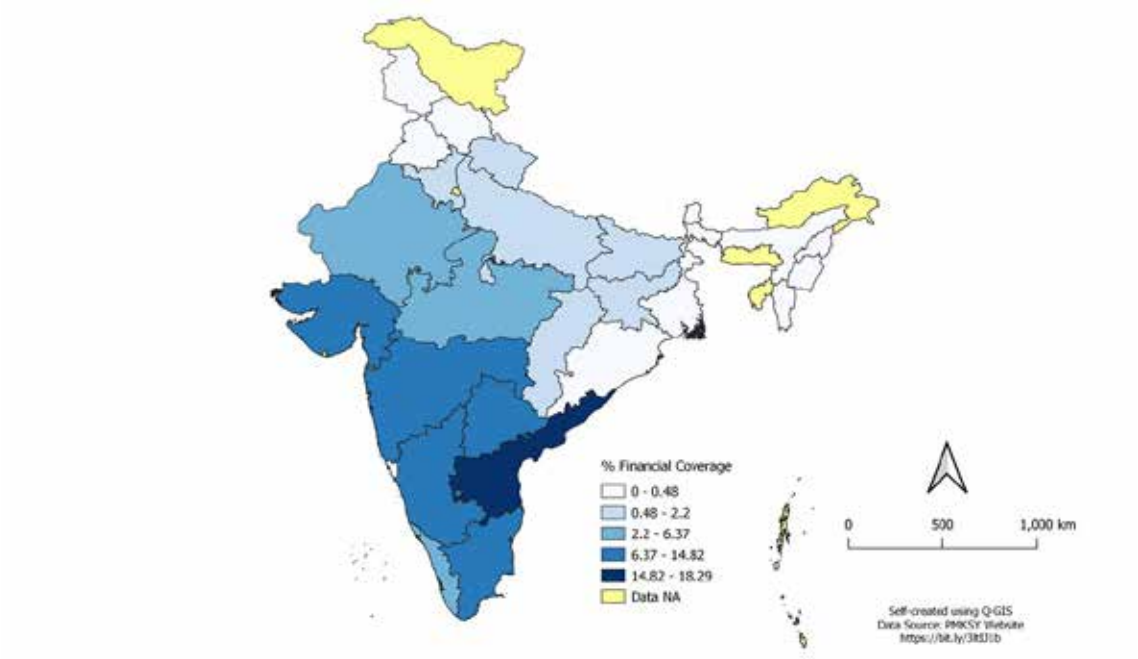
Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019

Figure 2. 6: State-wise percent physical coverage under PDMC from 2015-2020



Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019, Created by Authors

Figure 2. 7: State-wise percent financial coverage under PDMC from 2015-2020



Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019, Created by Authors

Table 2.6 examines the performance of PDMC implementation in the of the 5 sample study states over 2015-2020 by comparing the actual to the target in MI. It shows that there is considerable variation across the states and years – making it a good sample to examine. Madhya Pradesh shows good achievement and substantial overshooting in the final year. Uttar Pradesh performed poorly in the first year but then shows consistent performance. Sikkim and Telangana appear to have achieved the targets in the initial years but not achieved well later. Maharashtra shows variation but improvement towards the end.

Table 2. 6: Percent MI achievement relative to target in sample states.

States	2015-16	2016-17	2017-18	2018-19	2019-20
Madhya Pradesh	80	68	35	0	733
Maharashtra	35	53	63	74	86
Sikkim	100	0	0	0	0
Telangana	101	106	72	34	4
Uttar Pradesh	12	172	70	99	99

Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019

The expenditure per hectare is examined by dividing financial expenditure by physical MI coverage achieved for each state and the results are given in Table 2.7. A GIS map is also presented. The Table shows that Kerala, Himachal Pradesh,

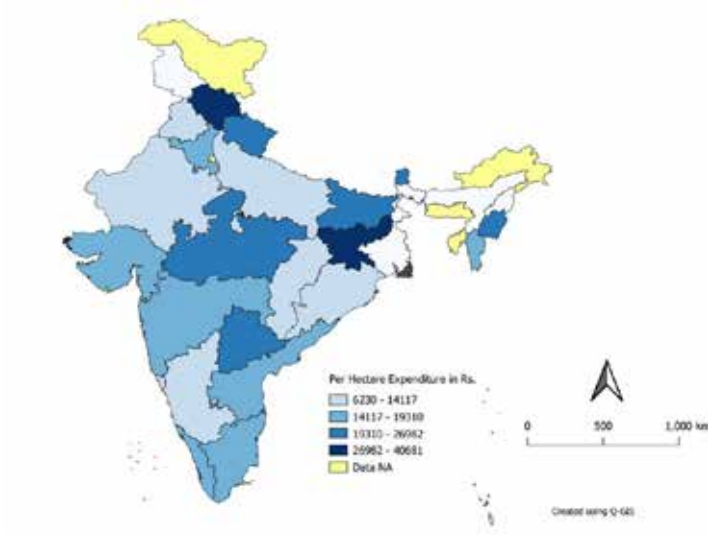
Jharkhand and Bihar have the highest cost/expenditure per hectare on an average in five years of the PDMC scheme. For the sample states of UP, MP, Maharashtra, Telangana and Sikkim it ranges from Rs. 2600 to 9000 per hectare, with least being for Uttar Pradesh. It is seen that states such as Himachal Pradesh, Sikkim, Uttarakhand, Manipur, Bihar are states with highest per hectare financial cost for coverage. There can be several reasons for this. The first three states are hilly states and the subsidies and the operational cost of implementation are higher in hill states. Interestingly the states with the highest physical and financial coverage also have the best performance in terms of cost per hectare. These include Gujarat, Karnataka, Andhra Pradesh, Rajasthan. These states have been promoting MI for a long time as compared to other states. State-wise visualization can be seen in the Figure 2.8 in the Indian map, using the data from the Table 2.7.

Table 2. 7: Expenditure per hectare of MI achievement by states over 5 years

State	2015-16	2016-17	2017-18	2018-19	2019-20	Average of 5 years
Kerala	14,527	7,395	31,780	13,839	4,820,902	977,689
Himachal Pradesh	35,367	29,612	46,457	37,277	54,691	40,681
Jharkhand	32,347	32,195	37,509	31,623	51,941	37,123
Bihar	12,310	5,711	26,143	29,966	60,778	26,982
Uttarakhand	27,282	24,859	23,314	28,808	29,533	26,759
Sikkim	**50,186**	**-**	**-**	**-**	**79,999**	**26,037**
Madhya Pradesh	**15,960**	**25,046**	**36,230**	**17,515**	**21,341**	**23,219**
Manipur	-	-	-	50,000	64,632	22,926
Telangana	**25,688**	**26,612**	**16,016**	**19,348**	**19,784**	**21,490**
Andhra Pradesh	18,881	20,447	18,589	18,594	20,040	19,310
Haryana	30,079	13,506	21,458	19,188	9,162	18,679
Maharashtra	**19,624**	**18,841**	**15,791**	**19,601**	**13,375**	**17,446**
Mizoram	51,764	-	-	-	34,489	17,251
Tamil Nadu	22,057	20,001	16,179	11,963	11,714	16,383
Gujarat	14,595	12,979	15,018	18,698	19,440	16,146
Rajasthan	15,710	24,688	10,432	9,166	10,589	14,117
Punjab	13,182	14,584	16,176	15,801	10,032	13,955
Karnataka	15,230	13,272	11,131	12,081	13,144	12,972
Goa	12,918	12,492	15,995	-	22,101	12,701
Chhattisgarh	9,466	10,294	13,927	14,579	13,438	12,341
Odisha	12,732	10,495	10,731	9,909	10,762	10,926
Uttar Pradesh	**9,630**	**7,468**	**9,058**	**9,452**	**11,968**	**9,515**
Nagaland	-	-	-	-	31,152	6,230
West Bengal	-	-	5,379	2,176	23,111	6,133
Jammu and Kashmir	-	-	-	-	25,800	5,160
Assam	-	-	18,578	-	933	3,902

Note: Bold Highlighted are sample states

Figure 2. 8: State-wise per hectare budgetary expenditure in PDMC (2015-2020)



Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019, Created by Authors

Table 2.8 below shows the compound annual growth rate (CAGR) of physical and financial coverage over the five years of the programme from 2015 to 2020 for various states. The highest growth rate in physical coverage is shown by Uttar Pradesh, and that for expenditure by Bihar. Both states are among top two in the growth rates. UP showed the least coverage under micro irrigation as a share of total irrigated area, and shows high CAGR for the coverage in both physical and financial terms indicating a catching-up. Other top-performing states are Tamil Nadu, Uttarakhand and Haryana.

Table 2. 8: State-wise CAGR of Physical and Financial in 5 years of scheme (in decreasing order of coverage)

States	5 years CAGR in Expenditures in MI	5 years CAGR in Coverage of MI	States	5 years CAGR in Expenditures in MI	5 years CAGR in Coverage of MI
Uttar Pradesh	**1.135**	**1.044**	Odisha	0.198	0.239
Bihar	1.709	0.969	India	0.148	0.152
Tamil Nadu	0.333	0.513	Jharkhand	0.163	0.058
Uttarakhand	0.521	0.497	Andhra Pradesh	0.066	0.053
Haryana	0.172	0.487	Rajasthan	-0.069	0.008
Mizoram	0.315	0.426	Gujarat	0.001	-0.055
Maharashtra	**0.235**	**0.334**	Punjab	-0.168	-0.121
Karnataka	0.275	0.313	Kerala	1.677	-0.162
Chhattisgarh	0.373	0.280	Himachal Pradesh	-0.127	-0.200
Sikkim	**0.391**	**0.267**	**Madhya Pradesh**	**-0.198**	**-0.243**
Goa	0.396	0.254	**Telangana**	**-0.385**	**-0.352**

Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019. Bold Highlighted are sample states

Table 2.9 presents the data on the coverage of different crops in micro irrigation in the study states. The major crops covered under MI for which information is available are vegetables, cotton, pulses, tomato, and sugarcane. Vegetables have by far the highest coverage, substantially coming from Madhya Pradesh, Telangana and Uttar Pradesh. Cotton has a high coverage in Maharashtra. The coverage in water-intensive crops such as sugarcane and banana is the highest in Maharashtra while area brought under micro irrigation in sugarcane in Uttar Pradesh very small. In Maharashtra the farmers are often supported by sugar cooperatives to adopt micro irrigation, and per acre incentive is often given to the farmers for adopting micro irrigation. Finance and subsidy including bank linkages are often managed by sugar cooperative factories, and deductions are made from the final product supplied to the factory. Many farmers also report that MI sugarcane is given priority as it has a better recovery rate of sugar. This makes it a win-win for both the factory and the farmer to adopt MI technology. This indicates that an institutional mechanism that takes care of financing and marketing of products strongly facilitates micro irrigation.

Table 2. 9: State-wise Area coverage under Micro Irrigation for Major Crops from 2015-2020 (in hectares)

Major Crops	Madhya Pradesh	Maharashtra	Sikkim	Telangana	Uttar Pradesh	Total
Vegetables	89500	17483	-	72441	32793	212216
Cotton	1264	92185	-	2631	-	96080
Pulses	4360	29785	-	148	6613	40906
Tomato	13963	891	-	21595	2658	39106
Sugarcane	22	17945	-	13599	3238	34805
Fruits crops	4223	26173	-	3683	14	34093
Soybean	-	26730	-	-	-	26730
Banana	5928	6869	-	379	224	13399
Wheat	3013	2577	-	-	7376	12966
Bajra (Pearl millet)	-	376	-	3	1472	1851
Spices/Herbs	573	6	220	-	462	1261
Groundnut	-	392	-	156	54	602
Paddy	-	-	-	-	459	459
Cardamom (Large)	-	-	220	-	-	220
Other Crops	67936	380493	773	63486	117545	630233

Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019

Micro Irrigation Coverage in relation to Potential for Micro Irrigation

Internationally, many countries recognized the merit of micro irrigation in since the 1980s, and many countries with poor water availability have developed micro irrigation to manage within the limited water. A well-known such country is Israel which is very poorly endowed in water. There, within the irrigated area, they have almost 100 percent adoption of micro irrigation. The share of irrigated area under micro irrigation by country for the top 15 adopter countries is given in Table 2.10. It shows that UK, Finland, Slovakia and Israel are on top in adoption of micro irrigation as a share of irrigated area and have converted all their irrigated area under MI (ICID, 2019). Relative to this, share under MI for India is low at 13.5 percent.

Table 2. 10: Top 15 Countries with % MI in net irrigated area

Ranks	Country	Share of MI of Total Irrigated area (%)	Reference Year	Ranks	Country	Share of MI of Total Irrigated area (%)	Reference Year
1	UK	100	2005	9	South	77	2007
2	Finland	100	2010	10	Spain	73.7	2015
3	Slovak	99.9	2000	11	Moldova	70.2	2012
4	Israel	99.6	2000	12	Canada	65.4	2004
5	Germany	98.1	2005	13	Italy	57.1	2013
6	Malawi	88.4	2000	14	Russia	56.6	2012
7	Hungary	87.3	2008	15	USA	56.5	2009
8	Brazil	77.3	2013	38	India	13.5	2020

Source: ICID, 2019

Where do the Indian states stand on this measure? Table 2.11 shows the top and bottom ten states in percent micro irrigation within the net irrigated area. It is found that Sikkim, Andhra Pradesh and Maharashtra are at the top. (Note that irrigated area is actually very limited in Sikkim.) Two of the study sample states Sikkim and Maharashtra are in the top ten, while UP, MP have among the least share under MI in India. Uttar Pradesh has crops such as sugarcane, wheat and rice which are also water demanding crops, and study can help examine the benefits of MI in the context.

Table 2. 11: States according to their performance in MI adoption- Ten highest and lowest states MI share of net irrigated area

S. No	State (Top 10)	% of Net-Irrigated	State (Bottom 10)	% of Net-Irrigated
1	**Sikkim**	**69.9%**	**Uttar Pradesh**	**0.5%**
2	Andhra Pradesh	46.4%	Punjab	1.2%
3	**Maharashtra**	**43.5%**	West Bengal	1.7%
4	Karnataka	29.5%	Uttarakhand	1.7%
5	Gujarat	26.9%	Bihar	3.8%
6	Rajasthan	23.4%	**Madhya Pradesh**	**5.1%**
7	Haryana	19.9%	**Telangana**	**5.8%**
8	Chhattisgarh	19.4%	Himachal Pradesh	7.2%
9	Tamil Nadu	14.8%	Kerala	7.8%
10	Jharkhand	14.2%	Odisha	8.8%
India 13.5%				

Source: Ministry of Agriculture and Farmer's Welfare, 2018, Bold highlighted states are sample states of the study.

Not all the area under irrigated area may have potential to be brought under MI in India, since all land and crops may not suited for MI. In this context, Raman, (2010) has calculated the potential MI area for some states of India as shown in Table 2.11. The study calculated MI potential using the secondary data on cropped area, irrigated area, source of irrigation, and crop suitability to MI. For example, rice fed on canal irrigation is not included in MI potential, and several plantation crops such as tea, coffee, oil palm are also included since they were not supported under the government schemes of micro irrigation. The estimates are now somewhat outdated and may be under-estimated. Thus, some states such as Andhra Pradesh and Chhattisgarh have crossed the MI potential by over 41 percent (see Table 2.11), indicating underestimation. Conversation with some experts of Jain Irrigation in Jalgaon indicates that drip technology is now so advanced that it is amenable to almost all the crops and geographies in India. So the potential area for micro irrigation may now be much greater.

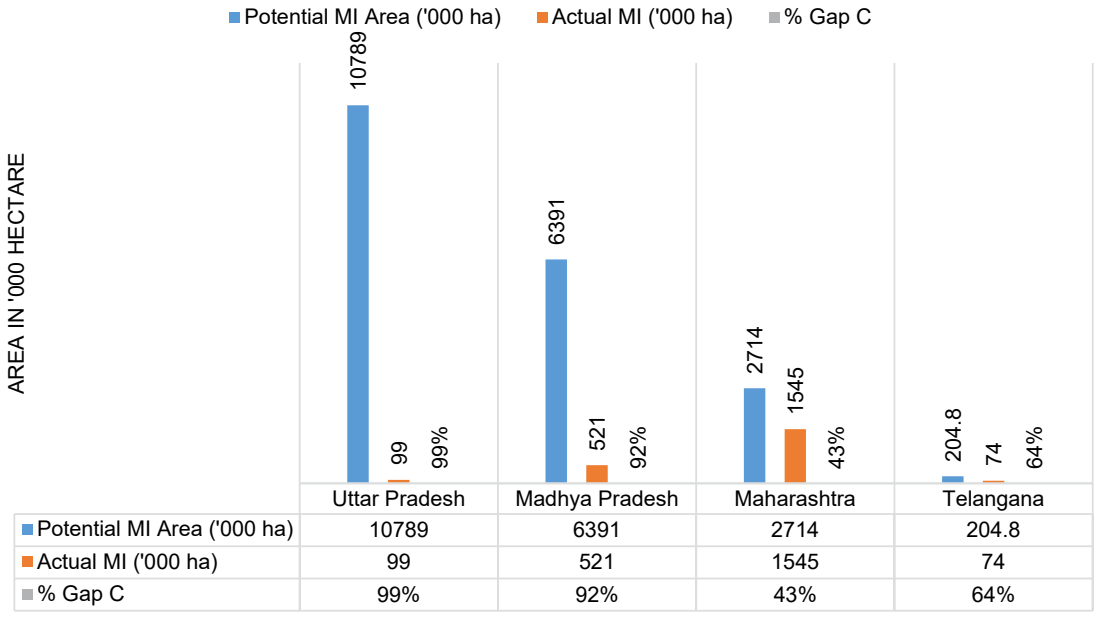
Findings in Table 2.12 also show that the UP (10 million ha) and MP (6 million ha) are two states with the highest potential for MI and the two states have achieved less than 5 percent of the potential. Since data on MI-potential for Sikkim and Telangana was not available, they could not reflect much about the two states.

Table 2. 12: Percent gap in MI adoption of potential in selected states

S. No	State	Potential MI Area ('000 ha)	Actual MI area as of 2018 ('000 ha)	% Gap	Area under MI as a % of total Groundwater Irrigated agriculture
1	Uttar Pradesh	10789	99	99%	1.2%
2	Madhya Pradesh	6391	521	92%	5.1%
3	Rajasthan	5658	1837	68%	23.4%
4	Punjab	3378	48	99%	1.2%
5	Gujarat	3278	1281	61%	26.9%
6	Maharashtra	2714	1545	43%	43.5%
7	Haryana	2390	595	75%	19.9%
8	Bihar	1850	115	94%	3.8%
9	Karnataka	1442	1287	11%	29.5%
10	West Bengal	1232	53	96%	1.7%
11	Andhra Pradesh	1117	1585	-42%	46.4%
12	Tamil Nadu	702	503	28%	14.8%
13	Orissa	219	113	49%	8.8%
14	Kerala	214	31	85%	7.8%
15	Chhatishgarh	211	297	-41%	19.4%
16	Jharkhand	157	32	79%	14.2%
17	Himachal Pradesh	115	9	92%	7.2%
18	Nagaland	53	5	90%	6.0%
19	Goa	11	2	79%	5.5%

Source: Raman 2010, Kuppannan & Raman, 2012), (MoA, 2018)

Figure 2. 9: MI area actual vs estimated potential

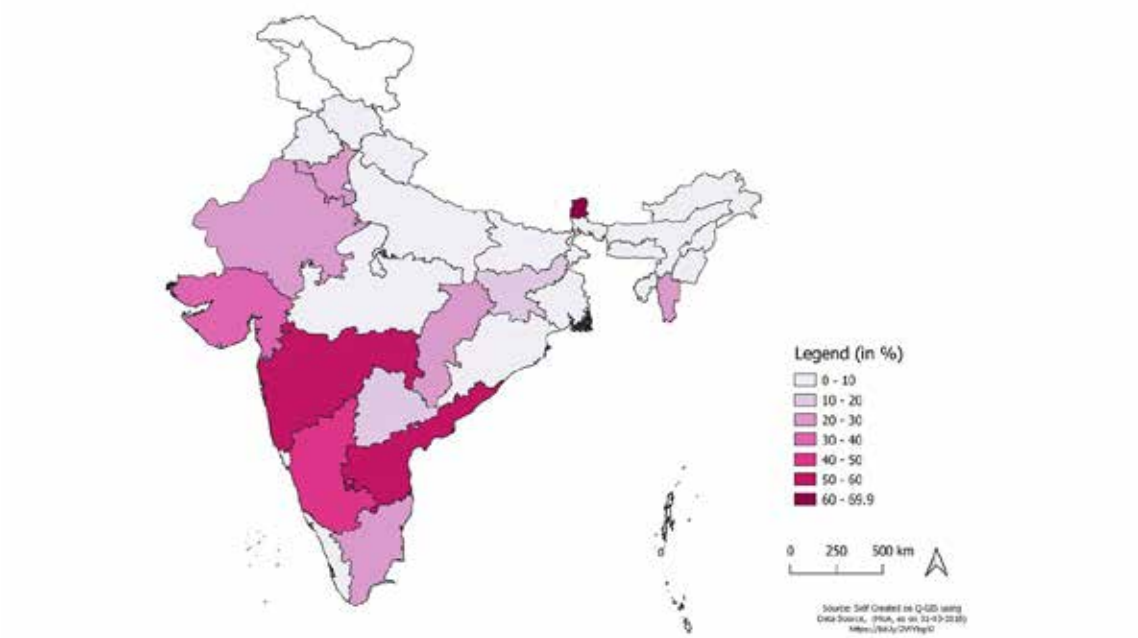


Note: Analysis based on data in Raman 2010, Kuppannan & Raman, 2012), (MoA, 2018)

Note: Data for Sikkim was not available for the potential area in Raman 2010, so not included in the analysis

Figure 2.10 shows the percentage of MI irrigated area compared to estimated potential in the different states of India in a GIS map. It shows that the states of Maharashtra, Sikkim, Andhra Pradesh, and Karnataka have a high percentage achievement in MI as compared to potential.

Figure 2. 10: State-wise percent MI area relative to MI potential



Source: Pradhan Mantri Krishi Sinchayee Yojana, 2019, Created by Author

CHAPTER 03

Sampling and Sample Profile

To carry out an in-depth examination of micro irrigation under the different objectives of the study, a substantial amount of primary data was collected through a sample survey of farmers. The sampling plan followed in the study is described in this section. As described in the methodology section above, five states across the country were selected for the study, namely Uttar Pradesh, Madhya Pradesh, Maharashtra, Telangana and Sikkim. It was planned to sample and cover 120 farmers in each state including the 96 adopters and 24 non-adopters of micro irrigation. The plan of sampling followed within each state is described in Table 3.1 below. In each state two districts that had micro irrigation and different cropping and agro-ecology were selected in consultation with the relevant departments/ agencies of the government. On similar lines, in each district, two blocks/ talukas were selected. Then in each block/ taluka, three villages or clusters were selected. In each village/ cluster ten farmers were sampled, eight MI adopters and two non-adopters assuring diversity in landholding and socio-economics. Thus in each state two districts, 4 blocks/ talukas, 12 villages/ clusters, 120 farmers, including 96 adopters and 24 non-adopters were planned to be covered in the sample survey. Thus, across five states 600 farmers were planned to be covered. A special questionnaire was developed to collect all the relevant information.

Table 3. 1: Sampling Plan in Each State

State												Total
District 1						District 2						2 districts
Block/Taluka 1			Block/Taluka 2			Block/Taluka 3			Block/Taluka 4			4 blocks
Villages/ Clusters												
1	2	3	4	5	6	7	8	9	10	11	12	12 Villages/ Clusters
Farmers												
10	10	10	10	10	10	10	10	10	10	10	10	120 Farmers
Adopters												
8	8	8	8	8	8	8	8	8	8	8	8	96 Adopters
Non-Adopters												
2	2	2	2	2	2	2	2	2	2	2	2	24 Non-Adopters
Total												= 120 Farmers

Table 3.2 below gives the details of the actual/ final sample coverage with the names of the states and districts. The Table shows that the survey covered 500 MI adopters and 121 non-adopters. Of the adopters, 282 reported drip irrigation, 216 reported sprinkler irrigation, and 2 reported both. The Table 3.2 shows that the primary data collection survey covered a total of 621 farmers across 95 villages, 10 districts and 5 states.

Table 3. 2: Sample coverage

State Name		District surveyed	No. of Village	No. of Adopters surveyed	Drip	Sprinkler	Both	No. of Non-Adopters	Total	State Total
Uttar Pradesh		Sonbhadra	6	48	16	32	0	12	60	120
		Saharanpur	7	48	28	20	0	12	60	
Madhya Pradesh		Dhar	6	48	48	0	0	12	60	120
		Sagar	17	48	0	48	0	12	60	
Maharashtra		Pune	14	52	51	0	1	12	64	141
		Jalgaon	19	64	64	0	0	13	77	
Telengana		Nizamabad	7	48	9	38	1	12	60	120
		Nalgonda	10	48	48	0	0	12	60	
Sikkim		East-Sikkim	4	48	15	33	-	12	60	120
		South-Sikkim	5	48	3	45	-	12	60	
Overall Total	**5**	10	95	500	282	216	2	121	621	621

The following sections and chapters below examine the data and provide the findings from the sample of MI adopter farmers. The non-adopter farmer data is examined in a separate chapter below.

Table 3.3 and Figure 3 below shows the distribution of the sample farmers based on the age of the farmer/ primary respondent. The findings show that most of the farmer respondents are of 30 to 50 years in age, with very few younger farmers and many over 50 years age. This indicates that the adopters are not just young farmers but are mainly of middle age or older. This indicates a wider interest and adoption.

Table 3. 3: Age of adopters

Age Years	Frequency	Percent (%)
<20	0	0
20-30	36	7
30-40	135	27
40-50	150	30
50-60	109	22
>60	70	14
Total	500	100

Figure 3.1: Age of adopters

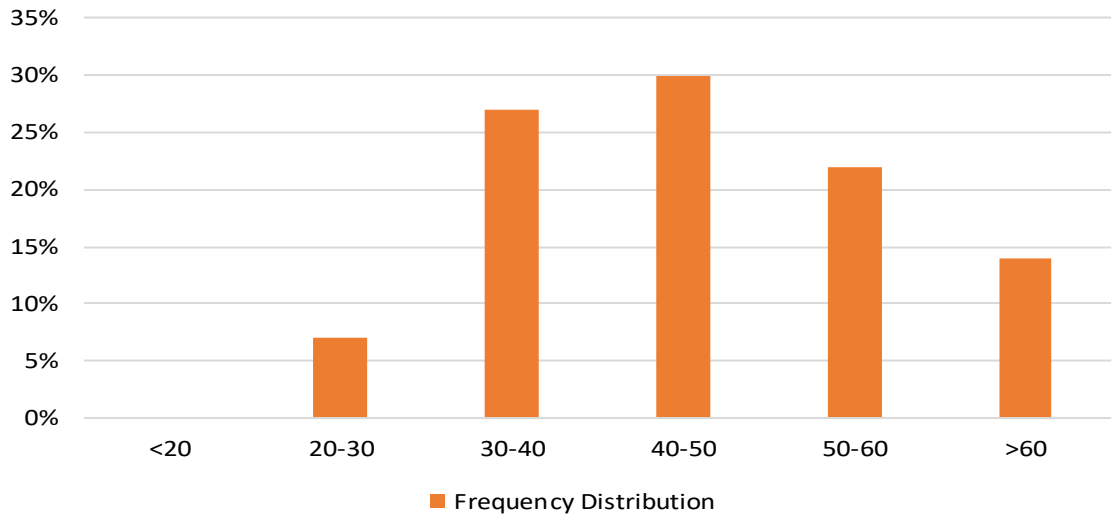


Table 3.4 provide the distribution of the adopters in terms of education. They show that almost 50 percent of the adopters have at least a 10th standard education or more. However, a large percentage have less education, and 17 percent are illiterate. The findings indicate that education may be conducive but is not necessity in the adoption of MI, and a large number of adopters are not even 10th pass and many are illiterate.

Table 3. 4: Education of adopters

Education	Frequency	Percent
Illiterate	87	17.4
Primary	76	15.2
Middle	89	17.8
10th	102	20.4
12th	62	12.4
Graduate	65	13
Post-Graduate	17	3.4
Technical	2	0.4
Total	500	100

Table 3.5 show the findings on the source of water available for irrigation / micro irrigation to the adopter farmers. They show that the major source of water is tubewell followed by wells. Thus, groundwater is the major source of water for micro irrigation as indicated by almost 70 % of the farmers. Some also indicate other sources such as streams and storage tank. Surface sources and direct sourcing from water conservation structures are not very common, though they may be indirectly contributing through groundwater recharge.

Table 3. 5: Water sources

Source	Frequency	Percent (%)
Canal	14	3
Canal-Lift	5	1
River-Lift	29	6
Tubewell	241	48
Well	104	21
Tank	1	0
Farm Ponds	1	0
Check dam	5	1
Any other*	100	20
Total	500	100

*Any other: including mountain streams and storage tanks used in Sikkim.

Table 3.6 shows the findings regarding the reported water situation for farming on adopter farms. It shows that whereas 62 percent report sufficient water, 36 percent report scarcity though very few have acute scarcity. The majority of adopter farmers by and large seem to have sufficient water for irrigation.

Table 3. 6: Water situation for farming

Situation	Frequency	Percent
Excess Water	12	2
Sufficient Water	312	62
Occasional Scarcity	146	29
Scarcity	27	5
Acute Scarcity	3	1
Total	500	100

Table 3.7 shows the type of soil on the farm and Table 3.8 shows the kind of terrain reported by the respondents. The Tables indicate that the most of the farmers have medium to heavy soil and not light soil, and most of the farms have a flat terrain. But 20 percent of the farmers undertake micro irrigation even on a hilly terrain.

Table 3. 7: Type of Soil

Soil Type	Frequency	Percent (%)
Light	8	2
Medium	319	64
Heavy	173	35
Total	500	100

Table 3. 8: Type of Terrain

Terrain	Number	Percent (%)
Flat	354	71
Up & Down	46	9
Hilly	100	20
Total	500	100

The Table 3.9 below provides the findings on when the farmers first started using micro irrigation. The Table shows that most of the farmers have started using micro irrigation in the recent years. 33% of the farmers have started using micro irrigation only in the last year where as 16% have started using two years ago, and 25% have started using three years ago. However, there are some farmers who started using micro irrigation up to 10 years ago, that is 11%. Thus most have adopted MI less than 3 years ago, thought a few adopted earlier.

Table 3. 9: Year started using micro irrigation

Years	Frequency	Percent (%)
Current Year (2019-20)	8	1.6
Last Year (2018-19)	166	33.2
2 years ago	83	16.6
3 years ago	125	25.0
5 years ago	62	12.4
Up to 10 years ago	55	11.0
More than 10 years	1	0.2
Total	500	-

The Table 3.10 below provides findings on the availing of subsidy by the farmers. It indicates that almost all the farmers who have adopted micro irrigation have availed of subsidy, that is 98% of the farmers. Thus almost all farmers having MI have used the subsidy support.

Table 3. 10: Whether Availed of Subsidy

Response	Frequency	Percent (%)
Yes	491	98
No	9	2
Total	500	100

The Table 3.11 below gives the profile of the MI sample farmers with respect to the farm size, average holding and the extent of micro irrigation/ irrigation.

It shows that the sample is spread across farm sizes, with 28 percent marginal farmers, 27 percent small, 41 percent medium and 4 percent large. It shows that the overall average landholding is 2.74 hectares which is around the small to medium farmer range. Within the farm land of the MI adopters, 71 percent is found to be under micro irrigation, 23 percent under non-micro irrigation and 6 percent unirrigated. Those with smaller land holding sizes have a larger percentage of land under micro irrigation but they also have a larger percentage of land unirrigated. Within micro irrigation, about 60 percent is drip and 40 percent is sprinkler, except that the marginal farmers show somewhat more land under sprinkler than drip. The findings indicate that those adopting MI put most of their irrigation land under micro irrigation and the smaller farmer put even a larger proportion.

Table 3. 11: Land Area (Hectares) Mean

Farm Size	Sample Farmers	Percent| Sample Farmers	Land Average (ha)	Total Micro %	% of Micro		Non-Micro	Un-irrigated
					Drip	Sprinkler		
Marginal	141	28.2	0.67	81.5	43.5	56.5	8.6	9.9
Small	135	27.0	1.47	81.4	59.6	40.4	15.9	2.7
Medium	205	41.0	3.95	70.1	59.7	40.3	23.1	6.8
Large	19	3.8	13.95	64.7	60.4	39.6	35.6	3.6
Total	500	100.0	2.74	71.6	58.5	41.5	23.4	5.8

CHAPTER 04

Cropping Pattern and its Change with Micro Irrigation

The Table 4.1 below reports the findings on the major crops reported by micro irrigation adopter farmers. Among the most frequently crops are wheat and cotton, but there is substantial variation across states. Wheat is mainly reported in UP and MP and Sugarcane is reported in UP and Maharashtra. Chickpea is reported under micro irrigation in MP and Telangana and Cotton is reported under micro irrigation in MP, Maharashtra and Telangana. Chilli is reported under MI in UP and MP, and Soybean as reported in Telangana. Thus there is a large amount of diversity across states in the crops that are brought under micro irrigation. Whereas some crops such as wheat and soybean are irrigated through sprinkler irrigation others such as sugarcane, cotton and banana are irrigated through drip. MI is seen in both Kharif and Rabi seasons as well as long duration crops. In Sikkim the only crops micro irrigated are vegetable crops of cauliflower and broccoli.

Table 4. 1: Crops under MI by State in the Sample Farmers – reporting frequency

Crops	UP	MP	Maharashtra	Telengana	Sikkim	Total	Percent	Type of MI	Season
Wheat	53	48	1	0	0	102	15.0	Sprinkler	Rabi
Sugarcane	28	0	52	2	0	82	12.0	Drip	All year
Chickpea	0	45	0	35	0	80	11.7	Drip/Sprinkler	Rabi
Cauliflower	0	0	0	0	90	90	13.2	Drip/Sprinkler	Rabi
Cotton	0	22	36	44	0	102	15.0	Drip	Kharif
Broccoli	0	0	0	0	76	76	11.1	Drip/Sprinkler	Rabi
Banana	0	3	43	9	0	55	8.1	Drip	Perennial
Chilli	22	33	1	0	0	56	8.2	Drip/Sprinkler	Kharif/Rabi
Soybean	0	1	0	38	0	39	5.7	Sprinkler	Kharif
Total	103	152	133	128	166	682	100.0		

The Table 4.2 below shows all the crops that are taken up by the MI adopter farmers. It shows that the most commonly reported crops are wheat, cotton and beans. The Table shows the distribution of the area by irrigation type. It shows, for example that wheat is largely grown under sprinkler irrigation whereas sugarcane is largely under drip irrigation. Chickpea and cauliflower are under sprinkler

irrigation whereas cotton is grown under drip irrigation. Similarly, banana and chilli are grown under drip irrigation where is peas and groundnut are largely grown under sprinkler irrigation. The horticulture crops of cauliflower broccoli and cabbage are grown through sprinkler irrigation whereas orange is grown under drip irrigation. Thus, the kind of micro irrigation varies substantially by crop. The Table also shows that a large number of different crops can be and are brought under micro irrigation, showing wide adoption across crops when adopted. Fertigation through MI is very common in sugarcane, cotton, banana, chilli, ginger and a few vegetable crops, but not in others.

Table 4. 2: Crops reported, area by irrigation type and Fertigation

Crop name	No. of reporting farmers	Mean area under the crop	Distribution of Area					MI Fertigation Adopters (%)
			% Area under the crop	% Drip area	% Sprinkler area	% Irrigated Non-Micro area	% Un-irrigated area	
Wheat	102	1.6	100	-	96	4	-	48
Sugarcane	82	1.6	100	95	-	3	0	98
Chickpea	80	2.4	100	7	90	3	0	19
Cauliflower	90	0.1	100	1	85	14	-	0
Cotton	102	2.8	100	69	-	17	16	73
Broccoli	76	0.1	100	1	91	8	-	0
Banana	55	3.0	100	94	-	6	0	85
Chilli	56	0.7	100	78	7	15	-	89
Soybean	39	3.5	100	-	95	5	-	0
Cabbage	62	0.1	100	3	84	13	-	0
Ginger	44	0.5	100	85	-	5	10	80
Beans	106	0.2	100	39	36	25	-	6
Pea	75	0.1	100	2	75	23	-	3
Bitter Gourd	16	0.7	100	96	-	4	-	100
Tomato	53	0.6	100	36	6	62	-	57
Orange	24	0.7	100	83	-	-	17	0
Cowpea	4	0.3	100	55	-	45	-	100
Groundnut	4	3.9	100	13	87	13	-	0
Capsicum	7	0.2	100	74	-	26	-	43
Red chilli	5	1.5	100	100	-	-	-	40

The Table 4.3 below examines the impact of drip irrigation on the increase in cropped area, based on the responses obtained in the survey from the farmers. The results indicate that on the whole for most crops there is no impact on area due to drip irrigation but for some crops such as soybean, broccoli, chilli, ginger

and banana a positive impact is indicated by a large number of respondents. By across crop average, 64 percent indicate no impact on area, and 34 percent indicate an increase in area, with about 2 percent showing a decrease in area perhaps due to shift to other crops.

Table 4. 3: Change in area due to micro irrigation in the different crops

Crops	No. of farmers reporting	Change in Area due to Micro Irrigation (%)					Mean
		5	4	3	2	1	
Wheat	102	7.8	20.6	71.6	0	0	3.4
Sugarcane	82	3.7	8.5	82.9	4.9	0	3.1
Chickpea	80	12.5	37.5	40	10	0	3.5
Cauliflower	90	0	34.4	65.6	0	0	3.3
Cotton	102	2.9	23.5	62.7	8.8	2	3.2
Broccoli	76	0	38.2	61.8	0	0	3.4
Banana	55	3.6	27.3	61.8	7.3	0	3.3
Chilli	56	8.9	30.4	60.7	0	0	3.5
Soybean	39	15.4	30.8	53.8	0	0	3.6
Cabbage	62	0	32.3	67.7	0	0	3.3
Ginger	44	15.9	25	59.1	0	0	3.6
Beans	106	0	19.8	80.2	0	0	3.2
Pea	75	0	12	88	0	0	3.1
Bitter Gourd	16	43.8	25	31.3	0	0	4.1
Tomato	53	3.8	24.5	71.7	0	0	3.3
Orange	24	0	0	100	0	0	3.0
Cowpea	4	0	50	50	0	0	3.5
Groundnut	4	0	25	75	0	0	3.3
Capsicum	7	0	42.9	57.1	0	0	3.4
Red chilli	5	40	20	40	0	0	4.0
Average		7.9	26.4	64.1	1.6	0.1	3.4

Scale: Large Increase =5 Increase =4 No Change =3 Decrease =2 Large Decrease =1

The Table 4.4 below examines the impact of drip irrigation on the crops yields, based on the responses obtained in the survey from the farmers. The positive impact on yield is widely indicated and confirmed across most of the crops. In particular, there is a positive impact on the yields is widely indicated in wheat, chickpea, soybean, cotton, sugarcane, chilli, banana and ginger. Thus, the findings indicate that there is a positive impact is very commonly seen in increase of the yields of the crops due to micro irrigation. On an average across crops responses, 20 percent indicate no change in yields, whereas 55 percent indicate increase in yields, and 24 percent indicate large increase in yields.

Table 4. 4 Change in yield due to micro irrigation in different crops

Crops	No. of farmers reporting	Change in Yield due to Micro Irrigation (%)					Mean
		5	4	3	2	1	
Wheat	102	5.9	94.1	0	0	0	4.1
Sugarcane	82	17.1	80.5	2.4	0	0	4.1
Chickpea	80	26.3	71.3	2.5	0	0	4.2
Cauliflower	90	0	62.2	37.8	0	0	3.6
Cotton	102	19.6	70.6	9.8	0	0	4.1
Broccoli	76	0	69.7	30.3	0	0	3.7
Banana	55	12.7	70.9	16.4	0	0	4.0
Chilli	56	21.4	75	3.6	0	0	4.2
Soybean	39	25.6	74.4	0	0	0	4.3
Cabbage	62	0	64.5	35.5	0	0	3.6
Ginger	44	50	27.3	22.7	0	0	4.3
Beans	106	0	50	50	0	0	3.5
Pea	75	0	66.7	33.3	0	0	3.7
Bitter Gourd	16	75	25	0	0	0	4.8
Tomato	53	5.7	62.3	32.1	0	0	3.7
Orange	24	29.2	8.3	45.8	16.7	0	3.5
Cowpea	4	25	75	0	0	0	4.3
Groundnut	4	75	0	25	0	0	4.5
Capsicum	7	42.9	0	57.1	0	0	3.9
Red chilli	5	40	60	0	0	0	4.4
Average		23.6	55.4	20.2	0.8	0.0	4.0

Scale: Large Increase =5 Increase =4 No Change =3 Decrease =2 Large Decrease =1

CHAPTER 05

Changes in Incomes, Inputs and Farm Economics with Micro Irrigation

This chapter reports the findings on the changes in the crop economics due to micro irrigation, including production, prices, revenue/ gross income, various inputs and costs, and the net profits, by comparing the with MI vs without MI numbers reported by the farmers based on recall. This is done by major crops reported, also giving the overall averages.

Sugarcane, Banana and Wheat

The Table 5.1 below gives the findings on the changes with MI in the area, production, and revenue for sugarcane, banana, wheat and all crops. The Table indicates that there is 6% increase in the sugar cane area as well as wheat area, but a substantial increase in the banana area of 87%. Overall the crop area increases by 30%. In production, there is a 35 to 40% increase in the production of sugarcane and wheat. However, there is a substantial 216% increase reported in the production of bananas. This comes both from area and yield increase. Overall there is a production increase of 88% in all crops. The market price also shows some increase and this is 12% for sugarcane, 40% for banana and 5% for wheat. Overall there is a 17% increase in the prices. The result of this is a large increase in the sales revenue of 56% for sugarcane, 387% for banana, and 43% for wheat. For all crops the sales revenue increases by 166%. Thus, there is a substantial impact of micro irrigation on the sales revenue reported, coming from area, production and price increases.

Table 5. 1: Changes in area, production and revenue

Item	Sugarcane			Banana			Wheat			All Crops Average		
	No. reporting 82			No. reporting 50			No. reporting 99					
	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change
Area	1.49	1.42	6	2.93	1.57	87	1.53	1.44	6	2	1	30
Production (quantity) in quintals	1994	1422	40	1797	568	216	64	47	35	465	247	88
Mean Market Price	290	260	12	879	629	40	1793	1712	5	3176	2719	17
Total Sales Revenue	566185	363376	56	1676850	344473	387	115335	80860	43	385547	145169	166

In the shift to micro irrigation there is also an increase in the cost of inputs reported. The results for seed, fertilizer, farm yard manure (FYM) and pesticides are given in the Table 5.2 below. The Table 5.2 shows that the input costs increase in the range of 9 to 19% in case of sugarcane, but the increase substantially in the range of 134 to 253% in the case of banana. In the case of wheat whereas the seed, fertilizer and FYM costs increased by 15 to 22% the pesticide cost reduces by 34%. Overall there is 122% increase in seed cost, 78% increase in fertilizer cost, 79% increase in FYM cost, and 72% increase in pesticide costs. The findings indicate that with micro irrigation, because of the improved and assured good cropping conditions, the farmers tend use more and better inputs resulting in higher input costs.

Table 5. 2: Changes in Input Costs

Item	Sugarcane			Banana			Wheat			All Crops (Average)		
	No. reporting 82			No. reporting 50			No. reporting 99					
	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change
Seeds/ Plants cost	26902	23840	13	139431	39555	253	7813	6429	22	25305	11393	122
Fertilizer cost	48625	42377	15	189410	77966	143	8744	7589	15	43710	24538	78
Farm Yard Manure/ Organic cost	36580	30801	19	109590	46904	134	3380	2767	22	22441	12505	79
Pesticides cost	16265	14927	9	40485	13722	195	2085	3159	-34	19275	11225	72

The results on changes in irrigation costs are given in the Table 5.3 below. The results indicate that overall the electricity cost reduces by 6%, the water charges reduce by 13%, and the hours of pumping reduce by 33%. There is some increase in the diesel cost, and the number of irrigations – perhaps because these are easily possible in micro irrigation. The largest reduction is seen in the case of sugarcane where the water charges reduced by 69% and the hours of pumping reduces by 53%. This is a notably positive result of water savings in a high water using crop.

Table 5. 3: Changes in Irrigation Costs

Item	Sugarcane			Banana			Wheat			All Crops (Average)		
	No. reporting 82			No. reporting 50			No. reporting 99					
	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change
Electricity cost	6036	6801	-11	10868	10490	4	3324	3114	7	3676	3901	-6
Diesel cost	6411	8728	-27	500	N.A	0	5995	4182	43	5817	5943	-2

Item	Sugarcane			Banana			Wheat			All Crops (Average)		
	No. reporting 82			No. reporting 50			No. reporting 99					
	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change
Water Charges paid	2721	8750	-69	1816	2767	-34	1140	500	128	4915	5653	-13
No of irrigations	40	37	8	130	97	34	5	5	-4	32	24	34
Hours of pumping	180	380	-53	540	626	-14	112	228	-51	164	244	-33

The Table 5.4 below shows the changes in other costs and profits. Overall it indicates that there is a 53% increase in farm power and equipment cost and an increase in labour mandays by 27% and labour cost by 53%. The marketing and other costs also increase leading overall to 93% increase in the total cost. However, because of the substantial increase in revenue, the profits show an increase by 359%. The profit increase is 153% in the case of sugarcane, 105% in the case of wheat, and substantial 3095% in the case of banana. It may be noted that because of historical costs without MI and a longer history of adoption in banana, the increase may be exaggerated in the case of banana.

Table 5. 4: Changes in Other Costs and Profits

Item	Sugarcane			Banana			Wheat			All Crops (Average)		
	No. reporting 82			No. reporting 50			No. reporting 99					
	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change
Farm power & Equipment cost	22955	20385	13	62443	34983	78	8819	7844	12	18529	12075	53
Total man-days	218	286	-24	526	351	50	87	98	-11	166	130	27
Labour cost	56334	78928	-29	162246	83576	94	18182	19787	-8	46858	30674	53
Marketing cost	22763	20137	13	68246	29200	134	1627	1228	32	14106	7322	93
Other costs	9570	13046	-27	71600	0	0	264	314	-16	12991	3145	313
Total Cost	222003	227326	-2	753295	315566	139	54270	51131	6	171319	98534	74
Net Profit/ Income	344183	136051	153	923555	28907	3095	61065	29728	105	214227	46635	359

Chickpea, Cotton and Cauliflower

The Table 5.5 below reports on the area, production and revenue changes in the case of chickpea, cauliflower and cotton. Whereas the area of chickpeas and cauliflower increases by 21 and 30%, the area under cotton falls by 11% - this may be because of a shift to other crops. In the case of production there is a substantial

increase of 36 to 95% in all the crops, with an overall increase of 88%. There is also a price increase ranging from 14 to 25%. The overall result is a revenue increase ranging from 55% to 145% across these crops. As indicated above, overall there is 166% increase in the revenue of all crops. Thus, substantial increases in revenue are reported in all crops even where the area reduces.

Table 5. 5: Changes in area, production and revenue

Item	Chickpea			Cauliflower			Cotton			All Crops (Average)		
	No. reporting 71			No. reporting 69			No. reporting 68					
	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change
Area	2.38	1.97	21	0.14	0.11	30	2.05	2.3	-11	2	1	30
Production (quantity) in quintals	52	27	95	7	5	36	59	41	43	465	247	88
Mean Market Price	4293	3464	24	3786	3333	14	4990	3979	25	3176	2719	17
Total Sales Revenue	226629	92614	145	26566	17121	55	296400	165226	79	385547	145169	166

The Table 5.6 below gives the changes in the cost of inputs for chickpea, cauliflower and cotton. It shows that whereas the seed cost increases in every case in the range of 19 to 74%, the fertilizer cost increases in chickpea but falls in the case of cotton. The FYM cost reduces by 26% in the case of chickpea, but increases for cauliflower and cotton. The pesticide cost increases substantially by 129% in the case of chickpea, but falls by 4% in the case of cotton. This is very significant since cotton uses large quantities of pesticide. Overall as indicated above there is 122% increase in the seed cost, 78% increase in fertilizer cost, 79% increase in FYM cost and 72% increase in pesticide cost. But there is considerable variation across crops.

Table 5.6: Changes in Input Costs

Item	Chickpea			Cauliflower			Cotton			All Crops (Average)		
	No. reporting 71			No. reporting 69			No. reporting 68					
	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change
Seeds/ Plants cost	11521	7022	64	5098	2925	74	10098	8504	19	25305	11393	122
Fertilizer cost	9595	5684	69	N.A	N.A	0	22319	23108	-3	43710	24538	78
Farm Yard Manure/ Organic cost	6083	8250	-26	1958	1190	65	21048	14331	47	22441	12505	79
Pesticides cost	14597	6379	129	N.A	N.A	0	21694	22651	-4	19275	11225	72

The Table 5.7 below shows that in the case of irrigation cost, no changes indicated in the case of cauliflower but changes are reported for chickpea and cotton. In the case of chickpea, the electricity cost and the diesel cost reduce, but the number of irrigations and the hours of pumping increase. In the case of cotton there is a reduction in the electricity cost, increase in the number of irrigation, but a substantial reduction of 52% in the hours of pumping. This is very significant since cotton is a major crop and this would amount to substantial saving in water.

Table 5.7: Changes in Irrigation Costs

Item	Chickpea			Cauliflower			Cotton			All Crops (Average)		
	No. reporting 71			No. reporting 69			No. reporting 68					
	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change
Electricity cost	1562	2206	-29	N.A	N.A	0	2607	3180	-18	3676	3901	-6
Diesel cost	7689	9406	-18	N.A	N.A	0	N.A	N.A	0	5817	5943	-2
Water Charges paid	2940	250	1076	N.A	N.A	0	15875	16000	-1	4915	5653	-13
No of irrigations	12	9	27	9	9	0	26	19	34	32	24	34
Hours of pumping water for irrigation	63	49	27	N.A	N.A	0	60	126	-52	164	244	-33

The Table 5.8 below gives the changes in other costs and in profits in case of chickpea, cotton, and cauliflower. The results show that there is an increase in the farm power cost in every crop ranging from 22 to 60%. The number of mandays and labour cost also increases considerably ranging from 44% to 168%. The marketing cost reduces in case of chickpea but increases in the case of cauliflower. The total cost increase by 102% in case of chickpea, 50% in case of cauliflower, and 29% in case of cotton. However, because of substantial increases in revenue, the net profits increase in every case. They increase substantially by 182% in case of Chickpea, 230% in case of cotton, and 67% in case of cauliflower. Thus, the findings here once again indicate that there are substantial increases in profits due to micro irrigation in various crops. Cotton being a major crop, the profit increase of 230 percent in it due to MI is very significant.

Table 5.8: Changes in Other Costs and Profits

Item	Chickpea			Cauliflower			Cotton			All Crops (Average)		
	No. reporting 71			No. reporting 69			No. reporting 68					
	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change
Farm power & Equipment cost	15388	9615	60	1643	1094	50	23071	18957	22	18529	12075	53
Total man-days	102	69	48	24	22	7	222	154	44	166	130	27
Labour cost	32414	12092	168	7343	5634	30	64416	39786	62	46858	30674	53
Marketing cost	771	1203	-36	1689	1053	60	6830	6390	7	14106	7322	93
Other costs	5255	1794	193	143	93	53	6380	6584	-3	12991	3145	313
Total Cost	87569	43338	102	17807	11892	50	159373	123718	29	171319	98534	74
Net Profit/ Income	139060	49276	182	8758	5230	67	137027	41509	230	214227	46635	359

Soybean, Chilli and Broccoli

The Table 5.9 below shows the changes in area production and revenue in the case of soybean, chilli and broccoli. The results indicate that there is an increase in area in every crop ranging from 30% to 71% which is substantially higher than the overall average. The production increases vary substantially. In the case of Soybean this is very substantial at 166%, but also substantially in the case of broccoli by 46%, and in Chilli by 56%. The prices also increase due to quality by 25% in case of soybean, 14% in Chile and 8% in broccoli. Overall there is a considerable increase in the sales revenue, the highest being in soya bean at 232%, followed by Chilli at 86%, and broccoli by 56%. Thus, there is a substantial positive impact on the sales revenue for all these crops. The increase in the case of soybean is very significant since it is a major crop.

Table 5.9: Changes in area, production and revenue

Item	Broccoli			Chilli			Soybean			All Crops Average		
	No. reporting 55			No. reporting 42			No. reporting 38					
	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change
Area	0.14	0.11	30	0.63	0.41	54	3.5	2.05	71	2	1	30
Production (quantity) in quintals	4	3	46	132	84	56	75	28	166	465	247	88
Mean Market Price	6905	6407	8	2166	1894	14	3482	2789	25	3176	2719	17
Total Sales Revenue	29163	18660	56	271113	145434	86	261679	78758	232	385547	145169	166

The Table 5.10 below reports on changes in some of the input costs in broccoli, chilli and soybean. The results show that the seed cost increases in every case ranging from 69% to 105%, the fertiliser cost also increases in the case of soybean by 148%, and in the case of chilli by 48 percent. The farmyard manure cost also shows increase substantially in the case of soybean by 276%, and 66 to 75% in the other crops. The pesticide cost also shows a considerable increase at 184 percent in the case of soybean and 65% in the case of chilly. The increases are in many crops is higher than the average increase across all crops, particularly in soybean.

Table 5. 10: Changes in Input Costs

Item	Broccoli			Chilli			Soybean			All Crops (Average)		
	No. reporting 55			No. reporting 42			No. reporting 38					
	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change
Seeds/ Plants cost	5757	2920	97	9968	5893	69	11159	5445	105	25305	11393	122
Fertilizer cost	N.A	N.A	0	14893	10055	48	12380	4986	148	43710	24538	78
Farm Yard Manure/ Organic cost	2755	1578	75	3736	2248	66	16841	4475	276	22441	12505	79
Pesticides cost	N.A	N.A	0	14735	8907	65	25063	8832	184	19275	11225	72

The Table 5.11 below shows the changes in irrigation cost with the adoption of micro irrigation. It shows that the electricity cost in the case of chilly reduces by 12%, and in the case of soybean by 2%. The diesel cost reduces by 30% in the case of chilly but increases by 121% in case of soybean. No changes are reported in the case of water charges. The number of irrigation increase considerably in the case of chilly by 182% and in soybean by 17%. However, there is a considerable reduction in the hours of pumping, which reduces by 35% in the case of chilli, and 33% in the case of soya bean. Most of these changes are less than those seen in all crops average.

Table 5. 11: Changes in Irrigation Costs

Item	Broccoli			Chilli			Soybean			All Crops (Average)		
	No. reporting 55			No. reporting 42			No. reporting 38					
	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change
Electricity cost	N.A	N.A	0	1239	1414	-12	98	100	-2	3676	3901	-6
Diesel cost	N.A	N.A	0	940	1350	-30	13364	6050	121	5817	5943	-2
Water Charges paid	N.A	N.A	0	N.A	N.A	0	5000	N.A	0	4915	5653	-13
No of irrigations	8	8	0	42	15	182	15	13	17	32	24	34
Hours of pumping water for irrigation	N.A	N.A	0	146	225	-35	49	73	-33	164	244	-33

The Table 5.12 below reports on changes and other costs and profits. Farm power and equipment costs show a fall overall, but shows increases in the case of these crops, by 46% in broccoli, 144% in Chilli, and 98% in the case of Soybean. The mandays and labour costs show considerable increases particularly in soybean at 206%, and 77% in case of chilli for labour cost. The marketing and other costs also increases in all these crops, and the total cost shows increases ranging from 168% for soybean to 53% in the case of broccoli. However, because of considerable increase in the revenue, the net profit increases in every case ranging from 333% in soybean, 86% in Chilli and 63% in broccoli. The substantial increase in net profits in soybean is very significant since it is a major crop.

Thus, micro irrigation has a substantial positive impact on the net profits across all the crops. The figures for all the crops indicate an increase of 359% in the net profit. Not only overall but in each of the crops studied in the research, a significant increase in net profit is seen due to micro irrigation.

Table 5. 12: Changes in Other Costs and Profits

Item	Broccoli			Chilli			Soybean			All Crops (Average)		
	No. reporting 55			No. reporting 42			No. reporting 38					
	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change	With MI	Without MI	Percent Change
Farm power & Equipment cost	1381	947	46	8995	3680	144	22066	11170	98	18529	12075	53
Total man-days	27	26	4	154	96	60	132	70	87	166	130	27
Labour cost	8226	6396	29	25733	14556	77	46830	15307	206	46858	30674	53
Marketing cost	1493	981	52	9433	3843	145	N.A	1867	0	14106	7322	93
Other costs	181	104	75	18717	4870	284	4807	1496	221	12991	3145	313
Total Cost	19728	12872	53	98678	52782	87	129151	48185	168	171319	98534	74
Net Profit/ Income	9435	5788	63	172436	92652	86	132528	30573	333	214227	46635	359

The statistical impact or differences with and without the adoption of MI are tested through regression analysis and results are given in Table 5.12A below. The results are equivalent to those of ANOVA analysis, and are based on after adoption and before adoption data as reported by the same farmer. The results show that the impact/ difference is statistically significant for area, production, price, revenue, seeds/plants cost, fertilizer cost, farm yard manure/ organics cost, water charges paid, no. of irrigations, total hours of pumping-irrigation, farm power & equipment cost, total man-days, labour cost, marketing cost, total cost, and net profit-income. It is not statistically significant for pesticides cost,

electricity cost, and diesel cost. The extent of impact found in the analysis is also reported in the Table.

Table 5.12A: Regression Analysis giving Statistical Test Results for the Impact of MI Adoption

				N=1484
		Coefficient		
Dependent Variable		Constant	MI-Adoption	Percent Impact of MI-Adoption
Area Ha	Coefficient	1.094	0.235	21.5
	t-stat		2.809	
	Signifi.		**	
Production	Coefficient	224.60	162.34	72.28
	t-stat		3.58	
	Signifi.		***	
Price	Coefficient	2800.18	593.67	21.20
	t-stat		4.689	
	Signifi.		***	
Revenue	Coefficient	148010.27	202760.249	136.99
	t-Stat		6.111	
	Signifi.		***	
Seeds/Plants cost	Coefficient	11313.473	12456.119	110.10
	t-Stat		5.084	
	Signifi.		***	
Fertilizer cost	Coefficient	24797.984	12184.919	49.14
	t-Stat		2.627	
	Signifi.		**	
Farm Yard Manure/ Organic cost	Coefficient	12853.149	7686.418	59.80
	t-Stat		2.518	
	Signifi.		**	
Pesticides cost	Coefficient	14224.990	5062.766	35.59
	t-Stat		1.567	
	Signifi.		NS	
Electricity cost	Coefficient	3705.213	-398.783	-10.76
	t-Stat		-0.981	
	Signifi.		NS	
Diesel cost	Coefficient	6585.446	541.938	8.23
	t-Stat		0.317	
	Signifi.		NS	

				N=1484
		Coefficient		
Dependent Variable		Constant	MI-Adoption	Percent Impact of MI-Adoption
Water Charges paid	Coefficient	6847.619	-3254.478	-47.53
	t-Stat		-2.276	
	Signifi.		**	
No of irrigations	Coefficient	20.289	8.506	41.92
	t-Stat		4.104	
	Signifi.		***	
Total Hours of pumping -irrigation	Coefficient	232.52	-84.142	-36.19
	t-Stat		-5.097	
	Signifi.		***	
Farm power & Equipment cost	Coefficient	10011.208	4928.024	49.23
	t-Stat		3.796	
	Signifi.		***	
Total man-days	Coefficient	123.981	23.512	18.96
	t-Stat		2.202	
	Signifi.		**	
Labour cost	Coefficient	28771.846	10578.416	36.77
	t-Stat		3.560	
	Signifi.		***	
Marketing cost	Coefficient	4918.672	3846.061	78.19
	t-Stat		3.252	
	Signifi.		***	
Total Cost	Coefficient	94132.646	52092.062	55.34
	t-Stat		3.926	
	Signifi.		***	
Net Profit Income	Coefficient	53878.67	150667.143	279.64
	t-Stat		6.742	
	Signifi.		***	
Note: *** = significant at 99 percent, ** = significant at 95 percent, * = significant at 90 percent Dependent Variables: Area, Production….Net Profit Income Independent Variable (dummy): Adoption (1=With MI Adoption, 0=Before Adoption)				

Reduction in Water Use with Micro Irrigation

Table 5.13 below provide an analysis of the reduction in water use in terms of pumping hours observed in the different states and district. It indicates that substantial reduction by 55 percent is seen in Saharanpur district UP, 51 percent in Pune district Maharashtra, and 66 percent in Nalgonda district Telangana.

Table 5.13: District-wise average hours of pumping groundwater per cropping cycle

State	District	N	With MI	Without MI	Difference	Percent Change
UP	Sonbhadra	56	36	64	28	-43.75
	Saharanpur	50	68	154	85	-55.19
MP	Dhar	96	173	190	18	-9.47
	Sagar	84	130	222	92	-41.44
Maharashtra	Pune	53	248	509	262	-51.47
	Jalgaon	69	432	512	81	-15.82
Telangana	Nizamabad	88	52	75	23	-30.67
	Nalgonda	54	21	63	42	-66.67
Sikkim	East-Sikkim	-	-	-	-	
	South-Sikkim	-	-	-	-	
	Overall Mean	550	110	168	58	-34.52

*Sikkim reported null values because the water source is from the river.

Table 5.14 below give the reduction in water use with micro irrigation crop-wise. It indicates that there is 51 percent reduction in wheat, 52 percent reduction in sugarcane and 52 percent in cotton. Thus, there is evidence of substantial reduction in water use due to micro irrigation.

Table 5.14: Crop-wise difference in mean total hours of pumping groundwater per cropping cycle

Crop	Type of MI	N	With MI	Without MI	Difference	Percent Change
Wheat	Sprinkler	99	112	228	117	-51.32
Sugarcane	Drip	82	180	380	200	-52.63
Cotton	Drip	68	60	126	65	-51.59
Banana	Drip	50	540	626	86	-13.74
Chilli	Drip	42	146	225	78	-34.67
Soybean	Sprinkler	38	49	73	24	-32.88

CHAPTER 06

Capital and Maintenance Cost of Micro Irrigation

Micro irrigation is a capital intensive proposition, and the Table 6.1 below gives the findings on the capital cost of micro irrigation as reported by the farmers. Most users report investing in micro irrigation through drip irrigation or sprinkler irrigation kits. The average expenditure on drip irrigation kits comes to Rs 181820 of which Rs 65889 is paid and Rs 117374 is received as subsidy. This amounts to a subsidy of 65% on an average. The average expenditure for sprinkler irrigation kits comes to Rs 47166 of which Rs 14511 is paid and Rs 33714 is received as subsidy. This amounts to a subsidy of 71%. Some users report other expenditures such as on filters, pipes, pumps, and tube wells. These are reported by very few users except for pumps which are reported by a large number of users. Overall on an average the total expenditure reported comes to Rs 176967 of which Rs 89792 is paid and Rs 81843 is received as subsidy. By this estimate, the subsidy amount comes to 46%. These numbers are reported separately by different users and will not necessarily add up. The reporting sample numbers are given and they vary. The averages of the numbers reported are presented above. Very few farmers report taking loans - 12 percent for drip irrigation kits, and 10 percent for pumps. Given that the average net profit increase per farmer with and without MI (assuming only one crop per year) is Rs 148852 (see Chapter 5), and the reported average total investment in MI is Rs. 176967 as given below, the rate of return works out to 84 percent on total investment cost (payback in 1 year 2.3 months), and 166 percent on investment cost to the farmer (after deducting subsidy) (payback in 7.2 months). This shows that the return to micro irrigation is extremely high, and the investment in micro irrigation is highly viable and profitable both on a total cost basis as well as a cost to farmer basis.

Table 6. 1: Initial Capital Cost/ Investment in Micro Irrigation

Item	Amount Paid Rs		Subsidy Availed Rs		Cost Rs		Percent reporting loan
	Mean	N	Mean	N	Mean	N	
Drip irrigation Set/Kit	65889	260	117374	263	181820	264	12
Sprinkler irrigation Set/Kit	14511	140	33714	137	47166	141	-
Filters (Cyclone, Disc, others)	2325	4	-	-	2325	4	-

Item	Amount Paid Rs		Subsidy Availed Rs		Cost Rs		Percent reporting loan
	Mean	N	Mean	N	Mean	N	
Pipes (Micro, Distribution, Drip, PVC, PE, others)	40083	6	-	-	40083	4	-
Pumps	26519	173	-	-	26519	173	10
Tube well cost (only if addl. for MI	74709	154	-	-	74709	154	7
Mean of total Capital	89792	401*	81843	402	176967	404	-

*Sikkim reported null values because whole system is supplied by the government

The Table 6.2 below gives the information on annual replacement and maintenance costs of micro irrigation as reported by the respondents. Different respondents have reported on different items and the mean values are given in the Table 6.2. The total annual expenditure is reported to be Rs 2877 and there is no subsidy on these items. The figures indicate that the annual maintenance cost is not very high and amounts to about 1.6% of the initial capital cost.

Table 6. 2: Annual Replacement/Maintenance Cost of Micro Irrigation

Item	N	Mean			Percent reporting loan
		Amount Paid	Subsidy Availed	Total Cost	
Filters (Cyclone, Disc, others)	32	2029	-	2029	-
Pipes (Micro, Distribution, Drip, PVC, PE, others)	113	2637	-	2637	-
Valves	66	670	-	670	-
Any others	87	1561	-	1561	-
Total- Mean	208	2877	-	2877	-

The Table 6.3 below gives the names of the top companies reported in capital investment for MI and maintenance of MI. In capital investment Jain irrigation is reported by 21% and other companies are reported by 57% apart from Netafim and Shakti. Respect to maintenance products the top company is Jain irrigation reported by 43% followed by Netafim by 29% and Kastha by 10%. The results indicate the presence of a large number of companies in the supply of MI equipment and its maintenance.

Table 6. 3: Top companies for Capital investment in MI and maintenance

Top companies for Capital investment in MI		
Number reporting	Number reporting	Percent
Jain	119	21
Netafim	77	13
Shakti	53	9
Others	331	57
Total	580	100
Top companies for MI Maintenance products		
Brand	Number reporting	Percent
Jain	100	43
Netafim	67	29
Kasta	23	10
Non-ISI-Local	16	7
Others	26	11
Total	232	100

CHAPTER 07

Factors and Determinants Affecting Micro Irrigation Adoption

What determines the adoption of micro irrigation by the farmers? The literature indicates that the adoption behavior is complex and a large number of different factors may play a role in the adoption of agricultural inputs and technology by the farmers. A framework has been developed to conceptualize the adoption and this has been reported in Gandhi (2014), Gandhi and Patel (2000) and Desai and Gandhi (1992). The framework indicates that the adoption of technologies such as micro irrigation in agriculture is determined by five different groups of determinants or factors. This includes the agronomic potential, the agro-economic potential, effective demand, aggregate supply and distribution. This framework is used here to examine the adoption of micro irrigation by the farmers, and identify the status and problem areas in the adoption.

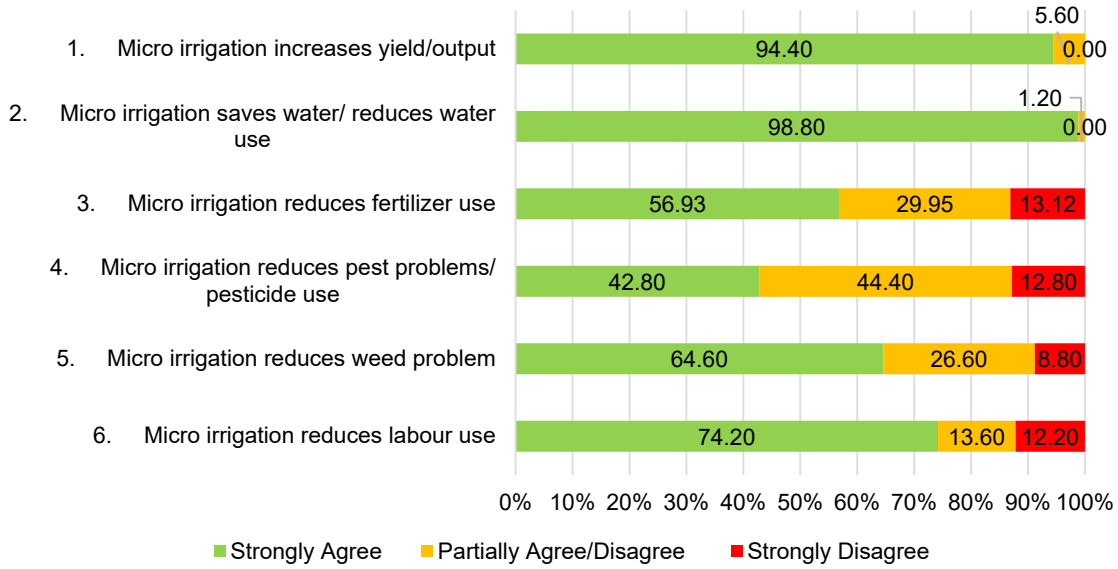
The first group of determinants come under agronomic potential and findings related to this are given in the Table 7.1 and Figure 7.1 below. A major factor/ driver for any technology adoption is the performance in increasing yield and output, and 94% of the respondents strongly agree/ agree that micro irrigation increases yield and output. 98% also agree that it saves water and reduces water use which is another major driver. These two major agronomic benefits appear to the major drivers for the adoption of micro irrigation. 57% report that micro irrigation use reduces fertiliser use, 43% report it reduces pesticide use, 64% indicated it reduces weed problem and 74% indicate that it reduces labour use. These are other agronomic benefits are also reported coming from micro irrigation, and they all constitute a strong potential for adoption of micro irrigation.

Table 7.1: Agronomic Potential

	Strongly Agree (%)	Agree (%)	Partially Agree/ Disagree (%)	Disagree (%)	Strongly Disagree (%)	Mean (Weighted)	No. reporting
	5	4	3	2	1		
1. Micro irrigation increases yield/output	30.60	63.80	5.60	0.00	0.00	4.25	500
2. Micro irrigation saves water/ reduces water use	39.00	59.80	1.20	0.00	0.00	4.38	500

	Strongly Agree (%)	Agree (%)	Partially Agree/ Disagree (%)	Disagree (%)	Strongly Disagree (%)	Mean (Weighted)	No. reporting
	5	4	3	2	1		
3. Micro irrigation reduces fertilizer use	16.34	40.59	29.95	11.39	1.73	3.58	404
4. Micro irrigation reduces pest problems/ pesticide use	5.80	37.00	44.40	10.40	2.40	3.33	500
5. Micro irrigation reduces weed problem	9.60	55.00	26.60	7.60	1.20	3.64	500
6. Micro irrigation reduces labour use	14.40	59.80	13.60	10.60	1.60	3.75	500

Figure 7.1: Agronomic Potential



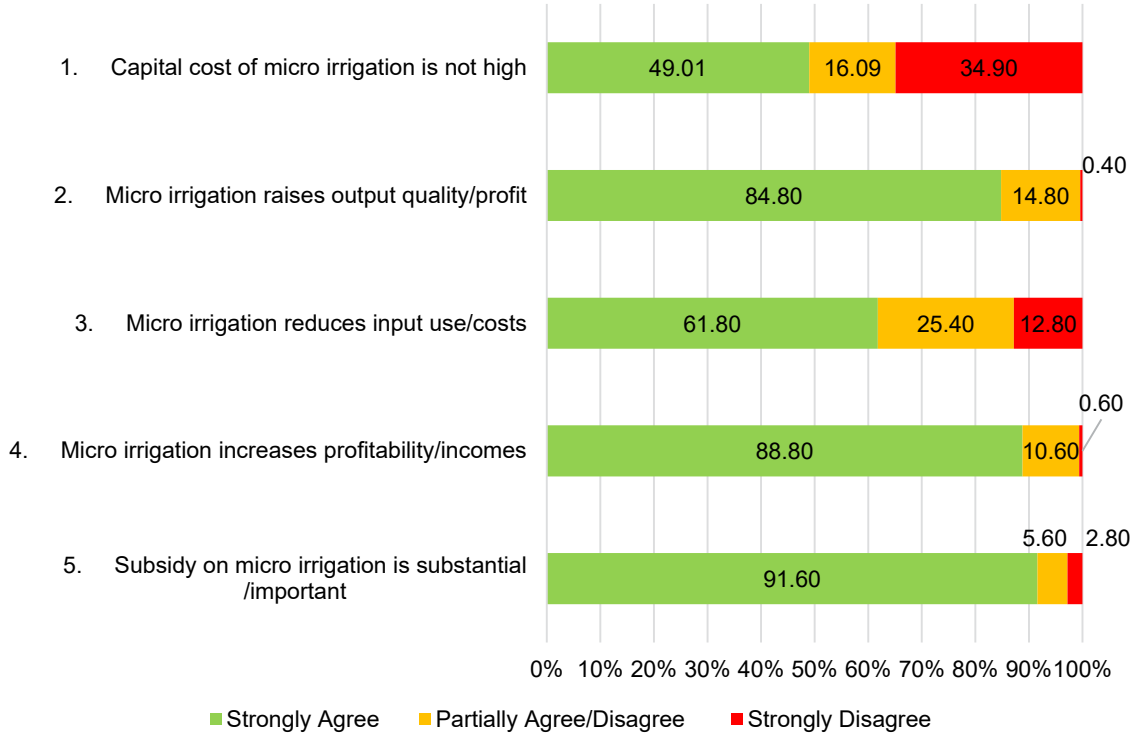
Note: Strongly Agree = Strongly Agree (5) + Agree (4) and Strongly Disagree = Strongly Disagree (1) + Disagree (2)

Table 7.2 and Figure 7.2 below reports on the agro-economic factors. The strongest agro-economic determinants are the subsidy that is available for micro irrigation reported by 92%, increase in profitability reported by 89%, and increase in output quality and price reported by 85%. The high capital cost of micro irrigation is an important negative factor indicated by about 50% of the respondents. Apart from this, reduction in input use/ cost as a positive factor is reported by 62% of the respondents.

Table 7.2: Agro-Economic Potential

	5	4	3	2	1	Mean (Weighted)	No. reporting
1. Capital cost of micro irrigation is not high	11.88	37.13	16.09	28.47	6.44	3.20	404
2. Micro irrigation raises output quality/price	22.40	62.40	14.80	0.40	0.00	4.07	500
3. Micro irrigation reduces input use/ costs	15.80	46.00	25.40	12.60	0.20	3.65	500
4. Micro irrigation increases profitability/incomes	30.40	58.40	10.60	0.60	0.00	4.19	500
5. Subsidy on micro irrigation is substantial /important	36.20	55.40	5.60	2.60	0.20	4.25	500

Figure 7. 2: Agro-Economic Potential



Note: Strongly Agree= Strongly Agree (5)+Agree (4) and Strongly Disagree= Strongly Disagree (1)+Disagree (2)

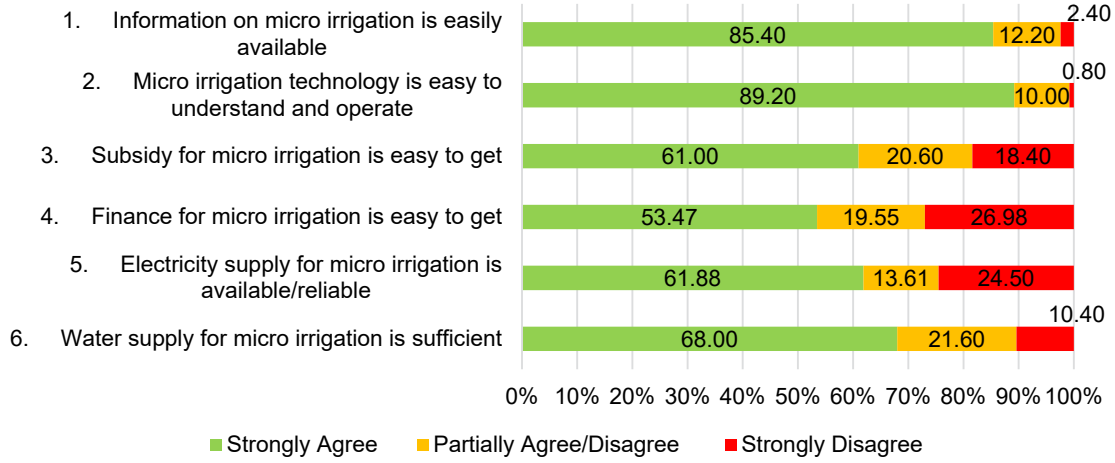
Table 7.3 and Figure 7.3 report on the issues of effective demand, that is conversion of potential into effective demand. 85% of the respondents indicate that information on micro irrigation is easily available, and 89% report that micro irrigation technology is easy to understand and operate. Therefore, these issues do not seem to come in the way of the adoption of micro irrigation. To an extent, ease of getting subsidy and the ease of getting finance are indicated as important factors/ barriers by a large number of respondents. Some also indicate that the

availability and reliability of electricity supply as a problem and some report difficulty in getting sufficient water supply. These factors of effective demand may be coming in the way of greater adoption of micro irrigation.

Table 7. 3: Effective Demand

	5	4	3	2	1	Mean (Weighted)	No. reporting
1. Information on micro irrigation is easily available	27.20	58.20	12.20	2.20	0.20	4.10	500
2. Micro irrigation technology is easy to understand and operate	24.80	64.40	10.00	0.80	0.00	4.13	500
3. Subsidy for micro irrigation is easy to get	9.40	51.60	20.60	15.00	3.40	3.49	500
4. Finance for micro irrigation is easy to get	8.17	45.30	19.55	24.50	2.48	3.32	404
5. Electricity supply for micro irrigation is available/reliable	13.86	48.02	13.61	10.40	14.11	3.37	404
6. Water supply for micro irrigation is sufficient	14.00	54.00	21.60	8.20	2.20	3.69	500

Figure 7.3: Effective Demand



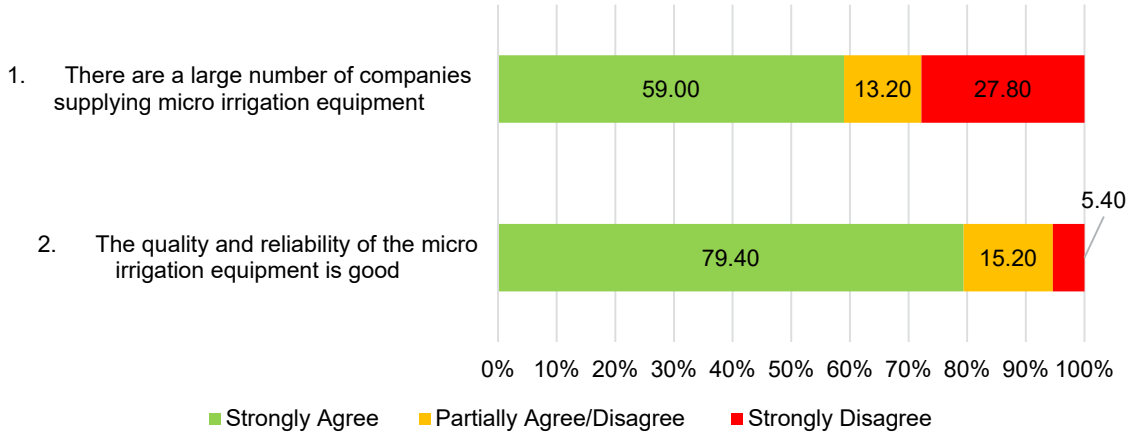
Note: Strongly Agree = Strongly Agree (5) + Agree (4) and Strongly Disagree = Strongly Disagree (1) + Disagree (2)

Table 7.4 and Figure 7.4 report on the factor of aggregate supply. The results indicate that the reliability and quality of micro irrigation equipment available are found suitable/ not a problem by about 80% of the respondents indicating that this is not a difficulty faced. However, with respect to the access and the number of companies supplying micro irrigation equipment, about 40 percent have some difficulty.

Table 7. 4: Aggregate Supply

	5	4	3	2	1	Mean (Weighted)	No. reporting
1. There are a large number of companies supplying micro irrigation equipment	13.20	45.80	13.20	15.60	12.20	3.32	500
2. The quality and reliability of the micro irrigation equipment is good	16.20	63.20	15.20	4.00	1.40	3.89	500

Figure 7.4: Aggregate Supply



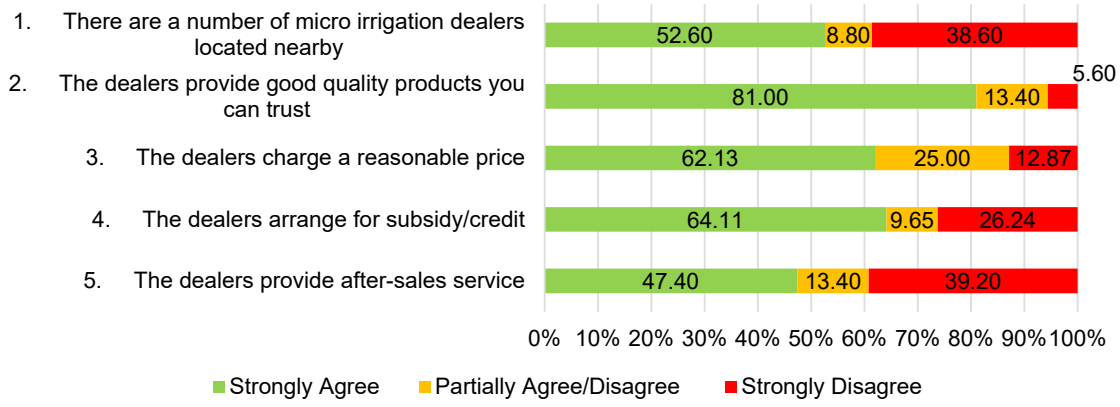
Note: Strongly Agree= Strongly Agree (5)+Agree (4) and Strongly Disagree= Strongly Disagree (1)+Disagree (2)

The Table 7.5 and Figure 7.5 report on the issue of distribution. With respect to the number of micro irrigation dealers nearby 52% of the respondents do not have a problem but the remaining have some difficulty. 81% are happy with the kind of equipment supplied by the dealers and 62% think that the prices also reasonable. On whether dealers arrange for subsidy or credit, 64% indicate that this is not a problem but the rest find some difficulty and this could be an issue. With respect to dealers providing after-sales service whereas 47% indicate that they do not have a problem, but the remaining have some difficulty with respect to the provision of after sales service by the dealers. Thus, after-sales service, the number of micro irrigation dealers and the arranging of subsidy/ credit are some important factors which may be inhibiting the adoption of micro irrigation.

Table 7. 5: Distribution

	5	4	3	2	1	Mean (Weighted)	No. reporting
1. There are a number of micro irrigation dealers located nearby	17.00	35.60	8.80	21.80	16.80	3.14	500
2. The dealers provide good quality products you can trust	14.20	66.80	13.40	4.60	1.00	3.89	500
3. The dealers charge a reasonable price	8.66	53.47	25.00	11.39	1.49	3.56	404
4. The dealers arrange for subsidy/ credit	18.81	45.30	9.65	16.09	10.15	3.47	404
5. The dealers provide after-sales service	11.20	36.20	13.40	17.80	21.40	2.98	500

Figure 7.5: Distribution



Note: Strongly Agree = Strongly Agree (5) + Agree (4) and Strongly Disagree = Strongly Disagree (1) + Disagree (2)

CHAPTER 08

Advantages, Impact and Problems of Micro Irrigation

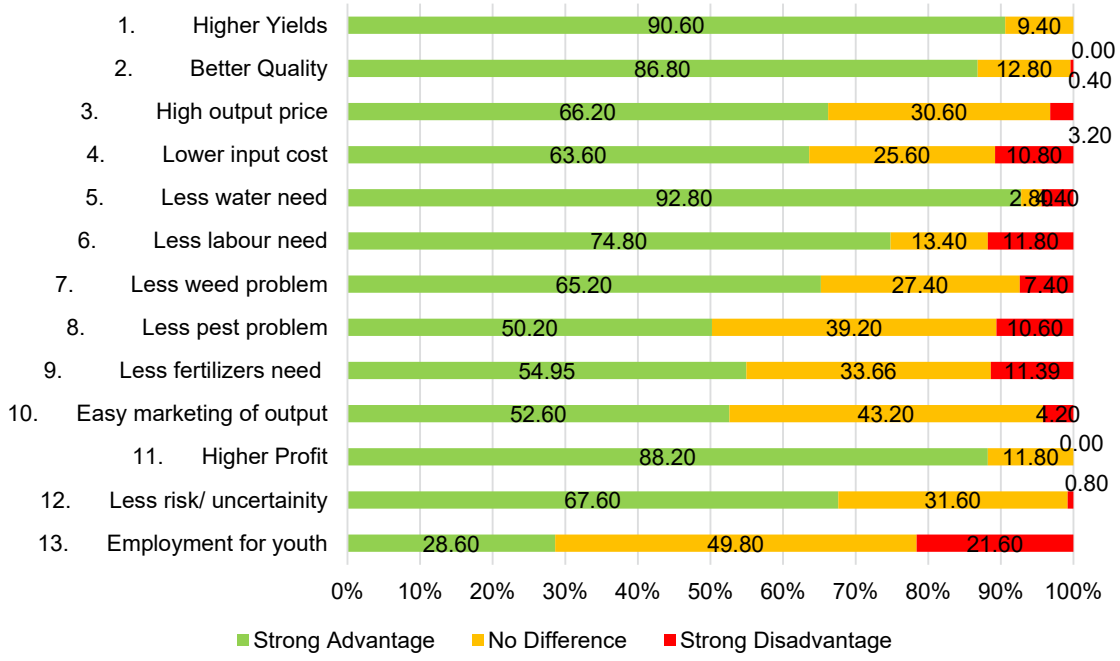
This chapter examines the advantages, impact and problems of micro irrigation. The Table below provides the responses of the farmers on major advantages and disadvantages of micro irrigation. The results in below Table 8.1 and Figure 8.1 indicate that the biggest advantage seen by the farmer farmers is less water needed indicated by 93% of the farmers. This is followed by higher yield as indicated by 91% of the farmers, higher profits by 88% of the farmers, and better quality of output by 87% of the farmers. On the other hand, significant advantage is not indicated in terms of employment of youth, less pest problem, ease of marketing of output, and less fertiliser need. Micro irrigation also appears to reduce the risk and uncertainty as indicated by 67% of the farmers, and micro irrigation has a lower labour need as indicated by 75% of the farmers. Thus overall the major advantages of micro irrigation appear to be less water needed, higher yields, higher profits, and better quality. It also reduces risk and labor need. Advantages such as lesser pest problem, less fertiliser need, ease of marketing and employment of youth are not perceived significant by many.

Table 8.1: Perceived Advantages and Disadvantages of Micro Irrigation

Item	Strong Advantage (%)	Advantage (%)	No Difference (%)	Disadvantage (%)	Strong Disadvantage (%)	Mean (Weighted)	No. reporting
	5	4	3	2	1		
1. Higher Yields	28.40	62.20	9.40	0.00	0.00	4.19	500
2. Better Quality	20.40	66.40	12.80	0.40	0.00	4.07	500
3. High output price	19.20	47.00	30.60	3.00	0.20	3.82	500
4. Lower input cost	10.80	52.80	25.60	10.80	0.00	3.64	500
5. Less water need	33.80	59.00	2.80	2.40	2.00	4.20	500
6. Less labour need	17.40	57.40	13.40	10.40	1.40	3.79	500
7. Less weed problem	17.40	47.80	27.40	6.40	1.00	3.74	500

Item	Strong Advantage (%)	Advantage (%)	No Difference (%)	Disadvantage (%)	Strong Disadvantage (%)	Mean (Weighted)	No. reporting
	5	4	3	2	1		
8. Less pest problem	10.60	39.60	39.20	8.20	2.40	3.48	500
9. Less fertilizers need	14.85	40.10	33.66	9.65	1.73	3.57	404
10. Easy marketing of output	6.80	45.80	43.20	4.20	0.00	3.55	500
11. Higher Profit	25.60	62.60	11.80	0.00	0.00	4.14	500
12. Less risk/ uncertainty	10.40	57.20	31.60	0.60	0.20	3.77	500
13. Employment for youth	3.20	25.40	49.80	19.60	2.00	3.08	500

Figure 8.1: Perceived Advantages and Disadvantages of Micro Irrigation



Note: Strong Advantage= Strong Advantage (5)+Advantage (4) and Strong Disadvantage = Strong Disadvantage(1)+Disadvantage (2)

If the responses to some of the above mentioned questions show a statistically significant difference from state to state is examined through Chi-square tests and the results are given in Table 8.1A below. The results show that there is

a statistically significant difference in the responses across the states to the questions: Micro- irrigation increases yield output, Micro- irrigation reduces input use costs, and Micro irrigation increases profitability incomes. The Chi-square statistic is highly significant in each case indicating statistically significant differences in responses across the 5 sample states.

Table 8.1A: Non-parametric Chi-Square test for variation in responses between sample states on three major perception variables

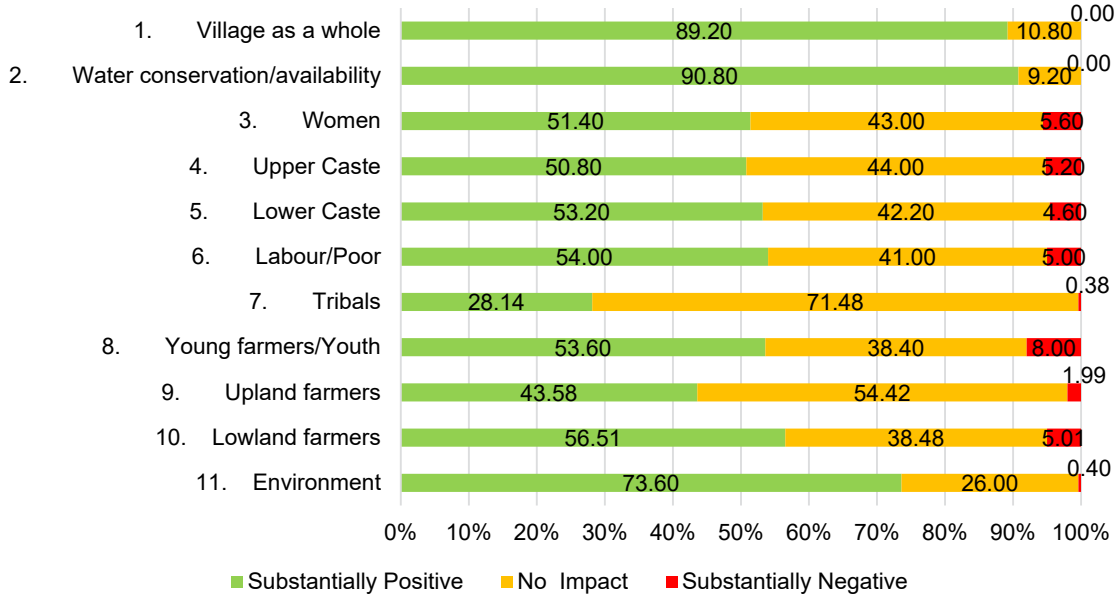
State		Scale					Chi-Square Tests
		Strongly Disagree	Disagree	Partially Agree/ Disagree	Agree	Strongly Agree	
Micro- irrigation increases yield output							
Maharashtra	Count	0	0	0	67	49	147.270***
	Expected Count	0	0	6.5	74	35.5	
MP	Count	0	0	1	63	32	
	Expected Count	0	0	5.4	61.2	29.4	
Sikkim	Count	0	0	27	69	0	
	Expected Count	0	0	5.4	61.2	29.4	
Telangana	Count	0	0	0	60	36	
	Expected Count	0	0	5.4	61.2	29.4	
UP	Count	0	0	0	60	36	
	Expected Count	0	0	5.4	61.2	29.4	
Micro- irrigation reduces input use costs							
Maharashtra	Count	0	14	27	69	6	228.477***
	Expected Count	0.2	14.6	29.5	53.4	18.3	
MP	Count	1	9	45	31	10	
	Expected Count	0.2	12.1	24.4	44.2	15.2	
Sikkim	Count	0	0	42	54	0	
	Expected Count	0.2	12.1	24.4	44.2	15.2	
Telangana	Count	0	38	0	37	21	
	Expected Count	0.2	12.1	24.4	44.2	15.2	
UP	Count	0	2	13	39	42	
	Expected Count	0.2	12.1	24.4	44.2	15.2	
Micro irrigation increases profitability incomes							
Maharashtra	Count	0	1	0	79	36	199.896***
	Expected Count	0	0.7	12.3	67.7	35.3	
MP	Count	0	0	21	61	14	
	Expected Count	0	0.6	10.2	56.1	29.2	
Sikkim	Count	0	2	28	62	4	
	Expected Count	0	0.6	10.2	56.1	29.2	
Telangana	Count	0	0	0	22	74	
	Expected Count	0	0.6	10.2	56.1	29.2	
UP	Count	0	0	4	68	24	
	Expected Count	0	0.6	10.2	56.1	29.2	

The Table 8.2 and Figure 8.2 below provides the responses of the farmers regarding the impact of micro irrigation on different overall aspects and groups. The biggest impact is expressed in terms of water conservation indicated by 91% of the farmers, and there is also positive impact on the village as a whole indicated by 89% of the farmers, and benefits to the environment are indicated by 74% of the farmers. The benefits to low land farmers maybe more common compared to upland farmers, with 57% of the farmers against 44% indicating positive impact. The opinion is divided between substantial positive impact and no impact with respect to social groups such as women, upper caste, lower caste, labour and poor. On the other hand, there appears to be no advantage to tribals and with respect to young farmers and youth the opinion is once again divided. Thus, the findings indicate that there is substantial impact on water conservation, to the village as a whole, and to the environment. On the other hand, different social groups such as women, labour, poor, and young farmers/ youth have a positive impact in the opinion of some but no impact in the opinion of many. Negative impacts are indicated by very few.

Table 8.2: Larger impacts of micro irrigation

Impact on	Substantially Positive (%)	Positive (%)	No Impact (%)	Negative (%)	Substantially Negative (%)	Mean (Weighted)	No. reporting
	5	4	3	2	1		
1. Village as a whole	35.60	53.60	10.80	0.00	0.00	4.25	500
2. Water conservation/ availability	29.80	61.00	9.20	0.00	0.00	4.21	500
3. Women	2.40	49.00	43.00	5.40	0.20	3.48	500
4. Upper Caste	4.40	46.40	44.00	5.20	0.00	3.50	500
5. Lower Caste	5.80	47.40	42.20	4.60	0.00	3.54	500
6. Labour/Poor	9.60	44.40	41.00	5.00	0.00	3.59	500
7. Tribals	3.04	25.10	71.48	0.38	0.00	3.31	263
8. Young farmers/ Youth	8.80	44.80	38.40	7.80	0.20	3.54	500
9. Upland farmers	8.19	35.40	54.42	1.99	0.00	3.50	452
10. Lowland farmers	8.22	48.30	38.48	5.01	0.00	3.60	499
11. Environment	15.20	58.40	26.00	0.20	0.20	3.88	500

Figure 8.2: Larger impacts of micro irrigation



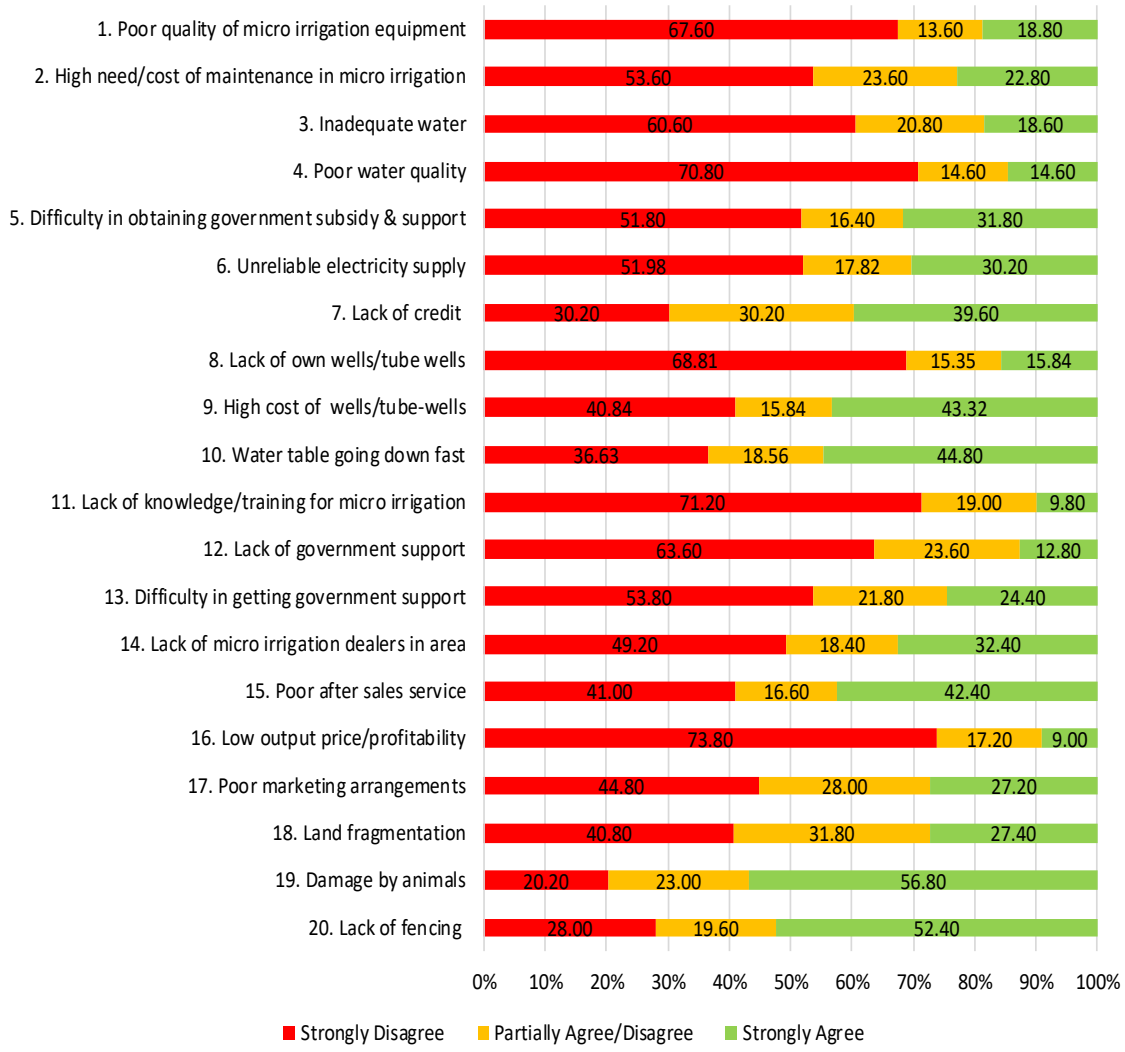
Note: Substantially Positive= Substantially Positive (5)+Positive (4) and Substantially Negative = Substantially Negative (1)+Negative (2)

What are the major problems faced by farmers in the adoption and use of micro irrigation? The findings on these are given in the Table 8.3 and Figure 8.3 below. It is interesting to see that the major problems of micro irrigation are not related to the technology. The most common problem indicated is damage by animals indicated by 57%, followed by lack of fencing indicated by 52%. The other disadvantages more frequently indicated include water table going down fast indicated by 45%, high cost of tube wells/ wells by 43%, and poor after sales service by 42% of the respondents. On the other hand unreliable power supply, poor price profitability, lack of knowledge/ training for micro irrigation, poor water quality, poor quality of micro irrigation equipment, lack of tube well and inadequate water is not seen as a problem by 60 to 75% of the respondents. Lack of government support, and difficulty in getting government support is not seen as a problem by a majority of the respondents. Lack of credit, land fragmentation, and poor marketing arrangements are seen as a problem by some but not by others. Thus, the major problems are seen in damage by animals, lack of fencing, water table going down fast, and high cost of tube wells.

Table 8.3: Major problems faced by farmers in relation to Micro Irrigation

Problems	Strongly Disagree	Disagree	Partially Agree/ Disagree	Agree	Strongly Agree	Mean (Weighted)	No. reporting
	1	2	3	4	5		
1. Poor quality of micro irrigation equipment	12.40	55.20	13.60	15.00	3.80	2.43	500
2. High need/cost of maintenance in micro irrigation	11.40	42.20	23.60	22.00	0.80	2.59	500
3. Inadequate water	10.40	50.20	20.80	15.80	2.80	2.50	500
4. Poor water quality	17.60	53.20	14.60	14.60	0.00	2.26	500
5. Difficulty in obtaining government subsidy & support	9.20	42.60	16.40	25.40	6.40	2.77	500
6. Unreliable electricity supply	12.62	39.36	17.82	10.64	19.55	2.85	404
7. Lack of credit	3.47	26.73	30.20	35.15	4.46	3.10	404
8. Lack of own wells/ tube wells	14.36	54.46	15.35	14.85	0.99	2.34	404
9. High cost of wells/ tube-wells	8.66	32.18	15.84	40.35	2.97	2.97	404
10. Water table going down fast	8.91	27.72	18.56	30.20	14.60	3.14	404
11. Lack of knowledge/ training for micro irrigation	14.20	57.00	19.00	7.20	2.60	2.27	500
12. Lack of government support	15.00	48.60	23.60	11.60	1.20	2.35	500
13. Difficulty in getting government support	13.00	40.80	21.80	18.20	6.20	2.64	500
14. Lack of micro irrigation dealers in area	20.60	28.60	18.40	28.00	4.40	2.67	500
15. Poor after sales service	10.60	30.40	16.60	32.60	9.80	3.01	500
16. Low output price/ profitability	18.20	55.60	17.20	7.80	1.20	2.18	500
17. Poor marketing arrangements	8.60	36.20	28.00	19.20	8.00	2.82	500
18. Land fragmentation	14.00	26.80	31.80	15.60	11.80	2.84	500
19. Damage by animals	4.00	16.20	23.00	34.60	22.20	3.55	500
20. Lack of fencing	5.60	22.40	19.60	33.40	19.00	3.38	500

Figure 8. 3: Major problems faced by farmers in relation to Micro Irrigation



Note: Strongly Agree= Strongly Agree (5)+Agree (4) and Strongly Disagree= Strongly Disagree (1)+Disagree (2)

CHAPTER 09

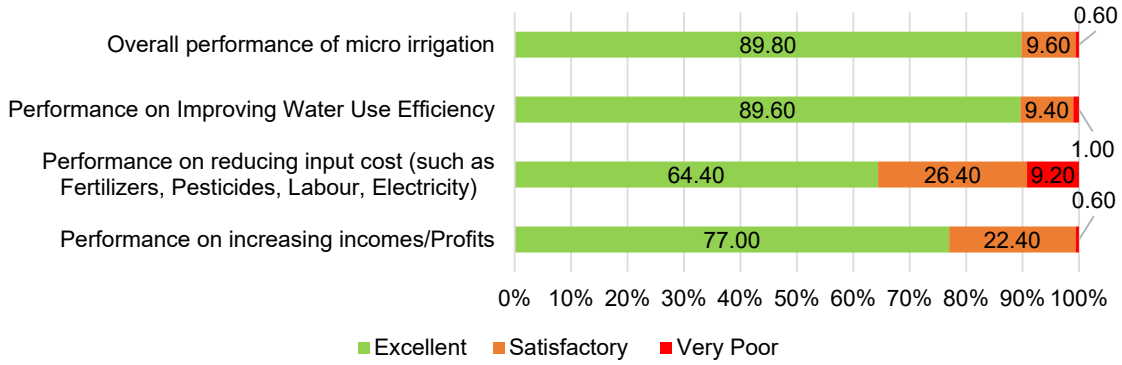
Overall Assessment of the Performance of Micro Irrigation

The Table 9.1 and Figure 9.1 below provides the responses of the farmers on their overall assessment of micro irrigation. The overall performance is seen as excellent to good by 90% of the farmer respondents, and the performance on improving water use efficiency is also seen as excellent to good by 90% of the farmers. The performance on reducing input cost is seen as good buy 64% of the farmers, whereas the performance of increasing incomes and profits is seen as excellent to good by 77% of the farmers. Thus, the responses indicate a higher level of satisfaction with respect to the performance of micro irrigation, especially overall and in improving water use efficiency.

Table 9. 1: Overall assessment of micro irrigation by the farmers

Item	Excellent (%)	Good (%)	Satisfactory (%)	Somewhat Poor (%)	Very Poor (%)	Mean (Weighted)	No. reporting
	5	4	3	2	1		
1. Overall performance of micro irrigation	25.20	64.60	9.60	0.40	0.20	4.14	500
2. Performance on Improving Water Use Efficiency	32.60	57.00	9.40	0.80	0.20	4.21	500
3. Performance on reducing input cost (such as Fertilizers, Pesticides, Labour, Electricity)	10.80	53.60	26.40	8.80	0.40	3.66	500
4. Performance on increasing incomes/Profits	21.00	56.00	22.40	0.60	0.00	3.97	500

Figure 9. 1: Overall assessment of micro irrigation by the farmers



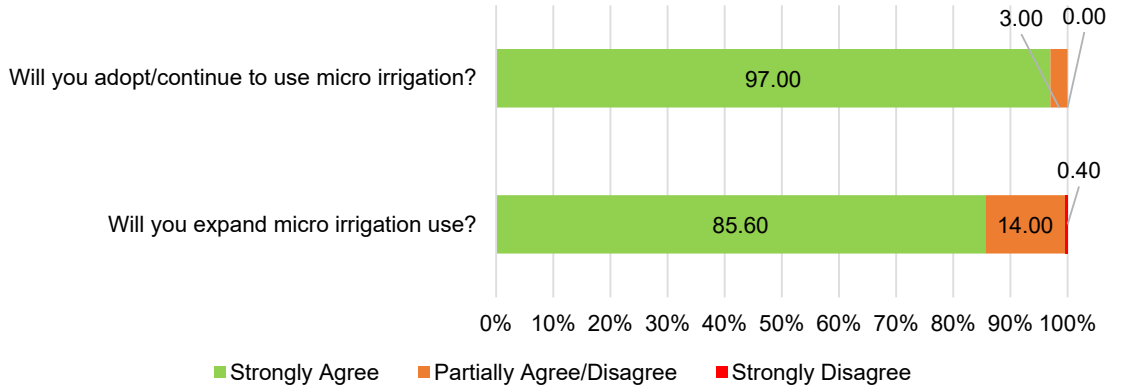
Note: Excellent= Excellent (5)+Good (4) and Very Poor= Very Poor (1)+Somewhat Poor (2)

To additionally confirm regarding the satisfaction with the technology, the farmers were further asked whether they would like to continue with micro irrigation. Here 97% of the farmers indicate that they would continue with micro irrigation, and 86% of the farmers indicate that they would like to expand the use of micro irrigation (Table 9.2 and Figure 9.3). These responses also indicate a high level of satisfaction of the farmers in micro irrigation, as well as the willingness to continue and expand its use.

Table 9. 2: Willingness to Continue

Item	Strongly Agree (%)	Agree (%)	Partially Agree/ Disagree (%)	Disagree (%)	Strongly Disagree (%)	Mean (Weighted)	No. reporting
	5	4	3	2	1		
1. Will you adopt/ continue to use micro irrigation?	34.80	62.20	3.00	0.00	0.00	4.32	500
2. Will you expand micro irrigation use?	26.00	59.60	14.00	0.40	0.00	4.11	500

Figure 9. 2: Willingness to Continue



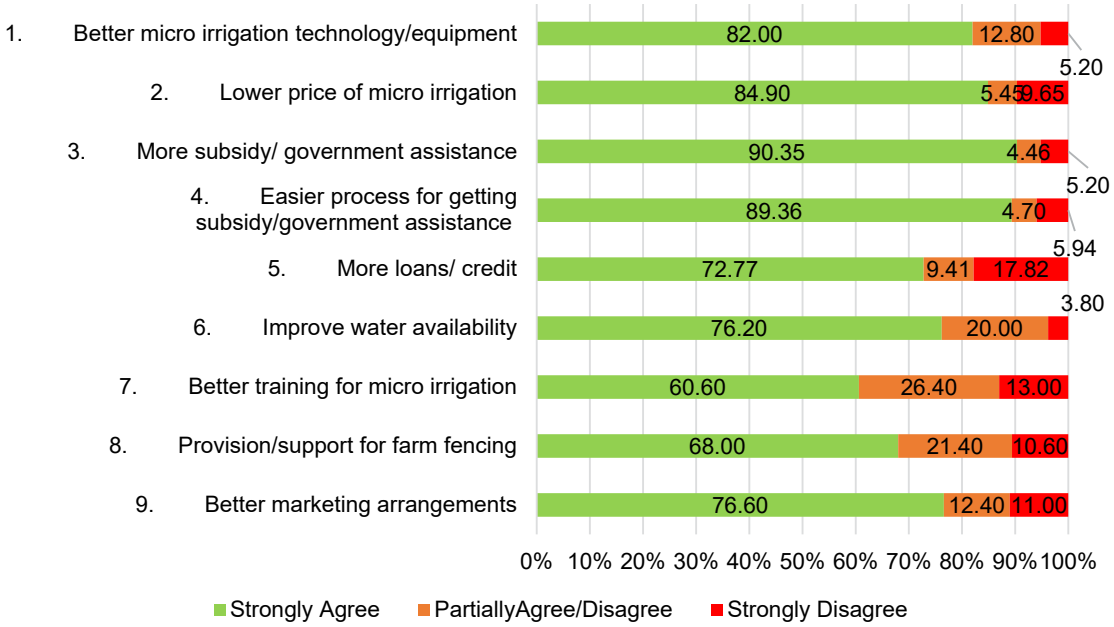
Note: Strongly Agree= Strongly Agree (5)+Agree (4) and Strongly Disagree= Strongly Disagree (1)+Disagree (2)

The farmers were also asked to give their suggestions on increasing the adoption and improving the impact of micro irrigation. Most of the suggestion questions received a positive response but the most important ones were more or subsidy and government assistance indicated by 90% of the farmers, followed by easier process for getting subsidy and government assistance indicated by 89% of the farmers. 85% of the farmers also wish for lower price of micro irrigation equipment, and 82% for better micro irrigation technology and equipment (Table 9.3 and Figure 9.3). Some also express the need for better marketing arrangements, improved water availability, and more loans and credit. Thus, the major demand expressed is for more subsidy or government assistance and easier process for getting the subsidy and government assistance.

Table 9. 3: Suggestions for increasing the adoption and impact of micro irrigation

Suggestions	Strongly Agree (%)	Agree (%)	Partially Agree/ Disagree	Disagree (%)	Strongly Disagree (%)	Mean (Weighted)	No. reporting
	5	4	3	2	1		
1. Better micro irrigation technology/ equipment	32.20	49.80	12.80	5.00	0.20	4.09	500
2. Lower price of micro irrigation	35.40	49.50	5.45	9.41	0.25	4.10	404
3. More subsidy/ government assistance	48.02	42.33	4.46	4.95	0.25	4.33	404
4. Easier process for getting subsidy/ government assistance	37.13	52.23	4.70	5.69	0.25	4.20	404
5. More loans/ credit	17.33	55.45	9.41	17.82	0.00	3.72	404
6. Improve water availability	19.00	57.20	20.00	3.80	0.00	3.91	500
7. Better training for micro irrigation	7.60	53.00	26.40	11.60	1.40	3.54	500
8. Provision/support for farm fencing	36.60	31.40	21.40	10.20	0.40	3.94	500
9. Better marketing arrangements	33.80	42.80	12.40	10.60	0.40	3.99	500

Figure 9. 3: Suggestions for increasing the adoption and impact of micro irrigation



Note: Strongly Agree= Strongly Agree (5)+Agree (4) and Strongly Disagree= Strongly Disagree (1)+Disagree (2)

CHAPTER 10

Non-Adopters of Micro Irrigation: Profile & Reasons

The study also sought to cover a sample of non-adopters of micro irrigation to understand their profile in relation to the adopters, and to find the issues, concerns reasons for non-adoption of micro irrigation. The Table 10.1 below gives the sample coverage of non-adopters across the states and indicates that 121 non-adopters across five states, 10 districts, and 53 villages were covered. The Table 10.1 indicates that all of them had access to irrigation.

Table 10.1: Sample coverage of non-adopters

State	District	No of farmers	No of villages	With Irrigation	Without-Irrigation
UP	Sonbhadra	12	6	12	-
	Saharanpur	12	6	12	-
MP	Dhar	12	6	12	-
	Sagar	12	7	12	-
Maharashtra	Pune	12	6	12	-
	Jalgaon	13	6	13	-
Telangana	Nizamabad	12	6	12	-
	Nalgonda	12	4	11	-
Sikkim	East Sikkim	12	2	12	-
	South Sikkim	12	4	12	-
Total		121	53	121	-

The Table 10.2 below gives the age profile of the non-adopters. A comparison with that of adopters shows that there is hardly any difference in the age profile between adopters and non-adopters. The average age is the same, though the non-adopters have a slightly higher percentage of people above 60 years in age.

Table 10.2: Age profile of non-adopters

Age Category	Number	Percent
Under 20	0	0
20-30	9	7
30-40	37	31

Age Category	Number	Percent
40-50	30	25
50-60	24	20
Above 60	21	17
Total	121	100

The Table 10.3 below gives the education profile of the non-adopters. Comparison with the adopters indicates that the non-adopters have a somewhat higher percentage of illiterates, and a slightly lower percentage of those having education of 12 standard and above. Thus, even though the education of adopters and non-adopters is not very different, the adopters seem to be slightly more educated as compared to non-adopters.

Table 10.3: Education profile of non-adopters

Education	Frequency	%
Illiterate	27	22
Primary	15	12
Middle	27	22
10th Std	29	24
12th Std	9	7
Graduate	10	8
Post-Graduation	4	3
Total	121	100

The Table 10.4 below gives the landholding profile of the non-adopters. It indicates that the non-adopters frequently have smaller land holdings sizes compare to the adopters. The percentage of marginal farmers in the non-adopters is greater, and the percentage of medium and large farmers in the non-adopters is smaller. This indicates that the adopters generally have larger farms as compared to the non-adopters. Therefore, small farm size may be an issue in adoption.

Table 10.4: Land profile of non-adopters

Farmer Size	N	Percent
Marginal	45	37.2
Small	30	24.8
Medium	45	37.2
Large	1	0.8
Total	121	**100.0**

The Table 10.5 below shows the water sources of non-adopters. A comparison with the adopters indicates that larger percentage of the adopters have tube wells and wells as compared to the non-adopters. Some non-adopters do not have their own sources of water and may buy water from others. The finding indicates that water sources maybe an important issue with the non-adopters. In non-adopters, fewer have access to tube wells and wells and some do not have any water source of their own.

Table 10.5: Water sources

Water Source	Frequency	%
Canal	6	5
Canal-Lift	10	8
River-Lift	3	2
Tubewell	46	38
Well	23	19
Tank	1	1
Any other	26	21
No Source	6	5
Total	121	100

The Table 10.6 below gives the water situation on the firm has indicated by the non-adopters. Comparison with the adopters indicates that fewer non-adopters report having sufficient water and a greater number of non-adopters indicate scarcity of water. Thus, the availability of water may be an important factor differentiating adopters and non-adopters.

Table 10.6: Water situation in farm

Water Situation	Frequency	Percent
Excess Water	25	20.7
Sufficient Water	46	38.0
Occasional Scarcity	14	11.6
Scarcity	32	26.4
Acute Scarcity	4	3.3
Total	121	100.0

The statistical difference between adopters and non-adopter on most of the characteristics discussed above has been tested through regression analysis using the combined sample in which the number of adopters was 500 and the non-

adopters 121. The dependent variable is the characteristic and the independent variable is a 0 – 1 dummy, 1 for adopters and 0 for non-adopters. The results are given in Table 10.6A below and show that education (years), the presence of tubewells, and area operated are significantly different between adopters and non-adopters, with the adopters having higher or better values for each of them. On the other hand, there is no statistically significant difference on all the other characteristics between adopters and non-adopters.

Table 10.6A: Regression Analysis Statistically Testing the Differences in the characteristics of Adopters and Non-Adopters

				N=621
		Variables		
Dependent Variable		Constant	Adopters	Percent Difference
Age	Coefficient	47.529	-0.339	-0.71
	t-stat	42.947	-0.275	
	Signifi.	***	NS	
Number of family member	Coefficient	5.298	0.392	7.39
	t-stat	24.313	1.613	
	Signifi.	***	NS	
Education Years	Coefficient	3.198	0.3	9.37
	t-stat	20.112	1.691	
	Signifi.	***	*	
Distance km to nearest market	Coefficient	14.876	-0.076	-0.51
	t-stat	23.077	-0.106	
	Signifi.	***	NS	
Dummy Road Pucca	Coefficient	0.992	-0.022	-2.19
	t-stat	68.847	-1.354	
	Signifi.	***	NS	
Water Situation	Coefficient	0.058	-0.030	-51.60
	t-stat	3.522	-1.631	
	Signifi.	***	NS	
Water source TubeWell	Coefficient	0.380	0.102	26.79
	t-stat	8.402	2.019	
	Signifi.	***	**	
Water source Well	Coefficient	0.190	0.018	9.43
	t-stat	5.176	0.438	
	Signifi.	***	NS	
Area Operated	Coefficient	2.158	0.56	25.95
	t-Stat	8.188	1.907	
	Signifi.	***	*	

Note: *** = significant at 99 percent, ** = significant at 95 percent, * = significant at 90 percent, NS not significant

No of Observations = 621, Adopters = 500, Non-adopters = 121

Dependent Variables: Age, Education Years, Area Operated and others

Independent Variable: Adoption (1=Adopters 0=Non-Adopters)

The Table 10.7 below gives the cropping profile of the non-adopters as indicated by the frequency of reporting different crops. When compared with the adopters it indicates that a much larger percentage of non-adopters grow staple and field crops such as wheat, paddy, chickpea, soybean and cotton as compared to the adopters. In a significant contrast, no adopters report growing paddy whereas many non-adopters report growing paddy. Adopters seem to stop growing paddy and shift to other crops. A large percentage of adopters grow commercial and horticultural crops such as sugarcane, orange, and vegetable crops such as cabbage, cauliflower, and beans. This indicates that the adopters may be more oriented/ shift towards growing commercial crops rather than subsistence for field crops.

Table 10.7: Cropping profile of non-adopters

Crop	N	Percent Reporting	Mean Area
Wheat	50	41.3	1.31
Paddy	49	40.5	1.03
Chickpea	30	24.8	1.72
Soybeans	29	24.0	2.45
Cotton	28	23.1	1.25
Sugarcane	23	19.0	2
Fodder	18	14.9	0.24
Maize	18	14.9	0.74
Broccoli	14	11.6	0.11
Cauliflower	13	10.7	0.1
Beanss	12	9.9	0.2
Chilli	12	9.9	0.48
Ginger	11	9.1	0.32
Urd	10	8.3	1.72
Buckwheat	9	7.4	0.24
Cabbage	9	7.4	0.09
Banana	7	5.8	1
Lentil	7	5.8	1.1
Peas	7	5.8	0.09
Tomato	6	5.0	0.17
Total	121	100.0	0.818

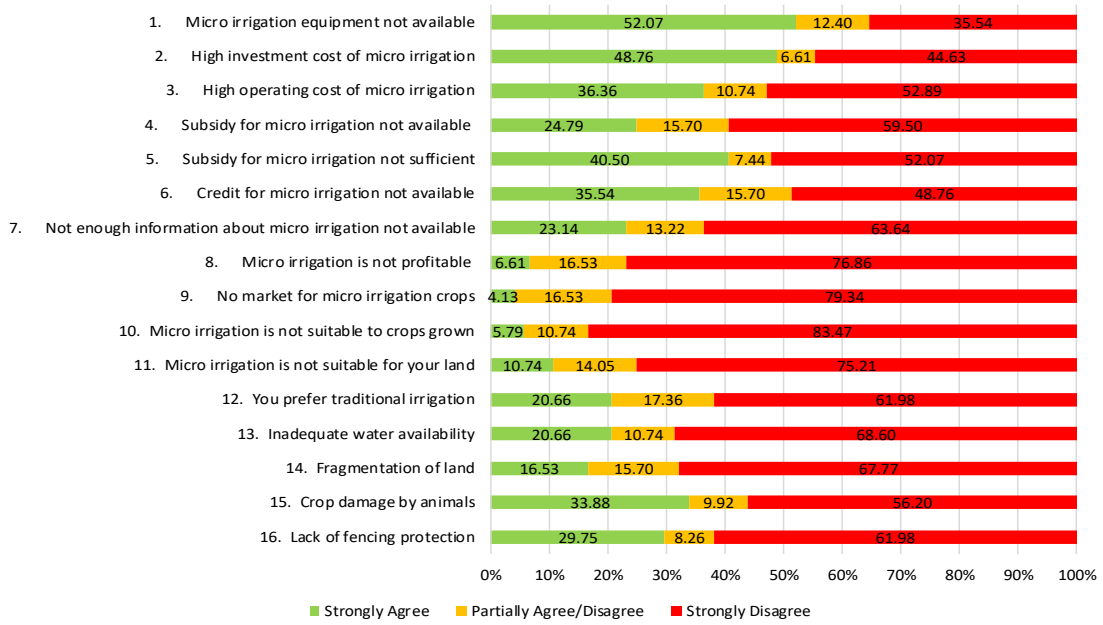
The Table 10.8 and Figure 10.1 below explores the reasons for non-adoption of micro irrigation through a number of different questions. The responses indicate no overwhelming reason but a variety of different reasons. The major reasons indicated are micro irrigation equipment is not available by 52%, high investment cost of micro irrigation 49 percent, and subsidy for micro irrigation not sufficient

41 percent. Some also indicate the higher operating cost of micro irrigation, and crop damage by animals. Some which are not constitute reasons for non-adoption, or on which the non-adopters strongly disagree are micro irrigation is not profitable, no market for micro irrigation crops, micro irrigation not suitable to the crops grown and micro irrigation not suitable for their land as indicated by 70 to 80% of the responses. Thus, these are not the reasons. Preference for traditional irrigation, inadequacy in water availability, and fragmentation of land holdings are also not indicated as major reasons. Subsidy for micro irrigation not available and subsidy for micro irrigation not sufficient is also not indicated as a reason by a large number of respondents. Thus, it appears that the higher investment cost of micro irrigation, micro irrigation equipment not available, and subsidy is not sufficient are the important reasons for the non-adoption of micro irrigation.

Table 10.8: Reasons for Non-Adoption

Item	Strongly Agree (%)	Agree (%)	Partially Agree/ Disagree (%)	Disagree (%)	Strongly Disagree (%)	Mean	No. reporting
	5	4	3	2	1		
1. Micro irrigation equipment not available	32.23	19.83	12.40	23.14	12.40	3.36	121
2. High investment cost of micro irrigation	17.36	31.40	6.61	22.31	22.31	2.99	121
3. High operating cost of micro irrigation	9.92	26.45	10.74	28.10	24.79	2.69	121
4. Subsidy for micro irrigation not available	4.96	19.83	15.70	33.06	26.45	2.44	121
5. Subsidy for micro irrigation not sufficient	12.40	28.10	7.44	26.45	25.62	2.75	121
6. Credit for micro irrigation not available	7.44	28.10	15.70	22.31	26.45	2.68	121
7. Not enough information about micro irrigation not available	10.74	12.40	13.22	31.40	32.23	2.38	121
8. Micro irrigation is not profitable	0.83	5.79	16.53	36.36	40.50	1.90	121
9. No market for micro irrigation crops	1.65	2.48	16.53	34.71	44.63	1.82	121
10. Micro irrigation is not suitable to crops grown	0.00	5.79	10.74	33.88	49.59	1.73	121
11. Micro irrigation is not suitable for your land	3.31	7.44	14.05	28.93	46.28	1.93	121
12. You prefer traditional irrigation	4.13	16.53	17.36	27.27	34.71	2.28	121
13. Inadequate water availability	6.61	14.05	10.74	36.36	32.23	2.26	121
14. Fragmentation of land	5.79	10.74	15.70	28.10	39.67	2.15	121
15. Crop damage by animals	14.05	19.83	9.92	24.79	31.40	2.60	121
16. Lack of fencing protection	11.57	18.18	8.26	23.97	38.02	2.41	121

Figure 10.1: Reasons for Non-Adoption



Note: Strongly Agree = Strongly Agree (5) + Agree (4) and Strongly Disagree = Strongly Disagree (1) + Disagree (2)

CHAPTER 11

Conclusions and Recommendations

Conclusions

Micro irrigation which includes drip and sprinkler irrigation are being given substantial importance in India in the recent years to address the objective of improving the water use efficiency given increasing water scarcity, and for enhancing agricultural production and farmer incomes. Micro irrigation is being actively promoted by the government under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) - Per Drop More Crop (PDMC) scheme since 2015–16. The study has examined the performance of the scheme and its impact from the point of view of the agricultural economy, the farmers, and the government.

About Rs.2500 crores have been spent under the scheme on micro irrigation in the year 2017–18. The largest amount has been spent in Andhra Pradesh followed by Maharashtra and Karnataka. The number of beneficiaries is the highest in Andhra Pradesh followed by Gujarat and then Telangana. Over the last five years from 2015 to 2020 a sum of Rs.7817 crores has been spent on drip and sprinkler irrigation under the scheme. The budgetary expenditure has been the highest in the states of Karnataka Andhra Pradesh and Gujarat, and the physical achievement is also the highest in these three states closely followed by Maharashtra. The study has sought to cover a range of states having micro irrigation adoption under the scheme, and these include Uttar Pradesh, Madhya Pradesh, Maharashtra, Telangana and Sikkim. The states were selected for diversity in level of adoption, cropping and agro-ecology. It is found that Maharashtra and Sikkim have among the highest share of micro irrigation in their net irrigated area whereas Uttar Pradesh, Madhya Pradesh and Telangana have among the lowest share. Uttar Pradesh has the highest growth rate in micro irrigated area in the last five years. The major crops reported under micro irrigation in these states are vegetables, cotton, pulses, sugarcane, banana and wheat.

The study sampled 621 farmers across the five states, and these included 500 micro irrigation adopters and 121 micro irrigation non-adopters. The study covered 95 villages across 10 districts in the above named five states. Most of the adopters are of 30 to 50 years age and most of them have education of 10th and above, but 17% of the adopters are illiterate. The main source of water for micro irrigation is

groundwater through tube wells and wells. Most of the adopters report having sufficient water but about 35% report scarcity. About 75% of the adopters have started using micro irrigation only in the last three years, with 35% only since last year. Almost all adopters have availed of the subsidy for micro irrigation under the scheme. In terms of land area the majority are small and marginal farmers though many are medium farmers. Thus, marginal and small farmers are not excluded. The average landholding is 2.74 ha. The adopters devote about 70% of the land to micro irrigation with the rest being in non-micro irrigation and about 6% without Irrigation.

The most commonly reported crops under micro irrigation for the adopter farmers are wheat, sugarcane, chickpea, cauliflower, cotton, broccoli, banana, chilli, and soybean. In the case of wheat, 96% of the area of the crop is put under sprinkler irrigation by the adopter farmers. For sugarcane 95% is put under drip irrigation, for chickpea 90% under sprinkler irrigation, for cauliflower 85% under sprinkler irrigation, for cotton 69% under drip irrigation, for broccoli 91% under sprinkler irrigation for banana 94% under drip irrigation, for Chilli 78% under drip irrigation, and in soybean 95% under sprinkler irrigation. Thus, the adopter farmers bring substantial part of the irrigated area/ crops under micro irrigation, but the kind of micro irrigation varies by crop between drip and sprinkler irrigation. Do the area and yield increase with micro irrigation. For area, on an average across crops, 64% indicate no change in area after micro irrigation, whereas 35% indicate increase in area, and 2% report decrease in area of a few crops. For yield, on an average across crops, 70% of the farmers adopting micro irrigation report an increase in the yield, whereas 20% report no change in the yield. Thus, with micro irrigation some report increase in area, and get large majority report increase in yield. Thus, yield increase is a common phenomenon with micro irrigation. The study of the economics of the major crops covered in the study under micro irrigation indicates that on an average there is 22% increase in the area and 73% increase in the production. 16% higher prices are realised due to better quality of the produce, and overall on an average, the total sales revenue increases by a substantial 141%. The adoption of micro irrigation is also found to be accompanied by an increase in costs. Cost of seed or planting material cost increases by 101% and the fertiliser cost increases by 64%. The expenditure on farmyard manure increases by 70%, and the pesticide cost increases by 53%. Thus, farmers tend to use more/ better of these inputs with micro irrigation. However, adoption of micro irrigation leads to reduction in irrigation costs. The electricity cost reduces by 11%, the water charges per reduced by 48%, and the hours of pumping reduce by 50%. Thus, there is a sizeable reduction in the use of water and the cost of water as indicated by the results of the study - amounting to its reduction to almost half. The farm power and equipment cost also reduces by 41%. On the other hand, there is increase in labour use and the total labor mandays increase by

44% and the labour cost by 18%. Marketing costs increase by 38% and other cost by 64%. Overall the study indicates that there is a 59% increase in the total cost of growing crops with micro irrigation. However, with the substantial increase in revenue as indicated above, the net profit made by the farmers increases by 310% on an average from Rs. 48080 to Rs. 196932 for sample farmers. The profit increases in some of the important crops are 153% in sugar cane, over 3000% in banana, 105% in wheat, 182% in chickpea 230% in cotton, and 333% in Soyabean. In almost all major crops there is also a substantial reduction in the water charges and the hours of pumping irrigation water, generally by 50% as indicated above. The water pumping hours reduce by over 50 percent in Saharanpur Dist UP, Pune Dist Maharashtra, and Nalgonda Dist Telangana, and reduces by over 50 percent in wheat, sugarcane and cotton. This indicates that micro irrigation reduces the water requirement to half in many areas and crops.

The average investment cost of drip irrigation kits is reported to be Rs 181820 and the average cost of sprinkler kits is reported to be Rs 47166. The subsidies on these on an average are found to be 65% in the case of drip and 71% in the case of sprinkler. The total investment on an average on micro irrigation is reported to be Rs 176967. Given the estimates of crop returns of the farmers reported above, the rate of return works out to 84% on total investment and 166% on investment cost to the farmer. The payback periods respectively work out to just 1 year 2 months, and 7 months. This indicates that the returns on investment in micro irrigation are extremely high both on total investment cost basis as well as on cost to farmer basis.

The factors leading to/ affecting adoption of micro irrigation have been studied using a comprehensive framework of technology adoption in agriculture. The major agronomic drivers are found to be reduction in water use, and increase in the yield. The major agro-economic drivers are increase in profits, and subsidy on micro irrigation, apart from improvement in output quality/ price. The major effective demand drivers are found to be information on micro irrigation being easily available, and micro irrigation technology easy to use. The major aggregate supply driver is the quality and reliability of micro irrigation equipment. The distribution drivers are dealers providing good quality product that can be trusted. However, some difficulty is reported with respect to after-sales service and the number of dealers nearby.

The major advantages of micro irrigation are reported to be higher yields, less water needed, better quality, and higher profits. Advantages such as reduction in risk, less labour needed and higher output price are also reported. Micro irrigation is widely reported to have a strong positive impact on water conservation and availability, the development of the village as a whole, and the environment. The

impact on upland farmers is somewhat less than for lowland farmers, and tribals and youth/ young farmers do not appear to benefit much.

In the problems faced by the farmers in the adoption and use micro irrigation, technical issues and problems are not found to be important/ frequent. The major problems reported are damage by animals, and the lack of fencing to prevent this. Some of the other problems are water table going down fast, and high cost of tubewells. Some report poor after sales service. On the other hand, lack of government support, and difficulty in getting government support not reported as problems by most respondents.

In overall assessment, the overall performance of micro irrigation is reported to be good to excellent by 90% of the respondents, and similarly the performance on improving water use efficiency is reported to be good to excellent by 90% of the respondents. Performance on increasing profits and incomes is reported to be good to excellent by 77% of the respondents and satisfactory by 22%. 97% of the respondents indicate that they plan to continue using micro irrigation, and 86% report that they will expand micro irrigation. These responses indicate that there is a very high level of satisfaction with the performance of micro irrigation.

The suggestions for improving adoption and impact of micro irrigation include more subsidy assistance, easier process of getting subsidy, lower price of micro irrigation equipment and better micro irrigation technology.

A look at the sample of non-adopters indicates that they have the same age profile as adopters but have somewhat less education. They have smaller farm sizes with substantially more percentage of marginal farmers. A smaller percentage of non-adopters have tube wells and wells and many don't have their own source of water. A larger percentage report having scarcity of water. In the cropping pattern, a larger percentage non-adopters grow staple and field crops such as wheat, rice and chickpea, whereas adopters report more commercial crops such as sugarcane, orange and vegetable crops. In a strong contrast, the non-adopters commonly report growing of rice, whereas no adopters report growing of rice – indicating a sharp crop shift. No overwhelming reasons are indicated for not adopting micro irrigation but many report micro irrigation equipment not available, high investment cost, and subsidy not sufficient.

The results of the study clearly indicate that micro irrigation technology is highly beneficial in saving water/ reducing water use, and it substantially increases yields, profits and incomes of the farmer. It provides an extremely high return on the investment, including on farmer investment after subsidy (166%) and on total investment cost (84%). The results also show that the PMKSY-PDMC scheme is playing a major role in significantly inducing the promotion and adoption of this

very potent and useful technology, which brings substantial water savings and a sizable increase in profits and incomes of the farmers. 90 percent of adopter farmers consider the performance of micro irrigation technology to be excellent or good, and almost all wish to continue using the technology and expand its use.

Recommendations

- The PMKSY-PDMC scheme promoting micro irrigation shows very good overall performance and impact on improving water use efficiency, water conservation, enhancing farmer incomes, and increasing employment, and it is strongly recommended that the scheme should be continued.
- There is a strong demand and need for expanding the coverage of the scheme in terms of the number of beneficiaries covered. This calls for increasing its budget. Beneficiaries find the current mode of implementation through state government agencies and private service providers quite satisfactory, though a few suggestions are made in points below.
- There is a strong request for increasing the subsidy component/ percentage. However, the present level of subsidy is invoking a good response and demand from the farmers for the adoption of the technology with a high rate of return.
- There is a demand for reducing the GST percentage on micro irrigation equipment, which may be helpful in further popularizing the use of this water saving technology.
- Many requested for training programs to be regularly organized for micro irrigation to provide good up-to-date technical guidance to the users, and for its popularization. These should be made a regular feature and may be undertaken through training institutes such as Water and Land Management Institutes, and also agricultural universities. These will help the farmers to learn the correct use of the technology, solve problems, and make the best use of it.
- A major problem expressed by the adopters is damage by animals which is a serious problem. A component of support can be added for this in the scheme such as for fencing of an effective or natural kind which can help to protect the investment in micro irrigation and enhance its sustainability. In case animals are causing damage due to thirst of water, separate provision of water can be made for them to prevent this.
- Many non-adopters report water scarcity and lack of water sources such as tube wells. Assisting them to access credit for creating these assets may be considered where groundwater availability is good.

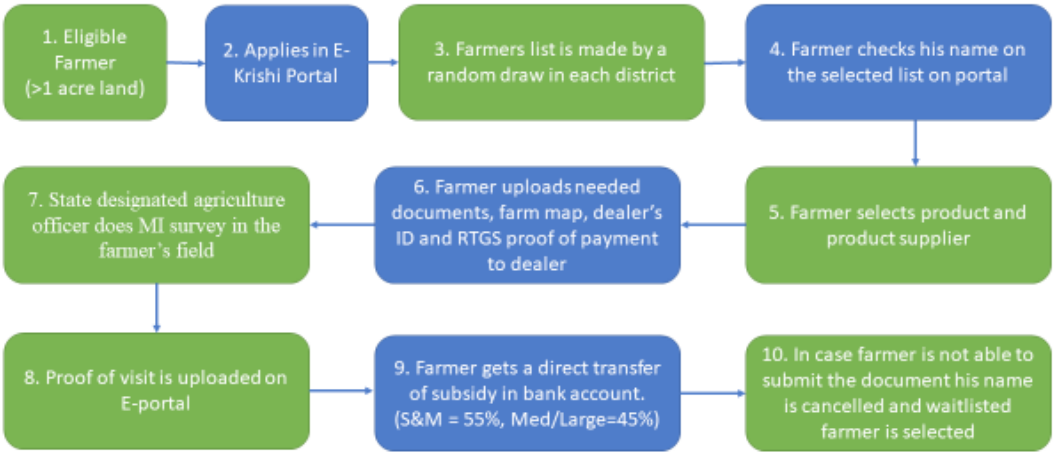
- Need for improving the marketing arrangements for micro irrigation crops is frequently expressed in some states, and this may be addressed.
- In some states such as Maharashtra, farmer or other institutions such as sugar cooperatives assist the farmers in obtaining the subsidy and making the investment in micro irrigation. They also assist with financing and recovery. Wherever possible, such institutions can be involved to facilitate the implementation of the scheme.
- Other ways of making easier the process of getting subsidy/ government assistance and for making available the latest and improved MI technology/ equipment should be explored.
- If feasible, the extent of subsidy could be varied inversely with land holding size in 2 to 3 slabs/ levels. Since the rate of return is very high, this may not affect adoption, and could help in covering more farmers with the same budget.
- In hilly terrains/ states such as Sikkim, micro irrigation is eminently suited to spring irrigation. Many such areas are also suited for horticulture crops such as vegetables and fruits and these can benefit immensely from micro irrigation. Thus, special focus should be there in such area where other kinds of irrigation are not possible.
- Improving aftersales service in micro irrigation is also indicated as a significant need, and effort should be made to improve it. Entrepreneurial or skill building training can be imparted for this to village artisans/ mechanics/ input outlets or to educated youth in villages and rural towns.
- Rather than having separate scheme implementing bodies such as horticulture department and agriculture department as in states such as UP and Sikkim, it may be better to have one window/ body for the promotion of micro irrigation.
- In some states such as Gujarat and Andhra Pradesh, special purpose vehicles (SPV) such as the Gujarat Green Revolution Company, have been used very effectively to facilitate focused scheme implementation for micro irrigation. The SPV can be a non-profit or profit-making entity as in Gujarat Green Revolution Company which can be run professionally. This would be especially relevant for states such as eastern states which need a boost from the low adoption of micro irrigation.
- Special focus and priority may be given in the scheme to micro irrigation implementation in high water using crops such a sugarcane and banana. Much greater water saving is obtained from micro irrigation in such crops. Such farms and areas may be given priority in receiving support.

- Given the large boost in profitability that micro irrigation gives, the technology can be promoted not just as a water-saving technology but as a substantial yield, profit and income boosting technology. It will always give water saving as an additional benefit. This would attract wider interest and following.

Special Issues and Findings

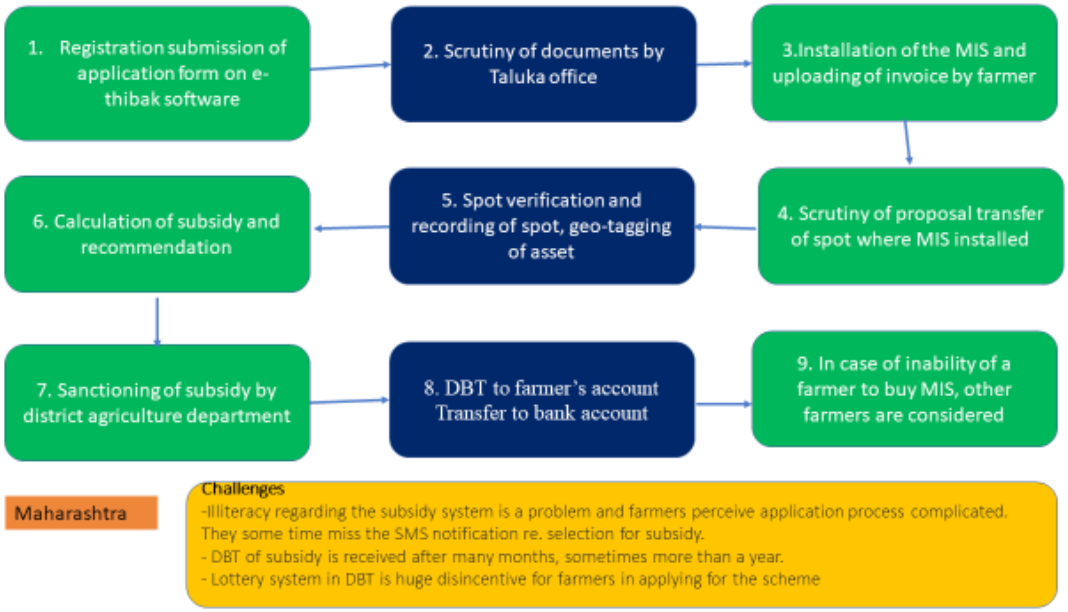
Direct Benefit Transfer (DBT): The Status of Adoption

All the states report that the Direct Benefit Transfer (DBT) process is being followed. However, the exact process and the efficiency varies. Examples of the process followed in MP and Maharashtra are shown in the figures below. The majority of the farmers (53.47%) surveyed indicated that the subsidy for MI is easy to get, but others (26.98%) indicate some problems in availing subsidy. Although the subsidy process of MI is not very difficult, there are gaps in the disbursal process, and some farmers felt that DBT should be processed faster. Many farmers reported that they initially take a loan or requirement is taken care of by supplier through a cheque given by farmer but not encashed. Some reported that they have to wait for a long time, sometime 6 months or more to get the subsidy in the account. This is reported to be a problem and increases transaction costs. This could be speeded up by using IT applications and monitoring. A suggestion given was after the application, a fixed time should be specified for the processing and crediting of the subsidy amount to the farmers' account. For example, it may be within 30 days of submission of application/ purchase invoice.



Madhya Pradesh

Challenges:
-DBT process is smooth and timely but GST on MI cost is a concern for farmers
-Farmers sometimes face high transaction cost in making the initial application on the e-portal given the role of agents
-The announcement of selection of the farmer for subsidy is often not very well communicated



Geo-Tagging of the Assets Created under the Scheme through the Android-Based Bhuvan Integration App: Status of Adoption

The field survey staff reported that Geo-Tagging through the Android-Based Bhuvan Integration App was being done for all the beneficiaries when the assessment was done in the farmer's fields in the surveyed states. It was suggested that to improve its usefulness, the farmers could be trained to update their information on the geo-tagging micro-irrigation app.

Micro-Level Water Storage/ Conservation/ Management Activities Supported under the Scheme to Supplement Water Source Creation for Micro-Irrigation: Linkage and Efficacy

Secondary data indicates that in the last five years under the PMKSY scheme, a total 480,720 hectares of land was covered under Other Interventions (OI). Rajasthan, Maharashtra, Andhra Pradesh, and Tamil Nadu were major states by the area brought under OI. However, the Table reproduced below based on the survey indicates that the main sources of water for micro-irrigation were tube-wells and wells reported by about 70 percent of the respondents. Tanks, farm ponds and check dams were reported as sources by only 7 respondents (about 1 percent). However, wells and tube-wells can also benefit from OI activities but the extent of the linkage was not reported. Among the five states covered in the study, Sikkim reported 100 % OI coupled with micro-irrigation. The OI in Sikkim mainly includes water flow diversion and storage which is linked to micro-irrigation. This is reported by 100 respondents in the survey (20%) which is all the adopter respondents covered in Sikkim. There is good demand for both OI and micro-irrigation in Sikkim state because of topography and lack of alternatives.

Water Sources for Micro-Irrigation

Source	Frequency	Percent (%)
Canal	14	3
Canal-Lift	5	1
River-Lift	29	6
Tubewell	241	48
Well	104	21
Tank	1	0
Farm Ponds	1	0
Check dam	5	1
Any other*	100	20
Total	500	100

*Any other: including mountain streams and storage tanks used in Sikkim.

Farmers in UP reported expansion of irrigated area through micro-irrigation in sloppy fields with or without OI where otherwise no irrigation was possible. This is mainly from the Sonbhadra districts of UP. Thus it appears that UP has benefitted from Other Interventions (OI) done in PMKSY scheme coupled with micro-irrigation.

Selection of Beneficiaries for Micro-Irrigation under the PMKSY-PDMC Scheme: Suggestions on Better Methods and Further Improvement.

The existing process of beneficiary selection in most of the states is by a random draw. Farmers are randomly selected and given the subsidy from among the farmer applications received. In the covered states, this random draw method is followed in Maharashtra, Telangana, and Madhya Pradesh. In UP the selection of farmers is on a first come first serve basis after the application process is opened for farmers to apply for subsidy. In Sikkim the famers are selected on the basis their application also considering those who are a part of irrigation projects.

Thus, beneficiaries are selected either by a random draw or on first come first serve basis, or after evaluation of their applications by the officials of the concerned department. There is usually a substantial demand from farmers to get micro-irrigation but supply is limited by policy and budgets. There are chances of adverse selection of farmers which may favour large farmers who may have better access to knowledge and the network to get the subsidy. There is of course some criterion of selection such as the minimum amount of land required (one acre), but this may exclude marginal farmers. In Telangana it was observed that some small farmers in village Taggeli went ahead and purchased micro-

irrigation equipment and implemented without subsidy knowing the benefits of the technology.

Some suggestions for improving the selection of beneficiaries for MI

- A random process of selection is better than first come first serve basis
- Publicity and awareness building to generate more applications across a wide geographic and socio-economic spread. Training in the application process
- Greater involvement and development of facilitating institutions such as cooperatives, FPOs and NGOs
- Well announced dates and transparency in the process using IT
- Quotas for small and marginal farmers in the selection for subsidy
- Area based targets and monitoring/ reporting of beneficiary distribution
- Group micro-irrigation projects for farmers with less than one-acre land for providing subsidy. The model is practiced by Gujarat Green Revolution Company.
- Farmers/ areas growing more water demanding crops where more water-saving is possible through MI and water is scarce, may be given priority
- To promote crop diversification, the farmers who show more diversified cropping patterns can be given priority.

Summary of the Impact on Various Parameters/ Indicators of the Performance and Impact of Micro-Irrigation and the Scheme

The Table below provides a summary of the impact on various parameters/ indicators of performance due to micro-irrigation, including water use efficiency, input cost, crop productivity, employment generation, change in income of farmers and others parameters/ indicators as found through the study survey and data, to help assess the performance and impact of the scheme

With the adoption of micro-irrigation, there is substantial water-saving overall but this varies from crop to crop. Overall, the study finds a 50 percent reduction in hours of water pumping, with crop-wise variation from 14 to 53 %. 98% of the sample farmers believe that micro-irrigation saves water. Overall the total input cost increases by 59 percent as farmers use more fertilizers, better seeds and more labour to benefit the most from the investment in assured and accurate irrigation. However, this gives a 73 percent increase in the yields/ productivity – varying across crops from 35 to 216%. It also gives an increase in prices due to better quality of output. As a result the revenue or gross income increases substantially by 141 percent and the net profit/ income increases by 310 percent. There is also a positive impact on employment generation. The labour man-days

used increase by 44 percent and the payment for labour increases by 18 percent. There is substantial variation in this from crop to crop due to the nature of the operation and the location.

Summary of Performance Indicators

S. No	Parameter/ Indicator	Crop									
		Sugarcane	Banana	Wheat	Cotton	Chilli	Soybean	Brocolli	Chickpea	Cauliflower	Overall Average
		Percent Change									
1	Change in Hours of Pumping Water	-53	-14	-51	-52	-35	-33	-35	27	NA	**-50**
2	Change Fertilizers Cost	15	143	15	-3	48	148	NA	69	NA	**64**
3	Change Seeds Costs	13	253	22	19	69	105	97	64	74	**101**
4	Change in Pesticide Cost	9	195	-34	-4	65	184	NA	129	0	**53**
5	Change in Electricity Cost	-11	4	7	-18	-12	-2	NA	-29	0	**-11**
6	Total man-days	-24	50	-11	44	60	87	4	48	7	**44**
7	Labour cost	-29	94	-8	62	77	206	29	168	30	**18**
8	**Change in Total Cost**	**-2**	**139**	**6**	**29**	**87**	**168**	**53**	**102**	**50**	**59**
9	Change in Productivity/ Yield	40	216	35	43	56	186	46	95	36	**73**
10	Change in Revenue/ Gross Income	56	387	43	79	86	232	56	145	55	**141**
11	**Change in Net Income/ Profit**	**153**	**3095**	**105**	**230**	**86**	**33**	**63**	**182**	**67**	**310**

Farmer response regarding performance

Question	Response
Micro Irrigation Increases yield/output	94 % Strongly Agree
Micro Irrigation saves water	98.8 % Strongly Agree
Micro-irrigation increases income	89 % Strongly Agree
Advantage of micro-irrigation in increasing employment	29% Strong Advantage

Specific Innovative Initiatives Captured in the Study

This is reported below through examples and accounts based on the field visits, and conversations with farmers, groups and others involved.

Box 1: Mulching of crop residue and crop diversification with micro-irrigation

Farmer Name: Mr. Sudheer
Village Name: Mukhai, Indapur Block, Pune District, Maharashtra
Mr. Sudheer is a progressive farmer who cultivates sugarcane on seven acres land. He also cultivates other crops such as baby corn maize, papaya, wheat, and vegetables. He cultivates sugarcane in three acres. He had availed MI subsidy through support of the sugarcane cooperative factory. The farmer got an additional incentive of Rs 5000 per acre to adopt micro-irrigation from the sugarcane factory. The payment of the farmer's share of micro-irrigation was done by the cooperative. So, the farmer only has to agree to buy MI and give document support. His cost of micro-irrigation was deducted from his sugarcane payment. The farmer has experienced an increase in the yield of sugarcane from 25 tons per acre to 48 tons per acre after adopting micro-irrigation. In terms of labor, the farmer thinks the MI reduces the cost of production in terms of labor cost, fertilizer cost, weeds costs, and pesticides to some extent. The farmer is also an innovative farmer who does not burn the sugarcane bagasse residue while after harvesting he uses a shredder machine to chop the residue to be left on the top of the soil. This adds to the compost to the soil and also improves the water-holding capacity of the soil. So, the farmer says it doubles the water-saving. Mulch of sugarcane does not allow soil moisture to go away and thus further reduces the need for water application.

Box 2: Switching irrigation off by a missed call

Farmer Name: Mr. Ganesh Bapu Bhujbal
Village Name: Mukhai, Shirur Block, Pune District, Maharashtra
Ganesh Bapu Bhujbal is a medium farmer with 2.4 acres of operated land. He cultivates sugarcane and pomegranate through MI in his given land and has adopted a unique way of operating his pump. Whenever he has to switch off his pump he has to give a miss call to a given number and the software system recognizes the missed call and thus switches on or off the irrigation pump of his field. By the innovation, he saves a lot of time and money in traveling to the field and switching off-pump. This is a kind of innovation that many local farmers are also adopting

Box 3: Canal Irrigation coupled with sprinkler irrigation – improved land asset value and adoption of MI without subsidy

Village Name: Taggelli, Bodhan Block, Nizamabad District, Telangana
The village Taggelli, used to be a rainfed village and agriculture gave the farmers a subsistence income only from rainfed Kharif crops cotton, and soybean. After the introduction of canal water in the village farmers switched to sprinkler irrigation and have started to grow two grows – soybean and chickpea adding one more crop to the crop cycle. So now they can have two crops rather than one crop under protective irrigation with the coupled effect of canal irrigation. This is a good example where a minor irrigation project combined with micro-irrigation is fulfilling the two objectives of the programme, i.e., *"Har Khet Ko Pani"* and "Per Drop More Crop". The value of the land and rental price has also increased in the village. Earlier farmers reported that the land would be priced at Rs five lakhs per acre, which now is Rs 12 lakhs per acre. The effect is such that some marginal farmers, with land less than one acre, have reported buying micro-irrigation without subsidy. By rule of policy farmers with less than one-acre land cannot have subsidy. There were two marginal farmers which we met, who had bought sprinkler set at Rs. 28,000 per acre without subsidy. The rule of the maximum area of one hectare institutionally culls such farmers. But the returns of investment are very high in the case of the black gram. This makes farmers ready to adopt sprinkler even if it is without subsidy. In a group discussion with the farmers have reported a doubling of productivity by adopting sprinkler irrigation, but there was an increase in fertilizer and pesticide cost because of better growth of plants.

Box 4: Diversification of crops with adoption of micro-irrigation

Farmer Names: Mr. Kashiram Ahirwar and Mr. Basant Ahirwar
Village Names: Billaiya and Majhera, Khuraj Block, Sagar District, Madhya Pradesh
Two farmers Kashiram Ahirwar and Basant Ahirwar in the village Billaiya and Majhera in Khurai Taluka of Madhya Pradesh used to cultivate only soybean and wheat. But after the adoption of sprinkler irrigation, they have diversified their crop cultivation. Their diversification index, i.e., Herfindahl Index<?> has changed from 0.285 and 0.58 to 0.233 and 0.50, respectively which means they grow more crops in same piece of land and with the same amount of water applied. This they achieve by growing vegetable and other essential crops with the main crops of soybean and wheat. Their income due to the adoption of micro-irrigation and diversification of crops has increased their income by 60 and 80 per cent respectively.

Box 5: Crop and risk diversification by cultivation of 49 crops each year

Farmer Name: Mr. Babu Lal
Village Name: Manpur, Robertsganj Block, Sobhadra District, Uttar Pradesh
Babu Lal a small farmer with 2 acres of operated land under cultivation. He had adopted micro-irrigation in the year 2017-18. He grows 49 crops in his given land. He cultivates all type of major vegetables and cereals meant for market. After the adoption of micro-irrigation, his Herfindahl index has changed from 0.5 to 0.25. A reduced index number means increased crop diversification in the field. He has observed an increase in income of his field while a reduction in the cost of fertilizer, insects, and pests. He can now cultivate the land at a higher slope where he could irrigate crops. The ability of micro-irrigation to irrigate at a high slope also made him expand his area under cultivation. So as per his communication, there has been a clear fulfillment of the two mandates of "Har Khet Ko Pani" and "Per Drop More Crop" after the adoption of drip irrigation.

References

Alcamo, J., & Henrichs, T. (2002). Critical regions: A model-based estimation of world water resources sensitive to global changes. Aquatic Sciences, 64(4), 352-362.

Ayog, N. (2019). Composite water management index. New Delhi: Government of India

Bates, B., Kundzewicz, Z., & Wu, S. (2008). Climate change and water. Intergovernmental Panel on Climate Change Secretariat.

Bhamoriya, V. and Mathew S. (2014). An Analysis of Resource Conservation Technology: A Case of Micro-irrigation System (Drip irrigation), Report, Centre for Management in Agriculture, Indian Institute of Management, Ahmedabad.

Bhamoriya, V. (2016). Irrigation and Entrepreneurship: Status and Lessons for Improvement and Expansion. Ahmedabad: Center for Management in Agriculture, Indian Institute of Management

Caswell, M., & Zilberman, D. (1985). The choices of irrigation technologies in California. American journal of agricultural economics, 67(2), 224-234.

CBPS. (2013). Study on Micro-irrigation in Karnataka (Drip and Sprinkler Irrigation). Bangalore: Directorate of Economics and Statistics, Karnataka.

CIIE. (2013). Impact Survey Micro Irrigation. Vadodara: GGRC.

CWC (2019) Water and related statistics. http://www.indiaenvironmentportal.org.in/files/file/water-and-related-statistics-2019.pdf. (Accessed on11/28/2020)

Dar, E. A., Brar, A. S., Mishra, S. K., & Singh, K. B. (2017). Simulating response of wheat to timing and depth of irrigation water in drip irrigation system using CERES-Wheat model. Field Crops Research, 214, 149-163.

Department of Agriculture, Cooperation and Farmers Welfare 2019, "Pradhan Mantri Krishi Sinchai Yojana", Ministry of Agriculture and Farmers Welfare Government of India

Falkenmark, M. (1989). The massive water scarcity now threatening Africa: why isn't it being addressed? Ambio, 112-118.

Fan, Y., Wang, C., & Nan, Z. (2018). Determining water use efficiency of wheat and cotton: A meta-regression analysis. Agricultural water management, 199, 48-60.

FAO. (2015, September 02). TOWARDS A WATER AND FOOD SECURE FUTURE Critical Perspectives for Policy-makers. Rome: Food and Agriculture Organisation of the United Nations From United Nations Food and Agriculture Website.

FAO. (2018, September 12). AQUASTAT - FAO's Global Information System on Water and Agriculture. From HYPERLINK "http://www.fao.org/aquastat/en/" http://www.fao.org/aquastat/en/

Fereres, E., Orgaz, F., & Gonzalez-Dugo, V. (2011). Reflections on food security under water scarcity. Journal of experimental botany, 62(12), 4079-4086.

Gandhi, Vasant P and Desai, Gunvant M. (1992). Converting Potential into effective demand for the use of fertilizers, in "Service Provision and its Impact on Agricultural and Rural Development in Zimbabwe", edited by Sudhir Wanmali and Jonathan M. Zamchiya, IFPRI, Washington DC

Gandhi, Vasant P. (2014). "Growth and Transformation of the Agribusiness Sector: Drivers, Models, and Challenges", Indian Journal of Agricultural Economics, Vol.69, No.1, Jan-Mar, 2014.

Gandhi, Vasant P. and Patel, N.T. (2001). The Impact of WTO on Agricultural Inputs, in "Impact of WTO Agreements on Indian Agriculture", Vol.II, CMA, Indian Institute of Management, Ahmedabad, and New Delhi: Oxford IBH.

GoI. (2018). Agriculture Census. New Delhi: Department of Agriculture, Cooperation and Farmers Welfare.

GoI.(2018,March).Guideline.FromPradhanMantriKrishiSinchayiYojana:https://pmksy.gov.in/MicroIrrigation/Archive/GuidelinesMIRevised250817.pdf

GoI. (2019, March 13). RKVY. Retrieved from HYPERLINK "http://rkvy.nic.in/static/schemes/SprinklerIrrigation.html"

ICID. (2019, January 01). International Commission on Irrigation and Drainage (ICID). Retrieved from https://www.icid.org/

Jackson, T.M., Khan, S., &Hafeez, M. (2010). A comparative analysis of water application and energy consumption at the irrigated field level. Elsevier. Agriculture Water Management 97, 1477-1485.

Kumar, D. S. (2016). Social Benefit-Cost Analysis of Drip Irrigation. In M. D. P.K Viswanathan, Micro-irrigation Systems in India- Emergence, Status and Impacts (pp. 113-131). Singapore: Springer

Kumar, D. S., & Palanisami, K. (2010). Impact of drip irrigation on the farming system: Evidence from southern India. Agricultural Economics Research Review, 23(347-2016-16921), 265-272.

Kumar, M. D., & Singh, O. P. (2001). Market instruments for demand management in the face of scarcity and overuse of water in Gujarat, Western India. Water Policy, 3(5), 387-403.

Kumar, N.A., Poddar, R.S. (2015). An economic evaluation of micro-irrigation programme in Vijayapura district. Karnataka Journal of Agricultural Science. 28(3): 373-376.

Kuppannan, P., & Raman, S. (2012). Potential and challenges in up-scaling micro-irrigation in India: experiences from nine states.

Malik, R. P. S., Giordano, M., & Rathore, M. S. (2018). The negative impact of subsidies on the adoption of drip irrigation in India: evidence from Madhya Pradesh. International Journal of Water Resources Development, 34(1), 66–77. https://doi.org/10.1080/07900627.2016.1238341

Mekonnen, M.M. & Hoekstra, A.Y. (2011) The green, blue and grey water footprint of crops and derived crop products, Hydrology and Earth System Sciences, 15(5): 1577-1600.

Namara, R. E., Nagar, R. K., & Upadhyay, B. (2007). Economics, adoption determinants, and impacts of micro-irrigation technologies: empirical results from India. Irrigation Science, 25(3), 283-297

Narayanamoorthy, A. (2004). Drip irrigation in India: can it solve water scarcity?. Water Policy, 6(2), 117-130.

Narayanamoorthy, A., Devika, N., & Bhattarai, M. (2016). More Crop and Profit per Drop of Water: Drip Irrigation for Empowering Distressed Small Farmers. IIM Kozhikode Society & Management Review, 5(1), 83–90. https://doi.org/10.1177/2277975215617270

Palanisami, K., Mohan, K., Kakumanu, K. R., & Raman, S. (2011). Spread and Economics of Micro-irrigation in India: Evidence from Nine States. Economic and Political Weekly, xivi(26 & 27), 81–86.

Rai M., S. M. (2006). Hand Book of Agriculture. New Delhi: ICAR

Raman, S. (2010). State-wise micro-irrigation potential in India-An Assessment. Unpublished Paper, Natural Resources Management Institute, Mumbai.

Singh, H. and Singh, B. (2018). Micro-irrigation in india: an option for improving waterproductivity and profitability. InXXX International Horticultural Congress IHC2018:VII Conference on Landscape and Urban Horticulture, IV Conference on 1279, pages 279–286

Vaidyanathan A. and K. Sivasubramaniyan 2004. Efficiency of Water Use in Indian Agriculture, Working Paper no 138, Madras Institute of Development Studies, Chennai.

Image Source: Singh, Shaurya. Rajras. 9 Feb. 2018

CENTRE FOR MANAGEMENT IN AGRICULTURE (CMA)
Indian Institute of Management Ahmedabad (IIMA)
Vastrapur, Ahmedabad, Gujarat 380015
e-mail: cma@iima.ac.in | **Phone:** +91-79-7152-4650, 7152-4651, 7152-4652
Web: www.iima.ac.in