Economic Affairs, Vol. **69**(01), pp. 487-502, March 2024
DOI: 10.46852/0424-2513.2.2024.11

RESEARCH PAPER

Water-saving and Economic Gains of Micro Irrigation Adoption Scheme "Per Drop More Crop": A Case of Sugarcane, Banana and Cotton Cultivation in Maharashtra

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Received: 23-11-2023 **Revised:** 27-02-2024 **Accepted:** 08-03-2024

ABSTRACT

Paper estimates the savings in water, electricity, and economic gains of the micro irrigation adoption scheme "Per Drop More Crop" of the Government of India for the cultivation of three crops, namely, sugarcane, banana, and cotton in selected districts of Maharashtra (India). The before-after comparison method is adopted using the data collected from the pre-tested interview schedules from 116 drip irrigation adopters in Maharashtra. Results indicate that after drip irrigation adoption, farmers experienced higher yields, profits and saved water across the three crops. The per hectare yield of banana, sugarcane, and cotton increased by 73%, 36%, and 80%, respectively. After adopting drip irrigation, the power usage for irrigation per hectare was approximately half for banana and sugarcane and 86% for cotton. With drip irrigation, farmers could grow the sample crops with higher intensity. Thus, overall power consumption for irrigation for banana cultivators increased by 20%, while for sugarcane and cotton it was still lower. The benefit-cost ratio indicated that the drip investment for all three crops is economically viable with and without subsidy. Interaction with farmers reveals that marginal and small farmers need financial assistance to deal with the increasing cost of cultivation. Thus, the government must continue to promote the usage of drip technology through extension services as well as provide the subsidy.

HIGHLIGHTS

- With the adoption of drip irrigation, the per hectare yield and net returns of banana, sugarcane, and cotton increased considerably.
- Drip irrigation has benefitted the farmers and is economically viable even without subsidy for commercial crops like sugarcane, cotton, and banana.
- Power consumption with drip irrigation adoption reduces. However, it is not a sure-shot strategy to conserve water.

Keywords: benefit–cost ratio, cropping intensity, electricity consumption, irrigation efficiency, rebound effects, water productivity

The increasing use of water is leading to acute shortage of water in many Asian countries. This trend will continue as the gap between water demand and supply is expected to increase, due to population growth and economic development. With increasing water scarcity and supply variability, the ability to meet the growing demand for food, due to increase in population accompanied by limited resources per capita, is a global challenge. Addressing this challenge requires adopting technologies that would

How to cite this article: Shroff, S. and Miglani, V. (2024). Water-saving and Economic Gains of Micro Irrigation Adoption Scheme "Per Drop More Crop": A Case of Sugarcane, Banana and Cotton Cultivation in Maharashtra. *Econ. Aff.*, **69**(01): 487-502.

Source of Support: None; **Conflict of Interest:** None

enable crops to grow faster, require less water and fertilizers and produce higher yields (Dinar *et al.* 2019).

Water in India is a scarce resource and has several competing uses. Irrigation is a crucial input for agriculture and has a major role to play in the production process. Irrigation significantly increases the cropping intensity and crop productivity. The potential of other key yield-enhancing inputs such as seed and fertilizer can only be realized with the combination of irrigation as a complementary input. Irrigation for agriculture consumes about 70% of the global freshwater withdrawal from surface/subsurface water systems (Siebert & Döll, 2010). In accordance with Sustainable Development Goal 6.4, irrigation is the largest and most inefficient water user, and small improvements in agricultural water productivity are expected to improve water security (cited in de Jong *et al.* 2021). The climate change has resulted in increase in temperatures and incidences of droughts. Drought intensifies water shortage and overdrawing water from systems such as open wells and tubewells. Howden *et al.* (2007) note that changes in practices at the farm-level, is a key component in adapting agriculture to climate change. The crucial ways of adopting irrigation are to change the amount of irrigated land, adopt risk-reducing technologies and adjust water application rates for specific crops. Risk-reducing irrigation technologies, viz. micro irrigation consisting of sprinklers and drips[1], can save water and reduce crop damage due to extreme weather conditions (Olen *et al.* 2015). Thus, using micro-irrigation technologies is a central way of promoting water conservation.

Need for drip irrigation adoption assistance

United Nations Sustainable Development Goal 6.4 aims that "by 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity, and substantially reduce the number of people suffering from water scarcity". Efficiency of water use in India's agriculture is very low compared to global standards. As cited in Gandhi, Johnson and Singh (2021), water use efficiency is reported to between 25 and 35 per cent (maximum 40 and 45 per cent). This is due to the widespread practice of conventional flood irrigation techniques for agriculture in the country. The micro-irrigation (MI) potential in India is 69.5 million hectares (Government of India, 2004). Prior to 2006, the central government used to provide financial assistance to the state governments so as to enable them to provide subsidy for installation of micro irrigation systems. In 2006, the Government of India (GoI) implemented a centrally sponsored scheme for promoting micro irrigation, through which direct assistance to farmers was provided in the form of matching grant. Under this scheme, for small and marginal farmers, the central government and the state government used to bear 50% and 10% of the cost respectively, while the rest was borne by the farmer/beneficiary. However, till 2014 only 7 million hectares was brought under micro irrigation which indicated that only 10% of the potential was realized. In view of this, when the National Democratic Alliance formed the government in 2014, it launched the *Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)* in 2015. The Department of Agriculture, Cooperation & Farmers Welfare (DAC &F W), GoI implemented a Centrally Sponsored Scheme of *'Per Drop More Crop'* component of *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY-PDMC) from 2015-16 in all the Indian states[2]. The scheme focuses on enhancing water use efficiency at the farm level through MI viz. drip and sprinkler irrigation systems. The Government of India acknowledges:

"Micro Irrigation helps in efficient water use at farm level through precision irrigation as well as reduced fertilizer usage through fertigation, labour expenses and other input costs. Micro Irrigation helps in overall income enhancement of farmers" (Government of India, 2022).

[1]*Drip irrigation is one form of micro irrigation using pipe laterals and emitters (in-line, on-line, or integral). It transmits a higher percentage of applied water to crop consumption compared to gravity technologies (Caswell and Zilberman, 1986)*

[2]*Under this scheme, the Government provides financial assistance @ 55% for small and marginal farmers (operating on land less than 2 ha and @ 45% for other farmers for the installation of drip and sprinkler irrigation systems. Assistance for installation of micro irrigation system is limited to five hectares per beneficiary. Out of the total funding assistance, the share of central government is 60% and the rest is contributed by the state government (Government of India, 2021). From June 2015, till December 2022, an amount of ₹ 13,136 crore was provided to the states and an area of 7.16 million hectares (ha) was covered under micro irrigation (Government of India, 2022).*

Gains of drip irrigation adoption: Literature review

A number of studies have indicated the positive impact of MI (Bhamoriya and Mathew, 2014; Deshmukh and Shinde, 2019; Global AgriSystem, 2014; Gorain *et al.* 2020; Narayanamoorthy, 2001; Narayanamoorthy *et al.* 2020). Bhamoriya and Mathew (2014, 61) revealed that farmers in Maharashtra reported an improvement in timeliness of water availability due to drip irrigation adoption. Farmers reported huge saving in water usage, improvement in groundwater table, incomes and social status. Water saving in sugarcane due to drip method of irrigation was observed to be about 44% in sugarcane, while the same was estimated to be 37% in grapes and 29% in banana (Narayanamoorthy, 2004a). Gorain *et al.* (2020) estimated water saving upto 26.4% and 44.4% for sugarcane and banana growers respectively in Maharashtra.

Narayanamoorthy *et al.* (2020, 1121-1122) observed that the adoption of drip irrigation for groundnut in Tamil Nadu, resulted in savings of about 34% in cost of cultivation, 36% of water and electrical energy and also increased productivity by 79% compared to conventional flood method of irrigation. The net present worth (NPW) and benefit-cost ratio (BCR) revealed that investment in drip irrigation is economically viable for groundnut cultivating farmers. Similarly, Narayanamoorthy (2004a, 2004b) found that the BCR of drip method as compared to flood method was positive[3] to the tune of 1.9 for sugarcane, 1.8 for grapes and 2.9 for bananas. Singh (2008) and Narayanamoorthy *et al.* (2016, 2018, 2020) also found that drip irrigation investments were viable for capsicum, red chillies, and brinjal respectively. Narayanamoorthy *et al.* (2018, 2020) reported that the payback period for investment in drip irrigation for brinjal and groundnut cultivation is one year while Raut *et al.* (2014) found the payback period for cotton to be 1.5 years

The benefits of drip irrigation are not just confined to water saving and improvements in yield but also reduces the working hours of pumpsets. Therefore, the electricity consumption is reduced and in turn the efficiency of the pumpset is increased (Gorain *et al.* 2020; Narayanamoorthy, 2004a). Drip irrigation adoption also reduces fertilizer, pesticides and labour costs (Wang *et al.* 2020). The cost of labour for applying water and fertilizer was reduced by nearly 50% in commercial tea production in Tanzania (Möller and Weatherhead, 2007). Further, a study conducted in China observed that drip fertigation proved to be effective in not only increasing yields but also in the quality of crops viz. grapes in China (Zhang *et al.* 2019).

From the literature it is revealed that MI has several economic benefits, besides promoting optimal water use. However, the literature on diverse benefits of drip irrigation is scanty. Moreover, Bhamoriya and Mathew (2014) found that the response from beneficiaries with respect to reduction in costs and improvement in quality of produce was not strongly positive. Moreover, a few studies also raise concerns that adopting water-saving technologies has increased the demand for irrigation water. This phenomenon is also referred to as "The rebound effect" or "Jevons' Paradox" (refer Pfeiffer and Lin, 2014; Wang *et al.* 2020; Ward and Pulido Velazquez, 2008). Similarly, Contor and Taylor (2013) mention that adopting water-saving technology is not bad. Using the case from the USA, they found that improving irrigation efficiency from 60-80%; lowers field delivery of irrigation water by 15% but increases consumptive use by 3%. Whittlesey (2003) notes that improving irrigation efficiency through technology adoption improves yields, but such technology generally should not be advocated to conserve water. Fishman *et al.* (2003) using randomised control trial in Andhra Pradesh, finds drip adoption increases irrigation efficiency, but does not save groundwater.

Issues related to PMKSY: PDMC

In view of the potential benefits of drip irrigation the Government of India introduced the PMKSY:PDMC scheme, through which farmers can avail of subsidies for adopting MI. In this context, it was reported in a study (Narayanamoorthy, 2018), that the Government subsidy plays an important role in incentivizing the farmers to invest in the drip irrigation system. However, there are certain constraints experienced by farmers in availing the subsidy as proposed in the PMKSY: PDMC. A study (Saravanan, 2022) reported that the farmers in Tamil Nadu faced a delay of more than four months, in receiving the approval from the state government,

[3] *Greater than one BCR indicates investment is viable.*

in order to participate in the scheme. One of the reasons for the delay, was due to different rates prescribed by private agricultural engineering companies and the Department of Agriculture. The private agricultural engineering companies suffer from cost escalation of the drip system, as the rates have not been revised since 2015-16. Hence, they have been persuading the government to consider the cost escalation and accordingly revise the subsidy component in the scheme. However, since the pandemic of 2020, the finances of the state governments have been adversely affected, and the total deficit in the budget of all states has increased by 78 % in the financial year 2021-22 (Reserve Bank of India, 2022). In order to cope up with the fiscal deficit, several state governments are finding ways of reducing the fiscal burden by undertaking various measures. In tune with measures to tighten fiscal space, the Government of Maharashtra has put a cap on the number of beneficiaries who can avail of subsidies for MI system. In Maharashtra since 2020-21, the applications for availing the subsidy for various agricultural schemes are to be made in MAHADBT online portal and it was observed that in 2020, while 1.34 million farmers registered on this portal for availing subsidy under various schemes, only 0.2 million farmers were selected through online draw (Times Now Marathi, 2021). The number of applications for the drip irrigation subsidy exceeded the budget for the same (MahaDBT will speedup drip 2021). In case of Karnataka, in July 2021, the State Government of Karnataka, removed the subsidy on drip irrigation investment, only to restore it later after receiving backlash from scientific and farming community ("Govt. comes under attack for removal of drip irrigation subsidy", 2021). Overall, it appeared that there is also frequent delay from State governments in issuance of notifications and guidelines which affect the timely disbursement of the subsidy, and tends to dissuade farmers from applying for the same (Mehta, 2021).

Given the tight fiscal space, it is essential to check the economic viability of drip irrigation adoption with and without subsidy. Venot *et al.* (2014) noted that there is a need to identify the supply/demand gap between what the government is supporting and the requirements of the farmers. Moreover, with increasing costs of inputs over the years, it is important to examine the viability of drip irrigation investment from time to time. Hence it is important to study the economic viability of drip irrigation adoption on a continuous basis. Since the studies will observe the payback period of the drip system with and without subsidy, the government will be in a position to address policy issues relating to implementation of MI schemes

Few studies viz. Narayanamoorthy (2004a, 2004b) have demonstrated that the investment in drip irrigation is economically viable without subsidy for sugarcane, banana and grapes and also observed the same in another study (Narayanamoorthy *et al.* 2018, 2020) for brinjal and groundnut cultivation. Similarly, Suresh Kumar and Palanisami (2011) also found that drip irrigation investment is viable even without subsidies. Sharma and Kaushal (2015) reported drip irrigation investment for okra cultivation in Punjab is viable only with 30% subsidy. The current paper is one more attempt to study the economic viability of drip irrigation investment as changing fiscal and financial dynamics require fresh inquiry periodically.

Maharashtra is a water stressed state and the availability of water in the state is extremely uneven both temporally as well as spatially. The state also faces frequent droughts and the ground water resources are rapidly declining. Agriculture is the largest user of water in Maharashtra, which consumes more than 80% of the province's exploitable water resources. Barely 18% of the gross cropped area is irrigated (Government of Maharashtra, 2019). A large part of the water resources of the state are used for sugarcane and horticultural crops, thus causing a strain on the limited availability of water. Therefore, expansion of area under micro-irrigation and enhancing artificial groundwater recharge structures are the policy priority of the Government of Maharashtra (Kumar, Sebastian and Kumar, 2022). It is therefore important for the government to provide extension services to farmers so that they are aware of the economic and social viability of drip irrigation methods. Due to the scarcity of water in Maharashtra, the Government is making all round efforts to increase the area under MI.

In view of the above, an economic analysis of drip irrigation adoption of major commercial crops in Maharashtra is timely. The paper examines (a) yields and net returns of sample farmers before and after the adoption of drip irrigation; (b) water, electricity and cost savings in various inputs of sample crop cultivation; (c) economic viability of drip investment of sample crops with and without capital subsidy. Our paper adds to the literature of adoption and gains of drip irrigation. It adds to the scanty literature on economic viability and gains of inputs saving for three water guzzling crops of sugarcane, banana, and cotton. The rest of the paper is structured as follows: Section two discusses the data sources, empirical settings and the methodology. Section three presents the results of survey and discusses the findings. Section four summarizes the broad conclusions.

Empirical settings and methods

This research is based on field survey conducted in Maharashtra (Western region of India). The main purpose of this paper is to estimate the economic viability of drip irrigation investment, and understand the changes in input usage, notably water which is a scarce. The study is an evaluation research, in which before/after design is adopted. This method allows for comparison of the same set of individuals on certain parameters before and after an intervention is completed (O'Leary, 2010). Therefore, we compare the data collected from farmer-household survey for specific variables such as cropped area, production, costs, and returns before drip irrigation adoption as well as post-drip irrigation adoption and yield, for the three selected crops, viz. sugarcane, banana and cotton. These three crops commands the largest area under MI in Maharashtra (Table 1), and were thus selected for the study

Table 1: Profile of State of Maharashtra 2020-21

Particulars	**Unit in million hectares**
Total Geographical Area (2020-21)	30.76
Net Sown Area (2020-21)	16.65
Cropping intensity (%)	144.00
Area under Horticulture Crop (2020-21)	2.10
Area covered under MI through PMKSY-PDMC (2015-16 to 2022-23*) (million hectares)	0.85
Funds received from Central Government (₹ in billion)	21.39
Crops acreage under drip Irrigation (uptill 2018-19)	
Cotton	0.60 (24.0%)
Sugarcane	0.29 (11.7%)
Banana	0.16 (6.5%)
Pomegranate	0.15 (5.9%)

Source : Economic Survey of Maharashtra 2021; Commissionerate of Agriculture, Maharashtra; Government of India, 2023.

Note: Units in parenthesis indicate % share of crop area from the total area under MI in Maharashtra.

**till January 2023.*

The primary data was collected from the field with the help of a pilot-tested structured interview schedule from 116 farm households (52 from Pune and 64 from Jalgaon district of Maharashtra)[4]. The secondary data was collected from various governmental sources like Office of the Commissioner of Agriculture, Pune, Maharashtra, Office of District Agriculture Officer, Pune and Jalgaon districts.

Selection of region and crops

Maharashtra is one of the leading states in MI adoption in India. It is the fourth-largest state in terms of area brought under MI as part of PMKSY-PDMC (Government of India, 2023). A brief profile of the state, as well as the crop wise share of area under MI is indicated in Table 1. Out of total area under MI in the state, the share of cotton commands the largest area under MI in the state with a share of 24%. Besides, cotton, another major cash crop in Maharashtra is sugarcane which is well known as a water guzzling crop and the share of this crop in total area under MI is 11.7 %. The Government of Maharashtra is making concerted efforts to increase the area under sugarcane under MI so that water is saved and yield is improved. Presently only about 35 % of area under sugarcane in Maharashtra is under MI. The third crop selected for the study was banana, which is largely under drip irrigation.

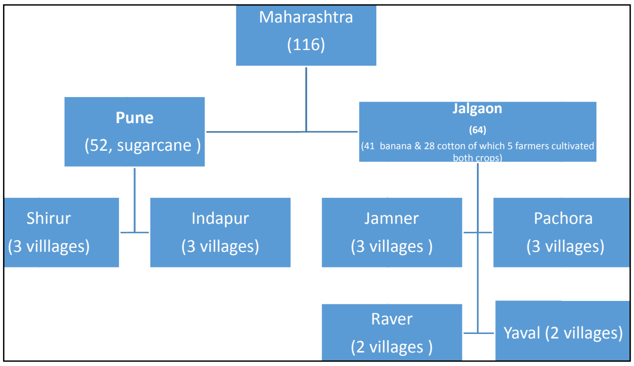
Our Sampling is four stage with selection of district at the first stage, followed by taluka[5] and then village from which farmer households were selected. The districts, talukas and villages were selected

[4]As it was time bound project, hence sample was restricted to 116 households. Data was also collected on qualitative aspects of drip adoption.

[5]Taluka is known as sub-district.

purposively. The districts, talukas and villages with large concentration of PMKSY beneficiaries were identified with the help of the respective District Agricultural and Taluka Agricultural Officer. Fig. 1 depicts the sample district and talukas. The two districts selected for the survey were Pune and Jalgaon. Pune district was selected for sugarcane crop as the district was a major sugarcane belt. At the second stage of sampling, two talukas were selected and finally in the third stage, three villages from the each of the two talukas were selected as there was high concentration of beneficiaries in these villages. From the six villages, 52 beneficiary farmers were selected from Pune district, who availed of subsidy in the PMKSY: PDMC. As we wanted first time drip adopters for the survey. There was no sampling frame for first time drip adopters in both the districts. Hence, purposive sampling criteria was used for respondent selection at last stage. The sample comprised only of farmer households in the villages who were growing the reference crop even before adopting drip irrigation under PMKSY: PDMC, before 2015-16 and continued to grow the crop. The farmers who were growing reference crop with and without drip irrigation in the reference period were also eligible. With respect to banana and cotton, the district selected was Jalgaon as this district is a leading one in the adoption of MI and much ahead of other districts. Jalgaon is a major banana growing region not only in the state but also in the country. Cotton is a major commercial crop in Maharashtra and largely unirrigated. However, there are pockets in the state where the area is irrigated and the same was observed in Jalgaon and the farmers in this district began to adopt drip irrigation for cotton. Hence, in Jalgaon, both crops, banana and cotton were selected across five talukas at the second stage. The third stage of sampling included 10 villages from Jalgaon district and a total of 64 beneficiaries were selected. Within these 64 sample farmer household, there were five farmers which cultivated both banana as well as cotton and hence from these five household, cost of cultivation, input usage and returns data was elicited for both the crops. Overall, a total of 116 beneficiaries who availed of subsidy under PMKSY-PDMC constituted the sample size across two districts and three crops.

The reference period for the study is 2019-20. Hence the costs and returns are based on the crop harvested in the agriculture year 2019-20. The year of adopting drip irrigation varies from year to year (Table 4) for each beneficiary. In order to compare the cost of cultivation of the reference period with the costs of cultivation before adoption of MI, we have extrapolated the costs before drip irrigation adoption based on composite input price index (CIPI)[6] for the year 2019-20. This allows us to make the costs comparable with the reference year. Earlier papers on gains on drip irrigation have not done this.



Source: *Primary Survey.*

Note: *Units in parenthesis denote the sample household surveyed.*

Fig. 1: Sample District and Talukas

To determine the economic feasibility of investing in drip irrigation for the cultivation of sample crops, the NPW and BCR are estimated using discount cash flow method (Gittinger, 1984). The NPW is the difference between the total value of benefits and costs for a certain period of the drip irrigation system. It combines total benefits with total costs taking into account variables such as capital costs incurred on account of installing the drip set. According to the NPW criterion, investment in drip sets can be considered economically viable if the present value of the benefits is greater than the current value of the costs. The BCR is closely related to NPW because it is achieved by dividing the present value of the benefit stream with that of the cost stream. The NPW and BCR can be mathematically defined as follows:

$$NPW = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t}$$

[6]*Commission for Agricultural Costs and Prices (CACP) constructs a composite input price index (CIPI) based on the latest prices of different inputs, including human labour, bullock labour, machine labour, manure, fertilizer, seed, pesticides, and irrigation. This index helps to know the increase in prices of the inputs.*

$$BCR = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}}$$

where, B_t is the benefit in year t, C_t is the cost in year t; t = 1, 2, 3,…….n; and i is the discount rate or the opportunity cost of the investment. The life period of the drip-set is five years[7] and discount rate is 10% per annum. As this study is cross-sectional and due to time and resource constraints, we assume that the cash inflows and outflows will remain constant. It is assumed that the cultivation technology of the select crops will remain constant throughout the lifetime of the drip kit. This methodology has been used across by Narayanamoorthy (2004a); Narayanamoorthy *et al.* (2016, 2018, 2020); amongst others. We also look at input savings (including power and water), which we discuss in the results section

RESULTS AND DISCUSSION

Sample Profile

In Table 2, the profile of the sample farmers/ beneficiaries of PMKSY: PDMC is indicated with respect to age and education. The average age of adopters was observed to be 46 years. Half of the adopters were in the age group of 40-60 years. Most of the adopters were literate and well educated, as three-fourth of respondents had completed schooling, while 22.41% were graduates. Table 3 shows the operational landholding pattern of sample farmers. While 16.38% were marginal farmers, small and medium were 36.21% and 39.66% respectively. The average operated area across all groups was 3.04 hectares per farmer. Within the sample, out of the total irrigated area, 86.5% was under MI. All the sample adopters had availed subsidy for the purchase of MI system. Almost all the operated area for the marginal and small farmers was brought under drip irrigation. In case of the larger farmers, about three-fourth of their operated area was under drip irrigation. On an average respondent had adopted drip set, three years prior to reference period. Table 4 shows the year in which the sample farmers adopted micro-irrigation. Almost all sample farmers have adopted drip irrigation in 2015-16 (of which one-fourth of respondents had adopted just preceding the reference year of the survey). Open-well is the source of irrigation for 72% of total growers, followed by tubewell, which accounted for 26% of water source of irrigation. 10% of growers depended on canal-lift irrigation for water.

[7]*This is based on the experience gathered from different farmers and drip-set dealers during the primary survey.*

Table 2: Age group and education profile

Particulars	Number in sample	Percent
Age group		
21-30	12	10.3
31-40	31	26.7
41-50	29	25.0
51-60	29	25.0
Above 60	15	12.9
Education		
Illiterate	2	1.72
Primary	10	8.62
Middle	18	15.52
10th Std	25	21.55
12th Std	28	24.14
Graduate	26	22.41
Post-Graduation	6	5.17
Technical	1	0.86

Source: *Primary Survey.*

Cropping profile before and after MI adoption

Table 5 shows the cropping pattern and area within micro-irrigation for the reference year 2019-20. Table 6 shows the cropping pattern of the respondents before adopting micro-irrigation. The cropping pattern revealed that cotton was the dominant *kharif* crop and cultivated in Jalgaon district. The average area of the farmers reporting cultivation of cotton was 2.59 hectares in the *Kharif* season (Table 5). It can be observed that 91.1% of the area under cotton was under drip irrigation while 8.9% was irrigated by non-micro or conventional sources. Maize was another crop cultivated in the *kharif* season, but only 16% area was under MI. The crops cultivated in the *rabi* season were horticultural, besides maize, wheat and horse gram and bajra. The perennial crops cultivated were sugarcane and banana. The average area under sugarcane, cultivated in Pune district, was 1.76 hectares, of which 96.6% are was under drip while 3.4% was under flood irrigation.

Table 3: Operational holding of sample adopters (Area in hectares)

Group (ha)	Number of Farmers	Percent (%)	Total Area Operated	Micro-Irrigated area Total	Drip	Sprinkler	Non-Micro Irrigated	Un-irrigated
Marginal (<1)	19	16.38	0.67 (100.0)	0.67 (100.0)	0.67 (100.0)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)
Small (1-2)	42	36.21	1.38 (100.0)	1.32 (95.7)	1.32 (95.7)	0.00 (0.0)	0.06 (4.3)	0.00 (0.0)
Medium (2-10)	46	39.66	3.51 (100.0)	3.16 (90.0)	3.12 (88.9)	0.04 (1.1)	0.33 (9.4)	0.01 (0.3)
Large (>10)	9	7.76	13.26 (100.0)	10.18 (76.8)	10.03 (75.6)	0.15 (1.2)	2.99 (22.5)	0.09 (0.7)
Total	116	100.00	3.04 (100.0)	2.63 (86.5)	2.60 (85.5)	0.03 (1.0)	0.38 (12.6)	0.01 (0.3)

Source: *Primary Survey.*

Table 4: Year when micro-irrigation was adopted by sample farmers

How many years ago Did you adopt MI	Number	Percent (%)
Current Year (2019-20)	6	4.31
Last Year (2018-19)	19	17.24
2 years ago	24	20.69
3 years ago	25	21.55
5 years ago	42	36.21
Overall Average: 3.1 years		

Source: *Primary Survey.*

The average area under banana[8] for the sample farmers was 3.23 hectares, with 93% of the area under drip and 7% being irrigated through flood irrigation. Fertigation[9] was also given to all crop under drip method.

It can be observed from Table 6 that cotton was the most important *kharif* crop before MI adoption as well. The average area under sugarcane and banana increased respectively after MI adoption. Thus, MI adoption is associated with higher crop acreage for commercial crop. Most of the farmers in the sample completely shifted the cultivation of the selected crops, viz. sugarcane, banana and cotton, from flood irrigation to drip irrigation.

Changes in Yield, and Input Costs

In Table 7, the production, cost of cultivation and returns of sample farmers for all three selected crops is presented. The data on cost of cultivation, yield, incomes and acreage with drip irrigation is of the reference year, while without drip irrigation is of the time period, when the same farmers cultivating the crop were using flood irrigation. While the data prior to use of drip method belong to different years, the same have been made comparable as explained earlier.

Sugarcane

The total variable costs for sugarcane cultivation under drip irrigation was ₹ 152,893 per hectare as compared to ₹ 184,910 per hectare without drip irrigation. Fertilizer and labour costs are the major cost components of sugarcane. The water soluble fertilizers used by sample farmers resulted in fertilizer costs and plant-protection costs being 7.7% higher in drip cultivation as compared to without drip as water soluble fertilizers are costlier than granular fertilizers. Labour mandays and labour costs in drip irrigation reduced by 37% and 47% respectively. The use of drip has resulted in 72% reduction in water charges. This is mainly because

[8]*Banana is also a perennial crop and sown either in June or November. Jalgaon district is a banana belt of the state of Maharashtra. In our sample, it is observed that farmers sow cotton in early kharif season – normally in the first week of June and harvest it by November. The harvest of cotton is followed by the sowing of banana.*

[9]*Fertigation refers to the process of fertilizer entering the field with irrigation water through drip laterals. According to Fan, et al. (2020) fertigation can greatly improve the utilization rate of fertilizers; improve the effectiveness of nutrients; and save time, transport, labor, and fuel costs.*

less water is consumed with drip in the cultivation of sugarcane. Further, less use of water also resulted in reduction in electricity cost which reduced by 20%. Marketing costs for sugarcane is low, as the entire sugarcane is procured by sugar mills. Some expenditure is also incurred towards hospitality of the tractor person and labour person post-harvest.

Under drip method, per hectare yield of sugarcane is 1446 quintals compared to 1067 quintals without drip which means that yield increased by 35.5%. Hence reduced costs, higher yields and higher prices, after extrapolation of sale prices resulted in sugarcane farmers receiving net profit of ₹ 2,45,542 per hectare with drip compared to ₹ 1,11,606 per hectare without drip i.e. an increase of 120%.

Banana

The total variable costs for banana cultivation under drip irrigation was ₹ 2,50,882 per hectare as compared to ₹ 2,29,811 per hectare without drip irrigation (Table 7). This indicates that the total variable costs increased by 17%. Planting material, fertilizer, plant protection and marketing costs were higher in drip method of banana cultivation. It was reported that in the reference period, the farmers used tissue culture banana saplings (planting material) which costs ₹ 12 per sapling compared to conventional banana sapling which costs Rs. 5 per sapling and used prior to the adoption of MI. The total planting material cost per hectare of land was ₹ 47,112 in drip method compared to ₹ 24,672 without drip. Similarly, fertilizer costs were 18% higher in drip method compared to without drip. However, this also brought about increase in yield. Tissue culture plant time duration is 11 months, while traditional plant time duration is 12 months. The labour mandays and labour costs in drip irrigation were observed to have been reduced by 20.3% and 13.4% respectively. With drip, 164 man days and without drip, 206 mandays of labour use was observed. Water charges and electricity charges, each reduced by 49%. There was reduction in electricity charges because total hours of pumping per hectare reduced by 43% in drip irrigation cultivation (Table 8). Under drip method, per hectare yield of banana was 604 quintals compared to 348 quintals without drip which means that yield increased by as much as 73.3%. Besides yield increase, the farmer also realized higher price due to better quality of output. On an average, the price realization was ₹ 875 per quintal under drip method, compared to Rs. 640 per quintal without drip. The higher yields and higher prices resulted in banana farmers receiving net profit of ₹ 3,16,785 per hectare with drip compared to ₹ 75,079 per hectare without drip. This indicates that the profit from banana cultivation using drip method of irrigation is phenomenal as compared to cultivating the crop using surface method of irrigation. However, it must be noted that farmers using drip also had the benefit of tissue culture technology[10] which provides disease free seedlings, early maturity of the crop and uniform growth of the crop with increase in yield. The plants are also more densely planted which increase the yield. Since the density of the plantation is more, a suitable temperature is created for the plants which facilitates the growth and improves the quality and quantity of the yield.

With increase in yields, farmers had more produce to sell and the cost of transport and other associated marketing costs also increased. Banana is a highly perishable crop and requires careful handling, failing which, the quality of the produce is likely to deteriorate. Hence, post-harvest handling plays a very important role in the cultivation of banana and farmers have to therefore incur higher marketing costs. The economic benefits from cultivation of banana is tremendous after adoption of drip system and hence the higher costs incurred in terms of seeds, fertilizer, farm yard manure and pesticides as compared to surface irrigation is highly beneficial for the farmers.

Cotton

The total variable costs for cotton cultivation under drip irrigation was ₹ 91,262 per hectare, as compared to ₹ 84,112 without drip irrigation, i.e. drip adoption had a higher variable cost as compared to use of surface irrigation by 8.5% (Table 7). Fertilizer, pesticides, and farm yard manure costs were higher by 61.5%, 16.9% and 11.4% respectively in drip method of cotton cultivation. Cotton crop has the tendency to get infested by pests and hence farmers began adopting *Bt* seeds to overcome the

[10]Tissue culture plants get 10-12 hands (bunch) compared to traditional banana plants which get 7-9 hands (bunch) per tree. Farmers also reported that average bunch weight per tree is around 23-25 kg incase of tissue culture plant compared 18-20 kg in traditional banana tree.

Table 5: Cropping profile and area **with** micro-irrigation (reference year: 2019-20)

Sl. No.	Crop name	No. of farmers reporting	Area - average in hectares (based on reporting farmers)					
			Area under the crop	Drip area	Sprinkler area	Irrigated Non-Micro area	Unirrigated area	Fertigation (%)
Kharif								
1	Cotton	36	2.59 (100.0)	2.36 (91.1)	0.00 (0.0)	0.23 (8.9)	0.00 (0.0)	100.00
2	Maize	15	1.69 (100.0)	0.27 (16.0)	0.00 (0.0)	1.36 (80.6)	0.06 (3.4)	100.00
3	Vegetables	2	2.12 (100.0)	0.91 (42.9)	0.00 (0.0)	1.21 (57.0)	0.00 (0.0)	100.00
4	Moong	1	2.43 (100.0)	0.00 (0.0)	0.00 (0.0)	2.43 (100.0)	0.00 (0.0)	0.00
Rabi								
1	Watermelon	3	1.82 (100.0)	1.82 (100.0)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	100.00
2	Maize	3	2.16 (100.0)	2.16 (100.0)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	100.00
3	Wheat	2	0.61 (100.0)	0.40 (66.7)	0.00 (0.0)	0.21 (34.6)	0.00 (0.0)	100.00
4	Cotton	1	6.07 (100.0)	6.07 (100.0)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	100.00
5	Onion	1	4.86 (100.0)	0.00 (0.0)	1.42 (29.2)	3.44 (70.8)	0.00 (0.0)	0.00
6	Eggplant	1	0.81 (100.0)	0.81 (100.0)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	100.00
7	Lettuce	1	2.02 (100.0)	0.00 (0.0)	2.02 (100.0)	0.00 (0.0)	0.00 (0.0)	0.00
8	Horse Gram	1	4.05 (100.0)	0.00 (0.0)	0.00 (0.0)	4.05 (100.0)	0.00 (0.0)	0.00
9	Bajra	1	0.61 (100.0)	0.00 (0.0)	0.00 (0.0)	0.61 (100.0)	0.00 (0.0)	0.00
Perennial								
1	Sugarcane	52	1.76 (100.0)	1.70 (96.6)	0.00 (0.0)	0.06 (3.4)	0.00 (0.0)	100.00
2	Banana	43	3.23 (100.0)	3.01 (93.0)	0.00 (0.0)	0.23 (7.0)	0.00 (0.0)	100.00
3	Pomegranate	3	1.01 (100.0)	1.01 (100.0)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	100.00
4	Chilli	1	0.81 (100.0)	0.81 (100.0)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	100.00
5	*Mosambi*	1	0.81 (100.0)	0.81 (100.0)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	100.00

Table 6: Cropping profile and area **before** micro irrigation

Sl. No.	Crop name	No. of farmers reporting	Area - average in hectares (based on reporting farmers)		
			Total area	Irrigated area	Un-irrigated Area
Kharif					
1	Cotton	42	2.56	2.56	0.00
2	Maize	16	1.80	1.80	0.00
3	Onion	3	1.35	1.35	0.00
4	Jowar	2	0.81	0.40	0.40
5	Horse Gram	1	0.81	0.81	0.00
Rabi					
1	Wheat	5	1.46	1.46	0.00
2	Jowar	3	2.61	2.61	0.00
3	Maize	3	1.01	1.01	0.00
4	Onion	2	2.83	2.83	0.00
5	Horsegram	1	4.05	4.05	0.00
6	Watermelon	1	1.21	1.21	0.00
7	Sweet corn	1	1.01	1.01	0.00
8	Groundnut	1	0.81	0.81	0.00
9	Eggplant	1	0.81	0.81	0.00
Perennial					
1	Sugarcane	53	1.56	1.56	0.00
2	Banana	41	2.42	2.42	0.00
3	Pomegranate	1	0.61	0.61	0.00
4	*Mosambi*	1	0.81	0.81	0.00

Table 7: Changes in production, incomes, inputs and costs with micro-irrigation for major crops (units in ₹ per hectare)

Item	Crop- Sugarcane No. reporting 52			Crop-Banana No. reporting 41			Crop- Cotton No. reporting 28		
	With MI	Without MI	% diff	With MI	Without MI	% diff	With MI	Without MI	% diff
Area (hectares)	1.76	1.55	9.82	3.11	1.45	114.15	2.31	2.18	5.98
Production (Quintals)	1,446	1,067	35.5	604	348	73.3	27	15	79.9
Price (₹/quintal)	278	232	20.0	875	640	36.7	4,929	3,921	25.7
Total Sales Revenue	398,435	250,138	59.3	567,667	219,957	158.1	134,460	55,430	142.6
Total Sales Revenue assuming price is same	398,435	296,516	34.4	567,667	3,04,890	86.2	1,34,460	73,100	83.9
Seeds/Plants cost	18,194 (11.9)	18,735 (10.1)	-2.9	47,112 (18.8)	24,672 (10.4)	91.0	3,696 (4.0)	3,727 (4.4)	-0.8
Fertilizer cost	39,471 (25.8)	39,410 (21.3)	7.7	66,439 (26.5)	56,229 (24.5)	18.2	15,422 (16.9)	9,547 (11.3)	61.5
Farm Yard Manure	29,511 (19.3)	29,221 (15.8)	7.6	36,769 (14.7)	35,049 (15.3)	4.9	8,277 (9.1)	6,184 (7.3)	33.8
Pesticides cost	11,502 (7.5)	11,209 (6.1)	12.7	12,614 (5.0)	8,660 (3.8)	45.7	12,710 (13.9)	7,942 (9.4)	67.5
Electricity cost	2,587 (1.7)	3,230 (1.7)	-19.9	3,997 (1.6)	7,844 (3.4)	-49.0	2,523 (2.8)	3,240 (3.8)	-22.1
Diesel cost	11 (0.0)	12 (0.0)	0.0	4 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
Water Charges paid	832 (0.5)	3,137 (1.7)	-72.4	142 (0.1)	282 (0.1)	-49.6	984 (1.1)	687 (0.8)	43.2
Farm power & Equipment cost	18,501 (12.1)	19,626 (10.6)	-5.7	21,366 (8.5)	24,362 (11.4)	-18.5	12,219 (13.4)	13,306 (17.4)	-8.2
Total man-days	128	206	-37.7	164	206	-20.3	81	120	-32.2
Labour cost	32,024 (20.9)	60,256 (32.6)	-46.9	47,456 (18.9)	60,533 (26.3)	-13.4	33,210 (36.4)	36,701 (43.6)	-9.5
Marketing cost	259 (0.2)	73 (0.0)	253.4	14,982 (6.0)	10,319 (4.5)	45.2	2,222 (2.4)	2,779 (3.6)	-20.0
Total Cost	152,893 (100.0)	184,910 (100.0)	-9.5	250,882 (100.0)	229,811 (100.0)	17.3	91,262 (100.0)	84,112 (100.0)	8.5
Net Profit	245,542	65,228	202.2	316,785	-9,854	3314.8	43,198	-28,682	250.6
Net Profit after sale price extrapolation	2,45,542	1,11,606	120.0	316,785	75,079	321.9	43,198	-11,012	492.3

Note: *Input prices of without MI period have been extrapolated to the reference year.*

problem of *American bollworm* which used to always destroy the cotton crop. However, these seeds are highly priced, but farmers use them in the hope of higher returns. Once the farmer has invested in costly seeds, he ensures that the plant gets suitable fertigation and as soluble fertilizers are costlier, the fertilizer costs increased substantially. Further, while Bt seeds may not be susceptible to *American bollworm,* the cotton fields have begun to experience secondary pests such as aphids, whitefly, etc. Hence farmers continue to spray pesticides to save the crop from other pests. Overall, with drip, there is a higher usage of yield enhancing inputs viz. fertilizers, pesticides and farm yard manure because farmers have already invested in costly seeds and water and hence want to reap the benefits by suitable application of complementary inputs.

The labour mandays for cotton in drip irrigation reduced by 32%, while labour charges were similar to that without drip. While drip farmers gave 30 irrigations, the number of irrigations without drip were 12 in number. Electricity charges reduced by 12% because total hours of pumping per hectare reduced by 13.5% in drip irrigation cultivation.

Under drip method, the per hectare yield of raw cotton was 27 quintals compared to 15 quintals without drip which indicates an increase of 79.9%. Further, the quality of output also improved after the adoption of drip irrigation as the plant receives optimal inputs. With higher yields and higher prices, the cotton farmers earned a net profit of ₹ 43,198 per hectare with drip as compared to losses of Rs. 11,012 per hectare incurred in surface method even after prices in the pre drip adoption period were extrapolated.

Water and Electricity Consumption:

In experimental studies, water consumption is generally estimated as the depth of applied water in centimeters (cm) or millimeters (mm). However, it was not possible for the study team to adopt such method[11]. Hence, we adopt methodology in Devika *et al.* (2017), Narayanamoorthy (2004b); Narayanamoorthy *et al.* (2016, 2018, 2020) whereby water usage is measured in horsepower (HP) watering hours. Water usage in HP-hours is calculated by multiplying the HP of the pump set by the hours of water usage for the farmers with and without the drip for irrigating the field. One of the field observations was that the farmer continued to use the same electric pump for water extraction under the drip system and earlier under the flood system. Ideally, in case of drip system, pressure should be increased and water discharge should be reduced.

Table 8 presents the water use, electricity consumption and productivity of crops with drip and without drip method. One of the advantages of drip irrigation is that a large plot of land can get irrigated in a shorter time period. Unlike flood irrigation which requires more than ten hours to irrigate a field of one hectare, the same can be done by drip method in less than five hours. The sample farmers reported that on an average they used to irrigate their sugarcane fields 57 times with flood method as compared to 52 times, without drip while the crop was standing on the field. For banana, the number of irrigations with drip was 107 while without drip it was 76[12]. For cotton, number of irrigations with drip was 30, while without drip it was 12.

Though the number of irrigations used with drip method of cultivation increased substantially across all the three crops, the number of hours used for each irrigation was lower in drip method than that of flood irrigated method. This resulted in hours of pumping per hectare significantly lower in drip method compared to flood irrigated method across the three crops. The total water consumption (measured in HP-hours) per hectare for sugarcane, banana, and cotton with drip irrigation is about 56.5%, 60% and 46% respectively lower, compared to without drip irrigation method. Under drip method, more plant area is covered under irrigation in short time span and farmers are able to manage their irrigation schedule in a better way as compared to flood irrigation method. With the help of drip, the water directly reaches the roots of plants and the entire cultivated area need not be irrigated, which happens in case of flood irrigation. The drip irrigation also leads to saving of electrical energy used to operate irrigation pump sets. With the reduction in water consumption, drip irrigation significantly reduces the working time of the pump unit, which leads to a reduction in the amount of electricity required. In this study, we estimated the electricity savings by assuming that 0.750 kWh of electricity is consumed per HP for each hour of pump-set running. This means sugarcane, banana, and cotton farmers saved approximately 1003, 1757, and 95 kWh of energy per hectare respectively. Reduced water and electricity usage under drip method of irrigation has led to substantial increase in water productivity and electricity productivity (Table 8). This indicates that for water-intensive annual crops such as sugarcane and bananas, drip method of irrigation can be an effective solution in water-stressed regions of Maharashtra. However, in the case of bananas, crop acreage after drip adoption almost doubled, which resulted in a 21.5% increase in overall power consumption at the farmer level.

[11]*As noted in Devika et al. (2017), it is difficult to measure the depth of water level in the farmer's field due to changes in the horsepower (HP) of the pump set, the height of the feed pipes, the different size of the water extraction machines, and the distance between the places of water source and to irrigating field, soil quality, terrain conditions etc.*

[12]*Banana has greater water requirement; each plant requires 25-30 litres of water daily. Hence number of irrigation is higher.*

Table 8: Water use, electricity consumption and productivity of crops with drip and without drip method

Item	Sugarcane			Banana			Cotton		
	With MI	Without MI	% diff	With MI	Without MI	% diff	With MI	Without MI	% diff
Pumpset HP	5.0	5.0		6.1	6.1		6.0	6.0	
Area (hectares)	1.76	1.55	9.8	3.11	1.45	114.2	2.31	2.18	6.0
No of irrigations (per farmer)	57	52	8.8	107	76	41.6	30	12	152.1
Hours required per irrigation (ha)	4.3	9.9	-56.2	4.7	11.6	-59.7	4.5	13.0	-65.4
Hours of pumping (ha)	247.4	514.8	-51.9	500.8	882.3	-43.2	135.0	156.0	-13.5
Total HP hours of water used	2176.9	3989.7	-45.4	9562.2	7855.5	21.7	1871.1	2040.5	-8.3
HP hours of water used per hectare	1236.9	2574.0	-51.9	3074.7	5417.6	-43.2	810.0	936.0	-13.5
Electricity consumption (kWh/ha)	927.7	1930.5	-51.9	2306.0	4063.2	-43.2	607.5	702.0	-13.5
Production (Qtl/ha)	1446.0	1067.0	35.5	604.0	348.0	73.6	27.0	15.0	80.0
Water productivity (kg per hectare/HP hours of water)	116.9	41.5	182.0	19.6	6.4	205.8	3.3	1.6	108.0
Electricity productivity (kg per hectare/kwh)	155.9	55.3	182.0	26.2	8.6	205.8	4.4	2.1	108.0

Source: *Primary Survey.*

Note: *HP: horse power; kwh: kilo watt hours; ha: hectare, Qtl: quintal; 1 Qtl = 100 kg; kg: kilogram.*

With this, there is a chance of water requirement overall increased for banana cultivation due to increased acreage. Thus, we might say that there is the rebound effect for bananas, as Contor and Taylor (2013) and Wang *et al.* (2020) noted. This is mainly due to area expansion, as banana acreage increased by 42% after drip adoption (refer Tables 5 and 6). While in the case of sugarcane and cotton, we see a reduction in overall power consumption, as an increase in crop acreage was less than 10%.

Economic viability of investment in drip irrigation

The net profits earned by farmers (Table 7) was calculated only by considering variable or paid out costs. However, drip system entails considerable fixed cost which many farmers are unable to afford to invest upfront. The capital costs of drip irrigation system for sample crops are presented in Table 9. The capital cost of drip irrigation installation without subsidy is ₹ 89,002, ₹ 87,100, and ₹ 97,171 per hectare for sugarcane, banana, and cotton farmers respectively. As stated in Section one, all farmers receive the capital subsidy @45-55% under PMKSY-PDMC for drip irrigation investment. Within our sample, the capital cost of drip irrigation installation with subsidy is ₹ 40,799, ₹ 39,503, and ₹ 43,924 for sugarcane, banana, and cotton farmers respectively. The capital required for drip system varies by crop; closely spaced crops require higher fixed capital investment, while wide spaced crops require relatively low fixed capital investment. Less pipe length, emitter and dripper requirement for widely spaced plants allows for lower investment. With respect to source of funds to purchase the drip system, it was observed that only 21% of the adopters availed of loans while 79% of adopters used their own funds for investing in the system.

To understand the economic viability of drip investment, we calculated the NPW and BCR. Importantly, the longevity of the drip system is an important factor in estimating NPW. In Table 9, the NPW and estimated BCR without subsidy and after accounting for subsidy for the sample farmers is presented crop wise. Both the NPW and the BCR calculated for all the three crops clearly shows that the drip investment for all the three crops cultivated is economically viable for farmers with and without

Table 9: Capital costs of drip system, NPW and BCR estimated using actual price received

Particulars	Sugarcane	Banana	Cotton
Capital cost of DMI (without subsidy) (₹/hectare)	89,002	87,100	97,171
Subsidy for DMI (₹/hectare)	48,203	47,597	53,247
Capital cost of DMI (with subsidy) (₹/hectare)	40,799	39,503	43,924
NPW without subsidy (₹/hectare)	8,41,796	11,13,715	66,580
NPW with subsidy (₹/hectare)	8,89,999	11,61,312	1,19,826
BCR without subsidy	2.26	2.07	1.15
BCR with subsidy	2.44	2.17	1.31

Source: *Field Survey.*

Note: *BCR and NPW are calculated at 10% discount rate with five years considered as life of drip system.*

subsidy. The BCR is marginally over one for cotton (1.15 with subsidy and 1.30 without subsidy), while the BCR is over two for banana and sugarcane. This means sugarcane and banana growers are able to realize atleast ₹ 2.1 for every rupee invested. The estimated BCR of 1.15 without subsidy for cotton growers indicates that cotton growers earn only marginal profits after bearing the full cost of the drip equipment, and hence incentive to cotton farmers through subsidy is required. Cotton is a short duration crop (140-150 days), which indicates that farmer can cultivate another short duration crop in another season and thus spread the fixed cost of the MI system which will enable higher returns. The annual NPW estimated suggests that sugarcane and banana farmers would be able to cover the entire capital cost of the drip kit in the very first year even without the 50% subsidy from the capital cost. Incase of cotton, it would take the farmers three years to recover the cost of drip system, without subsidy.

CONCLUSION

In this paper, we study the input usage, returns and the viability of drip irrigation adoption among the sugarcane, banana, and cotton growers within the PDMC-PMKSY scheme in Maharashtra. The per hectare yield of banana, sugarcane, and cotton increased by 73%, 36% and 80% respectively. The average operational costs of sugarcane declined by 9%, while for banana and cotton, it increased by 17% and 19%. However, net returns for banana, sugarcane, and cotton increased considerably. Both the NPW and the BCR calculated for all the three crops clearly indicated that the drip investment for all the three crops cultivated is economically viable for farmers with and without subsidy. The BCR is marginally over one for cotton, while the BCR is over two for banana and sugarcane. Farmers were able to recover the fixed cost of drip irrigation (after deducting subsidy) within the first year itself for sugarcane and banana. Moreover, with drip sets, large plots were irrigated in a short span of time and hence farmers began to increase the acreage under commercial crops. Our findings of economic and productivity gain per unit of land are in accordance with previous studies (Devika *et al.* 2017; Narayanamoorthy (2004a); Narayanamoorthy *et al.* (2016, 2018, 2020). Our study suggests that drip irrigation has benefitted the farmers and is economically viable even without subsidy for commercial crops like sugarcane, cotton and banana. Interaction with farmers reveal the marginal and small farmers are in need of financial assistance in order to deal with increasing cost of cultivation. Thus, the government must continue to promote the usage of drip technology through extension services as well as providing subsidy. Hence, considering the scarcity of water resource and the limitations in creating more water resources and the importance of water as a yield enhancing input, increasing the area under this method of irrigation must be promoted as a far better alternative to surface method.

After adopting drip irrigation, the power usage for irrigation per hectare was approximately half for banana and sugarcane and 86% for cotton. With drip irrigation, farmers could grow the sample crops with higher intensity. Thus, overall power consumption for irrigation for banana cultivators increased by 20%, while for sugarcane and cotton it was still lower. Thus, if farmers are depending on groundwater for irrigating the land. Adoption of drip irrigation is not sure-shot strategy to conserve water. Other means of water conservation for ground water have to be considered. Hence, farmers need to be made aware appropriate configuration of electric/solar pump required for extraction, which increases the pressure and reduces the water discharge per second is needed. With water savings, there will be higher availability of water downstream, facilitating crop diversification and enhanced cropping intensity.

The economic viability of drip irrigation as a water saving method must perhaps be conducted for other crops, especially horticultural crops, in water stressed states like Maharashtra, as this would help the policy makers to devise a suitable subsidy structure and also further promote this technology.

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