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Micro-irrigation in Drought and Salinity Prone Areas of Haryana: Socio-economic Impacts

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Abstract

Water has become increasingly scarce worldwide and is being presumed that shortly more than one-third of the global population would face absolute water scarcity. Rising demand for urban and industrial water supplies pose a serious threat to irrigated agriculture. However, to achieve the required food and fiber production for ever-increasing population, water is to be used most judiciously. One of the key ways to boost overall agricultural production is to implement better soil-water management techniques in arid and semi-arid areas. One of the water management strategies introduced relatively recently in Indian agriculture is micro-irrigation (MI). Unlike flood method of irrigation, MI supplies the water at the required interval and in desired quantity at a place where water is demanded using a pipe network, emitters and nozzles. Therefore, MI in principle results in low conveyance and distribution losses leading to higher water use efficiency. The net utilization of irrigation water in drip system is 90% and through sprinkler system, it is 82% and thus, MI is having paramount importance with brighter future prospects. The adaptations of MI, however, is not encouraging including in the agriculturally advanced states like Haryana. To find out the bottle-necks and other socio-economic impacts of MI, a NABARD-funded study was undertaken in salinity and drought-prone three districts of Haryana namely Bhiwani, Mohindergarh and Nuh. This study was completed through exhaustive consultation of literature, field observations, interaction with officers and farmers, and pre-designed proforma-based survey for collection of field data from 150 beneficiary farmers from 6 blocks (a cluster of 25 farmers in each block) in 3 districts. A detailed account of the socio-economic impact of MI has been reported in this paper.

Key words: Micro-irrigation, Drip and sprinklers, Drought and salinity-prone areas, Socio-economic impacts

Introduction

Water is one of the most important natural resources for sustaining human life on earth. However, it is becoming increasingly scarce worldwide and by the year 2025 more than one-third of the world population would face absolute water scarcity (Seckler *et al.* 1998, 1999). The situation in India is critical and absolute water scarcity is already affecting in many areas covering large population (Amarasinghe *et al.,* 2007).One of the key ways to boost overall agricultural production in the country is to implement better soil-water management techniques that would provide the arid and semi-arid lands better access to irrigation water, without actually increasing the stress on available water resources. In the states of Punjab, Haryana and Rajasthan, ground water levels are fast depleting due to excessive exploitation for agriculture use. To improve the situation, on-farm water management techniques and adoption of improved irrigation methods such as micro-irrigation is must.

Bhaskar *et al.* (2017) stressed the need of modern irrigation technologies due to the reasons that the productivity of irrigated land and per unit water is low compared to its potential. The water available for irrigation is becoming scarce day by day and the cost for generating water source is ever increasing. The predominance of soils with low water retention capacities and very low hydraulic conductivities makes the arid and semi-arid regions an ideal case for light and frequent irrigation through micro-irrigation. Micro-irrigation will increase the irrigation area using the existing available water, and fertigation it will further enhance production per unit input in the nutrient poor, shallow and sloppy lands.

Micro-irrigation (MI) systems are significant not only in water saving but also in efficient energy, labour and fertilizer management for more crop production. These are helpful in uniformity of water application, higher water use efficiency, no land leveling, assured irrigation to the agricultural fields, improving cropping intensity, increasing efficiency through judicious use of irrigation water, and improving socio-economic condition of the farmers. Besides higher water use efficiency, MI has other economic and social benefits too. The field observations show that the MI increases productivity by many-folds for different crops; reduces weeds, checks soil erosion; and minimizes cost of cultivation, especially in labor-intensive operations and lower energy use (electricity) for operating irrigation wells due to reduced water consumption.

In such a situation, refined methods of irrigation like sprinkler and drip irrigation were promoted under a centrally sponsored scheme. Haryana is a small state with 4.42 million ha of geographical area out of which 80 percent is under cultivation. About 84 percent of cultivated area is irrigated, 45.3 percent by canals and 54.2 percent by tube wells but 62 percent area is laid under poor-quality water. The conventional irrigation has caused problems of rise in water table resulting in problem of waterlogging and salinity which reduced the productivity of crops. Though overall growth rate is impressive, the agricultural growth rate is constrained by number of problems. The central districts have most productive irrigated lands under paddy-wheat system. The over exploitation of ground water, soil fertility depletion and several soil health problems have imposed limitation on farm productivity and net returns. Because of availability of ground water, fruit and vegetable cultivation is being promoted to diversify agriculture. This region is grain bowl of the state and has the facility of canal irrigation. The problem of salinity, alkalinity and waterlogging limits farm growth in several pockets.

The southern belt is most problematic mainly due to brackish water, non-availability of good-quality groundwater, sandy nature of soils, low rainfall and lack of canal irrigation network. The southern districts of Dadri, Mohindergarh at Narnaul, Rewari, Bhiwani, part of Jind and Nuh/ Mewat suffer from water availability problems and need most efficient use of limited water. The State Government through the Department of Agriculture and Horticulture is promoting micro-irrigation in these areas. Efforts are being made to promote the concept of more crops per drop. Government is providing subsidy on micro-irrigation schemes. However, there are several constraints on the acceptability of this program which is associated with the implementation of the program, equipment supplies and repairs and inherent defects in the model at small farm level. These problems needed a detailed study particularly in southern districts so that suitable financial, administrative and policy issues are flagged and remedial measures are taken to facilitate the promotion of this flagship program. To find out the bottle-necks and their socio-economic impacts, a study financed by the National Bank of Agriculture and Rural Development (NABARD) was conducted in three drought and salinity prone areas of three districts namely Bhiwani, Mohindergarh and Nuh in Haryana and the results are reported here in this article.

Materials and Methods

Six districts (Bhiwani, Mohindergarh, Rewari, Jhajjar, Gurugram and Mewat) with 29% of total area of the state of Haryana have sandy soils, scarcity of water and crops raised under salinity and drought prone conditions. Micro-irrigation (sprinkler and drip) has been promoted in these districts due to its suitability to the conditions of this region. In the present study, out of six, only three districts viz., Nuh, Mohindergarh at Narnaul and Bhiwani were selected for impact evaluation of micro-irrigation (MI) system. As per plan, two blocks from each district were selected having maximum area under MI and from each block 5 representative villages were randomly selected (Table 1) and from each village five beneficiary farmers were identified and information through pre-designed proforma was collected from these farmers.The data collected from 150 farmers in the survey formats was put in Excel Sheet which was converted to the Word Format tables for all the blocks and conclusions briefly drawn and reported.

Table 1. Detail of districts, blocks and villages in Haryana selected for the study

S.N.	District	Blocks	Villages
1	Bhiwani	Bahal	ShazmanPur, Sirsi, Baran, Nunshar, Chahar Kalan
		Tosham	Alampur, Hassan, Sandwa, Sahkwala, Isherwall
2	Mohindergarh	Ateli	Bhilwara, Bihali, Bochariya. Tajpur, Tigra
		Narnaul	Kunjpura, Neerpur, Patikara, Shapur-II, Sobhapur
3	Nuh	Nuh	Badka, Badwa, Khodbasai, Korali, Sadai
		Nagina	Ghagas, Ghumat Bihari, Kansali, Notky, Shahapur

In order to start the study, the local resource persons were selected who interacted with farmers and helped them in filling the formats. Before filling the formats, the resource persons' interaction and training programs were planned and conducted first at Narnaul and then at Chahal Kalan village of Bahal block of Bhiwani district. A detailed review of available literature on micro-irrigation was compiled with particular reference to Haryana. Focused group discussions were held in every district to express the views of the community about the MI program. Similar meetings were conducted at district and state level with the stake holders. The data on the progress, details of implementation arrangements and constraints experienced were collected at the district and state level. A draft report was compiled for review at the DARE, NABARD and comments were incorporated in the final report. The present article is based upon the report submitted to NABARD (SPACE, 2021).

Results and Discussion

Status of micro-irrigation in Haryana

Growing water crisis and need to produce more food per drop of water require adoption of water efficient irrigation methods instead of the conventional flood irrigation to increase the water use efficiency and to enhance crop productivity. Micro-irrigation systems have matured to their significance not only in water saving but also in efficient energy, labour and fertilizer management systems for more crop production. In the areas where canal irrigation is limited and farmers largely depend upon rain water and ground water which is very scarce and saline with no scope of ground water development, the only solution is creation of micro-irrigation infrastructure on canal outlets. Where the ground water table is very high with brackish water, there are chances of creating the situation of waterlogging, which is harmful for soil properties and may inculcate soil salinity. In these areas, it is essentially required to minimize the flood irrigation by replacing with micro-irrigation. Under the centrally sponsored micro-irrigation scheme, the area in Haryana under sprinkler irrigation increased from 1864 to 58814 ha and under drip irrigation from 812 to 24832 ha between 2006-07 and 2017-18. So, has increased the expenditure from Rs 23.57 million to Rs 3220.34 million in this period (Table 2).

It may be seen that Bhiwani and Mohindergarh districts have the maximum number of drip and mini-sprinkler beneficiaries followed by Rewari and Nuh districts. The Haryana State Micro-irrigation Committee was formed in the year 2006 to implement Centrally Sponsored Scheme of Micro-irrigation in the state. This was as per the guidelines of Government of India and a notification to this effect was issued by the State Government in 2006.Among advanced micro-irrigation (MI) techniques, drip and sprinklers were given special attention. While drip irrigation has little or no water losses through conveyance (INCID, 1994; Narayanamoorthy, 1997a, b; Dhawan, 2002), and the on-farm irrigation efficiency of a properly designed and managed drip irrigation system can be as high as 90 %, compared with 35 to 40 % efficiency in surface method of irrigation (INCID, 1994). However, sprinkler irrigation has relatively less water saving (up to 70 % efficiency), since it supplies water over the entire field of the crop (INCID, 1998; Kulkarni, 2005). Luhach *et al.* (2004) assessed the economic impact of sprinkler and drip irrigation in Haryana. The results of the study are summarized as under:

Table 2. Physical installation of micro-irrigation and budget position from 2006-07 to 2017-18 in Haryana

S. N.	Year	Area under of micro-irrigation (ha)			Financial position (In million Rs)		
		Drip	Sprinkler	Total	Available budget	Expenditure utilization	Percent
1	2006-07	812	1864	2676	58.37	23.57	40
2	2007-08	1041	6735	7776	112.44	64.52	57
3	2008-09	2139	20170	22309	211.36	189.14	89
4	2009-10	2468	790	3258	94.24	85.18	90
5	2010-11	3900	5254	9154	262.41	259.43	99
6	2011-12	2751	5961	8712	406.54	403.41	99
7	2012-13	2645	3914	6559	664.82	626.08	94
8	2013-14	2504	3860	6364	678.46	618.93	91
9	2014-15	1550	1850	3400	305.17	302.91	99
10	2015-16	1756	1360	3116	441.67	200.45	45
11	2016-17	1158	4624	5782	822.12	208.33	25
12	2017-18	2102	2436	4538	560.86	238.79	42
	Total	24826	58818	83644	4618.46	3220.34	70

Source: Niti Aayog (2017)

- In Haryana, MI is practiced on about 84000 hectares of land which was introduced in the canal irrigated areas of southern Haryana. This system of irrigation saves water and can irrigate much more area than surface irrigation. It also eliminates the needs for channels and land leveling and is particularly suited on sandy soils having a high infiltration rate. Small streams of irrigation water can be used efficiently and sprinkler distributes water uniformly.
- The investment in sprinkler irrigation (SI) was quite remunerative. The average benefit: cost ratio (1:1.97), NPV (Rs 7970) and IRR (17%) indicated that it was worth to invest in sprinkler irrigation. In case of drip irrigation (DI) also, the benefit: cost ratio, NPV and IRR were much higher than the furrow irrigation method.
- The SI and DI techniques are water-saving, cost effective and efficient in comparison to surface irrigation through flooding or furrow system. The higher values of NPV, IRR, and BC ratio indicate better economic viability of these systems. The results have indicated considerable savings in water from SI and DI methods. The SI has also been found to reduce operational costs as well as labour requirements. It has been suggested that it is worth to invest in the SI and DI systems.

Neeraj *et al.* (2018) reported the experiences of Installation of Community Based Solar/Grid Powered Micro Irrigation Infrastructure in existing canal commands in various districts of Haryana. They inferred that rice yield increased by 11.65 % in drip irrigation along with 42.03% saving of water. The drip system was found more profitable than flood irrigation due to higher yield, higher net return (Rs 83486 per ha) in comparison to flood irrigation (Rs 73414 per ha) which was 13.71% more net income than flood irrigation method. They elaborated that adopting MI technology we could reduce high release of greenhouse gases (CH_4 and CO_2) in comparison to flood irrigation in rice, reduce leaching of nitrogen rich irrigation water which causes ground water pollution; could use fertilizer, pesticide and weedicides to check weeds without manual labour; and reduce absorption of heavy metals from the soil and their accumulation under anaerobic condition.

Adoption of micro-irrigation in western Haryana (the present study area)

In the south western part of the state, especially in the districts of Bhiwani, Mohindergarh, Nuh, Rohtak, Sirsa and Hisar, the soil conditions, topography and the climate conditions that are prevailing have prompted the farmers to adopt micro-irrigation. During the process of

Table 3. Average annual returns (lakh Rs) of farmers of study-blocks from three irrigation systems (average of 25 farmers in each block)

District	Block	Annual net returns per farmer (Average of 25 farmers)			
		Flood	Mini-sprinkler	Drip	Main income source
Bhiwani	Bahal	1.57	2.30	2.68	Mustard and cotton
	Tosham	1.58	2.10	2.47	Mustard and cotton
Mohindergarh	Ateli	1.21	2.11		Mustard and wheat
	Narnaul	1.66	2.90		Mustard and wheat
Nuh	Nuh	3.40		6.99	Vegetables + livestock
	Nagina	5.08		10.86	Vegetables+ livestock
Average annual labour cost*(Rs ha^{-1})		22240	14830	4950	

*Input costs are discussed ahead at block level

implementation in last 20 years, several constraints were noted which were coming in the way of achieving the potential of this technology. The responses of the farmers to the pre-designed questionnaire across six study blocks of Bhiwani, Mohindergarh and Nuh districts were almost similar and hence combined and summarized as mentioned below:

The farmers held that there is no way to sustain agriculture in this drought-prone area suffering from an acute shortage of water, low rainfall and sandy soils without water saving through micro-irrigation. It was noted that in case of Bhiwani district covering data of Bahal and Tosham blocks, all the three components namely flood, sprinkler and drip irrigation were adopted. Whereas in case of Mohindergarh district, the main focus remained on flood and sprinkler irrigation and drip system was not adopted because of heavy nature of soils. While in case of Nuh district, the sprinkler system was not adopted by the farmers because of heavy nature of soils and problem of salinity and only flood and drip irrigations were adopted. It was noted that drip irrigation adopted on vegetable crops gave the highest annual returns in case of both the blocks of Nuh district as shown in Table 3.

In general, the B:C ratio was maximum in mustard followed by drip irrigated vegetables and sprinkler irrigated wheat. Though there was good gross income in case of cotton bur B: C ratio was low due to large number of irrigations required, high cost of picking and expenditure on chemicals and repeated sprays.

The field data collected from number of farmers across three districts comparing the cost of cultivation, gross and net returns from crops irrigated by flood, mini sprinkler and drip irrigation has conclusively proved that financial benefits increased by 60 to 70 percent upon shift from flood to mini-sprinkler irrigation and more than 80 to100 percent upon further shift to drip irrigation. Such benefits in vegetable crops with drip at times were more than 200 percent against flood irrigation.There is huge saving in labor cost of irrigation. For example, the average cost of flood irrigation is Rs 2500 per ha per irrigation; it is around Rs 750 in mini-sprinklers and Rs 250 in drip irrigation system. The annual irrigation labour cost per ha comes around Rs 22240 with flood, around Rs 14830 with mini sprinklers and Rs 4950 with drip irrigation. Due to time saving in MI, farmers get time to attend other farm operations.

It was interesting to note that the cost of cultivation varied across blocks and districts. For example, in Narnaul area, the cost of cultivation is high since farmers tend to put all inputs required to get better yield levels and their net returns are much higher than Bhiwani. In case of Nuh, the water table is shallow and water is of good quality near the hills where study farmers were located and have opted for drip irrigated tomato crop and earning profits ranging from Rs 6.99 to 10.86 lakh per ha. The economy is sustained by vegetable cultivation and because of improved economic conditions they maintain livestock also which sustains their annual income. Though pearl millet and mustard are the main Kharif and Rabi crops

but the economy of Bhiwani district is sustained by mustard and cotton. Mustard is a wonderful crop requiring less water and input costs yet provides handsome returns even by one or two irrigations by mini-sprinklers.

It is interesting to note that both the micro-irrigation systems (mini sprinkler and drip) are operational and are fully functional with all the 150 beneficiary farmers contacted during the survey. All of them by and large agree that their cases were processed by dealers of the company, but they all participated in planning, and the design was made with their consent and found no problems in installations. The implementing departments claim that payments are duly made after field verification at site and verification of bills.

Farmers' perspective and socio-economic impacts by adopting micro-irrigation systems

As was evident during field visits and interactions with farmers, the adoption of micro-irrigation by the farmers has changed the socio-economic structure of the beneficiaries. The responses across six study blocks were almost similar and hence combined for all the three districts and are presented as under (Table 4).

Block-wise analysis of all the three districts

In all the 6 blocks of 3 districts, there were 25 beneficiary farmers in each block who were representative of small (up to 2 ha land), medium (2-4 ha) and large (>4ha) categories of farmers. The water table and quality of underground water varied in different blocks.

For example, in foot-hill region of Arawali in Nuh district, the quality of underground water was good but it changed gradually to poor-quality when go away from the foothill. There was always rise in groundwater table after the monsoon season but on an average water table went down due to installation of tubewells during the project years. In all the blocks micro-sprinklers were installed except in block Narnaul where bigger sprinklers were introduced in 2007-08 and in Nuh district drip irrigation has been preferred because of heavy soils and salinity problems and farmers opt for vegetables such as brinjal, tomato and onion cultivation. It is interesting to note that all the micro-irrigation systems are operational in all the districts. The projects were planned mainly by the dealers of the company and the farmers participated in the planning of the project and do not have any problem except that the material supplied by some companies is not of good standard. For example, the life of drip is normally 2-3 years but the drip of Jain Irrigation and Macaft Companies are better and more durable lasting for 5 years if kept properly. The distinguished features of adaptation and farm income in different blocks have been summarized (Table 5). In summary, in all blocks of three districts, it was observed that the annual net returns per farmer was Rs 12.7, 17.9 and 26.3 lakh, respectively with flood, sprinkler and drip irrigation system.

District Bhiwani

Farmers prefer to retain Khejri (*Prosopis cineraria*) trees on their field while cultivating the arable crops like cotton (Fig. 1) or pearl millet (Fig. 2) as these trees do not affect the yield of the associated crops, rather these increase yield due to fixing of nitrogen in the soil. Pearl millet is the main Kharif crop and good short duration varieties have been adopted (Fig. 2). The weeds are culled and used as green fodder, the stalks are used as fodder and grain is the staple food of this area. In Kharif season, one finds pearl millet in the entire landscape. Cotton is the second most important cash crop of this area which is sown in lines and is generally drip irrigated (Fig. 1). It is the main commercial crop of this area and now short duration dwarf varieties have come up. Since sprinkler irrigation is not advisable in cotton after boll formation, drip irrigation came as a better choice. Drip is not suitable for grain crops like

Fig. 1 Large scale cotton cultivation in Bhiwani district of Haryana on sandy soils with drip irrigation

Table 4. Response of farmers to pre-formatted quarries related to micro-irrigation

S. No.	Quarry related to scarcity of irrigation water	Response
1	Why do you want micro-irrigation?	- Sandy soils require more irrigation - One tube-well could not cover whole farm and only 1-2 ha are covered - More loss of water in irrigation channels - More labour cost for irrigation. - Ever increasing shortage of water
2	What was the effect of irrigation related problems on normal living?	- Low crop yield, less farm income, poor status of living - More use of water, lowering of water table, more cost involved - Low return, borrowed money, no money for health, education and housing - Land leveling needed that adds to the cost of cultivation - More cost involved in farm operations
3	Impact on agricultural production?	- Choice of crop decreased and no fruit/ vegetable crops can be raised due to scarcity of water - Low and uncertain production and no market surplus - Difficult to raise commercial crops like cotton - Limited use of fertilizer and less crop yields
4	Impact of the problems on livestock and farming?	- Shortage of fodder for livestock - Difficult to keep high yielding animals - Low milk production hence no milk for sale - Livestock rearing cost not affordable
5	Problems in case processing?	- Takes more time in case processing - Completion of documents particularly obtaining land record causes problem - Less faith on the honesty of the dealer - Dealer do not stick to committed time
6	Way of solving these problems	- Help to complete the paper from those who earlier got the projects - Visit to department office to sort out the problem - Support from field staff of the department - Detailed discussion with the dealers of the company
7	Problems faced regarding services	- Drip and filters are blocked very frequently - Every work done by dealer and no local service providers - Average farmers do not have much knowledge about the procedure and formalities. - Used acid to unblock the filters and drips
8	Reasons of dissatisfaction	- Material supplied sometimes of not good quality - Drip system is not working properly - Subsidy often comes late and sometimes not released in the same year - Online system cannot be adopted by ordinary farmers - Ordinary farmer do not have knowledge about this system
9	Suggestions for improvement	- More involvement of the department required in implementation - Early release of subsidy must be ensured - Less dependence on company dealers - Quality of material must be ensured - More transparency needed - Workshops to make farmers aware of procedures and working of the micro-irrigation systems
10	Farm level constraints in adoption	- Lack of knowledge among farmers about water saving techniques and quality of materials used - High cost of drip system - poor farmers unable to share cost - Use of drip system in limited crops - Lack of awareness, hence camps/workshops in the field are needed - Dependence of farmers on dealers who lack transparency

Table 5. Distinguished features of adaptation and farm income in six blocks of three districts

Particulars	Bhiwani		Mohindegarh		Nuh	
	Bahal	Tosham	Ateli	Narnaul	Nuh	Nagina
Watertable (m)	106-207	45-100	100-215	130-300	3-20	~20m
Water-quality	poor	poor	good	good-marginal	good	average-poor
Tentative year of tubewell irrigation	1978-79	1975	1980 all by 1985	1968	1968 mostly by1975	1968 mostly by 2008
Initiation of micro-irrigation	2015-16	1982-83 project 2010	2012	2007 macro 2017 drip & mini sprinkler	2007-08 completed 2019-20	2008 completed by 2012
Time (hr) to irrigate	F 25-30	F 25-30	F 25-30	F 30-35	F 20-35	F 20-40
1 ha area	S 17-20	S 17-20	S 16-20	MS 20-22	S 12-15	S 12-15
	D 6-7			S 15	D 5	D 5
				D 5		
Average yield (q ha^{-1})						
Mustard	17	16-20	25	25	20	22
Wheat	40	38-45	49	50	50	52
Pearl millet	20	20-22	30	30	25	30
Cotton	20	20-25	-	-	-	-
Vegetables	620 (brinjal)	-	600 (brinjal)	630 (brinjal)	600 (onion) 500(tomato)	450 (tomato) 500-600(onion)
Cost of irrigation	9.8 F	9.5 F	9.0 F	8-10 F	10-11.0 F	11.0 F
per ha (Rs 000)	7.0 S	6.5 S	6.0 S	5 S	2.0 D	2.0 D
	3.0 D	3.0 D	-	-		
Annual labour cost	22.0 F	20.0-22.0 F	18-20 F	17-19 F	20-30 F	17-19 F
per ha (Rs 000)	15.0 S	15.0 S	13-15 S	10 S	5-6 D	4-6 D
	5.0 D	5.0-6.0 D	-	-		
Annual average family	F 157	F 158	F 121	F 166	F 340	F 508
income (Rs 000)	S 231	S 210	S 211	S 290	D 699	D 1084
	D 268	D 247				
Net annual income of the family (Rs 000)	656	615	332	456	1039	1592
B:C ratio						
Mustard	2.62	2.61	3.63	4.14	3.10	3.25
Wheat	2.11	2.13	2.88	2.91	2.34	2.45
Pearl millet	1.86	1.88	2.49	2.82	2.07	2.67
Cotton	1.67	1.65	2.13	1.84	-	-
Vegetables				3.08 (brinjal)	2.36 (tomato)	1.65 (tomato) 1.67 (onion)

Letters F, S and D depict as flood, sprinkler and drip modes of irrigation, respectively

Fig. 2 Khejri (*Prosopis cineraria*) in dry areas of Bhiwani (left) and cultivated pearl millet (right)

wheat but most suitable for line sown crops like cotton, sugarcane, fruit and vegetable crops. Line sown cotton cover large tracts of light textured undulating lands.

During the Rabi season, the choice of crops includes mustard as the main cash crop and wheat is sown in a limited area to meet the need of dry forage for livestock and as food for domestic use. Some farmers keep part of the land as fallow during the monsoon season and raise mustard on the residual moisture present in the soil after monsoon rains.

Farmers of Bahal block reported very low net returns from cotton due to high cost of inputs, irrigation, labour and harvesting costs. Yet they are opting for it using drip irrigation system mainly due to acute scarcity of ground water which is depleting fast (Fig. 1).Very small area has gone under fruit and vegetables in Bhiwani district perhaps because of marketing problems, water scarcity and long gestation period of fruit crops. Regarding projects, complete awareness about the procedure and financial arrangements is generally not given to the farmers and the services provided by the dealers are not to the satisfaction of the farmers. Bigger farmers have bigger share of subsidized work and in the process smaller farmers are marginalized. Up to 5 ha hectare of land, all farmers are eligible for subsidy.

The reasons why farmers are shifting to drip irrigation in cotton include that cotton cannot be irrigated with sprinkler after boll formation, sprinkler creates moist micro-environment which attract more diseases / pests, in hot summer months (May – June) sown cotton crop needs more irrigations. In case of sprinklers there are high evaporation losses but in drip there is 30-50% more saving of water, once installed drip has very low irrigation cost, there is high subsidy (almost free) on drip system, drip system ensures more uniform distribution of water than sprinkler system, there is 30-50% saving in fertilizer when used through fertilization system in drip system. Drip system required 30-50% less water than sprinkler system to mature cotton crop, drip irrigation result into 20-25% more cotton yield than flood /SP irrigation system, reduces irrigation labour cost, required less energy as water flows at low pressure where sprinkler system require high pressure to generate flow of jets, drip system can be used during night, contrary to sprinkler irrigation can be operate even when wind spread is high, and it is easy to remove and store at a safe place.

The data on crop production based on average of 25 farmers (Table 6) show that mustard during winter and pearl millet during *kharif* are ideal and remunerative crops of the district with sprinkler irrigation. Cotton is commonly grown and remunerative with drip irrigation but requires high in-puts. Farmers usually prefer wheat during winter because of food security and fodder (straw) for animals and cotton because of high income and fuel security from its sticks. The annual income of a family was primarily from agriculture and it was Rs 157100, 230607 and 267859 with flood, sprinkler and drip irrigation, respectively which was 46.8 and 70.5 percent higher in sprinkler and drip irrigation, respectively over flood irrigation. There was no major income from livestock component in Bhiwani. In cropping system pearl millet-wheat is more remunerative with net income of Rs 67 thousand per ha followed by pearl millet-mustard with net income of Rs 65 thousand and pearl millet-cotton with net income of Rs 62 thousand per ha. Some farmers also cultivated pearl millet-tomato sequence and got a net profit of Rs 337 thousand per ha.

Due to low rainfall, sandy nature of soils and water scarcity, micro-irrigation has been promoted in Tosham block. Some area is irrigated by canals also but it has caused salinity problem. Sprinkler irrigation was widely adopted and promoted through subsidy driven programs of the Government. In Tosham block also the cost of cultivation of mustard and pearl millet is low as compared to wheat and cotton and the cropping system of these two crops gives net profit of Rs 69 thousand (B: C ratio 2.15) as compared to Rs 104 thousand in wheat-cotton (drip) with B: C ratio of 1.97 (Table 6).

Mohindergarh district

The water quality was found good and the main crops include cotton, pearl millet, and cluster bean in Kharif and wheat and mustard in Rabi.Mini

Table 6. Economics of cultivation (Rs '000 per ha) of different crops under MI methods (sprinkler) of irrigation (average of 25 farmers in each block) in Bahl and Tosham blocks of Bhiwani district

Crops	Cost of cultivation		Gross income		Net Income		B: C ratio	
	Bahal	Tosham	Bahal	Tosham	Bahal	Tosham	Bahal	Tosham
Pearl millet	31.23	28.11	46.44	45.96	15.21	17.85	1.49	1.63
Wheat	43.83	46.60	95.80	98.25	51.97	51.65	2.18	2.11
Mustard	36.51	31.63	86.68	82.77	50.17	51.14	2.37	2.62
Cotton S	65.10	61.42	111.66	102.56	46.56	41.14	1.71	1.67
D	63.82	61.22	124.17	113.74	60.35	52.52	1.95	1.86

S= sprinkler irrigation, D= drip irrigation

sprinkler was stated to be a boon to this area. Water table was found receding to 35 m due to overuse and less recharge. Most of the farmers were found to use submersible pumps. They save more in mustard as compared to other crops. In Mohindergarh district, the main focus remained on flood and sprinkler irrigation and drip system was not adopted because of heavy nature of soils. Farmers, due to scarcity of water started adopting micro-irrigation systems of irrigation. Data show that when farmers were adopting the flood irrigation, the average cost of cultivation, gross income and net annual income per farmer was Rs 245, 542 and 297 thousand, respectively with B: C ratio of 2.21 but when started the micro-irrigation, the average cost of cultivation, gross and net income was Rs 260, 762 and 502 thousand, respectively with B: C ratio 2.93 with average increase in net income per farmer to Rs 205 thousand, which is 69% increase over flood irrigation.

In Ateli block, mustard with low cost of cultivation is found to be most remunerative with net income of Rs 78 thousand per ha with B: C ratio of 3.63 followed by wheat with net income of Rs 74 thousand per ha with B: C ratio of 2.88. During Kharif, pearl millet is most ideal crop with minimum in-put and quite profitable with B: C ratio of 2.49.

In Narnaul block, cotton is not cultivated with drip irrigation instead vegetables (mainly brinjal) are cultivated with drip irrigation. Brinjal has been found highly remunerative with Rs 424.47 thousand per ha net income (B: C ratio 3.09). Mustard with low cost of cultivation is most profitable (net income Rs 82 thousand and with B: C ratio of 4.14 (Table 7).

Evidently, the net benefits were very high in vegetable crops irrigated by drip system but the market risks are also very high. The low cost of irrigation and use of family labour in vegetable cultivation results in higher profitability.

As per farmers' explanation, the yield was higher in Narnaul than Bhiwani block because in Bhiwani the soils are sandy with less organic matter and more frequent irrigation is required, and deep ploughing is needed due to crust formation below root zone at about 40 cm depth. Contrary to this, in Narnaul block, soils are sandy

Table 7. Economics of cultivation (Rs '000 per ha) of different crops under micro-irrigation (average of 25 farmers in each block) in Ateli and Narnaul blocks of Mohindergarh district

Crops	Cost of cultivation		Gross income		Net Income		B: C ratio	
	Ateli	Narnaul	Ateli	Narnaul	Ateli	Narnaul	Ateli	Narnaul
Pearlmillet S	23.34	21.81	58.16	61.55	34.82	39.74	2.49	2.82
Wheat S	39.47	39.18	113.84	114.06	74.37	74.88	2.88	2.91
Mustard S	29.72	26.08	108.03	108.04	78.31	81.96	3.63	4.14
Cotton S	63.87	51.20	114.16	94.24	50.29	43.04	1.79	1.84
D	52.34	-	111.34	-	59.00	-	2.13	-
Brinjal D		203.16		627.63		424.47		3.09

S= sprinkler irrigation, D= drip irrigation

loam with more organic matter and water quality is good and no crust formation is there and 15 cm deep ploughing is enough.

Nuh District

The areas located in foot of the Aravali Hills have good quality ground water. As per the topo-sequence, a belt of about 1.5 km width along the hills has good quality water then comes a belt of highly saline soils and almost barren land with no crops. Some field bunding work has been done to conserve rainwater *in situ*. This is a pocket of low-lying area and the quality of land improves after rainwater harvesting by bunding.

In Nuh block of the district, farmers introduced sprinkler irrigation for different crops and due to excessive use of water they stopped cultivation of paddy from which they used to earn a net profit of about Rs 41 thousand per ha. After introduction of micro-irrigation (mainly sprinkler, drip in vegetables) besides saving water they earned 53 to 92 percent more net income as compared to flood irrigation except in mustard there was negligible difference because of less water and in-put requirement of the crop (Table 8).

From cultivation of tomato, farmers got handsome income but it is a crop which required very high in-put and a lot of risk is involved. They also cultivate pearl millet and multi-cut sorghum in Kharif used as green and dry fodder and pearl millet grain as staple food. They also grow Egyptian clover/berseem (*Trifolium alexandrinum)* as fodder. Farmers keep 4-5 buffaloes and sell milk. Farmers also grow onion with drip irrigation having net income of about 99 thousand per ha with B: C ratio of 1.67.

Some farmers also raised fruit trees and started taking extra income from fruits and buffalo milk after adopting the micro-irrigation system of irrigation. It was interested to note that the annual income of each farmer (average from 25 farmers) increased to Rs 699.34 thousand when adopted micro-irrigation as compared to Rs 340.55 thousand before that. Now, the farmers mostly use only flood and drip irrigation. Because of heavy soil, sprinkler irrigation is not suitable. Vegetable crops are cultivated on raised beds and drip irrigated.

One of the large farmers with 6 ha of land followed all three methods of irrigation and cultivated different crops. Before the introduction of micro-irrigation, the farmer cultivated pearl millet and cluster bean in 4.2 ha, fodder in 0.8 ha and kept fallow 1 ha during kharif and cultivated wheat in 4.2 ha, mustard in 1 ha and fodder (for home use worth Rs 20,000) in 0.8 ha. He got annual net income of Rs 2, 54,000 (Rs 42330 per ha). When cultivated with application of sprinkler irrigation, cultivating cluster bean and pearl millet (1.2 ha), cotton in 4 ha and fodder in 0.8 ha during kharif and wheat (4 ha), mustard (1.2 ha) and fodder (0.8 ha) during rabi season, the net income of Rs 4, 82,000 (Rs 80330 per ha) was obtained. Following the same method except cotton 2 ha with sprinkler and 2 ha with drip, a net profit of

Table 8. Economics of cultivation (Rs '000 per ha) of different crops under different mode of irrigation (average of 25 farmers in each block) in Nuh district

Crops	Cost of cultivation		Gross income		Net Income		B: C ratio		Percent increase in net income over flood irrigation
	F	S	F	S	F	S	F	S	
Pearlmillet	23.59	22.56	39.53	46.95	15.94	24.39	1.67	2.08	53.0
Wheat	49.91	38.79	80.72	90.93	30.81	52.14	1.61	2.34	69.23
Mustard	32.81	30.14	93.16	93.90	60.35	63.76	2.84	3.12	5.65
Fodder	14.83	12.35	24.70	30.89	9.87	18.54	1.67	2.50	87.8
Paddy	63.01	-	103.78	-	40.77	-	1.65	-	-
Tomato (D)	273.41	242.53	444.77	571.68	171.36	329.15	1.63	2.36	92.08

In all crops, the micro-irrigation mode was sprinkler except in tomato with drip irrigation
Paddy cultivation was stopped after introduction of micro-irrigation project
F= Flood (before introducing micro-irrigation), D= drip irrigation

Rs 505350 (Rs 84225 per ha) was obtained showing the importance of micro-irrigation.

In Nagina block, farmers are cultivating vegetables with drip irrigation on large scale and have increased their socio-economic conditions significantly. The total income from livestock also increased from Rs 30240 to Rs 46720 per farmer registering an increase of 64.72 percent. The main increase in income was from tomato cultivation with drip irrigation system. The net income of each farmer was Rs 5.08 lakh in case of flood irrigation which increased to Rs 10.84 lakh under drip irrigation. The B: C ratio was 1.79, 2.35 and 2.41 under flood, sprinkler and drip irrigation, respectively. The sprinkler system was found 63 % more efficient than the flood irrigation system as the water requirement per irrigation is quite less than that of the flood irrigation and cost of cultivation with micro-irrigation is far lesser than the flood irrigation (Table 9).

Drip system resulted in water saving up to 89% and was quite successful in case of tomato cultivation as it resulted in 50 % increase in yield. Drip system resulted in 25% less nitrogenous fertilizers and 50% less pesticides in comparison with the traditional flood irrigation method. Drip system was largely being used in vegetables which require good quality water that is restricted largely to the foothills of Aravali. The system is comparatively more sophisticated than sprinkler as demands greater care in operation and management. The perusal of data shows that the net returns of mini-sprinkler irrigated crops over flood irrigated crops are almost double but in drip irrigation further in cotton crop.

Limitation of micro-irrigation and way out

In spite of having many economic and other advantages, the growth of area under micro-irrigation has not so far been appreciable compared to the total potential. High capital investments depending upon the nature of crops and the material to be used little or no cost of surface irrigation supplies and free electricity for pumping groundwater have been the important impediments for faster adoption of micro-irrigation techniques. The main issues and concerns are flagged as under:

- Sprinkler irrigation has generally been promoted through subsidy schemes and not as an on-farm water and land management strategy. The design aspect is ignored so as to reduce the cost.
- In order to earn quick profit from the subsidy programs, many companies are marketing various sub-standard components which affect the working condition of the system and create enormous doubt in the farmer's mind about the functioning of the system. It is to be ensured that only good quality components having the certification of Bureau of Indian Standards (BIS/ISO) are supplied to the farmers.
- Efforts are to be made to manufacture improved sprinkler systems through joint ventures, with the condition that the imported

Table 9. Efficiency of sprinkler system over flood irrigation in wheat crop in sandy soils

Parameter	Flood irrigation	Sprinkler irrigation
Number of irrigation	7	7
Time (hrs) per irrigation per ha (considering electricity for 6 hrs per day)	59	22
Total time (hrs)	415	156
Pump capacity (HP)	10	10
Discharge ($m^3 hr^{-1}$) from 10 HP (5 cm pipe)	15.14	15.14
*Volume of water applied (m^3) per irrigation per ha	899	336
Total volume for entire season ($m^3 ha^{-1}$)	6296	2352
Conveyance losses/irrigation	20%	0
**Irrigation depth (cm per irrigation)	7.3	3.5
***Savings on water usage for entire season (%)	63.15%	

Source: SPACE (2021)

components and technology would be transferred to indigenous manufacturers within a period of 2 years. This would help in reducing the cost of the system and increasing the adoption of micro-irrigation at a large scale.

- One of the major reasons for the slow growth of micro-irrigation is the high initial investment. There is a need to look into the technological options, of which crop geometry modification is the most important one. Instead of adopting traditional spacing, adoption of paired row planting has been found to reduce the cost of the system by 40 % in many crops including tomato, brinjal, okra, etc. Therefore, micro-irrigation system should be tailor-made, i.e., planned and designed based on location specific parameters.
- It is understood from the field studies that capital cost required to install drip irrigation is relatively high. Because of this reason, considerable percentage of farmers have expressed that they are unable to adopt this technology for low- value crops. If drip system is made available at a low cost, area under drip irrigation can be increased at a faster rate. By recognizing drip industry as an infrastructure industry as well as announcing tax holiday for specific time periods to all those drips set industries which produce genuine drip materials, the competition can be increased to ultimately bring down the cost of the system.
- The rate of subsidy provided through government schemes is fixed uniformly for both water-intensive as well as less water-intensive crops. This needs to be restructured.
- While using salty water, nozzles of drippers get easily clogged that requires research to find out suitable materials and way out.
- Organizing frequent demonstrations at farmers' fields is equally important.

Conclusions

Since crop irrigation is the major user of water, efforts were needed to economize and improve water use efficiency. Fortunately, a breakthrough came in the form of sprinkler and drip irrigation (micro-irrigation). Seeing the large potential of this technology, the Government of India pushed through this program in a big way. In collaboration with the states, several policy reforms were made and subsidized incentives were given to make the program acceptable to the farmers. The water deficit state of Haryana gave a big push to the program particularly in southern districts where this was the most suited on light textured sandy soils and area with low rainfall. During the process of implementation in last more than 30 years, several constraints were noted which were coming in the way of achieving the potential of this technology. Based on the intensive study in three districts namely Bhiwani, Mohindergarh and Nuh the following conclusions are drawn:

- The efficacy of the MI system has been proved beyond doubt because several benefits were listed by the farmers and other stakeholders and also confirmed from the analysis of collected data. The farmers believe that there is no way to sustain agriculture in the drought-prone areas where people are suffering from an acute shortage of water, low rainfall and sandy soils without water saving through micro-irrigation.
- The field data collected from number of farmers across three districts comparing the cost of cultivation, gross and net returns from crops irrigated by flood, mini-sprinkler and drip irrigation has conclusively proved that financial benefits increase by 60 to 80 percent on shifting from flood to mini-sprinkler irrigation and more than 100 percent upon adopting drip irrigation. Such benefits in vegetable crops cultivated with drip irrigation were more than 200 percent as compared to flood irrigation.
- There is huge saving in labor cost of irrigation. The annual saving in irrigation cost goes very high and farmers use spare time to attend other farm operations. It was interesting to note that the cost of cultivation varied across blocks and districts. For example, in Narnaul area, the cost of cultivation was high since farmers tend to put all required in puts and

hence their yields and net returns are much higher than Bhiwani. In Nuh, water is of good quality in foot of the Aravali hills where majority of the farmers opted for drip irrigated tomato crop earning huge profits. The entire economy is sustained by vegetable cultivation and livestock rearing.

- Though pearl millet and mustard are the main crops during Kharif and Rabi seasons but the economy of Bhiwani district is sustained by mustard and cotton. Mustard is a very useful crop requiring less water and less input costs yet provides handsome returns even by one or two irrigations using mini-sprinklers.
- It is interesting to note that all the micro-irrigation systems may be mini-sprinklers or drip system are operational and in fully functional with all the 150 beneficiary farmers contacted during survey. All of them by and large agreed that their cases were processed by dealers of the company, they all participated in planning, and the design was prepared with their consent and they faced no problems in installation.
- The departments on the other hand complain of acute shortage of staff. But payments are duly made after field verification at site and verification of bills. It is also claimed that now portal system is followed where all the information upwards and downwards flow through portal system and with this, the complaints due to delays have been reduced. The dealers are clever enough to get no objection/ satisfaction certificate from the farmers so that there is no problem in release of grant.The officers handling the program and KVK scientists were of the view that small farmers are only to make payment of GST and rest of the system duly installed at farm is free, so farmers are seldom seen making complaints in interactive meetings and workshops
- It also came to notice that in order to earn quick profit from the subsidy programs, many companies are marketing various sub-standard components in the market which affect the working condition of the system and creates doubt in the farmer's mind about the functioning of the system. It is to be ensured that only good quality components having the certification of Bureau of Indian Standards (BIS/ISO) are supplied to the farmers.
- The sum total of discussions was that there is no survival without adopting micro-irrigation system as water table has gone down and availability of water is very low in these southern districts. After the adoption of the micro-irrigation system, there is tremendous improvement in socio-economic conditions of the farmers who adopted the system and it must be encouraged in all water scarcity areas.

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