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Averting Water Crisis by Drip Method of Irrigation: A Study of Two Water-Intensive Crops

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I

INTRODUCTION

Water is becoming increasingly scarce worldwide (Rosegrant *et al.*, 2002). With the fast decline of irrigation water potential and continued expansion of population and economic activity in most of the countries located in arid and semi-arid regions including India, the problem of water scarcity is expected to be aggravated further (see Biswas, 1993 and 2001; Rosegrant, 1997; Rosegrant *et al.*, 2002). Though India has one of the largest irrigated area in the world, its per capita or per hectare availability of water is one of the lowest in the world (Johansson, 2002). All the easily possible and economically viable irrigation water potential have already been developed in India, but the demand for water for different purposes has been growing continuously (Saleth, 1996; Government of India, 1999; Vaidyanathan, 1999). The water use efficiency in the agricultural sector, which still consumes over 80 per cent of water, is only in the range of 30-40 per cent in India, indicating that there is considerable scope for improving the existing water use efficiency.

Recognising the importance of sustainable water use especially in agriculture, a number of demand curtailing strategies/programmes (water pricing, *warabandi*, water user's association, turnover system, etc.) have been introduced since the late seventies to increase the water use efficiency especially in the use of surface irrigation water. While the various strategies introduced for improving the water use efficiency have been continuing, the net impact of these strategies in increasing the water use efficiency is not very impressive as of today. One of the technical means introduced recently in Indian agriculture to improve the water use efficiency is drip method of irrigation (DMI). Unlike surface method of irrigation (SMI), under drip method, water is directly supplied to the root zone of the crops through a network of pipes using drippers/emitters. The direct supply of water through the pipe network reduces the substantial amount of water losses that take place usually under surface method of irrigation. As a result, the water use efficiency increases upto 100 per cent in a

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properly designed and managed drip irrigation system (INCID, 1994; Sivanappan, 1994). Drip method of irrigation also helps to reduce the over-exploitation of groundwater that partly occurs because of inefficient use of water under surface method of irrigation (Narayanamoorthy, 1996; 1997 b; 2001). Besides increasing water use efficiency, this new method of irrigation also increases the productivity of crops and reduces the cost of cultivation especially in labour-intensive operations. Environmental problems associated with the surface method of irrigation namely water logging and salinity are also completely absent under drip method of irrigation (see Narayanamoorthy, 1997 a). Studies also suggest that through the spread of low cost drip irrigation systems, irrigation's benefits can reach the millions of small farmers by-passed by the green revolution technologies (Postel *et al.*, 2001).

Though drip method of irrigation can be efficiently used for various crops in water scarce countries like India, the coverage of area under DMI is very limited as of today except in Maharashtra state.[1] While studies have been carried out to find out the reasons for the slow growth of DMI, not many studies have attempted to analyse the importance of drip method of irrigation in the context of sustainable water use by utilising field level survey data. Most of the studies available in the Indian context are either based on experimental data or individual farmer case studies (see INCID, 1994; Sivanappan, 1994; VSI, 1998; Varma and Rao, 1998; Dhawan, 2002). Since the farm level situation is totally different from the situation prevailing at the experimental station, one requires a detailed study using data from properly designed survey for making any firm conclusion about its water use efficiency. The other issue of drip irrigation is related to its economic viability, as farmers are often reluctant to adopt this technology fearing that the technology may not be economically viable. In order to find out the real situation about the water saving including water use efficiency and whether or not the investment on drip irrigation is economically viable for farmers, an attempt has been made to study the importance of drip method of irrigation in the context of sustainable water use covering two water-intensive crops, namely, sugarcane and banana. The specific objectives of the study are: (i) To study the water use efficiency of drip method of irrigation by comparing the same with surface method of irrigation in sugarcane and banana. (ii) To study the productivity of sugarcane and banana under drip and non-drip irrigated conditions and (iii) To study the economic viability of drip method of irrigation in sugarcane and banana.

II

STUDY AREA, DATA AND METHOD

This study was carried out in Maharashtra state, where there is an immediate need of introducing policies to increase the water use efficiency because of severe water scarcity and increasing demand for water from different sectors (Government of Maharashtra, 1999).[2] Despite having the largest number of irrigation projects in

India, the area under irrigation in the state is only about 17 per cent of the gross cropped area as of today. This is not only very low when compared to the national average of about 38 per cent but also the lowest among the major states in India (see Deshpande and Narayanamoorthy, 2001). One of the important reasons for the very limited expansion of irrigation in the state is that the water use efficiency is very low. The available estimate indicates that nearly 70 per cent of water is consumed only by sugarcane, which accounts for barely about 2.50 per cent of gross cropped area in 2000-01 (see, World Bank, 2002). Considering poor water use efficiency, the state government has introduced various strategies to increase the water use efficiency so as to avoid water scarcity in the future. One such demand side strategy is drip method of irrigation which was introduced in the state during 1986 as a state sponsored programme. Because of the effort taken by the state government, the area under DMI increased from 236 hectares in 1986-87 to 1,60,287 hectares in 1999-2000, an increase of about 65 per cent per annum. The state also has the distinction of accounting for nearly 50 per cent of India's total drip irrigated area, which is 2,46,000 ha at the end of 1997-98 (AFC, 1998; Narayanamoorthy, 2001).[3]

In order to study the importance of drip irrigation technology, two important districts, where sugarcane and banana is cultivated extensively using drip method of irrigation, were selected from the data compiled from Commissionerate of Agriculture, Government of Maharashtra, Pune. The two selected districts are Ahmednagar for sugarcane and Jalgaon for banana. After having selected the districts, two important blocks, one for each crop, have been selected using similar method followed for selecting the districts. Since the purpose of the study is to compare the crops cultivated by drip method with surface method of irrigation, a sample of 50 farmers consisting of 25 drip adopters and 25 non-drip adopters have been selected for each crop from each district. That is, altogether, a total of 100 sample farmers, 50 drip and 50 non-drip adopters have been selected for this study. Though DMI can be used by using surface sources (canals, tanks) of water, currently, the farmers who own wells (groundwater) have only been adopting drip method. Therefore, in order to avoid the differential impact of sources of irrigation on productivity and other parameters, we have considered only those farmers who cultivated the two selected crops using groundwater under both drip and flood irrigated conditions. While the drip adopters have been selected by random sample method using the list of names obtained from the Agricultural Department of the respective districts, the farmers cultivating the same crops under flood method of irrigation nearest to the field of drip adopters have been selected purposively as non-drip sample farmers in order to reduce the variation in agro-economic parameters between the two categories of farmers. The field survey data from the sample farmers has been collected pertaining to the year 1998-99 for sugarcane and 1993-94 for banana. Using the discounted cash flow technique, net present worth (NPW) and benefit-cost ratio have been computed to judge whether or not the investment on DMI is economically viable. The study compares the drip adopters with the non-drip adopters in respect of various parameters underlined earlier.

III

WATER USE EFFICIENCY

Maximising water use efficiency is an essential criterion for achieving the sustainable water use. One way of studying the water use is to compare the amount of water used to irrigate one hectare of land between drip and non-drip irrigated crops. Water consumption is generally measured in terms of centimetres (CM) under experimental condition. But, it is difficult to estimate the water consumption in terms of CM at the field level because horse power of pumpsets, water level in the well, pump efficiency and distance between land to be irrigated and the water source vary considerably across farmers. Therefore, in the present study, water consumption is measured in terms of horse power (HP) hours of irrigation. HP hours of water is estimated by multiplying HP of pumpset with hours of water used in each pumpset. The estimated water consumption under drip and non-drip irrigated conditions is presented in Table 1.

TABLE 1. WATER CONSUMPTION AND PRODUCTIVITY OF DRIP AND FLOOD IRRIGATED CROPS

Particulars	Crops	Method of irrigation		Benefit over FMI	
		DMI	FMI	Per cent	Value
(1)	(2)	(3)	(4)	(5)	(6)
Water consumption (HP hours/ha)	Banana	7,884.70	11,130.30	29.20	3,245.60
	Sugarcane	1,793.92	3,425.88	47.63	1,631.96
Productivity (quintal/ha)	Banana	679.50	526.35	29.10	153.20
	Sugarcane	1,354.00	1,080.80	25.27	273.20
Water use efficiency (HP hours/quintal)	Banana	11.60	21.14	45.13	9.54
	Sugarcane	1.33	3.17	58.20	1.84

Source: Computed using field survey data.
Notes: Data on banana and sugarcane are related to the year 1993-94 and 1998-99 respectively.

It is clear from the table that water consumption by non-drip irrigated crops is substantially higher than the same crop cultivated under DMI. Water saving due to drip method of irrigation is about 47 per cent for sugarcane and nearly 30 per cent for banana. In absolute terms, water saving over the method of flood irrigation (FMI) is estimated to be 1,631 HP hours/ha for sugarcane and about 3,245 HP hours/ha for banana crop. There are three main reasons for substantial water saving through DMI. First, since water is supplied only at the root zone of the crop under DMI, the evaporation and distribution losses are completely reduced. Second, water is supplied only to the crop under DMI, whereas land is irrigated through FMI, which obviously consumes more water. Third, uneven land surface consumes enormous amount of water under FMI, this problem does not arise in drip method where water is supplied through pressurised system. Four, controllability (required quantity at required time) of irrigation is easier under drip method of irrigation, which helps the farmer to conserve the water.

Another way of judging the water use efficiency is to compare the water required to produce one unit (quintal) of output between the two methods of irrigation. In order to estimate the per quintal requirement of water under drip and non-drip irrigated conditions, we have divided per hectare consumption of water with per hectare of yield of the respective crops. As seen in total water consumption, water use efficiency in terms of output is substantially higher for those crops cultivated under DMI as compared to the crops cultivated under FMI. The estimate shows that sugarcane cultivated under DMI consumes only 1.33 HP hours to produce one quintal of sugarcane against the requirement of 3.17 HP hours under flood method of irrigation. Similarly, for producing one quintal of banana, drip irrigated crop consumed only 11.60 HP hours of water, whereas the same is estimated to be 21.10 HP hours for non-drip irrigated crop. As mentioned earlier, a significant reduction in water use due to reduction of water losses and controllability of water under DMI are the main reasons for the higher efficiency of water use.

TABLE 2. RELATIVE ECONOMICS OF DRIP AND FLOOD IRRIGATED CROPS

Particulars	Crop	Method of irrigation		Benefits over FMI	
		DMI	FMI	Per cent	Value
(1)	(2)	(3)	(4)	(5)	(6)
Cost of cultivation (Rs./ha)	Banana	51,437	52,740	2.50	1,303
	Sugarcane	40,257	47,507	15.26	7,250
Gross income (Rs./ha)	Banana	1,34,044	1,02,935	30.22	31,109
	Sugarcane	98,196	79,101	24.14	19,095
Farm business income (Rs./ha)	Banana	82,607	50,197	64.56	32,410
	Sugarcane	57,939	31,598	83.36	26,341
Cost of production (Rs./quintal)	Banana	75.70	100.20	24.45	24.50
	Sugarcane	29.73	43.96	32.37	14.23
Capital cost of drip set (Rs./ha)	Banana	33,595	-	-	-
(without subsidy)	Sugarcane	51,152	-	-	-
Capita cost of drip set (Rs./ha)	Banana	22,236	-	-	-
(with subsidy)	Sugarcane	31,782	-	-	-

Notes and Source: Same as in Table 1.

IV

PRODUCTIVITY OF DRIP AND NON-DRIP IRRIGATED CROPS

In order to increase the widespread adoption of any new water saving technology in agriculture, the technology should also augment the productivity of crops besides saving water. Our survey results indicate a significant difference in the productivity of crops cultivated under drip and non-drip irrigated conditions (see Table 2). The productivity difference between drip and non-drip irrigated crops comes to about

273.20 quintals/ha for sugarcane and about 153.20 quintals/ha for banana. That is, productivity gain due to drip method of irrigation is about 25 per cent in sugarcane and 29 per cent in banana. One may argue that the productivity difference is possibly due to higher use of yield increasing inputs by drip adopters. However, this argument is not validated by our survey data.[4] In both the crops, the cost of cultivation (it is a proxy for level of input use) of drip adopters is marginally lower than that of the non-drip adopters, as can be seen from Table 2. There are many reasons for the higher productivity of crops cultivated under DMI over the method of FMI. First, the moisture stress is less in drip irrigated crops as water is supplied at regular intervals and in required quantity (see Figure 1). Second, weed problem is less in drip irrigated crops as it does not supply water to non-crop zone. Third, the efficiency of fertiliser use is very high as losses through leaching and evaporation are very minimal while using drip method of irrigation.

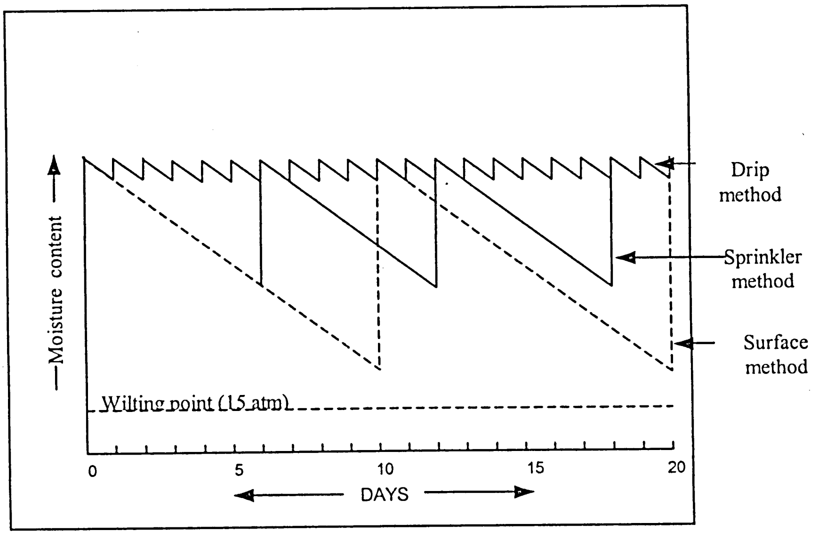

Figure 1. Moisture Availability for Crops in Different Irrigation Methods

V

ECONOMIC VIABILITY OF DRIP IRRIGATION

One of the important issues generally raised by the farmers about this water saving technology is whether this technology is economically viable. This issue arises because of the fact that drip irrigation is a capital-intensive technology. Therefore, there is a need to study the economic viability of drip method of irrigation using discounted cash flow technique. Before studying the economic viability of drip investment, it is necessary to understand the relative economics of DMI and FMI, as these details are useful for evaluating the economic viability of drip investment. The farm business income (FBI), which is the difference between gross income and total cost of cultivation (our cost refers to A2), explains the relative profit level of DMI and FMI. As expected, the FBI of drip adopters is significantly higher than non-drip adopters in both the crops considered for the analysis. The FBI of drip adopters is Rs. 26,341/ha higher than that of the non-drip adopters in sugarcane and the same comes to about Rs. 32,410/ha for banana (see Table 2). Since drip method of irrigation increases the productivity and that too with reduced cost of cultivation, the FBI of the drip adopters is substantially higher that of non-drip adopters.

Though the farm business income is substantially higher for drip adopters, one cannot straightaway suggest that drip technology is economically viable for farmers. This is because of the reason that the estimate of FBI does not include the capital cost of drip set, its depreciation, life period of drip set and interest accrued on the fixed capital. Therefore, we have computed both net present worth (NPW) and benefit-cost ratio (BCR) using discounted cash flow technique. Since drip irrigation involves fixed capital, it is necessary to take into account the income stream for the whole life span of drip investment. But, in the absence of observed temporal information on benefits and costs, the following realistic assumptions were used so as to estimate both the cash inflows and cash outflows. The assumptions followed are: (a) The life period of the drip set is considered as five years for both sugarcane and banana as followed by the INCID study (1994). (b) The cost of cultivation and income generated using drip method of irrigation is assumed to be constant during the entire life period of drip set. (c) Differential rates of discount (interest rates) are considered to undertake the sensitivity of investment. These are assumed at 10 and 15 per cent as alternatives representing the opportunity costs of capital, and (d) The crop cultivation technology is assumed to be constant for both sugarcane and banana during the entire life period of drip set.

In terms of the NPW criterion, the investment on drip set can be treated as economically viable if the present value of benefits is greater than the present value of costs. The BCR is also related to NPW as it is obtained just by dividing the present worth of the benefit stream with that of the cost stream. Generally, if the BCR is more than one, then, the investment on that project can be considered as economically viable. A BCR greater than one obviously implies that the NPW of the benefit stream is higher than that of the cost stream (Gittinger, 1984). The NPW and BCR can be defined as follows:

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

where, B_t - benefit in year t; C_t - cost in year t; t - 1, 2, 3,.......n; n-project life in years; i - rate of interest (or the assumed opportunity cost of the investment).

As mentioned earlier, all our sample farmers had received subsidy for installing drip system through state sponsored schemes. Knowing this well, we have estimated the NPW and BCR under both with and without subsidy condition specifically for two reasons. First, to find out whether or not investment in drip irrigation is economically viable without subsidy. Second, to study the role of subsidy in increasing the NPW and BCR at different discount rates. The estimated NPW and BCR with the assumption that there will not be any change in the cost of production and gross income during the entire life period of drip set are presented in Table 3.

TABLE 3. NET PRESENT WORTH AND BENEFIT COST RATIO OF DRIP IRRIGATED CROPS

Particulars	Discount rate (per cent)	Without subsidy		With subsidy	
		Sugarcane	Banana	Sugarcane	Banana
(1)	(2)	(3)	(4)	(5)	(6)
Present worth of gross income (Rs./ha)	15	329,251	449,449	329,251	449,449
	10	372,261	508,026	372,261	508,026
Present worth of gross cost (Rs./ha)	15	179,485	201,696	162,632	191,814
	10	199,164	225,484	181,536	215,159
Net present worth (Rs./ha)	15	149,766	247,753	166,619	257,635
	10	173,098	282,542	190,725	292,867
Benefit-cost ratio	15	1.83	2.23	2.02	2.34
	10	1.87	2.25	2.05	2.36

Source: Computed using sample survey data.

The estimated NPW and BCR clearly shows that investment in drip method of irrigation is economically viable even under without subsidy condition. The NPW estimated with subsidy is higher than that of without subsidy indicating the potential role of subsidy in increasing the viability of drip investment. For sugarcane, at 15 per cent discount rate, the NPW of drip investment is about Rs. 166,619/ha with subsidy and the same is about Rs. 149,766/ha without subsidy. For banana, the NPW of drip investment is about Rs. 257,635/ha with subsidy and Rs. 247,753/ha without subsidy at 15 per cent discount rate. As subsidy reduces the density of capital, the NPW of drip investment increases considerably after excluding the subsidy amount from the capital cost. Similarly, while reducing the discount rate from 15 per cent to 10 per cent, a significant improvement is observed in the NPW of drip investment under both with and without subsidy conditions in both crops. This implies that farmers will gain more by adopting drip method of irrigation if the lending rate goes down, which is possible in the new economic environment. The benefit-cost ratio estimated for sugarcane varies from 2.02 to 2.05 with subsidy and from 1.83 to 1.87 without subsidy, while the same ranges from 2.34 to 2.36 with subsidy and from 2.23 to 2.25 without subsidy for banana crop. Interestingly, our estimate of NPW also indicates that the adopters of drip irrigation technology from both the crops would be able to recover the entire capital cost from their income in the very first year itself. On the whole, the private cost benefit analysis presented above suggests that the investment in drip irrigation is economically viable in these two crops even if it is adopted without subsidy.

VI

CONCLUSION

Owing to fast decline of available water potential and continuous demand for water from different sectors due to agricultural intensification and expansion of population and economic activity, much attention has been given to increase the water use efficiency in agriculture in recent times. A number of demand management strategies have been introduced to curtail the demand for water as well as to increase the existing water use efficiency. One of the technical means introduced for increasing water use efficiency is drip method of irrigation. Unlike flood (conventional) method of irrigation (FMI), since water is supplied directly at the root zone of the crop using pipe network under drip method of irrigation (DMI), it increases the water use efficiency upto 90 per cent against the efficiency of 30-40 per cent under FMI. Besides saving water, it also increases productivity of crops, reduces cost of cultivation and energy (electricity) used to lift the water from the well. Despite this, not many studies have attempted to analyse the importance of drip irrigation in the context of sustainable water use. In this study, using field survey data, an attempt has been made to study what impact this technology has made in terms of increasing water use efficiency (output per unit of water) and whether or not drip investment is economically viable covering two water-intensive crops namely sugarcane and banana. The study shows that water saving due to drip method of irrigation over the method of flood irrigation is about 47 per cent in sugarcane and 29 per cent in banana. Water required to produce one quintal of sugarcane under DMI is only about 1.33 horse power (HP) hours of water against the requirement of 3.17 HP hours of water under FMI. The same trend is observed in banana crop as well. The private benefit-cost ratio estimated using discounted cash flow technique clearly indicates that drip investment is economically viable even without subsidy. Though this technology is economically viable and environmentally adaptable, the coverage of this technology is very limited except in states like Maharashtra, mainly because of lack of promotional programmes and poor awareness about the importance of this water saving technology among the farmers. As per some estimates, India's drip irrigation potential is about 21 million hectares. Therefore, considering the fast decline of irrigation water availability and low water use efficiency under FMI, appropriate measures need to be introduced to increase the area under DMI in order to avoid supply-demand gap in water use in the coming years.

NOTES

1. In India, the area under drip method of irrigation has increased from 1500 ha in 1985-86 to 2,46,006 ha in 1997-98. But, the area under DMI accounted for only 0.34 per cent in relation to gross irrigated area and 0.64 in relation to total groundwater irrigated area in 1997-98.
2. Sub-basin wise demand and supply position of water for different sectors upto 2030 is presented in Volume III of the *Maharashtra Water and Irrigation Commission Report* (Government of Maharashtra, 1999).
3. A detailed analysis on districtwise and cropwise area under drip method of irrigation from 1986-87 to 1999-2000 by central and state schemes pertaining to Maharashtra state are presented in Narayanamoorthy (1996 and 2001).
4. One of the important advantages of drip method of irrigation is that it reduces the cost of cultivation in many operations. In the present study also, we have seen a considerable reduction in the cost of cultivation especially in weeding, fertiliser, pesticides, etc. Due to brevity of space, we could not discuss the gains in cost of cultivation due to drip irrigation in this paper. For detailed analysis on cost of cultivation under drip and non-drip irrigated crops, see Narayanamoorthy (1996 and 2001).

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